New Crops and Uses:
Their role in a rapidly changing world

Edited by

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and

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International Symposium on New Crops and Uses: Their role in a rapidly changing world

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The Organising Committee expresses its gratitude to the following sponsors, without whose help the Symposium would not have been possible:

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First published in 2008 by
Centre for Underutilised Crops
University of Southampton, Southampton, SO17 1BJ, UK

Printed at RPM Print & Design, 2-3 Spur Road, Quarry Lane,
Chichester, West Sussex, PO19 8PR

ISBN 9 78 085432 89 18

British Library Cataloguing in Publication Data

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ISBN 9 78 085432 89 18

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New Crops and Uses: Their role in a rapidly changing world

Preface

The Centre for Under-utilised Crops in the University of Southampton organised the 5th International Symposium on New Crops and Uses on 3rd and 4th September, 2007. The ECUC (European Centre for Under-utilised Crops) Trust, the International Foundation for Science (IFS), the UK National non-food Crops Centre (NNFCC) and the Tropical Agriculture Association were partners in its organisation.

The purpose of the symposium was to review and assess the past work on under-utilised crops and to determine the focus of future endeavours by all stakeholders. Over 75 delegates attended the conference, from all parts of the world, and 33 papers were presented, together with many posters. Additional papers, which could not be accommodated in the conference, appear in these proceedings.

The symposium was deemed by the delegates to be highly successful in achieving its aims and provided guidelines on where future research should focus.

The papers and posters provided a wealth of information on completed and on-going research projects, and case studies from which successes and failures could be identified. This led to the identification of many issues which impact on the need to continue working on the domestication of numerous species and their incorporation into farming and marketing systems. The research work on under-utilised crops was justified for the following reasons:

1. Climate change and its effects on food production remains unpredictable although models are able to predict future changes in temperature, but not in rainfall and therefore its effects on soil moisture.
2. The present high energy costs and declining supply of fossil fuels are exacerbating the attempts to increase food production and assure food security.
3. Population growth is resulting in the need to use less fertile land and increase the use of farm and homestead gardens.
4. Our over-dependency on a few plant species for our staples is a trend which continues; e.g., rice is replacing other sources of carbohydrates such as sago.
5. Our dependency on high yielding (green revolution) varieties, which require inputs of fertilisers and pesticides results in increasing indebtedness of farmers.
6. Since women grow most of the under-utilised crops in developing countries, there is a need to further empower them and increase their incomes.
7. Under-utilised crops that grow in their natural environments are good indicators of soil characteristics and climate change

The time scale for plants to adjust to climate change is lengthy- at least 80 to 90 years. In order to speed up this process, or identify crops that are more suited to these changes in climate, more science and technological developments are needed to meet these challenges. A particular problem is the current inability to predict future changes in rainfall patterns and soil moisture. Immediate research on the water requirements of many of the crops was considered a priority.

Delegates agreed on the necessity to define desirable characteristics of new crops to address consumer needs and concerns, the need for determinate plant habits and their potential for domestication. It was also suggested that several negative characteristics of these new under-utilised crops need to be overcome by improving qualities such as bitterness, lodging and hard seed coats. However, these crops have abundant genetic diversity that remains unexplored, and the potential is therefore available for crop improvement.

It was agreed that the development of local and global markets is essential for the establishment of these crops as mainstream food sources. Attention will have to be given to consumer taste, shelf life, convenience, processing potential, length of growing seasons, the standardisation of products, presentation, demand creation and price stability. Global marketing will also require appropriate registration, covering food safety and uses in medicine, cosmetics and industrial uses.

The strengthening of farmer organizations will influence crop biology and agronomy research and improve marketing and business skills. It was highlighted that supermarkets should play a vital role through providing better labelling that recognises the importance of factors such as fair trade, food miles and organic production systems.

The role of under-utilised crops in maintaining and increasing biodiversity was considered particularly important for a large range of very diverse species. However, the logistics of the work was seen as a major challenge. The use of molecular marking techniques has the potential to reduce the workload through conserving the genes rather than whole genomes. Some International Centres are now reducing their core collections to some 10% of the total, and even establishing "mini-core" collections to a further 10% of those. However, the lack of global research funding is a serious constraint to all agricultural research and development. For example, research into biotechnology, agriculture and fisheries constitutes only 5% of the EU total research budget.

The case studies clearly show that developments at grass roots level, i.e., in the field, greatly benefit from farmers' knowledge through community based farmer participation.

The value of under-utilised crops was assessed throughout the symposium, and the following attributes were considered to be amongst the most important. Many of the species produced during the "hungry seasons" provide empowerment and income for women and extend the harvest periods. Many species are multi-purpose, providing a range of products with a high nutritional value for both humans and animals that often exceeds the food qualities found in common crops. They enable growers to spread the risks associated with reliance on a small basket of traditional crops, and many of them are good at stabilising fragile and risk-prone environments.

It was agreed that use must be made of a wide range of sophisticated modern techniques including GIS, molecular biology, phytochemistry research and computer models to improve efficiency and productivity within both village and global environments.

Events subsequent to this conference, particularly, the rising cost and potential future shortages of food and energy, and the change in use of several crops, from food to biofuels, further underlines the need for increased investment in research and development of under-utilised crops. It is my view that our first priority should be the use of crops for food, and that biofuels should, where possible, be manufactured from waste or by-products.

The recent report of the International Assessment of Agricultural Knowledge, Science and Technology (AKST) makes several references to under-utilised crops and highlights that the importance of these crops is now being recognised by policy makers. The report states that policy options for addressing food security include developing high value and under-utilised crops in rain fed areas. The report also makes reference to "traditional, local knowledge and community-based innovation". Traditional and local knowledge are recognised as being important for the conservation and utilisation of many under-utilised species, under the UN Convention on Biological Diversity. This local knowledge refers to capacities and activities, which include the use of indigenous and under-utilised species, which exist amongst the rural people in all parts of the world. The AKST report also gives much emphasis to the gender issue, by stressing the role of women in agricultural production and postharvest activities. Women's input ranges from 20% to 70%, particularly with the development of export-orientated farming, which is associated with a growing demand for female labour, including migrant workers. Meeting this demand depends on strengthening women's ability to benefit from market-based opportunities by institutions and policies, giving explicit priority to women farmer groups. This conference has identified the important role of women in the development of production, processing and marketing systems based on under-utilised crops.

In writing this preface I hope that readers will be encouraged to study the papers and posters in detail and be persuaded to assert their influence on government and policy makers, encouraging, indeed insisting, that new needed investments are put in place.

The editors apologise that the publication of the proceedings of the meeting has been delayed due to late submission of some of the manuscripts. Even after repeated reminders some of the manuscripts have not been received. The editors have therefore decided to include the relevant PowerPoint presentations instead. Where possible, the editors have tried to keep the manuscripts as submitted.

We thank Kirsty Rule and Liz Williams for formatting the text and making the manuscript camera ready for the printers and Colm Bowe for designing the cover page.

Roger W. Smith

SECTION 1

PAPERS

THE CONTEXT, JUSTIFICATION AND APPLICATION OF UNDERUTILISED CROPS IN A RAPIDLY CHANGING WORLD

1

Climate change: an exciting challenge for new and underutilised crops

Trevor Tanton and Nazmul Haq

The paper explores the challenges and opportunities posed by global warming. Global Climate Change Models suggest that the mid-latitudes will generally get appreciably drier, northern latitudes will get a lot hotter and wetter, while at the same time a considerable amount of the world's most productive agricultural land will be under water due to sea level rise. Under the most likely A2 and B2 scenarios of climate change the predicted changes for plants and crops in many parts of the world are severe, and although regional climatic change predictions have a wide level of uncertainty within a single human life time, cropping practices across the world are expected to change dramatically. Crops from other parts of the globe will replace crops that are no longer suited to a particular location, thus opening up appreciable opportunities for new/under utilised crops.

Although we have a good understanding of the environmental growth requirements of the major world crops, i.e. maize, wheat, cotton and potatoes, for most crops we have a very poor understanding. For example as the acceptable temperature range of many tropical and sub-tropical crops expands towards the poles as a result of climate warming, their climate range might also be expected to move towards the poles. It is possible however that for many species day length requirements or specific seasonal requirements could still restrict their range. It is therefore clear that with climate change cropping systems throughout the world and the crops grown within them will have to change if they are to adapt to the new climatic conditions. Unfortunately there is a lack of data on the physiological response of most crops to the environmental variables that restrict their development and yield, and hence it is difficult if not impossible to anticipate future cropping systems throughout the world. To enable effective introduction of new crops on a world scale research needs to concentrate on gaining a fundamental understanding of the climatic variables that constrain plant adaptation.

The paper draws attention to the steady decline of crop research infrastructure that has taken place which unless reversed in the near future will leave us ill equipped to adequately adapt to the anticipated rapid rate of climate change. Attention is also drawn to perhaps an even more deep seated problem and that is the lack of good qualified young scientists who are capable of undertaking the essential research in Europe (and to some extent in North America).

INTRODUCTION

It is generally accepted that climate change is happening and that anthropogenic CO_2 emissions are the cause. We know that climate is changing and that plant behaviour is changing and that where possible plant communities are adapting, for example in the northern hemisphere plants are progressively flowering earlier in the year (Franks *et al.*, 2007) and senescence is occurring later. In the Alps the alpine plant communities are progressively moving even higher up the mountains (Pauli *et al.*, 2007) and in the past 40 years the northern limit of maize production has moved north from central France to Finland.

The rate of climate change is already noticeable with increased temperatures and extreme events occurring more frequently. Unfortunately all Global Circulation Models (GCMS) predict that the rate of change will increase significantly. For the latest predictions of future climate change see the International Panel for Climate Change (IPCC) Fourth Assessment report on climate change, 2007 (see http://www.ipcc.ch/#). This paper looks at the likely changes that are expected to take place in the global climate, and the secondary consequences that are likely to affect the growth and development of crops and plant communities as a whole, before looking at the role of research in minimising the impact of change on global crop production.

CLIMATE CHANGE SCENARIOS

Intergovernmental Panel on Climate Change: Scenarios of Climate Change

Global climate change modellers make predictions of potential climate change based on predicted changes in the atmospheric concentration of forcing gases, $CO_{2,}$ CFCs etc. which are likely to occur with different potential world economic, political and population development scenarios. The two scenarios considered in this paper are the:

- A2 scenario. National self reliance, preservation of local identities, continuously increasing population and economic growth on regional scale.
- B2 scenario. Local solutions to sustainability; continuously increasing population at a lower rate than in A2; less rapid technological change than in B1 and A1 scenarios.

Change in temperature

Without a very significant change in the world's attitudes to economic growth and lifestyle and unprecedented global co-operation the A2 scenario appears the most likely to occur. For the A2 scenarios, below 15^{o} North most of the GCM's are in general agreement and anticipate an increase in average global temperature of between 3 to 4^{o} by 2585 (with a potential confidence range of 2 to +5.4), however this will not be globally uniform. For example, by 2085 in much of Western Europe and India an increase of about 4ºC is anticipated but little change is expected above the oceans. In general the magnitude of temperature rise increases towards the North Pole where a 7-9ºC rise in temperature is anticipated. It is also important to note that the largest rises in temperature are anticipated in summer months, so a mean annual temperature of 4^{o}C could be as large as 6^{o}C in summer and only 2^{o}C in winter, resulting in significantly higher crop water demands. For the B2 scenario the same general pattern is expected but the anticipated rise is likely to be a degree or two less than under the A2 scenario

The implications of an anticipated temperature changes arising from the A2 scenario in Western Europe by 2085 can clearly be seen in Table 1. London will experience the present mean annual temperature of Bordeaux and Helsinki is expected to have a temperature close to that of London.

Table 1. Anticipated mean annual temperature changes for a number of European cities with the A2 Scenario

City	*Mean Annual Temp . oC.*	*A2Predicted Increase in Temp.*	*Temp 2080*
London	*9.6*	*+3.5*	*13.1*
Paris	*10.8*	*+3.5*	*14.3*
Barcelona	*15.3*	*+3.5*	*18.8*
Bordeaux	*12.8*	*+3.5*	*16.3*
Helsinki	*5.7*	*+7*	*12.7*

Variability in precipitation and available soil moisture

For agricultural production precipitation characteristics interact strongly with seasonal temperature to dictate crop production. Unfortunately at the present time there is poor agreement between the different Global Climate General Circulation models in their prediction of precipitation distribution around the globe in the future, apart from a general trend upwards (Figure 1). The situation appears worse when the models are run for specific locations when there is even greater divergence with changes in precipitation greater than + 20% to -20% being predicted by the different models in some instances. Because of the importance in predicting precipitation locally these models are often downscaled using widely accepted procedures (see IPCC 2007). For example in Britain the output from the HAD models are downscaled to a 100km² grid and in 2008 will be downscaled to a 25 km² grid by the Hadley centre. However, although the basis for the downscaling is sound and gives more apparent precision it can be misleading as there is no gain in accuracy and hence give a false sense of reliability. The problem is made worse by many nations selecting one model, often their own national group's model and not considering the wide variability between different models.

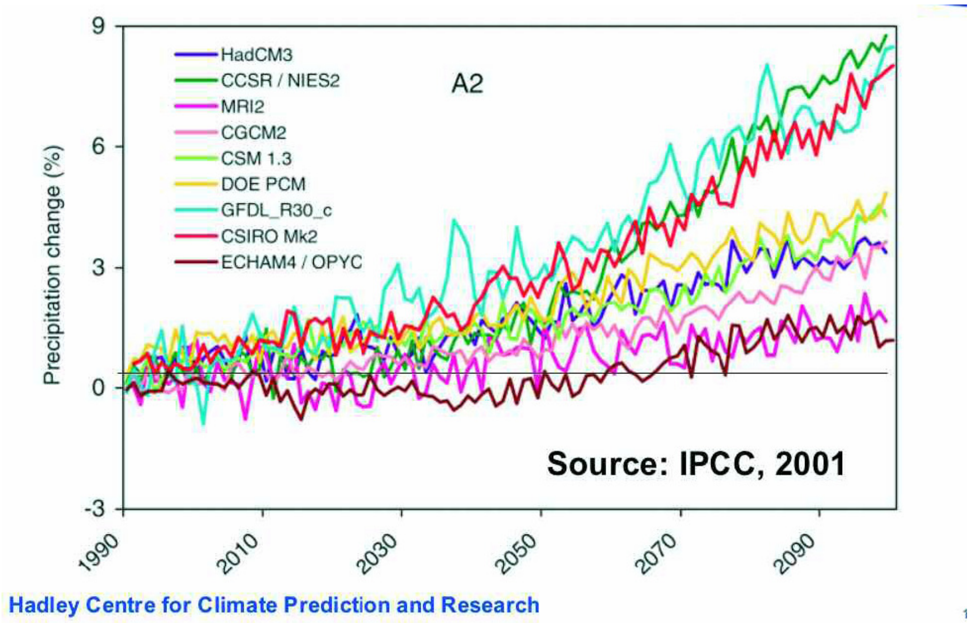

Figure 1. Nine GCM predictions of Percentage Change in Precipitation for the A2 scenario

Increase in evapotranspiration and change in soil moisture

As crop production is very much linked to soil moisture availability researchers have combined the precipitation and temperature output of the models to produce maps of potential changes in soil moisture. These maps show vast changes in the distribution of soil moisture throughout the World. For example the HAD 3 model data gives a reduction of available soil moisture in Europe of typically 10 to 20%, while in the Amazon it is anticipated to have a 50% reduction and in North Eastern Siberia a 50% increase is anticipated. Because for many locations the models have wide ranges of anticipated changes in precipitation, the colourful GIS output maps of predicted precipitation that are produced from them, although looking very seductive, need to be considered with great caution. In summary we can expect soil moisture balance to change, and in some areas this change will be dramatic but the models are still not accurate enough, and maybe never will be, to allow given countries to develop specific coping strategies for changes in the soil water balance. But what is clear is that we need to plan for uncertainty and in general where all models show a similar pattern of change the anticipated changes may be more robust.

Other anticipated changes that will affect cropping patterns and cropping systems as a result of climate change

- An expected 0.6m rise in sea level is now anticipated by 2080, resulting in loss of some of the world's most productive soils. For example, in Bangladesh where there is no construction material to provide effective coastal protection, with an anticipated sea level rise of 0.6m, 17% of the country's land area would be lost.

- With greater energy in the weather systems of the world the greater will be the extremes of climate, i.e. harder more frequent droughts, prolonged hot periods, more heavy storms, frequent tropical cyclones, floods and wetter monsoons.
- Changes in humidity are also expected but few have tried to quantify it but changes in humidity will be linked to changes in soil moisture balance.

Despite the uncertainty in what the climate will be in the future it is not an excuse for inaction. Climate is changing and all models are predicting changes that for many parts of the World will result in a very different climate by 2080. Given the scale of the problem and coupled with an energy crisis as oil production begins to decline we need to be in a position to guarantee the food supply for future generations.

WHAT DOES CLIMATE CHANGE MEAN FOR CROPS AND PLANT LIFE?

- Due to the rapid change in climatic conditions in many parts of the world plants will have inadequate time to adapt resulting in mass extinction and loss of biodiversity. For example much of the wild gene pool of potatoes could be lost as the temperature rises in the Andes and tubers are no longer formed, while only the most invasive species are likely to be able to easily adapt to changing climatic conditions.
- Many crops will not be able to grow in their existing climatic range. For example over most of Southern Africa maize is the staple food but over much of the region it is at the extreme of its range due to lack of soil moisture availability. As a result food shortages are common in dry years. With an anticipated increase in temperature of 2-3ºC and the associated increase in evapotranspiration coupled to a potential decrease in precipitation the future for maize in the region does not look good.
- A significant area of the world most fertile floodplains will be submerged below sea level resulting in loss of existing coastal communities.
- Crop production will move north into the more wealthy nations. For example in the past 50 years the northerly limit for maize production has moved north from central France to Finland. Although this has partly been brought about by plant selection it is also the result of a steady increase in temperature and number of frost free days. This move north is expected to accelerate in the coming decades.
- Because of the uncertainty of future precipitation distribution it is difficult to anticipate future soil moisture regimes and to identify how it will effect plant growth. It also makes it impossible to adapt a specific scenario to plan for the future but what is clear is that we need to plan for change.
- There will be changes in soil fertility. With higher temperatures humic matter in the soil will oxidise more readily leading to long term reduced fertility while in areas with increased rainfall there will be increased leaching of soil nutrients. This will occur against a background of very expensive artificial fertilisers, a result of the rapidly looming world energy crisis.
- As a result of climate change low yields of existing crop varieties within their present geographical locations could become the norm.

The world research efforts into crop adaptation and development is only at a fraction of the level it was in the 1960's and 1970's. This decline in research effort being justified by the fact that the research carried out in those years has allowed the world to feed it self to date. Unfortunately the severe threat posed by climate change is confounded with a world rapidly growing population coupled with rapidly increasing energy prices and hence fertiliser costs. Hence the future food security of the world is under an unprecedented level of risk. There are signs that this era of food security is drawing to a close and hence an already difficult time for future food security is going to be further aggravated by the fact that within a person's life span dramatic changes in climate are being predicted.

WHAT STEPS ARE BEING MADE TOWARDS CROP/ ADAPTATION?

Seed banks

Seed banks, such as The Royal Botanic Gardens Millennium Seed Bank (see website) and Norway's Svalbard Seed Vaults are attempts to try and preserve plant genetic diversity when it is clear that it is rapidly diminishing in the natural environment. However ambitious these attempts might be, they will only ever contain a fraction of what presently exists in the natural environmental today.

Research in crop adaptation

Research is underway on how a number of the major crops can be expected to respond to changing climatic and environmental conditions. For example there is adequate knowledge of how the potato crop responds to its environment to allow us to accurately predict dry matter production from environment variables, although it is not always possible to predict tuber yield (Haverkort and MacKerron, 1995). Wheeler *et al*. (2000) and Challinor *et al*. (2007) have reviewed the literature on the effect of a wider fluctuation of temperature on the seed production of crops noting that seed production in many species is sensitive to short periods of high temperature. There is also a number of ongoing studies looking at how most of the major crops respond to their environment and how they might respond to climate change (for example Hodges *et al.,*1987*,* Matthews, 1997).

Field trials

Field trials are the agronomic approach to selecting crops and they continue to be used widely throughout the world to adopt crops to their environment. This approach is well tried and tested. However, they are both time consuming and expensive. In time of rapid climate change and when in many locations new crops will be needed to replace crops that are unable to adopt to the new climate it is not a cost effective means of screening potential new varieties and crops.

WHAT ELSE IS NEEDED?

We have a growing understanding of how many of the world's major crops respond to the main environmental variables. Unfortunately few studies have looked at the variability that exists in gene pools to establish the range of climatic conditions within which a crop may adapt to a changing climate. For example research in Malawi showed that the base temperature of tea, (the temperature below which it does not grow) is 12.5ºC. This is widely accepted in environmental modelling work, but this work was carried out on a single clone (Tanton, 1979). It could be that there is a wide range of variability between different genetic material or equally there could be no range. What is clear is that for crops like tea that have very specific habitat requirements, much more information is needed about their adaptability to adapt to a changing climate if future production is to be guaranteed.

We therefore consider that it would be cost effective to carry out research into the genetic variability of the world's major crops to establish their capability to adapt to a changing environment and to have sufficient understanding of their requirements and adaptability to be able to predict future regional crop distribution from anticipated climatic changes.

Our understanding of the crop physiology of the major crops gives us a platform from which a more in depth understanding can be developed but unfortunately we have little or no understanding of how new/underutilised crops respond to their environment. If they are to fulfil their potential in helping us adapt to climate change it is essential that we have a clear understanding of their climatic/environmental tolerance.

Major changes in climate are predicted within a single lifespan and considerable knowledge needs to be gained on the adaptability of our crops if we are to be in a strong position to effectively adapt our cropping pattern throughout the world. Unfortunately in Europe we have wound down our agricultural research base, both in Europe and within our aid programmes. In addition the supply of good well trained scientists is of underlying concern with the number of Botany / Agricultural botany courses in the UK being countable on one hand. Hence we do not have a good trained pool of manpower to take up the challenge.

CONCLUSIONS

A. We urgently need an expansion of research into the understanding of the adaptability of all our crops, both staple crops and underutilised crops.
B. We need to educate graduates to provide the personnel who can rise to the challenge.

Even if the research effort has still got to get under way it is interesting that some sectors of the agro-industry are beginning to consider the future, for example French Champagne producers are reported to be buying chalk land in the south of England, (Kanter, 2008).

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2

Food and nutrition: the role of under-utilised crops in traditional crop improvement and new crop development

Patrick Van Damme

Projections on world population growth foresee a figure of 9 billion people by the year 2050. Food production will have to follow this ever increasing trend. As such, 'traditional' food crops such as rice, wheat and maize (to name the 3 most important) will have to increase in yield so as to continue to provide quality food to the world. In a world that for a number of reasons does not want to rely too much on GMOs, yield increases will depend heavily on the introduction of genetic material from landraces and related (under-utilised and wild) species into known or newly developed varieties. However, in order to continue to offer a diverse and quality-rich food basket, new crops and products need to be domesticated and developed, respectively. Recent trends and possibilities, based on examples from Latin America and Africa will show the scope, opportunities and limitations of this new crop development. The necessary policy measures will be highlighted with an emphasis on the expected (and needed) input of different stakeholders, with this the specific place and importance of niche commodities for greater food security and income generation will be emphasised.

INTRODUCTION

Needless to say, Africa is a big continent that harbours a wide agro-ecological variation, based on a variety of climates and soils. The latter interact to yield a number of biomes that cover a range comprising dry woodland and scrublands in the north, deserts (Sahara and Namib desert being the most prominent on and near the tropics), evergreen broadleaf forest, tropical deciduous forest, tropical scrub forest, tropical savannah and woodland, semi-desert and arid grasslands and mountainous vegetations (*sensu* White, 1983).

Annual rainfall figures range from < 25 mm to > 8000 mm. However, the natural environments they generate are mostly influenced and changed by human interventions. Sedentary farmers, transhumant and nomadic cattle growers use and shape the natural landscape in such a way that the original vegetation is altered into a man-made environment, with a specific biodiversity. Cropping can either be intensive or extensive, uses traditional – some would say primitive – implements or else rather modern inputs in an effort to lower production risks and low yields.

The continent typically harbours the whole range of agricultural production systems starting with (again) primitive hunter-gatherer systems (like the ones encountered with central African pygmies or southern African Kung San or Topnaar, formerly known as Bushmen and Hottentots, respectively), and developing into semi-nomadic and subsequently fallow systems, ley farming, permanent upland farming and when resources allow this irrigation farming and plantation farming; in limiting, i.e. arid, environments animal husbandry systems prevail and cattle, goats and sheep are raised for auto-subsistence and marketing (Ruthenberg, 1976).

The different vegetation types do not harbour the widest variety of plant biodiversity in the world. In fact, Latin America hosts some of the most biodiverse 'hotspots' of the world, whereas Asia also has some very rich sites. Wherever there is rich plant diversity available, this can be the basis for subsequent plant domestication into crops. Thus, both Latin America and Asia have been the cradle of a number of important crops. By comparison, Africa is rather poor. Still, and following Vavilov, Africa is the centre of origin of a number of well-known crops with worldwide importance. Moreover, it hosts a number of plant species with local and/or regional importance.

The present review wants to highlight a number of crops with African origins, but also draw the reader's attention to a number of useful species with domestication potential which are currently under consideration for domestication and/or actual development. Specific attention will be drawn to the methodology to 'find' new candidates for crop and niche product development, with a specific emphasis on market chain analysis and promotion, and development aspects of the latter process.

AFRICAN CROPS

Coffea arabica and *C. canephora* (better known as robusta coffee) together with the lesser known and used *C. liberica* are three coffee species that have entered the international markets over several centuries. *C. arabica* was first domesticated in the Horn of Africa, then moved into the Arab peninsula before it began its tour du monde. Robusta is a species that was first domesticated from the humid tropical lowland forests of central Africa. Both co-exist and have specific markets and customers, robusta being the source of soluble coffee as it has a strong, somewhat bitter taste that does not loose its properties too much after and with processing.

Amongst the different cotton species (*Gossypium spp.*), at least one originated from Africa. In fact, cotton is already mentioned in the New Testament. However, archaeological findings in Thailand and Machu Pichu point to a disjunct origin for the genus that indeed contains several species that each developed into commercial crops.

At the commercial level, *Elaeis guineensis* or oil palm is a real success. Originally coming from the Guinea Gulf area, it is now 'big money' in South East Asia, with Malaysia and Indonesia being the biggest producers, trailed by Vietnam. Oil palms offer a healthy vegetable oil whose properties have been altered for greater nutritious value and better health properties. The recent interest in biofuels based on energy-rich chemical compounds from oil crops has increased investment efforts to promote its cultivation in new areas (that are often situated in fragile humid tropical environments).

Even though *Oryza sativa* is globally the most important cereal crop (together - and depending on the years - with wheat, *Triticum* spp.), Africa has been the centre of origin of *O. glaberrima*, the so-called upland rice that still has its main cropping area centred around the West African Niger river watershed. Dr. Monty Jones, formerly with the Africa Rice Centre, or West African Rice Development Association as it was known before, was able to create a viable cross between both species which is currently known as NEw RICe for Africa. NERICA blends the high(er) production potential of *O. sativa* with the rusticity of *O. glaberrima*, and yields up to 30 % more than the latter without the need for costly inputs such as fertiliser or pesticides (www.warda.org). As such, NERICA can be a life saver for many resource-poor farmers, and should also allow them to secure some additional income over their meagre subsistence earnings.

In terms of acreage and cultural, food and commercial importance these four product groups are the most important amongst the crops which have their origin in Africa. The rest of the list covers species that only have a local and/or regional interest. If they or their by-products are exported, they serve specific 'niche' or seasonal markets with limited scope or impact.

Amongst the most important 'secondary' crops with African origin, we can mention *Pennisetum glaucum* (pearl millet), *Sorghum bicolor* (sorghum) and *Dioscorea* spp. (yam). Where they occur, the three of them are important staples. Pearl millet is a basic food item whose flour is prepared into a sort of porridge that is the basis for meals in the semi-arid areas of Africa. White-seeded sorghum serves the same purpose; the red-seeded variety, however, is *the* basis of sorghum beer. Its tannins guarantee a strong and specific taste that is appreciated both in the northern and southern hemispheres of Africa. The seeds of both species are also known on western markets where they are sold as birds' feed. Yams are another staple source of energy. Different species are still harvested from the wild, whereas others form an integral part of the farming system of the somewhat more (sub-) humid farming systems. As the vining *Dioscorea* needs a support, it is often grown in association with other crops, mainly cereals.

The continent gave birth to a number of other cereals such as finger millet/coracan (*Eleusine coracana*), fonio (*Digitaria exilis*), or teff (*Eragrostis teff*). The latter originated from Ethiopia, where it is a staple crop in part of the country – its flour is turned into *enjeera* which accompanies every 'proper' meal in Ethiopia. Teff is also grown in South Africa as cattle feed.

Vigna unguiculata (cowpea) is another crop that is typically grown in association with cereals. Especially in West Africa, it occurs in mixed stands of millet and/or sorghum. Its centre of origin is situated in Nigeria. The three crops typically grow in semi-arid, low resource settings, and have low yields. Improved varieties do exist for all three of them, but still yields are in the range of 1 t/ha only. Sorghum and millet are mandate crops for the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT, headquarters in Hyderabad, India), whereas cowpea is a focal crop for the International Institute of Tropical Agriculture (IITA, Ibadan, Nigeria). Both institutes try to develop varieties with high rusticity and resistance against the more common pests and diseases.

Apart from cowpea, there are still a few other legumes that have their centre of origin in Africa. *Cajanus cajan* is an important seed legume, whose grains are used for feed but also for human food. Pigeon pea is also a crop that is often used in improved agroforestry of agro-sylvopastoral systems in alley cropping configurations. It hereby improves soil fertility and can also protect the field from degradation and erosion. Lablab (*Lablab purpureus*) is another legume that was initially domesticated in Africa.

Africa also saw a number of vegetables being developed from the wild. *Solanum aethiopicum* is a species that is rich in a number of subspecies all of which are termed African eggplants. They have a somewhat bitter taste, and come in different forms and colours. Cucumbers (a wide variety of *Cucumis* spp.) were also and initially developed from African material. *Hibiscus sabdariffa* (bissap or roselle) and *H. cannabinus* (kenaf) are interesting Malvaceae. Red roselle is grown for its red succulent calices (that continue to develop once fruits are set) that once dried are the source of a sweet and sour beverage traditionally drunk by muslims during Ramadan. Kenaf is a source of coarse stem fibres. It is traditionally grown in garden plots; its fibres are made into cords with specific uses. *Lagenaria siceraria* was amongst the first domesticated plants in the world. This cucurbit is basically grown for its calabash fruits that once dried are used as containers. *Ricinus communis* (ricin) is also grown in garden environments, but its final uses are mostly medicinal. *Guizotia abyssinica* is the source of 'Niger seed'. It is an erect, stout, branched annual herb, grown for its edible oil and seed. Its cultivation originated in the Ethiopian highlands, and has spread to other parts of Ethiopia.

Apart from coffee, trees or perennials are quite absent from this list. There are, however, a few African perennials that made it into 'real' crops such as *Quercus suber*, a North African tree species whose bark is a source of cork, which has many uses (see *infra*). *Phoenix dactylifera*, date palm, forms an essential part of the North African oasis production system. Dates are a very useful survival food, rich in energy that is appreciated in numerous societies for its sweetness. On the other hand, *Cola nitida* (cola nut) has a huge local, cultural and - more widely - traditional importance. Although it is regionally widely traded, it has hardly any big interest beyond its initial centre of domestication. At the same level, *Ricinodendron heudelotii*, *Xylopia aethiopica* or *Tamarindus indica* serve local and regional markets, but have hardly made it into the international market, with an exception for the latter species for which there exists a ready market in Asia, and of late also Europe. With the exception of cork oak, there exist no improved varieties for the other species, 'real' domestication only having started recently. Interest in the latter species has recently risen, amongst others because of the research and development work initiated by the World Agroforestry Centre (ICRAF). The latter is also true for *Prunus africana*, a species once named as a 'cinderella species' by Leakey and Newton (1995) and Leakey and Jaenicke (1994) to indicate this is a species with a multitude of hidden valuable uses that are (as yet) not appreciated by the wider (scientific/development) community. *P. africana* is currently being domesticated as there is a huge market demand from the west for its medicinal bark.

UNDER-UTILISED AFRICAN PLANT SPECIES WAITING TO BE DOMESTICATED

From the above, it is clear that up till now Africa has been the source of only a few crops with 'universal' importance. Others remain confined to the continent. There are, however, a number of other useful species that are only known and used by local communities for food, medicine, rituals, dye, and timber. Within this group, especially non-timber forest products (NTFPs) would seem to have at least some potential on a wider scale.

Ethnobotanical survey work documents plants use by local and traditional communities, and allows these species to be 'discovered' for wider use and further development. Ideally, ethnobotanical inventories form the basis for plant germplasm characterisation using classic morphological description through descriptors specifically developed for the species under scrutiny and more detailed fingerprinting using AFLP, micro-satellites, etc. Thus, the taxonomical position of the useful species can be clarified, and the existence of specific eco- and genotypes evidenced. The latter information is important if and when one wants to improve the existing material through crossings and breeding. Better knowledge of the existing germplasm would allow for the better material to be domesticated. In order to achieve this, species have to be propagated and the plants developed into 'real' crops for introduction as food or medicine for auto-consumption and/or commercial, 'niche' crop development.

In a global economy, development of new commodities that address specific so-called niche markets seems imperative if one wants to guarantee ready market access to resource-poor farmers who often don't have the financial nor organisational means to start competing with established global-market products such as coffee, rubber, cacao or tea. With the latter crops, the economic positions have been taken for a long time already. New 'players' will only be able to enter these markets if they can offer specific quality products, or else can start producing enormous amounts (that would lower or compensate fixed production costs). Both strategies, however, necessitate high investments which more often than not are not available.

Box 1. The importance of niche commodities – Tonts & Selwood (2003)

Diversification and niche marketing have become very important economic strategies for many rural small businesses, farmers and communities. As part of these strategies, new opportunities often emerge for traditional products and industries. In the case of Western Australia, this has contributed to the revitalisation of the sandalwood industry. While sandalwood has been exported from Western Australia for more than 150 years, for much of the second half of the twentieth century it was of little economic significance. In recent years, however, the industry has become increasingly entrepreneurial, successfully marketing its products into niche markets in the global economy. For farmers and communities in rural areas, the revitalisation of the sandalwood industry has also provided opportunities for economic diversification and a profitable way of tackling land degradation.

Biodiversity as a whole, and African plant biodiversity in particular *'has emerged in the past decade as a key area of concern for sustainable development. It provides a source of significant economic, aesthetic, health and cultural benefits. Although estimates vary, there is general scientific consensus that the world is becoming less biologically diverse in terms of genes, species, and ecosystems. Rapid loss of biodiversity poses a global threat to human well-being*' (cited from web.worldbank.org).

Ethnobotanical research in Africa has come up with some promising candidates for new crop development. In what follows, we briefly present a few (NTFPs) that specifically cover food (and feed) uses.

DIRECT FOOD

Seeds and Nuts

From the Mediterranean area, *Argania spinosa* could be a source of argan oil, *Ceratonia siliqua* (carob tree, known from the bible as John the Baptist's survival food) is already commercialised as an alternative sweetener (and has been incorporated in chocolates and confectionery in general), whereas a number of *Pistacia* spp. either yield seeds or have been the source of 'mastic' for a very long time. *Vitellaria paradoxa* seed from the Sahel, is the source of shea (nut) butter which is used in food preparation but also in cosmetics: locally, women use it to treat their skin, whereas it is also exported to the West for more formal incorporation into cosmetics.

Fruits

Ziziphus mauritiana (jujube) yields sweet fruits. Through research, new varieties have been developed that produce bigger fruits with better/sweeter taste. The international market prospects of *Balanites aegyptiaca*, *Parkia biglobosa* (néré, or African locust bean) and *Parinari macrophylla* still need to be explored. However, locally and regionally commercial activities are quite intense. *Saba senegalensis* yields very acid fruits that could appeal to specific tastes. The fruit pulp of *Adansonia digitata* or baobab is the source of a sweet juice that is already produced in Europe (France, Italy); the fruit contains seeds that are locally used in sauces, whereas (dried) leaves, bark for rope, seedlings, are other sources for a number of useful products.

Palms

The Arecaceae family has a prominent place when useful plants are concerned. *Elaeis guineensis* has already been mentioned as a source of vegetable oil. Of late, the latter oil has attracted some interest as a possible source of biofuel. However, using a *food* oil as a source of *combustion* would seem in advisable in the light of the big problems with hunger that continue to prevail in the world, and in Africa specifically. Using limited soil resources for 'another' cash crop should thus not be promoted. Palm oil plants, however, can also be good sources of edible fruits, palm wine, and palm hearts. *Borassus aethiopum* yields a sweet sap rich in sugars, is a source of palm wine whereas fruits are also eaten. *Metroxylon* spp. (sago palm, amylaceous pith inside the trunk) and *Phoenix paludosa* (palm hearts, but also the host of the edible and eaten palm worm) are other possible contenders.

Mushrooms

Worldwide, mushrooms are collected and used for food and medicine. A number of them can be cultivated, thus adding value to organic waste (growth medium) and creating additional incomes for local communities. Their sustainable collection can feed into production-marketing chains with international importance.

Fodder

The African continent also has some species that are valuable sources of fodder or browse: *Acacia* spp. and *Atriplex* spp. occur in dry and saline environments, resp. *Prosopis* spp. have been introduced from elsewhere; their sweet pods are rich in energy and can also be used as fodder.

Alternative sources of employment/income generation

Southern Africa has a number of bamboo species that can be used in construction, as a source of fibre for paper, etc. Rosin and turpentine/resins, and gums are produced by a number of broadleaved species, such as *Sterculia setigera* (gum for cooking) or figs (*Ficus* spp., idem) whereas *Pinus* spp. bark can also be rich sources of resins. Tannins are collected from a number of *Acacia* spp. (notably *A. nilotica*), *Rhizophora* and *Avicennia* spp. (which are mangrove species) and also *Quercus* spp. Tasar silk (sericulture) is produced by *Antheraea* spp. (butterfly) feeding on *Terminalia tomentosa, T. arjuna,* or *Ziziphus mauritiana*.

A special case is offered by *Quercus suber*, the cork tree, whose bark is used in a wide variety of applications. Cork's elasticity combined with its near-impermeability makes it suitable as a material for bottle stoppers, especially for wine bottles. Cork stoppers represent about 60% of all cork-based production. Cork's low density makes it a suitable material for fishing boats and buoys, as well as handles for fishing rods (as an alternative to neoprene). Cork is also used in the manufacture of musical instruments, particularly woodwind instruments, where it is used to fasten together different segments of the instrument and make the seams airtight. Sheets of cork, often the by-product of more lucrative stopper production, are used to make floor tiles and bulletin boards. Granules of cork can also be mixed into concrete. The composites made by mixing cork granules and cement have low thermal conductivity, low density and good energy absorption characteristics. Some of the property ranges of the composites are density (400–1500 kg/m^3), compressive strength (1–26 MPa) and flexural strength (0.5–4.0 MPa) (Karade, 2003).

Honey and beeswax are interesting by-products of beekeeping. As such, the latter activity is well-suited to developing countries, requiring little capital injection, and making virtually no demands on natural resources. Beekeeping may be carried out in conjunction with subsistence and modern agriculture (any scale of operation) and can be an integral part of an agricultural management system.

Acacia senegal, a source of tannins, also provides gum arabic, fodder, fuelwood, poles, whereas its N-fixing properties make it well-suited for integration in agroforestry systems.

Aloë spp. are among the newer, niche commodities (see *infra*) that have entered formal commercial markets. The genus is native to Africa and is common in South Africa's Cape Province and the mountains of tropical Africa (especially East Africa), and neighbouring areas such as Madagascar, the Arabian Peninsula and the islands off Africa. Where they occur in Africa, they are collected and processed into cosmetics and skin products (Figure 1). *Aloë* species are also frequently cultivated as ornamental plants both in gardens and in pots. Many *Aloë* species are highly decorative and are valued by collectors of succulents. Some species, in particular *Aloë vera* are purported to have medicinal properties. Other uses of aloës include their role in alternative medicines and in home first aid. Both the translucent inner pulp as well as the resinous yellow exudate from wounding the aloë plant are used *externally* to relieve skin discomforts and *internally* as a laxative. To date, research has shown that *Aloë vera* produces positive medicinal benefits for healing damaged skin. Conversely, other research suggests *A. vera* can negatively effect healing (Vogler and Ernst, 1999). Some *Aloë* species have also been used for human consumption. For example, drinks made from or containing chunks of aloë pulp are popular in Asia as commercial beverages and as a tea additive; this is notably true in Korea. Aloë is used externally to treat a number of skin irritations. It has antiseptic and antibiotic properties which make it highly valuable in treating cuts and abrasions. It has also been commonly used to treat first and second degree burns, as well as sunburns and poison oak, poison ivy, poison sumac infections, and eczema. It can also be used as a hair styling gel and works especially well for curly or fuzzy hair. Aloe contains a number of medicinal substances used as a purgative. The medicinal substance is produced from various species of aloë, such as *A. vera*, *A. vulgaris*, *A. socotrina*, *A. chinensis*, and *A. perryi*. Several kinds of aloës are commercially available: Barbadoes, Socotrine, Hepatic, Indian, and Cape aloës. Barbadoes and Socotrine are the varieties most commonly used for curative purposes. Aloë juices are the expressed juice of the leaves of the plant. When the leaves are cut, the juice that flows out is collected and evaporated. After the juice has been removed, the leaves are sometimes boiled to yield an inferior kind of aloes. The juice of the leaves of certain species, e.g. *Aloë venenosa*, is poisonous.

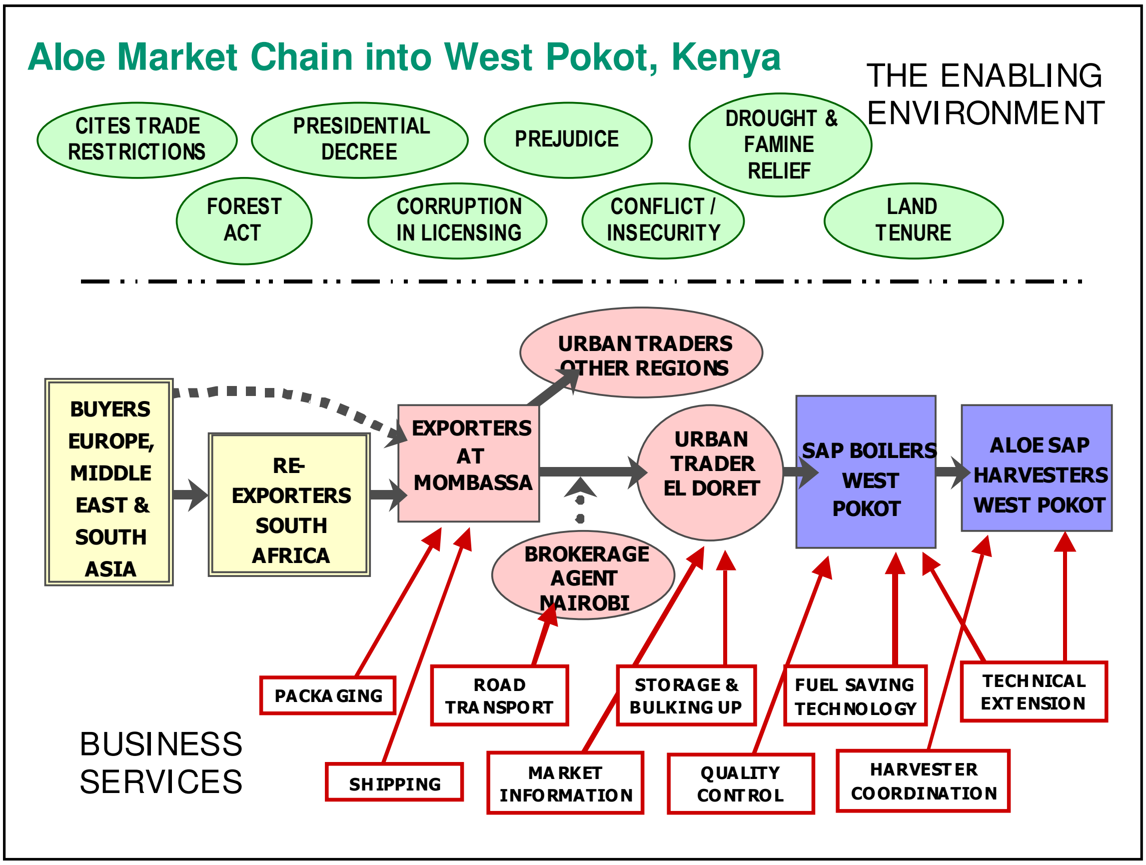

Figure 1. Specific 'market map' developed from figure 1 (in collaboration with local stakeholders) and applied to *Aloë* spp. market chain with red arrows showing which activities in the market chain require specific services (from Hellin *et al.,* 2005)

FROM UNDER-UTILISED CROP TO NICHE MARKET DEVELOPMENT

Ethnobotany and useful plant inventory work in general, can yield interesting information on which species could and should be developed into commodities for greater food safety and income generation. In a global market with increased competition for a limited number of 'universal' products, new players should try to focus on niche commodity production as the latter will allow conquering new markets with new products for which prices can be fixed by producers. Figure 2 provides a schematic representation of production, market chain and the (enabling) policy and socio-economic environment in which it operates, together with the business/extension services it needs in order to operate properly (from Hellin *et al.,* 2005)

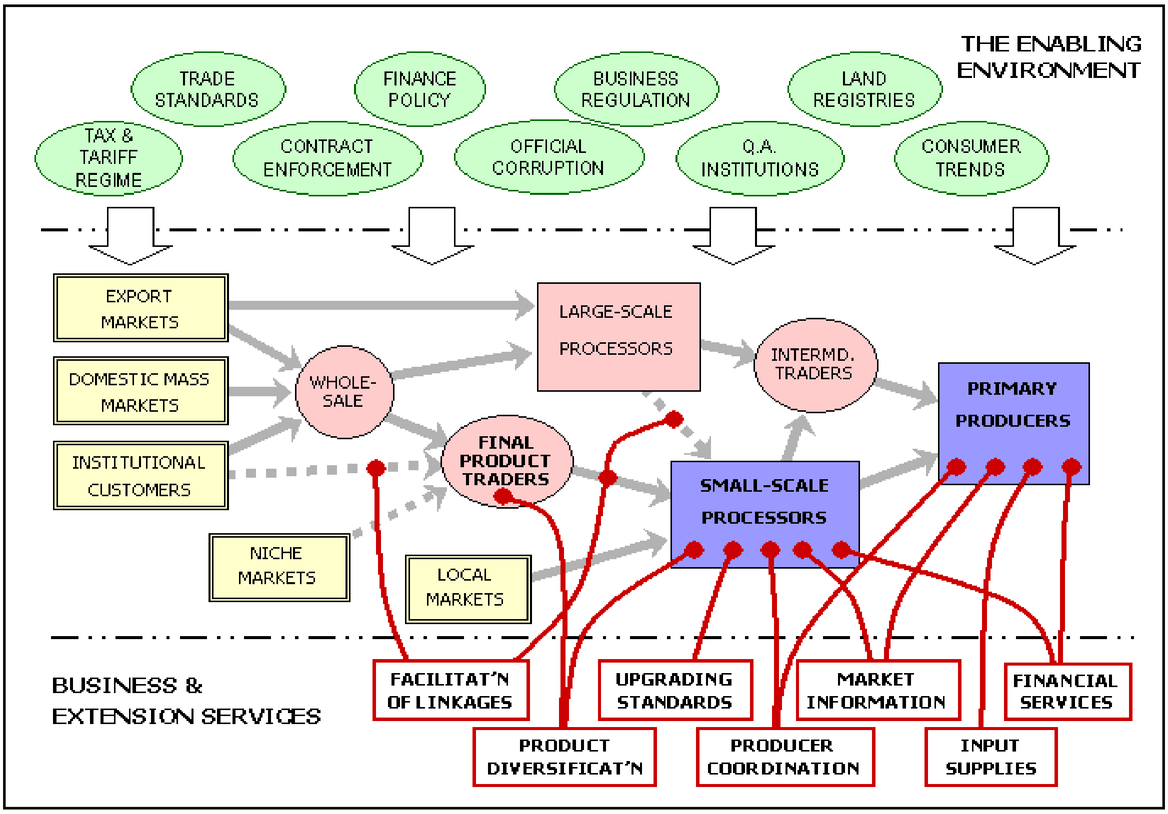

Figure 2. General 'generic' and schematic representation of any production (from Hellin *et al.,* 2005)

According to Van Damme (1998), niche crops (should) have the following profile:

(1) be *multi-purpose*, combining a subsistence and/or cash finality, with erosion control and/or another function which makes them interesting to integrate in the (existing) cropping cycle and farming system;

(2) have a *local market (potential)* so that dependency on regional and/or international markets and prices remains limited;

(3) preferably *combine food and non-food properties* so that when the formal market collapses, producers can continue to use the commodity for auto consumption;

(4) be *annual*, or *short-cycle, crops* as this allows for a quick, i.e. on a seasonal basis, change of commodity produced when economic/environmental needs arise;

(5) have *high rusticity*, i.e. be well-adapted to local circumstances and have enough plasticity to guarantee high yields in different and/or changing environments, whereas they are tolerant of/resistant to the most important pests and diseases which are known to be a problem; ideally, the latter property should be combined with

(6) *limited need for modern/imported inputs*; and
(7) *limited need for qualified/specialised labour*; whereas still
(8) *guaranteeing high yields* and (by extrapolation returns on investment through) *rewarding market prices*;
(9) be *easy to store* without excessive losses nor input use; whereas it should
(10) be *easy to dry/process harvests* locally with limited level of costly technology; and also
(11) easy to *transport* the commodity or its processed products at later periods over large distances at low cost;
(12) *bulking of produce* is a further plus; whereas it should also be possible
(13) to grow these crops *intensively on small plots*.

In other words, niche commodities respond to (new) needs and/but also allow creation their own markets, and thus market dynamics and prices. As they do not compete with existing products, unit selling prices will be rather high especially in the beginning of their development. In the recent past, *Simmondsia chinensis* (jojoba) and *Aloë* spp. have been developed into income-generating commodities for novel markets. Jojoba is the source of a wax that replaces sperm whale oil (for *Aloë*, cf. *supra*). A number of the species presented *sub.* 3 are good candidates for similar niche product development, if a number of crucial issues are addressed.

From a study carried out by Gabre-Madhin and Haggblade (2001) on successes in African agriculture, it became clear that few (African) countries have accorded agriculture the necessary priority, either in policy debates or investment allocations, to sustain agricultural support institutions capable of generating a steady stream innovations and growth. This persistent under-investment in frontline agricultural research and related support institutions appears puzzling at first. But after spending some time in African ministries of finance, it quickly becomes clear that narrow tax bases coupled with enormous debt loads and donor-imposed priorities on social spending leave little room for manoeuvre or debate over the relative role of productive investments in agriculture. An opening up of these budget debates will require a renewed commitment to agriculture by both African governments and donors.

Governments wishing to intensify smallholder agriculture under circumstances where the necessary markets were/are absent or weakly developed should leave market activities to the private sector and try to foster market entry, investment and technological progress via interventions that promote institutional development (such as appropriate legislation, improved transport and social infrastructure, and administrative and legal services).

Public policy and developmental initiatives to encourage linkages between farmers and agribusiness include both direct and indirect support to smallholder market linkages and more general support to the smallholder sector. Direct support measures include the promotion of grassroots cooperation and facilitation by a specialised non-governmental organisation (NGO) increasing the business and technical skills of groups and developing good working relationships between groups and agribusiness.

Major donors have an important role to play to help farmers' organisations enter the policy dialogue with governments and other stakeholders so that an enabling environment (legal context for cooperatives and associations, taxes, regulations, and input quality control, level playing field for all suppliers) can be created. Donors could support farmers' organisations and governments establishing forums for policy dialogue between government, farmers' organisations (FO) and donors. It can also facilitate the linkages/interactions between producers and other stakeholders, such as input suppliers.

Donors should ensure that funding for FOs' capacity building, advisory services, communication, networking, etc. is available at decentralised levels and that decisions to allocate funding be in the hands of FOs. Funding should be available not only for services but also for improving local infrastructure in support of input supply and marketing, such as storage facilities

Amongst the strong feelings that FOs are the key to future agricultural development were some warning voices against placing too much emphasis on FOs. These warnings came from different angles (Dirckx and Van Damme, 2001). In a field survey *cum* interviews organised by the latter authors, some companies expressed disillusionment with working with groups. They felt that it is wasting effort to do so and that it is forcing something onto rural areas that is not appropriate at this stage in their development. They believe that the focus should be more on individuals than on groups, the need is to strengthen the entrepreneurial base in the rural areas. That will have more impact than trying to force groups into existence. Therefore, the establishment of associations should only be promoted if that is the way that people in that particular area want to go.

Gabre-Madhin & Haggblade (2001) state that although some observers remain sceptical whether NGOs could replace government extension services, many respondents in their survey cite cases in which NGO projects provide extension support to understaffed and underfunded government extension services. Ultimately, the thorny issues of public salary levels, recurrent transport budgets and adequate staffing for government extension services remain closely linked to the debate over the relative role of NGOs in African agriculture.

NGOs often mandate themselves to concentrate substantial resources on a small number of villages, often in difficult areas. This favours the development of innovative, empowering approaches, but at levels of unit cost beyond the reach of the public sector. Wide-scale reliability should be a key design criterion for any future approaches developed by NGOs or 'special projects'.

During our field survey, it was also found that there was a lack of information sharing between **(international and local) (non-governmental) organisations** implementing projects to enhance rural development, marketing strategies for small-scale farmers, organisation of farmers in groups, etc. In this context, the Forum for Agricultural Research in Africa (FARA; www.FARA-Africa.org) has an essential role to play in guiding international policy makers in developing enabling policies for agricultural and niche commodity development in Africa. The Sub-Sahara Africa Challenge Programme which is lead by FARA offers a good opportunity to put theory into practice…

It could be of great value to look for mechanisms of information sharing between such organisations as much can be learnt from each others' experiences and the impact of certain activities could be improved.

CONCLUSIONS

To conclude, it can be said that donors and NGOs together with governments, have an important role to play in linking small-scale farmers to commercial sector activities, and to develop niche commodity value chains. By being a broker, NGOs can ensure that small-scale farmers' rights are protected in relations (e.g. in contract farming) with private agribusinesses that are in the early stages of privatisation. Contract farming often requires organisation of farmers in groups. Promotion of such groups should only be taken up if it is felt necessary by farmers themselves and in a way farmers feel confident with it. Through contract farming, farmers' organisations can grow and learn to undertake marketing activities by themselves. The final objective should always be to create independent farmers' organisations that are free to take their own marketing decisions, without being tied to an agribusiness company that has power to violate farmers' rights.

There are different crops or commodities which can be developed out of useful plant species that have shown potential to become the basis for niche products following ethnobotanical research, and which can become important cash crops for farmers, but choices on which species to develop should be made only after domestication trials have proven successful and following careful market studies as these will differ for each situation/species.

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3

Contribution of molecular genetics for new crops development

Kornelia Polok, Tadeusz Korniak and Roman Zielinski

Underutilised crops adapted to a wide range of environments, may constitute an important part of the diet, require a relatively low input and thus contribute to high agricultural sustainability. However, research in developed countries ignored or paid little attention to them and consequently, they are not able to compete with improved cultivars of major crops although they have potential to be economically viable. The major factors hampering the development of underutilised crops include lack of genetic improvement and knowledge of genetics of quality traits and agronomy. Further constraint to the wider utilisation of traditional crops is predominantly hampered by the low interest of farmers, who are afraid of the risks of cultivation, a lack of the market as well as a lack of experience together with inadequate financial resources.

In many cases key constraints to higher productivity and utilisation of traditional crops are caused by specific bottlenecks such as uneven maturity, lodging as a result of tall stem and narrow genetic diversity for important agronomic traits. All these limitations can be overcome by application of various modern genetic and biotechnological techniques already developed for major crops. Genomic studies are improving our understanding of complex characters as well as providing the basis for effective breeding strategies. The successful implementation of these studies to underutilised crops will have an impact on their wider utilisation. The present work describes several examples of successful implementation of advanced molecular genetic technologies to genetic improvement of traditional crops including cereals with special emphasis on bristle oat, *Avena strigosa* and legumes. The potential value of transformation technology will also be discussed. Moreover, the economic aspect of the application of molecular methods to underutilised crops is considered.

INTRODUCTION – RATIONALE FOR PROMOTING UNDERUTILISED CROPS

Agricultural productivity has increased in the second half of the twentieth century but has reduced the natural resource base including diversity of species used for food and the genetic diversity of crops. Moreover, other aspects of the ecosystem such as the water table have been altered in addition to soil erosion and acidification. It has been estimated that there are between 300,000 and 500,000 species, of which about 6000-7000 are known to have been cultivated at one time or another and another 25,000 species have been used as herbal medicines. Over the centuries economically more important crops have replaced many traditional varieties and landraces of minor crops and today only 120 plant species are cultivated on a wide scale, 30 of which have become the basis of the human diet providing 95% of calories and protein requirements. Of these only 12 provide

75% of the world's food supplies and the three major crops, rice, wheat and maize provide 50% of world food (FAO, 1996; Heywood, 1999; Thies, 2000). The decline in the diversity of crops is responsible for malnutrition caused by deficiencies in vitamins and minerals. For example, vitamin A deficiency affects about 40% of the human population, predominantly in South Asia and it is often accompanied by microelements deficiencies. An emphasis on major crops has led to neglect of fruits and vegetables, which are excellent sources of vitamins and micronutrients (GRAIN, 2000).

Not only is the number of cultivated plant species relatively small but also the genetic basis of major crops is very narrow. Modern cultivars, which are the products of plant breeding are characterised by their high level of genetic uniformity. They are sometimes called high-yielding or high-response cultivars because of the high yield produced when supplied with high levels of fertilisers. As a result today's large-scale agriculture is focused on monocultures in which large areas are planted with one or a few cultivars. For instance, over 67% of wheat fields in Bangladesh were cropped with a single cultivar, Sonalika in 1983 (unpublished). Similarly, in Ireland about 90% of the total wheat area has been sown with just six cultivars (FAO, 1996). These cultivars usually exhibit broad adaptability i.e., they can grow over a wide range of areas and climatic conditions but they demand a high level of fertilisers and pesticides, which poor farmers cannot afford. Furthermore, although they have high yield potential, it cannot be achieved in marginal lands, thus sowing modern cultivars involves a high risk of failure under adverse environmental conditions, and pest or disease attacks. Even if cultivars have different names, the degree of genetic difference between them may be small. One striking example involves hexaploid wheat, *Triticum aestivum*, genetic resources of which are limited due to both evolutionary processes and losses resulting from the "green revolution", which introduced semi-dwarf, lodging resistant and high-yielding cultivars. Our studies indicate that modern wheat cultivars are difficult to separate even if high resolution DNA markers, such as AFLP are used (Figure 1). Genetic similarities between five wheat cultivars of different origin, Elena, Eta, Monsun, NAD and Torka were very high and ranged from 0.91 to 0.98 with an average value of 0.94. Among 81 identified bands only five were specific to a single cultivar which made impossible cultivar identification based on AFLP fingerprints. Eventually, separation of wheat cultivars was possible when markers based on polymorphism of DNA transposon insertion sites were used. In total 18 cultivar specific bands (21%) were revealed and genetic similarities were significantly lower (from 0.65 to 0.80) with an average value of 0.76.

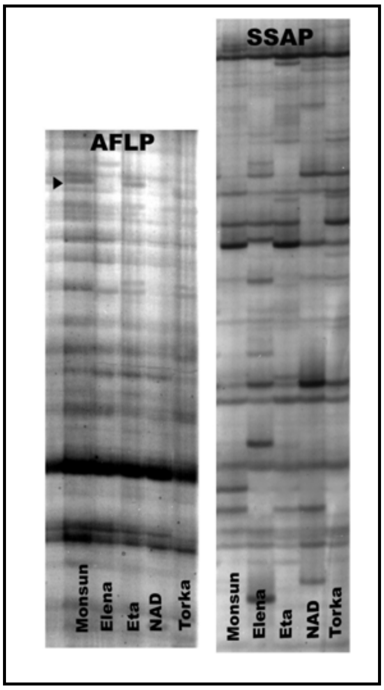

Figure 1. Comparison of AFLP and SSAP diversity of wheat cultivars

The immediate effect of genetic uniformity is similar susceptibility to pests, diseases and other environmental hazards. In the former Soviet Union, the winter wheat cultivar, Bezostaya had been grown over large areas until most crops froze during a severe winter in 1972. In 1975, a new pathogen *Sclerotinia trifolium* killed off populations of *Trifolium repens* (white clover) in Great Britain because all cultivars were susceptible (FAO, 1996).

In contrast, many minor crops contain a high level of genetic diversity. In wild barley (*Hordeum spontaneum*) 93% of AFLP loci are polymorphic, each genotype has a unique banding pattern and the genetic similarity coefficient varies between 0.74 and 0.98 (Turpeinen *et al.,* 2003). Another example involves wild rice (*Oryza granulata*), in which the high diversity is observed between populations originating from different regions of China as indicated by 73% of polymorphic RAPD and 49% of ISSR markers (Qian *et al.,* 2001). Extremely high enzymatic variability with more than nine alleles per locus has been recorded in 130 European traditional maize populations. A higher number of alleles are observed in South-Western Europe than in North-Eastern Europe which probably results from a loss of genetic diversity due to selection for tolerance of lower temperatures in the latter (Rebourg *et al.,* 2001).

The term “minor crops” or “underutilised species” cover a broad spectrum of species of varied uses whose potential has not been fully realised. These species are less used because they are not able to compete with modern cultivars of major crops in the same agricultural environment. Minor species are characterised by varying degrees of under-use and neglect. They include landraces or traditional varieties (farmers’ varieties) of major crops, that have been selected by farmers over many generations, neglected crops that used to be cultivated and that are still grown in their centres of origin but neglected by research and conservation, vegetables, fruits and wild species gathered for food, medicinal uses or other uses, multipurpose and wild trees important for agroforestry systems as well as cultivated and wild species that contribute to agricultural diversification (FAO, 1996; IAEA, 2004).

In many instances, these underutilised crops are adapted to a wide range of environments and soil conditions. Adaptation to slightly different conditions very often correlates with protein or DNA diversity. In wild emmer wheat (*Triticum dicoccoides*), for example, enzymatic and microsatellite diversity displays considerable regional and local differences (Nevo, 1983; Li *et al.,* 2002). The same is true for enzymes and hordein polymorphism in wild barley (*Hordeum spontaneum*), which is adaptive and selected by soil and topographic differences over very short distances. About 56% of all variant enzymatic alleles are not widespread but reveal localised and sporadic distribution (Nevo *et al.,* 1983). Accumulated data has also indicated that transposons respond to various environmental stresses. For example, in *H. spontaneum*, a simultaneous increase in the *BARE-1* copy number is connected with height and adaptions to drier conditions. This particular variation is remarkable as a nearly three-fold range in copy number has been observed. A noteworthy connection between the presence, within the *BARE-1* promoter of abscisic acid-response elements, and copy number variation suggests that transposon proliferation may be stress-induced (Kalendar *et al.,* 2000). Similar changes are observed in *Lolium multiflorum* and *L. perenne.* The copy number of the *Tpo1* DNA transposon reflects a slow, but significant increase in *L. multiflorum* in comparison with *L. perenne*. About 16% more *Tpo1* insertions are present in the former. Dramatic evidence for genome increase in *L. multiflorum* also emerged with *Lolcopia1*. About 40% more copies of this retrotransposon have been observed in *L. multiflorum,* suggesting that *Lolcopia1* is active in this species and may be correlated with adaptation to hotter and drier summers in Mediterranean countries, where it is predominantly sown (Polok, 2007).

Many underutilised crops constitute an important part of the diet being a source of vitamins, minerals, amino acids and other components which complement the daily demand for nutrients. *Avena strigosa*, (bristle oat, black oat) contains more proteins, lipids and carbohydrates than *A. sativa*, promoted for healthy food (Korniak and Kuszewska, 1999). The species has other commercially attractive characteristics such as high vitamin and β-glucans content. Another good example involves *Pisum sativum*, whose yield and utilisation are below its potential, but which has excellent protein content and may constitute an important complementation of major cereal-based diets.

Another advantage of underutilised crops is that they often require a relatively low input and thus contribute to high agricultural sustainability. Bristle oat, *A. strigosa* is especially adapted to marginal, acid soils with pH 4-5, and it is frequently found in the areas where even *A. sativa* or *Secale cereale* (rye) known as crops of poor soils do not grow well. Our observations suggest as well that it is drought resistant. On marginal lands or with no input of fertilisers, all bristle oat ecotypes produce significantly more grain than *A. sativa* and the majority of them produced two or three times higher as indicated by grain weight per plant (Table 1). With respect to the best ecotypes, grain yield was comparable to *A. sativa* when sown on high quality soil or when fertilisers where applied. However, some ecotypes still exhibited a higher seed number in comparison with hexaploid oat. Low soil fertility requirements make *A. strigosa* a species especially recommended for high mountains, rocky coastlines and other drought prone areas.

Table 1. Comparison of *A. strigosa* height and grain yield per a plant on different types of soil[1]

Ecotype[2]	**Country of origin**	**Height [cm]±SD**		**Seeds per a plant [n]±SD**		**Grain yield per a plant [g]±SD**	
		Low input	High input	Low input	High input	Low input	High input
51105	France	**99.5±9.6**	**08.4±11.4**	**139.8±9.1**	180.0±77.3	1.6±0.1	2.2±1.1
51499	Caucasus	**109.8±8.6**	**103.9±9.2**	**227.3±38.3**	221.6±96.9	**2.6±0.6**	2.9±1.0
51520	Poland	**90.6±9.9**	**92.2±2.6**	**182.4±45.5**	272.9±99.1	**2.2±0.4**	3.4±1.8
51523	Poland	**89.9±9.9**	**105.9±10.6**	**129.3±46.4**	234.2±82.1	1.4±0.4	3.4±0.7
51578	Uruguay	**109.6±5.9**	**86.2±10.9**	**179.6±28.8**	91.3±69.7	**2.0±0.7**	1.4±1.1
51579	Russia	**119.7±10.1**	**115.9±9.5**	**272.7±91.7**	222.6±99.9	**3.7±1.8**	3.1±1.4
51582	Spain	**106.4±16.3**	**116.6±9.7**	**187.2±69.9**	267.8±16.5	**2.8±1.0**	3.9±1.0
51584	France	**84.6±5.8**	**92.7±12.0**	**179.6±28.8**	218.5±90.1	**2.1±0.3**	3.0±1.3
51598	Poland	**97.8±6.5**	**102.0±6.7**	**167.6±18.4**	178.8±47.8	**2.2±0.1**	2.1±0.5
51730	Brazil	**101.8±0.4**	**96.0±1.4**	**105.1±75.1**	145.5±62.9	1.7±1.0	2.4±1.1
51731	UK	**109.6±5.4**	**110.4±16.7**	**188.1±25.9**	177.6±90.0	**2.1±0.3**	2.3±1.3
51733	Spain	**113.7±10.4**	**91.0±18.4**	**213.7±91.9**	72.5±57.3	**4.2±2.7**	1.4±1.1
51734	Slovakia	**102.3±5.1**	**113.0±7.3**	**209.7±12.5**	**320.3±92.9**	**2.6 ±0.1**	4.1±1.5
51736	Slovakia	**95.3±6.3**	**102.4±1.9**	**190.8±75.9**	157.0±31.4	**2.4±1.0**	2.0±0.3
51741	Spain	**106.9±4.0**	**93.1±7.1**	**200.0±60.3**	193.2±90.1	**2.9±0.6**	2.7±1.4
51742	Spain	**97.7±19.1**	**99.8±5.6**	**170.3±51.4**	261.2±77.4	**2.4±0.8**	3.4±1.1
51747	Unknown	**91.6±13.4**	**104.3±12.5**	**192.4±72.4**	158.2±81.2	**2.0±0.7**	2.1±1.0
51750	Poland	**114.5±4.0**	**103.8±11.9**	**174.1±72.9**	116.1±94.8	**2.6±1.3**	1.7±1.3
51755	Poland	**109.2±7.2**	**100.1±6.0**	**197.6±66.0**	274.0±37.7	**2.6±0.7**	3.6±0.4
Sub-pilosa[3]	Poland	**109.2±7.2**	**108.2±10.9**	**197.6±66.0**	191.7±12.1	**2.6±0.7**	2.6±0.3
Gla-brescens[3]	Poland	**91.3±3.6**	**100.0±7.1**	**153.5±43.8**	160.7±50.8	1.9±0.6	2.0±1.8
A. sativa	Poland	65.8±8.1	76.5±6.3	50.3±2.8	231.3±50.1	1.2±0.1	6.2±0.7

Bold - significantly higher values than in *A. sativa* for LSD test at P=0.05
[1]Experimental field was located in Trzebawie, West Pomerania, Poland
[2]Received from Institute of Plant Breeding and Acclimatisation. Radzikow, Poland
[3]Collected by Tadeusz Korniak in north-east part of Poland

Despite excellent features and an important role in sustaining food diversity and well being of urban populations' underutilised crops receive little attention in RTD policies which makes them unattractive to farmers and could ensure their extinction. The crops, which are currently underutilised or have become extinct, were greatly used in the past as for example naked barley, bristle oat and common buckwheat in Europe. *A. strigosa* used to be cultivated in mountainous areas of Poland, but now it is rare or extinct.

MOLECULAR GENETIC APPROACHES FOR OVERCOMING CONSTRAINTS TO HIGHER PRODUCTIVITY OF UNDERUTILISED CROPS – PERSPECTIVES OF APPLICATIONS

The major factors hampering development of underutilised crops include a lack of genetic improvement and knowledge not only of genetics of quality traits and agronomy but also there is little information about their distribution, diversity and reproduction. Increased knowledge of minor crops is a *sine qua non* of their rational utilisation. Wider utilisation of traditional crops is predominantly hampered by the low interest of farmers, who are afraid of the risks of cultivation, a lack of the market as well as a lack of experience together with inadequate financial resources. Thus, availability of improved cultivars, which could ensure a considerable economic profit, may significantly increase cultivation of traditional species, especially on small farms.

In many cases key constraints to higher productivity and utilisation of traditional crops are caused by specific bottlenecks such as uneven maturity, lodging as a result of tall stem and narrow genetic diversity for important agronomic traits. Broader cultivation of *A. strigosa* is seriously limited by its height that makes it prone to lodging (Figure 2). Even when grown on poor soil, all ecotypes were significantly taller, by 29% to 82%, than *A. sativa* (Table 1). The same problem is encountered in *P. sativum*, which tendril rich cultivars have not overcome. During wet and hot summers, the majority of modern pea cultivars tend to grow tall and consequently lodge. This in turn causes serious yield losses and it is the main reason of farmers' reluctance to cultivate it.

Figure 2. Comparison of *A. strigosa* height with modern cultivars of major crops
Left – *H. vulgare* (barley), right – *A. strigosa* (bristle oat)

Many of these limitations can be overcome with the help of various modern genetic and molecular technologies already developed for major crops. The application of these in underutilised crops should address the challenge of sustaining their diversity and improving their performance according to breeders' and consumers' needs. Nowadays, molecular approaches available for many plant species offer tremendous possibilities for genetic diversity assessment, improving our understanding of complex characters as well as providing the basis for effective breeding strategies when coupled with more traditional methods. Molecular markers are among the most promising, reliable and effective tools for basic and applied research. Their use can range from population genetic and evolutionary studies to construction of genetic maps and tagging genes responsible for economically important characters including loci associated with quantitative traits (Quantitative Trait Loci – QTLs).

A diverse array of molecular approaches including isoenzyme and DNA markers is available for genetic improvement of many crops. The advantage of all DNA methods is that they provide direct access to the genomes of many organisms, and permit making all possible intra- and interspecific comparisons using the same type of data and can be developed easily for any underutilised, neglected or wild species. The genome scanning molecular markers (Random Amplified Polymorphic DNA - RAPD, Amplified Fragment Length Polymorphism - AFLP), markers partially complementary to intron splice junctions (ISJ), markers based on repetitive sequences (Simple Sequence Repeats – SSR) or transposons (Sequence Specific Amplification Polymorphism – SSAP) have a wide variety of applications along the phylogenetic hierarchy, especially in estimating genetic diversity and pairwise similarity (distance) between individuals from the enormous number of loci. Furthermore, routes of species migrations can be studies by analysing chloroplast (cpDNA) or mitochondrial DNA (mtDNA).

Notwithstanding objections related to usefulness of some molecular markers in genetic diversity and evolutionary studies, the emerging consensus from our studies in *Lolium* seems to be that the most of DNA marker categories give similar results and that the parameters of genetic diversity are comparable to those obtained by means of isozymes (Table 2). The slightly higher efficiency of enzymatic markers argues for their further applications when DNA analyses are troublesome due to difficulties of obtaining high quality DNA extracts, a shortage of financial and technical resources and in simple initial studies, in which the overall view is important. From other markers, it is noteworthy that ISJs and RAPDs produce results almost the same as from enzyme studies. It transpires that in spite of many objections found elsewhere in the literature, if properly done, RAPDs do offer a quick way of screening potential molecular markers from many loci. However, a prerequisite is DNA of high purity, which cannot always be obtained using rapid isolation methods or commercial kits.

Table 2. Comparison of genetic variation parameters in *L. multiforum* and *L. perenne* based on different molecular markers

Method	**Parameter**								
	P	**A**	**N_e**	**H_T**	**H_S**	**D_{ST}**	**G_{ST}**	**F_{IT}**	**F_{IT}**
Enzymes	80%	1.86^{a}	1.57^{a}	0.342^{a}	0.271^{a}	0.117	0.340^{b}	0.207^{c}	0.002^{b}
cpDNA	45%	1.45^{d}	1.32^{de}	0.172^{f}	0.070^{c}	0.118	0.249^{b}	0.394^{bc}	0.383^{a}
mtDNA	52%	1.53^{cd}	1.38^{bcd}	0.214^{de}	0.078^{c}	0.131	0.303^{b}	0.502^{ab}	0.384^{ab}
RAPD	64%	1.73^{ab}	1.44^{bc}	0.254^{bc}	0.111^{bc}	0.160	0.590^{a}	0.565^{ab}	0.004^{b}
ISJ	82%	1.82^{a}	1.46^{b}	0.270^{b}	0.271^{b}	0.161	0.530^{a}	0.496^{ab}	0.022^{b}
SSAP	57%	1.56^{cd}	1.29^{e}	0.214^{de}	0.074^{c}	0.141	0.333^{b}	0.657^{a}	0.005^{b}

[a]Different letters mean significant differences for LSD test at P=0.05

Genetic maps based on molecular markers can be used to determine linkage between a marker and an important trait and this association can be used to select individuals with a desirable character (Marker Assisted Selection – MAS). For example, the QTL responsible for size of flag leaves in *L. multiflorum* and *L. perenne*, located in the first linkage group is tightly linked with the locus encoding the fluorescent esterase. Moreover, a linkage between transposon markers and many QTLs controlling important agronomic characters have been recorded (Polok, 2007). This is a major advance for plant breeding as many traits are difficult to select on phenotype owing to strong genotype x environment interaction. Furthermore, colinearity and synteny of genetic maps within a plant family suggest that genetical knowledge of some traits can be also useful for the identification of interesting genes in underutilised species. Synteny refers to the occurrence of two pairs of homologous genes on the same pair of chromosomes while colinearity indicates the conservation of gene order and content. Both phenomena are well recognised in the *Poaceae* and in some degree in other plant families. If a dense gene map exists for a given species, molecular markers or candidate genes can be used to manipulate traits in another closely related species. A cautionary point should be made however, that the majority of data about colinearity have been obtained using heterologous RFLP (Restriction Fragment Length Polymorphism) probes that demand 70-80% sequence identity to cross-hybridise (Vision, 2005) and thus they can overestimate the level of colinearity and synteny. The analysis of comparative maps in the *Poaceae* shows that the probability of two adjacent markers being syntenic can be as low as 50% (Gaut, 2002). The other limitation is the difficulty in obtaining readable signals in related species. The emerging approach likely to overcome the barrier of high DNA identity takes advantage of large expressed sequence tags (EST) or sequence specific tags (STS), of which dozens are deposited in GenBank. The primers can be designed for conservative regions and then used to amplify a sequence in a species of interest. If it is possible to obtain a reproducible amplification pattern, preferentially a single band, and if it is also possible to find polymorphism between parents of a cross then such ESTs or STSs can be mapped. Finally, putative homologs can be sought using appropriate software available elsewhere. Recently, more than 1 000 EST (Expression Sequence Tags) loci have been mapped in barley (Stein *et al.,* 2007) and, they can provide new tags for useful characters in underutilised cereals. However, although the idea is simple, is not as straightforward as previously thought as has been demonstrated in *Lolium* mapping studies and in *P. sativum* (Polok, 2007). In the former either it is difficult to amplify a specific band using primers derived from *H. vulgare* or *A. sativa* genes or no polymorphism was observed in amplification products after restriction digestion. It is even more difficult to obtain a discrete band in *P. sativum* when primers derived from a model legume, *Medicago truncatula* are used. Eventually, amplification products obtained do not reveal restriction site polymorphism.

Surprisingly, the marker system based on conservative sequences of bacterial genomes has proved to be much more promising in tagging genes. The idea is based on using primers complementary to bacterial genes (B-SAP – Bacteria Specific Amplification Polymorphism) to amplify plant DNA and reveal polymorphism (Zielinski and Polok, 2005). Despite the fact that plants and bacteria are very distant, primers derived from bacterial genes amplify highly reproducible bands, which are very often species specific. In particular, the approach has proved to be useful for species identification within the *Poaceae* but it is also effective in pines (Polok *et al.,* 2006) and bryophytes (Baczkiewicz *et al.,* 2007). Revealed markers are dominant i.e., the presence of a band is dominant over its lack. The high efficiency of bacteria derived primer probably results from the fact that some plant genes evolved from a common bacterial ancestor. This assumption has been confirmed by linkage between bacteria derived markers and enzymatic loci in *Lolium*. Several primer categories can be used, however the best results, useable in many taxa are obtained through using primers complementary to the *Mycobacterium tuberculosis KatG* gene encoding catalase-peroxidase (B-SAP/katG). Most katG markers are linked with *Lolium* peroxidases but tight linkage is also observed with hexokinase (HK), NAD-dependand malate dehydrogenase (MDH), aconitase hydratase (ACOH), glutamate dehydrogenase (GTDH) and esterase (EST4). The linkage of katG markers and QTLs is confirmed for basal leaf colour, basal leaf length, flag leaf size (width and area), crown rust resistance and days from spring rush to ear emergence (Polok, 2007). The data for *Lolium* demonstrate therefore, that it is reasonable to put B-SAP/katG markers into programmes focused on genetic improvement of underutilised species as potential markers of useful genes.

Nevertheless, it should be remembered that each molecular marker assay has an intrinsic bias, and only a combination of several methods gives a clear picture of genetic diversity, evolutionary relationships and enables effective genetic improvement. For example, the high genetic similarity of *L. multiflorum* and *L. perenne* revealed by isozymes and random DNA markers (RAPD, ISJ) demonstrates that both taxa have a common gene pool and cannot be regarded as biological species. Eventually, transposon based, SSAP markers while confirming high genetic similarity, additionally provide data about their diversification and prove that *L. multiflorum* is younger than *L. perenne*. Similarly, AFLP markers used for *Lolium* mapping tend to cluster in centromeric regions and AFLP-based maps tend to have large gaps. When several marker types are used the gaps are avoided and markers are then more equally distributed over all linkage groups (Polok, 2007).

At this point we can consider the economic aspect of using molecular approaches to new crops. It is true that the more molecular data we consider the more we can identify how these can be more effectively employed in genetic improvement. This requires adequate laboratory, staff and financial resources. Although, such limitations are not a problem in Europe or other developed regions (North America, Australia), they can seriously hamper the widespread use of more refined DNA-based methods for underutilised crops in developing countries. When start-up costs are taken into account, it is obvious that each DNA based method is more expensive than enzyme electrophoresis on starch gels. Isoenzymes can be successfully used for genetic diversity assessment of any underutilised crop with only modest investment. There is no need for sophisticated equipment and chemicals. The cheapest enzymes such as peroxides or esterases give quite a good overview of genetic diversity comparable to DNA data (Table 2). They do not need any special extraction methods or chemicals that have to be transported and stored at low temperatures. Where technical facilities are available, and the whole spectrum of DNA methods is available, reaction costs are the only problem to consider. However, such considerations should take into account costs of a single reaction, the number of individuals to be assayed and expected outcomes. For example, total costs of a single AFLP or SSAP reaction together with costs of gel and silver staining is almost seven times more expensive than enzyme or DNA analyses such as RAPD (Figure 3). Proportions become inverted if the total number of identified loci is considered. To obtain 100 bands or loci one would cost about 10 euros if AFLP or SSAP markers are used but 100 enzymatic loci would cost about 40 euros if it is possible to obtain to carry out the analyses (Figure 4). Indeed, even RAPD markers are more expensive than AFLP/SSAP. These differences are even more dramatic if polymorphic loci are taken into account. Hence, if only cost efficiency is taken into account enzyme or RAPD markers can be chosen when only a few individuals are to be analysed, and there is knowledge of a relatively high polymorphism in a species of interest or it is the preliminary step of analysis. In species with low polymorphism, the choice of more sophisticated methods such as AFLP and SSAP seems more reasonable.

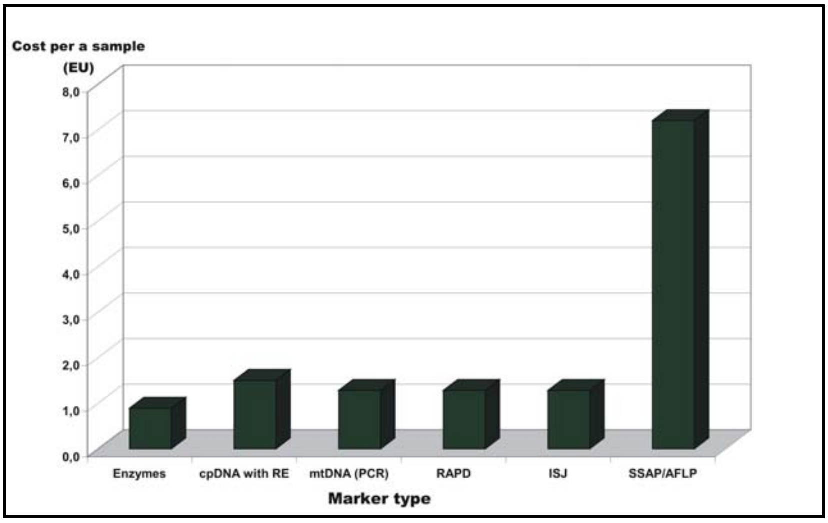

Figure 3. Total cost of a given marker type per a sample

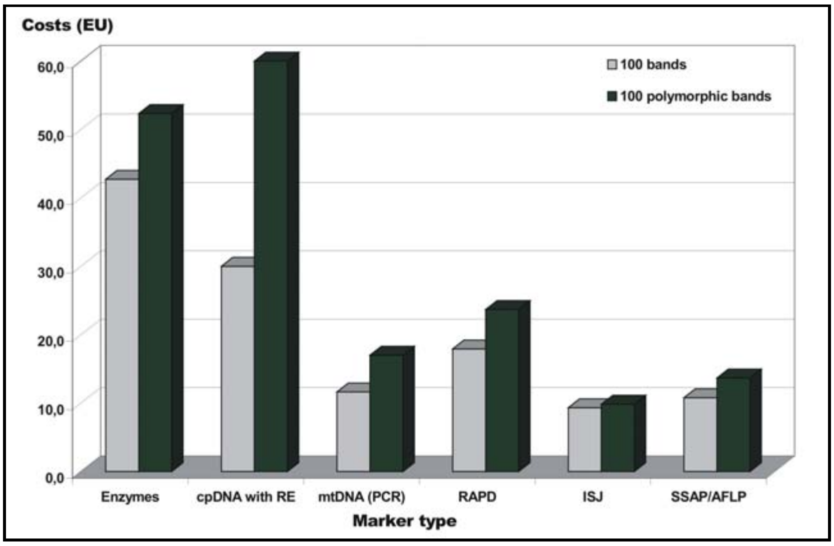

Figure 4. Costs to obtain 100 bands/loci and 100 polymorphic bands/loci per a sample

Genetic engineering is another method that has a great potential to increase the available gene pool. Not only genes originating from close relatives can be transferred but also previously inaccessible genes from virtually any species of plant, animal, fungi and bacteria. At present, genetic engineering is limited to one or a few genes that are introduced to high-yielding cultivars. However, its usage at present for underutilised species may be questioned.

Unfortunately, little attention has been given in applying all genomic technologies to underutilised species, especially those important for developing countries. The following sections present examples of application of molecular techniques in improvement of neglected, underutilised and wild species. Using *Lolium multiflorum* and *L. perenne* as examples, the possibilities of application of the most advanced molecular technologies to assess the potential of underutilised crops can be considered.

MOLECULAR APPROACHES FOR BIODIVERSITY AND CONSERVATION OF UNDERUTILISED CROPS

Rich genetic resources not only provide valuable genes but are also insurance against future hazards, pests and diseases. Agricultural biodiversity (agrobiodiversity) includes all species and crop cultivars, animal breeds and races, microorganism strains that are used directly or indirectly for food and in agriculture, both in human nutrition and animal feed (including grazing) for domesticated and semi-domesticated animals, and the range of environments in which agriculture is practised (Heywood, 1999). Analysis of genetic diversity in underutilised crops is necessary to find valuable characters, to determine evolutionary history in order to choose appropriate breeding strategies and to monitor genetic erosion (loss of genetic diversity) and gene flow between local and introduced species/cultivars.

In general, most of the diversity is found in landraces, ecotypes or local cultivars that have been developed through unconscious selection over centuries. These ecotypes are adapted to local environments, but they are at risk through replacement by modern cultivars of broad adaptability. Some landraces may represent very ancient, relict forms even from the periods before glaciations as has been proven for the *L. perenne* ecotype from the Tatras. The presence of cpDNA and mtDNA haplotypes together with a separate position in transposon based dendrograms as well as the presence of a unique peroxidase allele (*Per1-45*) suggests that this population has been genetically isolated for a considerable period of time. During the Quaternary Ice Ages, in contrast to the Alps, relatively small areas were covered by ice sheets in the Tatras. Presumably, perennial ryegrass populations in the Tatras were fragmented and more isolated but they survived the glaciation periods. Furthermore, due to difficult living conditions, and as a result of early protection, the local vegetation has not been disturbed for centuries. Traditional agriculture has prevented the extinction of old genotypes by crossing with modern cultivars (Polok, 2007). Foxtail millet, *Setaria italica* is another crop, for which higher genetic diversity has been preserved in some regions of Europe. This cereal of panicoid tribe is represented by three, rather homogenous genetically, geographical groups, one in Central Europe and two Asiatic groups. Studies based on RAPD polymorphism clearly show that lines from western Europe are highly heterogeneous with genotypes intermediate between the three other geographical groups whereas lines from central Europe are genetically uniform (Schontz and Rether, 1999).

Agricultural biodiversity involves also habitats and species outside farming systems but which benefit from agriculture or enhance it. Natural ecosystems form a part of the landscape within which agricultural systems are found and they are a source of valuable genes. They are responsible for soil stabilisation, water and air quality. Mossy peat-bogs that can be found in north-western parts of Europe constitute natural water reservoirs preventing floods and provide poor farmers with food (cranberries, medicinal plants) and fuels. However, the intensive drainage of peat-bogs has resulted in their drying out, and has affected the viability of agriculture in the vicinity and resulted in extinction of some genotypes. The process is well emphasised by disappearance of the relict genotype of *Pinus sylvestris* f. *turfosa* inhabiting some Polish peat-bogs both by invading peat-bogs by typical fast growing, forms of *P. sylvestris* and erosion of genetic resources through hybridisation between both forms (Polok *et al.,* 2005).

For centuries, exchange of genetic materials has led to the development of secondary centres of diversity for some crops but also resulted in disappearance of native species. At present agricultural production of developed countries is predominantly based on species originating from other regions. For instance, it is estimated that the whole food production in Australia and North America depends on alien species while Europe is 91% dependent on species from other parts of the world (FAO, 1996). This trend is also followed by minor crops. Even though Europe holds a significant diversity of native plants those that were spread many years ago alongside with the development of primitive agriculture, very often exotic or alien species to native flora are recommended for introduction as alternative crops. Examples include amaranth (*Amaranthus* ssp.) promoted in Europe as a nutritionally rich food and alternative source of energy, meadowfoam (*Limnanthes alba*) as a source of products for the cosmetic industry and others. The Polish Ministry of Agriculture recommends introducing *Solidago canadensis* as a nectar source for honey despite the fact that it is a highly invasive species, supplanting native *S. virga-aurea*. Moreover, hybridisation of both species may lead to genetic erosion of native forms. By contrast, Europe is a primary or secondary centre of diversity for many crops that used to be cultivated but are now abandoned or rarely found. This is true for such cereals as emmer (*T. dicoccoides*), spelt (*T. spelta*), naked barley, naked oat (*A. nuda*), bristle oat *(A. strigosa*), rye (*S. cereale*), foxtail millet (*S. italica*) and buckwheat (*Fagopyrum esculentum*), which is a pseudocereal. These species are well adapted to European conditions and could become a basic source for diversifying agriculture and food. For some of them sufficient genetic diversity exists providing rough materials for genetic improvements while others are genetically relatively uniform. An example of the latter is *A. strigosa*, genetic resources of which are highly homogenous and ecotypes from different parts of the world are much the same with respect to morphology and DNA profiles (Figure 5).

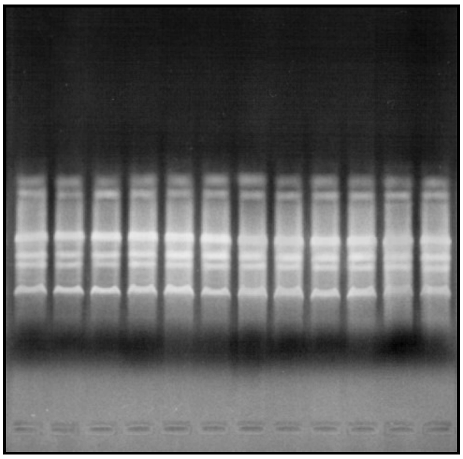

Figure 5. ISJ profiles of *A. strigosa* ecotypes

One of the key questions that have to be addressed when considering use of wild species as potential new crops is the availability of genetic material for genetic improvement. If there is not sufficient genetic diversity it should be widened. Induced mutagenesis is one of the most cost effective, simple and uncontroversial methods to reach this goal, but not often used for underutilised species. During mutagenic treatment many point mutations are induced in the genome and the diversity of induced mutants is often higher in comparison with cultivars or ecotypes. In *A. strigosa* it was possible to select 120 mutant lines originating from six ecotypes, 51499 (Caucasus), 51578 ecotype (Uruguay), 51584 ecotype (France), 51733 ecotype (Spain), 51730 ecotype (Brazil, old cultivar Saja3), and *A. strigosa* var. *glabrescens*, collected in north-east Poland. Owing to the selection goals, the majority of lines are dwarf or semi-dwarf, however other mutants were also found (Figure 6). Apart from morphological changes, high diversity of mutants was observed at the DNA level as indicated by ISJ or AFLP profiles (Figure 7). Similarly, induced mutants of pea fell into five morphological categories including dwarf mutants, root mutants characterised by a shorter root system but normal stem height, root mutants with a reduced number of lateral roots, a stem-less mutant (only roots developed), and *fasciata* mutants. The AFLP analysis of *P. sativum* mutants confirmed that chemical mutagens induce a high number of mutations in the genome. In total, more than 1000 bands were revealed and 51% of them were polymorphic. An average 14% of mutated AFLP loci were observed in each mutant. Once genetic diversity is available, the genetic improvement must be undertaken to obtain cultivars acceptable by farmers.

Figure 6. Examples of *A. strigosa* mutants

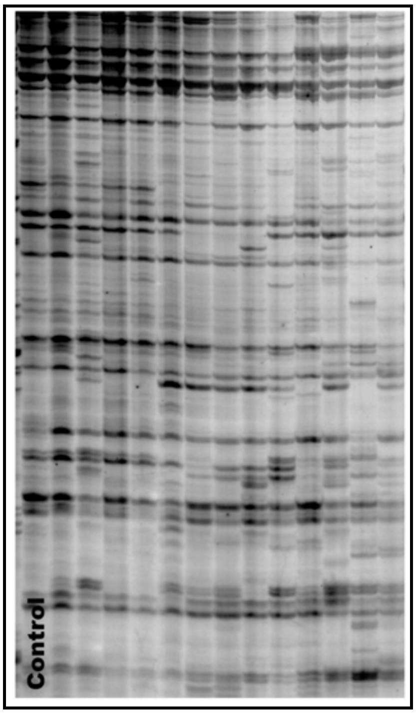

Figure 7. AFLP profiles of *A. strigosa* mutants

MOLECULAR APPROACHES FOR GENETIC IMPROVEMENT OF UNDERUTILISED CROPS

The broad gene pool of many underutilised species is not only a base for potential genetic improvement it also provides genes useful in plant breeding of major crops. The most common approach, introgression, is when a single gene is transferred into given genotypes through repeated backcrossing. Introgression is most frequently used for improving disease and pest resistance of modern cultivars. Resistant genes are obtained from either landraces or wild species. However, underutilised crops are also donors of such other useful characters as vigour and resistance to abiotic stresses. For example*, A. strigosa* can be a source of genes responsible for aluminium tolerance. Aluminum (Al) toxicity on acid soils is a major limitation to production of major cereals. It is a common element of the Earth surface, but only soluble forms are toxic. In pH above 5, Al is insoluble; hence it does not affect plant growth. In low pH, Al becomes soluble and toxic to plants inhibiting root growth. Among cereals, rye is one of the most Al-tolerant species, yet only half as tolerant as *A. strigosa*. The highest level of Al tolerated by rye did not exceed 300 µM whereas *A. strigosa* was not affected by 600 µM. The major component of Al tolerance throughout the Poaceae is controlled by the Alt_{BH} gene which presumably encodes malate transportase, ALMT1 (Caniato *et al.,* 2007). However, other minor epistatic genes also play a role and these genes may be responsible for the extremely high tolerance levels of *A. strigosa*.

Each species is valued for characters that are beneficial, including such traits as yield, biotic and abiotic stress resistance, some quality factors and many others. No species will be accepted by farmers, even it has excellent features unless it provides reasonable profits. The use of underutilised species is often limited by a single trait that seriously limits its productivity. Induced mutagenesis seems to be the most suitable method for improving lodging resistance in *A. strigosa* and *P. sativum*. A vast number of dwarf and semidwarf mutants were obtained in both species and some of them are very promising having a grain yield comparable to parental forms. In *P. sativum* the correlation between morphological changes and mutations at the molecular level was observed. All dwarf mutants derived from c.v. Piast carried an additional band in five AFLP loci while all dwarf mutants from cv. Kwestor had a null mutation (lack of a band) in one AFLP locus. This correlation suggests that these AFLP loci are located either within or are linked genes responsible for changed morphology and thus these markers can be ideal for screening candidate genes responsible for dwarfism. One of the most interesting mutants was characterised by a complete lack of stem. It is interesting to note, that it had the highest number of mutations revealed by AFLP. Changes were observed in 198 loci (18%). It can be supposed that some of these are concerned with stem development. Therefore this mutant provides very valuable material for studying the genetic basis of stem development in peas (Figure 8).

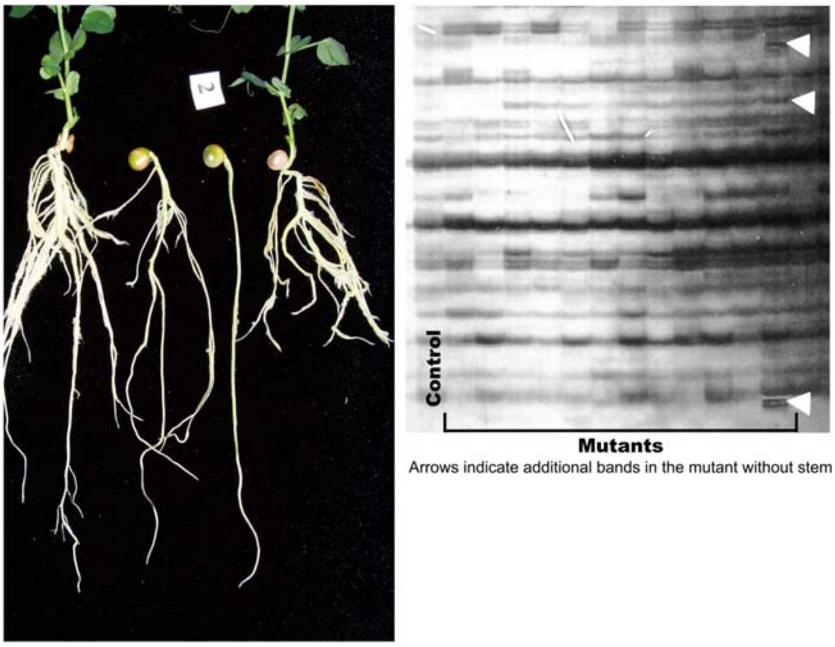

Figure 8. Pea mutant without stem and its AFLP pattern

The lack of winterhardiness in perennial species is another problem that makes their wider utilisation difficult. In *L. perenne* efforts to improve this character have been hindered by a lack of readily identifiable sources of winter-hardy germplasm. Single trait based selection for improvement in any turf trait results in decreases in winterhardiness. Therefore, modern turf cultivars have accumulated genes for the trait under selection, but are less winter hardy. That is why *L. perenne* ecotypes that are winter hardy in addition to acceptable green and dry weight are promising. Winterhardiness is the result of a combination of complex polygenic traits controlled by three major and one minor QTL with strong additive and dominance effects, mapped on four different linkage groups (Polok, 2007). At least some of them may be connected two key genes responsible for rhizomatousness that diverged from a common ancestor of the *Poaceae* about 50 MYA. In *Oryza longistaminata* two dominant genes *Rhz2* and *Rhz3* are responsible for many rhizome traits. They also contribute to regrowth and persistence of perennial grasses. The dominant nature of both genes means that a single mutation resulting in loss of function inhibits rhizome development (Hu *et al.,* 2003). Linkage between winterhardiness and enzymatic, AFLP, SSAP and B-SAP/katG loci in *Lolium* can be used to identify genes at mapped QTLs. Moreover, all markers identified in *Lolium* could be potentially useful in identifying the molecular factors underlying winterhardiness in other species.

Breeding pea cultivars with resistance to fungi of the ascochyta complex (*Mycosphaerella pinodes, Ascochyta pisi* and *Phoma medicaginis)* is difficult due to complex, polygenic inheritance. Using degenerate oligonucteotide primers designed on the conserved motifs of resistance gene analogs and defence-related genes Prioul-Gervais *et al.,* (2007) were able to isolate, clones and putative sequences responsible for fungal resistance. Co-location between them and QTLs controlling fungal resistance was found for three sequences suggesting an important role of these genomic regions in defence responses in pea. However, the identified genes are responsible only for partial resistance.

Transformation technology with the possibility of introduction to a given species of virtually gene has a great potential for helping to address fungal resistance in the pea. Three transgenic pea lines were derived from cv. Baroness at the University of Hannover, Germany (Prof. H-J Jacobsen), then the lines were checked for stability of introduced genes and the current seeds represent the T_7 or T_8 generation. The modified pea lines contained two antifungal genes which encode for proteins with different function, a *pgip* gene from raspberry (*Rubus idaeus)* encoding the polygalacturonase-inhibiting-protein (PGIP), which has an effect on the polygalacturonases of fungal pathogens, regulated by an enhanced *Cauliflower mosaic virus* (CaMV) 35S promoter and a *Vst1* gene from grapevine (*Vitis vinifera*) encoding stilbene synthase driven by its own elicitor-inducible promoter. Notwithstanding the inhibition of a fungal polygalacturonase from *Colletotrichum acutatum* that was observed in transgenic lines, the expression was not stable in different generations. Furthermore, all lines were variable with respect to morphological characters (Table 3) and highly diverse at the DNA level. Preliminary analysis of two stable transgenic pea lines (with *pgip* gene and *Vst1* gene) and their hybrid (*pgip* x *Vst1*) with the AFLP combination of primers (M-CTG/E-ACT) unexpectedly revealed a very high level of genetic change. In total, changes were observed at 45 loci of 71 i.e., at 63% (Figure 9). This number was comparable with the frequency of mutations observed in induced mutants by the same primer combination (64%). It is worth noting, that no differences in amplification patterns were observed between several pea cultivars (Kwestor, Piast, Paloma, DGV) with this primer combination. Transgenic lines differed from the parent cultivar, Baroness, at an average of 20% of loci. Lack of a band was most frequently observed, although from two to five additional bands, not present in Baroness were also identified (Table 4). The line with *pgip* from raspberry was characterised by the highest number of changes (in 24% of loci) followed by a hybrid (21%) and the line with the *Vst1* gene (17%). The comparison of induced genetic variation in transgenic lines and induced mutants clearly showed that this is about 1/3 higher in transgenic lines (Figure 10).

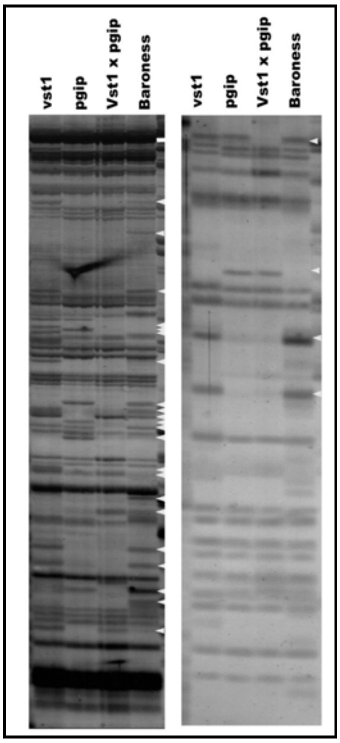

Figure 9. AFLP patterns of transgenic pea lines

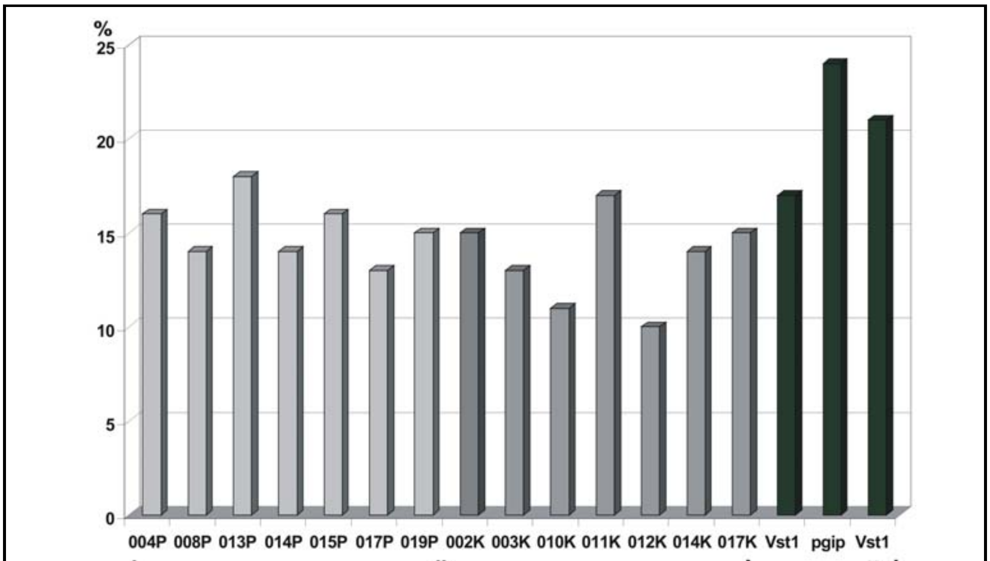

Figure 10. Comparison of AFLP variation induced by transformation and induced mutagenesis

Table 3. Reduction of germination and height in pea transgenic lines

Line	N° of germinated seeds[1] [N]	Height 6 weeks after germination [cm]
VST1	5.9[a]	29.6[b]
PGIP	8.4[b]	26.6[c]
PGIP X VST1	9.2[b]	28.6[b]
BARONESS	**8.4[b]**	**33.6[a]**

Different letters means the significant differences for LSD test at P=0.05
[1]The number of sown seeds were constant and always equal to 10.

Table 4. Changes in transgenic pea lines in comparison with the control (Baroness) revealed by AFLP

Line	N°of additional bands	N° of lacking bands	Total N° of loci with changes	% of loci with changes
VST1	5	7	12	16.9
PGIP	4	13	17	23.9
PGIP X VST1	2	13	15	21.1

Transgenic lines are thought to differ from the parent cultivar only in relation to the introduced gene/genes. However, our results clearly demonstrated much higher diversity of transgenic lines which was similar to that in induced mutants. Although these phenomena need further studies on a wider range of materials and markers, there can be at least two explanations for these results. The production of transgenic lines involves *in vitro* culture and somaclonal variation can be induced. In addition, in the pea, immature embryos were used and it has been shown that this kind of culture do not induce any mutations. It is highly possible that introduction of a foreign gene causes many more changes than expected. It is known (D. Michalczyk, 2006, personal communication) that about 20 and even more new secondary metabolites can be identified in GM plants. It must also be considered that the transgene was incorporated at many sites thus causing changes in many genes or noncoding sequences. On the other hand, it is also possible, that transformation induces the mobilisation of transposable elements and these changes can be observed in AFLP pattern as AFLP amplify a mixture of SSRs, transposons and unique sequences. Therefore it seems obvious that transgenic lines should be analysed through use of many markers, especially transposons (SSAP). Most notably, these results seriously question the use of this technology on underutilised crops.

To summarise, molecular appraisals when coupled with traditional methods can be successfully used for genetic improvement of underutilised species. While molecular markers remain the most powerful tool for genetic diversity assessment and gene tagging, wide applications of more sophisticated technologies such as genome mapping and genetic engineering may be hampered by limited technical, personal and financial resources, in particular in low income food deficit countries. Furthermore, current data demonstrating much broader alterations in genomes resulting from gene transfer seem to question the usefulness of this technology on underutilised species at least until more data are available.

Acknowledgements
This work was supported by the European Community Project: Marie Curie Warmia and Mazury University in Olsztyn Host Fellowships for the Transfer of Knowledge, GenCrop, coordinated by Department of Genetics, Contract No. MTKD-CT-2004-509834.

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4

The regulatory environment for commercialisation on new/underutilised crops

L.D. Phillips

New EU legislation governing the production and sale of both nutraceuticals and herbal medicinal products imply radical changes in the way agricultural raw materials destined for these uses are grown, harvested and transported.

In order to ensure a more integrated approach to the cultivation, harvesting and processing of medicinal plant based products a number of organisations including WHO, EUROPAM, EMEA and EHIA have drafted new codes of practice commonly known as "GAPs". This article reviews some of the key issues relating to this process.

WHAT ARE GAPs?

The term Good Agricultural Practice (GAP) is used, often rather loosely and interchangeably with Good Farming Practice (GFP), to define farm management activities which provide a minimum level of protection for some of the following:

- natural resources (energy, soil, air, water, wild plants and animals);
- cultural resources (landscape, traditional buildings, historic and archaeological features and public access);
- farm livestock (health and welfare);
- farm labour (safety);
- the general public (food safety and public health).

All EU Member States have a formal obligation to define GAP/GFP in their Rural Development Plans. For the medicinal plant and nutraceutical industry the definition and purpose of GAPs are somewhat more specific.

EMEA states "To ensure appropriate and consistent quality of medicinal plant/ herbal substances it is necessary to establish good agricultural and collection practices for herbal starting materials. The concept of Good Manufacturing Practice for the manufacture and process, packing and storage of Active pharmaceutical ingredients also applies to medicinal plants/ herbal substances" (EMEA 2005).

WHO maintains that GAP guidelines are required to "Contribute to the quality assurance of medicinal plant materials used as a source for herbal medicines, which aim to improve the quality, safety and efficacy of finished herbal products" (WHO 2003).

They furthermore state that GAP guidelines are needed to "encourage and support the sustainable cultivation and collection of medicinal plants of good quality in ways that respect and support the conservation of medicinal plants and the environment in general."

For the European Herbal Infusion Association (EHIA) the objectives are even more clearly defined (EHIA 2005). The aim is to ensure that herbal infusions are:

- safe for human consumption

- produced hygienically to minimise microbiological contamination and to prevent the formation of mould toxins (mycotoxins)
- produced with care to minimise physical and chemical contaminants
- to identify the potential food safety hazards from raw materials and related HACCP requirements
- of the highest quality

A PROFUSION OF NAMES!

Good Agricultural Practice	GAP
Good Farming Practice	GFP
Good Agriculture & Hygiene Practice	GAHP
Good Agricultural & Collection Practice	GACP
Good Agriculture & Sourcing Practice	GASP
Good Wild Crafting Practice	GWP
Good Sourcing Practice	GSP
Good Field Collection Practice	GFCP

The term GAP has many similes. Some are listed above. The differences in some cases is simply a question of which agency drafted the rules. In others the distinctions reflect the differences between cultivated and wild harvesting practices. The European Medical Evaluation Agency (EMEA) which has decided to include GAPs within the new legislative framework for Herbal Medicinal Products has opted for the name Good Agricultural and Collection Practice.

HISTORICAL BACKGROUND

It was in 1983 that the first attempts to elaborate the concept of GAPs appeared during a symposium in Angers, France. In 1988 The Chang Mai Declaration which drafted at WOCMAP I was probably the first reference to this concept within the context of plant conservation. In 1989 Professor Mathe a leading medicinal plant expert from Hungary published an article entitled "Biological aspects of GAP Guidelines" in the ISHS newsletter. By 1995 the Society of Medicinal Plant Research, probably the leading association of European medicinal plant scientists set up a permanent commission on breeding & cultivation of medicinal plants. The drafting of GAPs was a major part of their work.

Meanwhile a European wide trade association of growers of medicinal and culinary herbs known as EUROPAM began drafting standards primarily to cater for the increasing Quality control needs of the large supermarket chains. For over eight years EUROPAM has been a major driving force in developing GAPs for medicinal and culinary herbs. The chronology of their work is outlined in the table below. At a similar time EUROPAM aware that a very large quantity of raw materials used in the herbal and nutraceutical industry was wild crafted began to develop parallel standards for wild craft or wild collected materials. The Good Wildcrafting Practice (GWP) is very similar in many respects to the GAP but places much more emphasis on environmental conservation issues and the training of collectors in good harvesting practices. The

European Herbal Infusions Association (EHIA) which promotes herbal teas and infusions also began drafting similar GACPs

Key dates in the development of Europam code of Good Agricultural Practices (GAP)

Aug 1998	First Europam version
Feb 1999	Comments by EMEA ad hoc working group draft
June 1999	Updated to Europam working copy no.1
March 2000	Release for consultation by Europam
Nov 2000	Release of Europam working copy no.2
Sept 2001	Release of Europam working copy (no.3) no.4
Feb 2002	Review meeting Europam working copy no.5
May 2002	Release Europam working copy no.5
June 2003	Release for consultation Europam working copy no. 6
Nov 2003	Release Europam working copy no.7
July 2004	Release for consultation Europam working copy no. 7.1
Nov 2005	Release Europam working copy no.7.2
April 2006	Release Europam working copy no.7.3

Source www.europam.org

Why do farmers wish to follow Good Agricultural Practices especially as they will cost both time and money to set up and monitor the system?

- Identify critical steps in production process
- Minimise risk of production failures
- Win or retain a business customer
- Promote sustainability of supply
- Minimise the risk of quality failures
- Minimise the risk of pollution
- Increase yields
- Prevent pesticide /fungicide residues
- Ensure proper documentation of crop cycle
- Build up long term QC/QA system,identify critical steps in supply chain
- Identify reliable suppliers
- Simplifying the buying chain
- Reduce auditing & supervisory costs
- Minimise the risk of quality failures
- Ensure proper documentation of crop cycle
- Ensure full traceability
- Build up long term QC/QA system
- Reduce level of customer

Just as important why do buyers, importers and processors encourage their suppliers to set up Good Agricultural Practice networks. Many of the reasons overlap but for many of the larger companies it is becoming not only good business but also a legal requirement to source from GAP producers.

- Identify reliable suppliers

- Satisfy regional or international regulations
- Simplifying the buying chain
- Reduce auditing & supervisory costs
- Minimise the risk of quality failures
- Ensure proper documentation of crop cycle
- Ensure full traceability
- Build up long term QC/QA system
- Reduce level of customer complaints
- Build up public confidence

WHY ARE GAPS NEEDED?

So what are the most likely things that go wrong for the supplier of medicinal herbs? For the grower the first problem is with selection of seeds and plant materials. It is surprising how often the wrong plant or wrong variety is planted. Moreover the seed could be old or adulterated.

The next most common problem is growing the plant in the wrong place or habitat. Medicinal herbs are extremely sensitive to their environment especially in terms of their chemical composition and level of actives. If it is too hot, too dry too cold or too acid/alkaline yields and quality will vary greatly. Day length is also of great importance and so are changes in temperature between night and day. Altitude and solar insolation greatly affect the level of actives.

In areas where the crop has been newly introduced wrong cultivation methods may cause low yields and quality. Lack of weeding is commonplace resulting in undesirable weeds within the harvest. Spray drift or pesticide residues in irrigation water can also be a problem and more and more often industrial pollution

Harvesting is a skilled process whether by hand or machine. It is surprising how often the wrong part of the plant is picked or additional material is added.

All the post harvest handling, drying and storage issues can affect both the quality and as important level of active ingredients. If the plant is left in the sun too long or in the rain after harvest it can get damaged. If artificial dryers are used drying must be not too hot or too fast or the plant will be damaged.

EUROPAM guidelines

The EUROPAM guidelines for the Good Agricultural Practice of Medicinal and Aromatic (Culinary) plants are intended to apply to the production growing and primary processing practices of all such plants and their derivatives traded and used in the European Union. It applies to the production of all herbal materials utilised either in a direct or processed form for humans and/or animals used in the food, feed, medicinal, flavouring and perfume industries. EUROPAM - GAP also applies apply to all methods of production including organic production in accordance with the European regulations. Similar to the WHO guidelines for medicinal plant cultivation and the European Herbal Infusions Association the GAP guidelines cover almost exactly the same key topics. These include:

1. Personnel and Facilities

2. Seeds and propagation material
3. Cultivation
4. Soil and Fertilisation
5. Irrigation
6. Crop maintenance and plant protection
7. Harvest
8. Primary processing
9. Packaging
10. Storage and Transport
11. Equipment
12. Documentation
13. Education
14. Quality Assurance
15. Self Inspection

KEY ISSUES

In the case of cultivation and harvesting the key points highlighted include ensuring that clean seeds/plant materials of known origin are used make sure that the crop is planted in clean soil, free from contaminants. Water or irrigation water should be clean, free of pesticides and effluent. Although common with some crops in China human faeces should not be used with medicinal plants.

On the issue of the use of organic or non-organic fertiliser all the GAP recommendations do not take sides. They simply say that the use of pesticides and herbicides should be avoided if possible while artificial fertiliser should only be used if and when required.

Harvesting time is critical in order to get the proper level of maturity and active ingredients. Knowing the appropriate time to harvest requires skill. Of course rainfall at harvest can be disastrous. Placing damp product in poorly aerated sack can lead to moulding and yeast activity. Harvesting equipment must also be clean and the product left to dry in clean conditions out of the sun and the reach of rodents, birds and insects.

Proper post harvest handling and storage is also of critical importance. Contamination often takes place at this stage in the production process.
Storage should be clean and well ventilated to prevent mould and product should be kept off the floor, ideally on racks so that insects and rodents do not attack the materials. Staff should have washrooms and running water and animals should not be allowed anywhere near the facilities. In the case of organic produce no non-organic materials can be stored in the same place.

GAPs place considerable emphasis on staff and the workforce. Some issues are designed to protect the workforce others to protect the consumer. Open sores or wounds must be covered and workers with communicable diseases should be reported to the management.

EUROPAM maintains that "the welfare of all staff involved in the growing & processing should be ensured". This is surely easier said than done! It is important that those involved in the harvesting and collection should be educated about the plants and the environment and how they should be handled. If uneducated labour is used a suitably trained supervisor must be recruited. Nowhere does it say that personnel should be literate but that is critical for all the documentation that is implied under GAP.

It is in the area of documentation that GAP codes place great importance. Traceability and good record keeping is, in many ways, the essence of the process. All cultivation process & procedures should be recorded including the timing and amount and form of inputs such as seeds, fertiliser, and agrochemicals. Planting procedures, equipment and crop rotation at the site should also be noted. If floods, droughts or sudden pest attacks occur these should be recorded. When it comes to harvesting all the batches should be weighed and recorded separately. Records should also be kept of contracts and other agreements with input suppliers, collectors, sub contractors and buyers. Moreover records of any audits should be kept for at least 10 years.

A very considerable proportion of the plants used in European herbal medicinal Products are wild harvested. As is indicated in the table below more than 70% of the medicinal plants coming from Bulgaria and Albania, two major sources of raw materials, are wild harvested. (Lange, 2002) Wild crafting of medicinal and aromatic plants very often leads to negative situations, especially in developing countries. The present EUROPAM Good Wild crafting Practice Guidelines provide additional standards for the production and processing of raw materials.

Wild-collection of MAPs in S.E. Europe.

Courtesy :Lange 2004

Estimation of wild collection

(70) – 90 % in terms of species number

50 – (70%) in terms of quantity

South Eastern Europe

Rosehips collected in Turkey

Selected source countries	Share of wild-collection	Estimated annually wild-collected quantity	Source
Bulgaria	**75-80%**	**12,000 t**	Hardalova (1997)
Albania	**> 95%**	**500 t**	Vaso (1997)
Turkey	**almost 100%**	**4,400 t**	Atay, in litt., 19.2.1998; Lange (1998)
Hungary	**30-50%**	**c. 3000 t**	Bernàth (1996)
Poland	**20%**	**c. 2,000 t**	Lutomski & Gorecki (1999)
	Total	**c. 30,000 t**	

GWP recommendations state that harvesters of wild plants must ensure that they avoid damage to existing wildlife habitat. In particular they must avoid:

a) Extinction of particular species in certain zones or certain rare genetic populations due to over-exploitation. Where possible, the principle of "collection rotation" to facilitate biological propagation and resource renewal should be employed.

b) Destruction of the entire plant, due to carelessness and inexperience on behalf of the harvester, when in most cases it would be sufficient to harvest only a part of it.

c) Confusion (due to ignorance or bad faith) in the harvesting of different species that are similar at first sight.

d) Collection of endangered species, without abiding by local regulation.

For plants intended for export a Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES) certificate must be obtained.

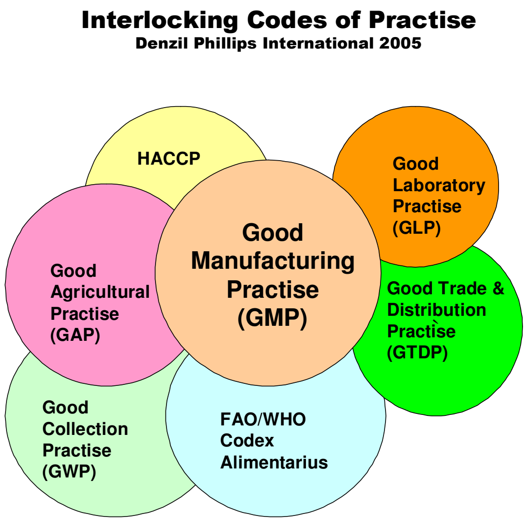
MEDICINAL PLANTS PROTECTED UNDER CITES

Aloe ferox
Aquilera malaccensis
Bletilla striata
Cibotium barometz
Cyprepedium pubescens
Cyprepedium calaceolus
Dendrobium spp.
Discorea deltoidea
Guaiacum officinale
Guaiacum sanctum
Hydrastis canadensis
Nardostachys grandifolia
Picrorhiza kurrooa
Panax quinquefolius
Podophyllum hexandrum
Prunus africanus
Pterocarpus santalinus
Rauwolfia serpentina
Taxus wallichiana
Gasteodia elata
Guajacum officinalis
Saussurea lappa
Selenicereus grandiflorus
Pterocarpus santalanum

Source: www.traffic.org

Interlinking Standards

GAPs or indeed GACPs cannot operate successfully in isolation from those Standards which help regulate the preparation, testing, processing, packing and distribution of herbal medicinal products. As can be seen from the diagram below GAPs form part of an interlocking network of standards which together help ensure the safety, integrity and efficacy of finished herbal products of many different kinds.



GMP or Good Manufacturing Practice is widely known and practised in The Phytomedicine Industry. Perhaps less well known are GLP (Good Laboratory Practice) and GTDP (Good Trading and Distribution Practice).

HACCP or Hazard and Critical Control Programmes which are standard procedures in the food processing industry are more and more being used in the herbal sector. HACCP is now also finding application in environmental management so Codex is a key technique in both the quality assurance (QA) and environmental management (EM) aspects of Good Agricultural Practice. Indeed the European Herbal Infusion Association makes references to this approach in the appendix to its GAP. HACCP forms an integral part of Codex Alimentarius standards.

The FAO/WHO Codex Alimentarius Commission develops and adopts standards, guidelines and related texts on all aspects of food safety and quality reflecting consensus at the international level. A limited definition of GAP is applied within established codes of practice for food safety, under Codex Alimentarius, to minimise or prevent contamination of food.

Codex defines GAP in the use of pesticides to include nationally authorised safe uses of pesticides at any stage of the production, storage, transport, distribution and processing of food commodities and animal feed. GAP in this context is used to define maximum residue levels for pesticides.

Conventions on pesticides and pesticide use including - International Code of Conduct on the Distribution and Use of Pesticides, the revised version of which was adopted by the FAO Council in November 2001. The actual conditions include any stage of the production, storage, transport, distribution and processing of food commodities and animal feed. GAP in this context is used to define maximum residue levels for pesticides.

Codex Code of Practice (General Principles of Food Hygiene) and other more specific codes, address good practices in primary production as well as post-production systems. Some national programmes have extended the use of the term Good Agricultural Practices to refer to practices to minimise microbial food safety hazards in fresh produce.

ETHICAL STANDARDS AND SOCIAL RESPONSIBILITY ISSUES

The EUROPAM, EMEA and WHO Good Agricultural and Collection Practices codes make only limited reference to the social or corporate responsibility issues which are inherent in many of the certification efforts that are presently related to medicinal plants and related nutraceuticals. For example there are:

- Ecologically responsible forest management standards (e.g. FSC) that assess water and soil conservation, preservation of wildlife and habitat, and maintenance of forest structure, function and processes;
- Fair trade certification programs that assure equitable sharing of profits with producers, worker's rights and decent working conditions;
- Organic certification standards that assure pesticide-free agricultural production (and are occasionally applied to agro-forestry and forestry production systems);

Forest Stewardship Council (FSC) was set up in 1990s and has now become the main international certification agency for forest products. It is increasingly being used to certify Non Timber Forest Products, especially medicinals, FSC sustainable forest management is environmentally appropriate socially beneficial and economically viable management of world's forests. As Certifier of certifiers FSC authorises, bestows credibility and monitors certification bodies working with FSC standards FSC could well play an important part in certifying GASP.

Main purpose of the Fairtrade Labelling Organisation International (FLO) is to achieve social goals including improving position of poor & marginalised producers in the developing world. Fairtrade Labelling Organisation International (FLO) is an NGO which includes 18 "national initiatives" as members. Each national member is authorised to certify products meeting FLO standards and award the FLO logo. The International Fair Trade Association (IFAT) is another global network working with similar goals.

Organic production is a holistic management of the agro-ecosystem, emphasising biological processes and minimising the use of non-renewable resources. In Europe and North America the terms "organic", ecological" or "biological" can only be used if a recognised certification process has taken place IFOAM is the worldwide umbrella organisation for the organic movement, uniting more than 750 member organisations in 108 countries. IFOAM provides a market guarantee for integrity of organic claims. The Organic Guarantee System (OGS) unites the organic world through a common system of standards, verification and market identity.

Many low-input traditional agriculture systems in other parts of the world are also de facto organic systems. In this respect the term "organic by default" or even "organic by neglect" have developed. These terms do give the false impression that any agriculture systems in which no agro-chemicals automatically comply with organic standards. This is not true.

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THE NEED FOR UNDERUTILISED CROPS IN A CHANGING WORLD

5

Underutilised species in Indonesian traditional farming systems

Setijati D. Sastrapradja and Anida Haryatmo

Indonesia has joined the global community in developing and trying to implement the concept of sustainable development since the Stockholm Conference in 1972. In term of biological resources, even before her independent conservation of biological resources, had been attempted. Therefore, when the Convention on Biological Diversity was launched in 1992, Indonesia was among the first countries to sign it. However, the ratification of the Convention on Biological Diversity itself was completed in 1994 after a long process of negotiation between promoters of national development.

Indonesia is a country of many islands located along the equator. From the biological point view Indonesia is interesting because of its diverse ecosystems, hence the diversity of organisms living within them. Culturally Indonesia is as diverse as her ecosystems. The number of languages spoken, the variety of wedding customs and cuisine found in her islands signify part of her cultural diversity.

Like many Asian countries, the backbone of Indonesian economy is agriculture. For centuries, Indonesia has been known as an exporter of coffee, tea, rubber, sugar, cocoa, vanilla, etc. Those estate crops are generally grown in large plantations. Small farmers grow black pepper, clove, nutmeg, cinnamon, and sometimes they also plant rubber, coffee and cocoa. In many areas of Indonesia traditional farmers are still practicing subsistence agriculture, which they deal mainly with food crops. Associated with food crops are other plants which are useful for their life style.

When Indonesia proclaimed her independence in 1945, the human population was only 60 million. Sixty years later, the number has become 220 million, putting Indonesia in a group of countries with the largest populations, i.e., after China, India, and the United States of America. Since 1980, Indonesia has imported rice, the staple, in millions of tons, to provide enough food for her population. At the same time, the success of introducing instant noodles has compelled Indonesia to import wheat in the same quantity as rice.

Realizing the danger of Indonesia's dependence on rice as a staple the Government has launched a programme of food diversification since early 1980. Unfortunately, there is no significant progress in this programme until the present. Indeed, in term of carbohydrate production Indonesia has much to offer. The same holds true for vegetables and fruits which are valuable for vitamins and minerals. There are also species that are useful spices. Most of those species are cultivated on small farmers' holdings thus they can be regarded as under underutilised species. Why does Indonesia fail to exploit the potential of these species for her food security? What factors can contribute to their development? What will happen if the species are not utilised? This paper tries to find answers for such questions.

INDONESIA: FARMERS AND FARMING SYSTEMS

Indonesia consists of more than 17.000 islands, making Indonesia the largest archipelago in the world. These stretch along the equator occupying an area as wide as the United States of America. Because of its area and the large number of islands Zen (2005) called the Indonesian territory the Maritime Continent of Indonesia (MCI). Though the majority of Indonesian territory is marine, the orientation of her national development is primarily terrestrial.

Floristically Indonesia belongs to Malesian Region (Malaysia, Indonesia, the Philippines, and Papua New Guinea). According to Li (1970) the Southern Island Belt of Southeast Asia, of which Indonesia is the main portion, contains the richest tropical flora in the eastern hemisphere. Information on the floristic richness, vegetation and ecology of Indonesia has been accumulated. The Flora Malesiana Foundation, which is based in the Netherlands, is very active in promoting plant studies in the region. A recent program on Plant Resources of South East Asia has just been completed (PROSEA, 1986 – 2005) enhancing base information on useful plants of Indonesia as well. On this existing information one can take the necessary steps to further develop economically with great species development potential.

About half of the population of Indonesia lives in rural areas from agriculture. In general farmers in Indonesia can be classified as small farmers since their land holding is small, average farmers have 500 square metres. Compared to Thailand, average farmers have 1.850 square meter production land and the USA about 10. 000 square metres of land. (KOMPAS, 2002) Moreover, there are also landless farmers who work for land owners. In this case, at harvest such farmers have to give half their income to the landlords. From residual income, framers have to invest in the next crop, to buy seed, pesticides and fertilisers. And from the money left they have to live until the next harvest (4 – 6 months). In many places where plantations exist, there is the opportunity for those who have no land to work there.

Of the many crops grown in Indonesia, estate crops such as coffee, tea, rubber, and oil palm have greatly contributed to the national economy. In fact they were introduced to Indonesia centuries ago while Indonesia was under Dutch administration. Since then these crops have been part of the agricultural systems in Indonesia. They are usually managed as mono crop plantations though in many places small farmers have adopted these crops. In the hands of small farmers the crops are generally grown in a mixed farming system with other crops.

Because of altitudinal variations which range from sea level to more than 5000 m above, the diversity of edaphic and climatic conditions, and the richness in biological diversity a number of ecosystem types are recognised in Indonesia. Coupled with the high cultural diversity, many of the natural ecosystems have been developed into man made agro ecosystems from which people get their food, energy for cooking, medicines, and materials for housing.

Rice is the most important food crop in Indonesia. As to when rice began to be cultivated in Indonesia it seems there is no definite information. However, according to an Indian scientist, rice cultivation started independently in three areas, i.e., India, Japan, and Java (Indonesia), hence the name of the rice group's *indica*, *japonica*, and *javanica.* In fact rice fields dominate the landscape of many areas in Java and Bali. In these two places rice cultivation has developed in both irrigated and non irrigated systems. Before the introduction of High Yielding Varieties of IRRI rice, it was estimated that in Java alone no less than 8000 varieties were planted by farmers (Fox, 1991) since the new introduction old varieties of rice have declined drastically.

Though rice is planted as a monoculture, farmers also plant minor crops, such as beans, taro or cassava along rice field borders. Maize is a second staple in Indonesia. It was introduced by the Portuguese in the 16th century. After centuries of adaptation, there are a number of maize varieties in Indonesia though variation is much less than that of rice. Quite often maize is grown as a subsidiary crop in association with other annuals such as legumes or leafy vegetables following rice crops. Maize is suitable for cultivation in dry areas of Indonesia where it is generally grown under rain fed conditions in various cropping systems, such as multi cropping with other annuals, relay cropping, sequential planting, and mixed cropping.

The other important staple in Indonesia is cassava. The origin of cassava is South America. Like maize after centuries of adaptation, diverse cassava varieties are found in Indonesia. In fact Indonesia is considered as a secondary centre of cassava diversity (Zeven and Zhukovsky, 1975**.)** Though the role of cassava as a staple is declining, because of its less demanding husbandary, its tolerance to various soil conditions, and its versatile uses, cassava dominates agriculture landscape in Indonesia. A grafting technique using Manihot glaziovii as root stock and Manihot esculenta as scion enable the grafter to harvest cassava roots gigantic size. The product of grafting is known as *ketela Mukibat.*

Other crops which are valuable as staples but very localised in term of importance are sweet potato and sago palm (*Metroxylon sago*). Both species are major crops in the highlands of Papua (sweet potato) and in the lowland/coastal area of Papua and Maluku islands (sago). Sweet potato is an introduced species but its adaptation capacity is high, hence the number of varieties has developed in Papua. Some varieties which are fibrous in nature are good only for pigs, but in times of scarcity it is for human consumption as well. Sago, on the other hand, is harvested from the wild. With the increase of human population in the study areas, the availability of wild sago is significantly affected. Attempts to cultivate the species have had no significant success (Suradisastra *et al.,* 1990). In drier areas of Indonesia, such as Nusa Tenggara Timur (NTT), borassus palm (*Borassus flaellifer*) and gebang (*Corypha utan*) take on the role of sago as a staple. Borassus palm is seemingly wild and its origin may be Africa (Zeven and Zukhovsky, 1970), while gebang is native to NTT. The population of both palms is declining fast since their cultivation has not been attempted.

Mixed cropping of corn-cassava, corn-sweet potato, and of these major crops and other crops such as beans, and other vegetables is common. Farmers know exactly what harvest they can g*et al.,*l year round from their land. The fact that there is a range of edaphic and climate conditions in Indonesia and a range of mixed cropping systems have been developed. In this way the combination of crops differ from one system to another.

In the tropics it is generally known that farmers have developed home gardens in which many useful species are planted together. In this way the selection of plants for whatever purposes depends on cultural preference. In many places of Indonesia home gardens are well developed in proximity to the home. Soemarwoto (1975) listed as many as 675 species of plants in a survey of 351 Javanese home gardens. The diversity of plant species in these home gardens is comparable to an overall species diversity of deciduous subtropical forests. The species are valuable for food (cassava, sweet potato), medicines (curcuma, etc), vegetables (sesbania, long bean, kangkung), fruits (mango, jambu air, ceremai, nangka), spices (galanga, salam, sereh), cash crops (cengkeh, pala), forages (rumput gajah), and fire wood (all kinds). Coconut, as one of the multipurpose species, is found almost everywhere. In term of plant genetic resources conservation, home gardens may be considered as *ex situ on farm* way of carrying this on.

Recently, agroforestry, a farming system based on tree crops that has been in existence for hundreds of years is promoted for rural sustainable development (Mellinkt *et al.,* 1991). For Indonesia, Kartadibrata (1991) discussed agroforestry programs that may offer alternatives in the restoration and development of degraded forest and land resources. He specifically mentioned three traditional agroforestry systems, i.e., Kebun-Talun-Pekarangan (garden-Mixed Treegarden-Homegarden) in Java, Multistoried Agro forestry Garden System in West Sumatra, and Damar Mata Kucing agroforestry system in Krui (Sumatra). Within each system annual crops and tree crops planted by the cultural group that developed them.

NATIONAL ISSUES RELATED TO AGRICULTURE

There is no doubt that at national level, the most compelling issue in agriculture is food security, and food security is effectively identical with rice availability. In this way, rice production becomes the priority action for the department of agriculture, a priority that nobody could argue against on short term grounds. A slight change of rice availability in markets is always followed by a long political debate.

The improvement of transportation and communication around Indonesia has stimulated change in food habits of many communities. Sago palm, for example, was once the staple of communities living in lowland Papua and Maluku. When rice becomes freely available and the price is subsidised by the government, then the role of sago is taken over by rice. The same situation also happen in communities of highland Papua which once dependent on sweet potato. Rice has also changed the food habits were of communities in dry areas of Indonesia, namely Nusa Tenggara Timur, where corn was the major staple.

While a slow but sure change in food habit is going on, the population number keeps on increasing. Before political reform, family planning was one of the top priorities of the government. There was awareness that only with family planning could development be planned so that basic needs could be met. The family planning program was so successful in decreasing the birth rate from 1.6 % per year to 1.3%. Unfortunately, after political reform in 1998 the program was no longer considered as important. Hence food security has become the most important agricultural issue nationally.

Though the work of KEPAS (the Agro ecosystems Study Group) clearly indicated the diversity of ecosystems in Indonesia and their recommendations as to crops species and the combination of those that can be grown in each agro-ecosystem, however, there is no real effort to implement the conclusions of these studies. Certainly, at the national level attention is given primarily to rice production and rice technology is kept up to date. The number of people dealing with each agro-ecosystem is however much lower than those who are in rice farming. Thus, in spite of technological inputs various agro-ecosystems many remain traditional in their management.

Since 1969, industrial development outside the agricultural sector has proceeded rapidly. Coupled with human population increase the needs of land for economic development have also become greater. Serious conflict in land use between sectors of the government cannot be avoided. Spatial planning as a way to reduce conflicts has been attempted; however, there are no significant impacts of such a plan.

AGRICULTURE IN CHANGING INDONESIA

Realizing the need for competent scientists to advance the agricultural sector, a great number of young scientists were sent abroad by the government through grants and loans. Many graduated from Los Banos, the Philippines, in which International Rice Research Institute is located. When the graduates returned, a significant impact on rice production resulted. A combination of a critical mass of scientists and an effective policy for rice production enabled the country to perform well in fulfilling its needs for rice.

A revolution in rice production has been performed since the late 1960s. Uniformity in plant performance signified success of the new rice technology. Considerable areas were sown with the new dwarf early maturing rice varieties. The government urged farmers to plant at the same time, so that management of pests and diseases could be handled easily. Farmers were subsidised with rice seeds, fertilisers and pesticides. To accompany modernization of rice production, the government has encouraged establishment of farmers associations. In this way, new varieties and the production technology associated with them could be disseminated rapidly.

In this era of globalization, Indonesia cannot shut its doors to foreign industries which like to establish here. Land is needed for developing industrial areas. Where electricity, water supply, road and other communication facilities exist there industries can be established. Therefore, lowland areas with good arable land became the first choice for the establishment of industrial areas and development of housing both for staff and the workers. So the area of arable land shrinks fast. It is recorded that yearly about 110.000 ha of rice paddy is being used for housing and industrial estates in Java in 1992 – 2002 or about 58.3 % rice paddy had been so developed (KOMPAS, 2007).

With globalization the flood of foreign goods to almost every corner of the country cannot be stopped. In consequence cash is needed to purchase new products that once were enjoyed only by the urban community. Subsistence farmers have become marginalised. Subsistence agriculture with many crops by definition may have stable performance but are not otherwise productive (Dover and Talbot, 1987). It is true that at the household level such a system of agriculture is considered sufficient to fulfill food needs, but a little is left to generate income for other needs.

UNDERUTILISED SPECIES OF SPECIAL INTEREST

In his review of new crops for the future, Janick (2001) classifies crops into: major crops, traditional specialty crops, underutilised crops, neglected crops, newly created crops, and genetically modified crops. Underutilised crops are "crops that were once more widely grown but are now falling into disuse due to various agronomic, genetic, economic or cultural factors”. Further he stated that rescued underutilised crops are a most likely source of new crops for many parts of the world. A more recent definition of underutilised species is offered by a group of scientists who attended a workshop in Colombo, Sri Lanka (Jaenicke and Hoschle-Zeledon. 2006). Species categorised as having exploited potential have made an important contribution to food security, health (nutritional/medicines), income generation, and environmental services. The second definition is broader in scope than the first, covering species that have never been brought into cultivation. Considering the large number of such species in Indonesia, we limit ourselves in discussing those which are cultivated in various current agro-ecosystems.

For decades scientists in Indonesia has discussed potential uses of various plant species native to this country. Unfortunately, there are no systematic research activities dealing with certain species potential or concerted efforts to realise their potential into reality. Almost all research institutes in Indonesia are government supported. Thus, the research funding system is identified as one of the limiting factors in enabling scientists to deal continuously with a crop for more than three years. Unfortunately, short term orientation colors all research projects.

Realizing the potential of underutilised plant species to improve the lifestyle of local communities, several initiatives to promote their uses have been undertaken by Non Government Organizations with financial supports from donors. The famous 2010 target of CBD to slow down the loss of biodiversity is the driving force behind these initiatives. The development of Non Timber Forest Products (NTFPs) has been going on for several years. Honey, rattan, coffee are examples of community NTFP products being developed in many regions such as Kalimantan, Sumatera and East Nusa Tenggara. To help promote further commercialization of the NTFPs an attempt was made to establish a “firm” that marketed forest community’s products for national and international markets, although the scale of operation was still small. Based on this success another initiative, Kalimantan Indah, will be launched. This initiative seeks to promote the commercialization of underutilised species, both introduced and native to Kalimantan. To narrow down the number of potential species into a manageable number, criteria have been developed. Therefore 6 species commonly grown in Kalimantan have been identified as potentially valuable.

There is no doubt that underutilised species have an important role in local food security. Moreover, some species have contributed also to income generation. The work of the Indonesian Biodiversity Foundation (KEHATI) has demonstrated these two aspects in Central Java. For generations village communities around Yogyakarta have grown root and tuber crops, e.g. ganyong (*Canna edulis*), garut (*Marantha arundinacea*), uwi (*Dioscorea alata*), and suweg (*Amorphophalus campanulatus*) in their home gardens. The tuber roots are easy to plant, easily grown in a poor soil and easy to maintain. The best way to store them is to let them grow naturally in the soil. When the rice harvest is not good they use the root as their staple food. It also helps them to earn some income. Of course the price of raw materials is always low; therefore an attempt to help increase their added value is important. By using simple technology NGOs together with communities develop tuber root flour which can be used as staple food or even cakes, cookies and chips. Through these efforts communities learn how to look for added value of tuber roots, thus they can generate additional income and store the product longer. In addition to root and tuber crops, minor legumes are grown as a source of vegetable protein, Kara

(*Phaeolus vulgaris*), kara wedus (*Dolichos lablab*), kacang tholo (*Vigna unguiculata*), kecipir (*Psophocarpus tetragonolobus*), and kara benguk (*Mucuna cochincinensis*) are among the species that are found in these areas. KEHATI has empowered communities there with a provision of simple technology for food storage and food processing as well as revitalise their knowledge and interest in underutilised crops and developed new products and marketing initiatives. It helps increase the community's income and food supply (KEHATI, 2004) KEHATI can only hope that empowered communities in Central Java will keep on utilizing minor crops for their livelihood even after KEHATI has completed its project there.

Another lesson comes from the study of winged bean.(*Psophocarpus tetragonolobus*). In mid 1970s, the US-National Academy of Sciences (US-NAS, 1975) promoted several species for new crops, and winged bean was one of them. The protein content of this species is almost equal to soya bean. Moreover, a wide range of variation is shown in its seed color, seed size, and pod size from the collection made, it become obvious that the center of winged bean diversity is eastern Indonesia and Papua New Guinea**.** The results were based on the study of the winged bean in Papua New Guinea (Kahn, 1976) The potential of winged bean as a candidate for new crops has attracted the attention of the Asia Foundation. The first international symposium on winged bean was organised in the Philippines while the second was in Sri Lanka. The promise of this bean was so high so that the government of Sri Lanka had expressed its intention to establish an International Winged Bean Research Institute in Sri Lanka, a statement of which was given by the President of Sri Lanka in the Second International Symposium on Winged Bean. Unfortunately, after several years of working together internationally it is proven that commercially the bean could not find a place in the market.

Recent international cooperation in research and development of minor crops is dealing with taro (*Colocasia esculenta*). This species has been in cultivation for generations. In the Pacific Islands and Hawaii, for example, taro is an important food crop. It has a broad genetic variability. Among the result of this cooperation, data on taro has been accumulated and selected varieties have been obtained.

In Indonesia, cultivated varieties are grown in monoculture after rice. Some varieties can be planted together with legumes. Whether or not the crop will be commercially viable on a large scale remains to be seen.

SPECIES WITH GREAT POTENTIAL

All useful plant species found in home gardens and other agro ecosystems in Indonesia certainly have potential to be developed into new crops either for food or for income generation. However, due to many reasons it is impossible to deal with all of them at the same time. Naturally priority setting is necessary. The question is then: which potential species among hundreds that are now available are good candidates for food security which will also generate income? The following species are proposed not because there have already solid basis for their development, they are chosen to stimulate thought.

Ornamentals
As far as new crops are concerned this group is by far the most attractive from the commercial point of view. Every year, new ornamental crops both leafy and flowering are offered in the market. They are the products of selection from wild populations (orchids) and the results of genetic improvement of existing crops (eupohorbias). The driving force in dealing with this group of plants is the attention of horticultural hobbyists.

Food crops
For local food security uwi (*Dioscorea alata*) and siwalan (*Borassus flabilife*r) are good candidates for dryer areas in Indonesia, while taro, suweg and sagu are sutiable for areas which are wet. For vegetable protein, winged bean can be considered seriously. Information on this species is well documented. Besides village communities in Java and Papua are familiar with these crops already.

Fruits and nuts
Matoa (*Pometia pinnata*) an edible fruit from Papua proves to be acceptable to the average Indonesian. Fruits resemble rambutan in taste and litchi in shape. This species is in the process of domestication. Genetically it is variable and readily adaptable to various climates. From Kalaimantan tengkawang nut (*Shorea sp.*) is good, not only for local uses but also for commercial purposes. No fewer than 10 species of *Shorea* are valued for their nuts (Peters, 2003).

Vegetables
It is true that in Indonesia there are no truly native vegetables as Li (1976) observed. However there are two species that can be considered as candidates for new crops: taleus Padang (leafy taro) and kangkung (*Ipomoea aquatica*). This variety of taro does not produce tubers but plantlets are profusely found around the mother plant. Its leaves are soft and taste better than spinach. A new variety of kangkung has been introduced a decade ago, whose leaves are much softer than the old variety. Moreover, unlike the old water variety this variety can be planted in normal soil and uprooted at harvest.

Medicinal species
Indonesia is known for its medicinal plant species. A mixture of leaves, roots, barks, woods, flowers, seeds, etc known as *jamu* are sold in a markets for a variety of complaints. Of the many hundreds of listed medicinal plants two species are worth mentioning, namely buah merah (*Pandanus conoideus*.) and mahkota dewa (*Haleria macrocarpa*). Many believe that the two species contain substance which can treat cancer. Buah merah (red fruit) is a native of highland Papua, while mahkota dewa can be grown anywhere.

Multipurpose tree species
There are many forest species that can be considered as multipurpose tree species (MPTS). Most produce edible fruits and leaves. Two species have potential for local commercial uses. They are melinjo (*Gnetum gnemon*) and nangka (*Artocarpus heterophyllus*). Mlinjo produces nuts which can be used commercially for chips. In

villages its young leaves and fruits are valued as vegetables. Though the fruits characters are variable there has been no serious study undertaken of its genetic variability. Mature nuts are gathered and either sold as a vegetable or shelled for chips. Nangka is highly variable. Young fruit can be used as a vegetable. Leaves are well liked by goats and cows. The wood is useful for local furniture, while the bark is used as a dye for textiles.

For environment services

Indonesia is rich in tree species and shrubs which have valuable environmental uses. In addition to known species for the greening program, i.e., jeungjing (*Periserianthus falcataria*) and petai cina (*Leucaena leucocephala),* are beringin (*Ficus benjamina*) and terap (*Artocarpus elastica*). Both species are easy to grow and fast growing. Beringin is often associated with water sources, because is often found near springs in holy places.

Oil producing species

Indonesia has also sought plants that may be useful for bio fuels. Jarak pagar (*Jatropha carcas*) is identified as the most promising species. Large scale cultivation is being promoted in many districts in Indonesia. What will be the outcome of this mass cultivation is imponderable as basic information on many aspects of its large scale management is not known.

Indonesia is indeed rich in plant resources. However, major food crops are all introduced species except rice. This is also true for industrial crops. It is true that most native species are traditional or neglected crops, or are in the process of domestication. Therefore the potential is exploring the key issue in utilizing those plants. The most disturbing fact is that many native species are declining fast before we are able to cultivate them. It is a great challenge as to how the work can best be done.

'HOW' IS ALWAYS THE QUESTION

Information on the potentials of plant resources of South East Asia (Indonesia comprises the largest area) -both native and introduced- have been accumulated (Lemmens *et al.,* 1989).. Recommendations on ways to assess the potential and the need for their conservation have been highlighted (Zakri, 1989) Thailand has been very successful in promoting her native fruits in foreign markets. Why then is Indonesia lagging behind its neighbours in developing under utilised crops?

Ensuring food security is indeed a high priority for national development. While it is true that technologies for major food production are available, looking to the future in every province the state university should take responsibility for developing local resources for food security. This would ease the burden of the central government in achieving food security at the national level.

It was somewhat disturbing for listeners to the comment of the President of the scientific community at the opening of the new Herbarium Bogoriense building early this year. He expressed his disappointment that the contribution of the Indonesian scientific community to national development was insignificant. It is unimportant whether or not the President was in fact disappointed or whether the media misrepresented his statement, a clear message was sent that the scientific community should work more effectively than in the past to play its role in national development.

For national food security, the government policy is clear, i.e., rice production should be enhanced. Recent development in biotechnology has shown that techniques in modern biotechnology promise new varieties that could not be developed by traditional breeding methods. Before long it is hoped that varieties of rice adapted to drier conditions and resistant to major rice pests would be produced.

Meanwhile the role of underutilised species for food security and income generation could be revitalised local level, thus a great opportunity exists. However, the challenge is how to realise the 'how' to answer the question 'why' and 'what' for the communities. This seems to be the most difficult portion of the scientist's task. We know answers to questions regarding what needs to be done on the farm practically, where and how to store products and how to bring the products to market, but how to do they need to be scrutinised? If farmers sell their harvest in form of raw materials, the price is very low. Therefore effort to increase the added value of each species selected is needed.

Perhaps in handling underutilised species we can learn from the success of the instant noodle project. With less than 10 cents a package, one can have a meal which in term of taste is good, in term of cooking is very easy, and in terms of price affordable. If similar processes can be applied to underutilised food tubers and legumes, then those species have a bright future. In fruit species, the seasonality should be broken so that one can harvest the species throughout the year. In terms of research and development most species are interesting, but if we are challenged by policy makers on our contribution to national development, we have to focus our attempts in dealing with underutilised species. It means that we have to have targets with in a certain time frame to fulfill our task.

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6

Indigenous vegetables in East Africa: sorted out, forgotten, revitalised and successful

D. Virchow

Although there are differences in attitude and perception towards African indigenous vegetables (AIV) from consumers in Tanzania and Kenya depending on their income level and education, AIV had lost their importance as vegetables compared to exotic vegetables (like tomato and onion) over the last few decades. Rejection was fuelled by associating indigenous vegetables with poverty and backwardness, at the same time the taste – esp. of the young generation – had changed. In addition, the missing knowledge concerning their nutritive value and the unavailability in the formal and informal markets both in urban and rural areas increased the downward trend of AIV. Not only consumers, but also producers of vegetables were losing interest in AIV. Besides growing AIV in their fields, collecting these vegetables from the wild and fallow land was (and still is) the major source of harvest of AIV. Because of comparative advantages in production and marketing of exotic vegetable crops, the production of AIV has been marginalised. Consequently, most of the farmers have applied little or no agronomic technologies on production of indigenous vegetables.

AVRDC – The World Vegetable Center, Regional Center for Africa implemented a project in East Africa aimed at promoting sustainable production, seed supply and marketing of AIV. The major tasks were to improve the productivity for the target crops, increase marketing and streamline the efficiency of the AIV sub-sector value chain as well as to increase consumer awareness.

Besides capacity building of farmers and farmers' groups on technologies for production, processing and marketing, appropriate technologies were disseminated (incl. seeds), business support groups established, market linkages and channels developed and consumer awareness for AIV was raised. The consequences of all these interventions are that farmers in the target areas started to appreciate farming of indigenous vegetable crops as a commercial business enterprise; whereas in former times, farmers were planting indigenous vegetables primarily for subsistence, and they have now become commercial farmers with a demand driven scheduled production. The farmers are even reducing the cultivated land under other crops to expand their production and marketing of AIV. In addition, the partnership between high value chain stores (supermarkets), other formal markets, institutions and groceries enabled small scale producers to participate in highly competitive horticultural business.

INDIGENOUS VEGETABLES IN EAST AFRICA: UNDERUTILISED AND ON THE DOWNWARD TREND

African indigenous vegetables (AIV) (e.g. Amaranthus *spp.*; African nightshade – *Solanum scabrum/villosum/tarderomotium*; African eggplant – *S. aethiopicum/*

macrocarpon/anguivi; jute mallow – *Corchorus olitorius/tridens*; Ethiopian mustard – Brassica carinata; Spiderplant - *Cleome gynandra*, Hyacinth bean – *Lablab purpureus*, Cowpea – *Vigna unguiculata*, bitter leaf – *Venomia amygdalina*, etc.) have had an important historical role to play in the farming and consumption systems across sub-Saharan Africa. Production and consumption in much of sub-Saharan Africa was until recently based upon subsistence crops and edible weedy species as well as on the cultivation or utilization of a wide diversity of food crops whose total number of species is among the largest in any region of the world (Martin, 1984; Leakey and Wills, 1977; Tindall, 1977). The success of the traditional production patterns, based on subsistence agriculture in much of Africa, including Tanzania, was based on a wide diversity of food crops, including cultivated and weedy species, grown in a mixed cropping system. The wide diversity of crops utilised included several important cereals, roots and tubers, legumes and many leafy vegetable crops, (Harlan *et al.,* 1976; Martin, 1984; Tindall, 1977; Chweya, 1985; Prescott-Allen and Prescott-Allen, 1990).

During colonization and increasing globalisation, cash crops as raw materials for international export markets were introduced and started to replace and change traditional farming systems and production patterns. In addition, new ("exotic") crops were introduced, changing the consumption patterns as well.

Vegetables, especially leafy vegetables, played an important role in the sub-Saharan African agriculture; besides the production always included the collection of wild vegetables from the wild and fallow land while some were cultivated and others weedy. In addition, these vegetables supplied (and still supply in specific rural areas of Africa) much, if not most, of the population's required vitamins (especially A, B's, and C), minerals, fibres, carbohydrates and proteins (Ruberto, 1984; Martin, 1984; Okigbo, 1983; Chweya, 1985; Platt, 1965; Imbamba, 1973; Schmidt, 1971; Keller *et al.,* 1969).

Tanzania also contained and still contains many indigenous vegetables which are little known outside of Africa but are important contributors to the diets of people not only in Tanzania but in much of SSA; hence playing an essential role in the nutritional well-being of tens of millions of people (Prescott-Allen and Prescott-Allen, 1990; Keller *et al.,* 1969). However, the frequency of consumption has decreased over time (Weinberger and Msuya, 2004).

As Weinberger and Msuya (2004) show in their study on Tanzania, the 'nutrition transition' has reached developing countries, so as well Tanzania, particularly the urban population and those with higher incomes. This transition is characterised by a decline in consumption of traditional food crops, and increasing consumption of refined and processed foods, fats, sugars, and animal foods (Millstone and Lang, 2003). Based on the consumption patterns dominant in Africa at present, the AIV, once the backbone for vegetable consumption/micronutrient uptake, disappear more and more from the consumers' plate and hence become underutilised crops on their downward trend. Although these crops seem to have passed their climax of importance and are now on the way to be forgotten and extinct, but still, the AIV have the potential to play a much greater role in the fight against malnutrition and poverty in Africa. The changing world has diminished their importance, but their potential is still so high that it can be anticipated that AIV will play a future role in contributing to food security, health, and income generation in Africa.

Such crops thus hold the potential to serve as important drivers for rural growth and improved livelihoods. In their present status, they are already an important component but with potential for a much greater role i.e. they are said to be underutilised.

Although there are differences in attitude and perception towards AIV from consumers in Tanzania and Kenya depending on their income level and education, it can be predicted that over the long-run, the consumption of AIV will diminish even more, if countermeasures are not taken. This prediction is based on the general development of consumption patterns (the above stated 'nutrition transition' as well as Engel's Law, meaning that AIV as "inferior goods" will lose their importance by increasing income of the consumers and hence, will be pushed out of the market soon) and verified by the studies undertaken in Tanzania and Kenya by AVRDC and its partners in the recent years (Weinberger and Msuya, 2004; AVRDC unpublished, 2004). These surveys show that AIV had lost their importance as vegetables compared to exotic vegetables (like tomato and onion) over the last few decades. The rejection was fuelled by associating indigenous vegetables with poverty and backwardness, at the same time taste had changed. In addition, the missing knowledge concerning their nutritive value and the unavailability in formal and informal markets both in urban and rural areas increased the downward trend of AIV. Not only consumers, but also producers of vegetables were losing interest in AIV. All these different causes are discussed in the following paragraphs.

A consumer survey was carried out by AVRDC on consumers from various income levels; low, medium and high to determine their knowledge about AIV, their attitude and perception, the preparation method, social cultural aspects of these vegetables, outsourcing and frequency of consumption. It was very clear that high income earners are associating AIV with poverty and only a few of them were consuming these vegetables in the target areas of both countries, Tanzania and Kenya (AVRDC unpublished, 2004). The middle and average earners consumed these vegetables but were wary of the source especially urban centre sources where most of the vegetables are believed to be grown with untreated sewage water which is a health risk. In this class, most of the consumers were optimistic that if these vegetables were available in formal markets and grown and handled in a cleaner way they would highly appreciate and utilise them. In the low earners level, the number of people consuming AIV was the highest.

The attitude against AIV corresponds with the reality on the ground: according to a study conducted by Weinberger and Msuya (2004), the richer the consumers are, the less AIV they consume. In addition to substituting AIV with exotic vegetables, it has been shown that the wealthier a household becomes, the more different vegetables are consumed, but the additional vegetables are all from the exotic segment (Weinberger and Msuya, 2004).

Besides the perception of being the poors' food, the taste especially of the young generation and also urban population in general had changed. Most young consumers interviewed in the process of the survey, did not even know what these indigenous vegetables were or knew some but with a very negative attitude and image towards them since they viewed them as not trendy and unfashionable as compared to fast food. Further to being rejected by the young generation, AIV seem to have less comparative advantage regarding the "better" or more intensive flavour of exotics like onions and tomatoes.

With the present process of modernization, the decline in consumption of AIV is accompanied by the loss of indigenous knowledge on production methods, preservation, utilization, as well as nutritive and other values, because the information is not being systematically transmitted from one generation to the next anymore. In addition, most scientific and agronomic research and development has focused on exotic varieties (Gockowski *et al.,* 2003), leading to a gradual loss of indigenous knowledge relating to production methods, preservation, use and nutritive value (Keller, 2004). And modern knowledge accumulation regarding AIV is still in its infancy. Relatively few systematic studies in any area have been conducted on AIV. The scarce research work on AIV has been concentrating on species identification and nutrient analysis (e.g. Mathooko and Imungi, 1994; Vainio-Mattila, 2000; Bhat and Rubuluza, 2002; Lyimo *et al.,* 2003; Ogoye-Ndegwa and Aagaard-Hansen, 2003).

Not only consumers, but also producers of vegetables were losing interest in AIV. Besides growing AIV in their fields, collecting these vegetables from the wild and fallow land was (and still is) the major source of harvest of AIV. Because of comparative advantages in production and marketing of other (exotic vegetable) crops, the production of AIV has been marginalised. Most AIV (especially all the leafy AIV) are highly perishable and hence have a higher marketing risk for the producers or traders compared to other, exotic vegetables, especially cabbage. Cabbage, as non-perishable has an advantage for all actors in the supply chain, starting with the producer to the trader and finally to the consumer. In addition, cabbage has a very filling and satisfying effect (for instance compared to nightshade), hence increasing the demand esp. by the poorer consumers. The consequence is that in the target areas, AIV were mostly grown as weeds in the farmers' fields and were less appreciated as vegetables or as a reliable business opportunity for commercialization, with strong doubts on AIV market availability among the producers. Eventually, as part of the erosion of indigenous knowledge of AIV, the farmers had little or no knowledge regarding agronomic production technology of leafy vegetables anymore.

Apart from the marketing aspect, AIV have another comparative disadvantage compared to the exotic vegetables: The seed availability for exotics (through farmers own reproduction or from the market) is much higher and easier to access than AIV, which simplifies the decision of the producers as what to cultivate. Until recently, farmers relied on informal and weak seed production systems for their AIV production. Consequently, in a rapidly changing world, with internal and external influences, not only agricultural production patterns for staple crops are changing drastically in Africa. Similar to the situation that over 50 percent of the daily global requirement of calories and proteins is met by just three crops – maize, wheat and rice (Virchow, 1999), the source of vegetable consumption is narrowing down to fewer and fewer crops. Hence, many former vegetables, indigenous to Africa and African consumption are tending to disappear from farmers' fields and consumers' plates, most of them condemned to become "underutilised crops" and some of them are even threatened by extinction, with the consequent loss in agrobiodiversity (Keller, 2004).

WHY CARE ABOUT UNDERUTILISED VEGETABLES?

Hunger and malnutrition remain among the most devastating problems facing the majority of the world's poor and needy people. Over 2,000 million people suffer from iron deficiency anaemia (FAO/WHO, 2001). Vitamin A deficiency remains the single greatest preventable cause of needless childhood blindness and increased risk of premature childhood mortality from infectious diseases, with 250 million children under five years of age suffering from sub-clinical deficiency. The situation is particularly bleak in sub-Saharan Africa, where, compared to other underdeveloped regions in the world, no progress in reduction of child malnutrition has been made over the past decade and nearly a third of all under five remain malnourished (FAO/WHO, 2001). Up to 25% of the East African population is under-nourished due to poor energy and protein intake. Furthermore, about 40% of women of childbearing age have anaemia while an almost equal percentage of children under five do not consume enough nutrients to maintain normal physical health (IFPRI, 2004).

Vegetables, especially AIV, are not able to solve the food insecurity problems on their own, but looking at nutritional security, as one part of the food security complex, vegetables can be one of the most cost-effective and sustainable solutions to micronutrient deficiencies (Ali and Tsou, 1997; Bouis & Hunt, 1999). AIV were and in certain areas are still an important part of farming and consumption systems throughout Africa and are crucial for food security particularly during famine and natural disasters. They are easy to grow, require minimal external inputs and are very suitable to resource-poor farmers (Opole *et al.,* 1991). They are an integral component to many traditional dishes (Yusuf *et al.,* 2003), and are a cheap and easily accessible source of nutrients for both the rural and urban population (Chweya and Eyzaguirre, 1999). On a unit cost basis they are nutritionally rich (Gockowski *et al.,* 2003), contributing micronutrients and some of them increase the bioavailability and effective absorption of micronutrients from other staple food crops, provided that they are prepared and cooked properly to maintain their nutritional value and consumed regularly.

Studies have shown that leafy vegetables are high in vitamins, minerals, protein and fibre (Chweya, 1985; Keller, et. al, 1969; Weinberger and Msuya, 2004; Yang *et al.,* unpublished data 2007). Vegetables especially African Indigenous Vegetables (AIV) are excellent sources of vitamin A, C, iron as well as protein, minerals and fibre; and can release and make available micronutrients as well as increase the bioavailability and absorption of micronutrients. In addition, AIV have been found to be high in antioxidants (AVRDC, 2004) and other health related phytochemicals with anti-malaria and anti-microbial properties (Park *et al.,* 2002; Erasto *et al.,* 2004; Van den Berghe *et al.,* 1991; Veluri, *et al.,* 2004).

According to a study conducted by Weinberger and Msuya (2004) in the frame of an AVRDC project, among the rural population of selected districts in Tanzania, only about one-quarter of all vegetables consumed were indigenous, the remaining were exotic vegetables. By comparing their findings to earlier reports from the 1970s, it could be shown that the frequency of AIV consumption has declined. However, AIV continue to be an important contribution to the diet, particularly so in the rainy season, when they are readily available. Nearly 80% of interviewed households reported that they collected AIV during the rainy season. It was also reported that the share of AIV consumption among all vegetables is much higher among poor households (40%) than among the wealthiest households (11%) and also the variety in consumption of indigenous vegetables decreases as households become wealthier, while at the same time the variety in consumption of exotic vegetables increases.

The importance of AIV is often discussed only in the context of (micro-)nutrional benefit to the consumers. However, AIV as wild and collected crops contribute as well to food safety in times of hunger and civil unrest and war (Grivetti and Ogle, 2000). In addition, experience and studies show that vegetable production, marketing and consumption has the potential to contribute significantly to the development of especially the rural and poor population and hence being a motor of rural development. A review by Gockowski *et al.,* (2003) indicates that the market potential of available indigenous vegetables is very large and several studies have documented their significant contribution to household income (Weinberger and Msuya, 2004).

As long as agriculture remains the key economic sector for virtually every country in Africa, promoting growth in agriculture will have positive economy-wide spill-over effects (Commission for Africa, 2005). Agriculture still provides livelihoods to around 80% of the African population (UNECA, 2004). Consequently, promoting vegetables and especially AIV will have significant impacts on SSA economies and income levels.

Diversification into vegetable production contributes to poverty alleviation through increasing income and employment opportunities in rural areas (Weinberger and Lumpkin, 2005). In addition, low input AIVs are the only cash resource at the disposal of women for the welfare of their families. Thus their improved consumption and utilization is the most direct, low-cost way for children, lactating mothers and urban and rural poor to improve their nutritional, health and income status. Based on the Asian experience, positive health and economic effects can be projected by increasing vegetable consumption and production in Africa. Besides the positive nutritional and economic effects of increased production and consumption of AIV for the rural population, IVs have good potential to be exploited commercially as examples from South East Asia (i.e. Thailand), where urban supermarkets increasingly stock a wide variety of IVs for affluent consumers.

It is forecasted that an increase in production will lead to an increase in employment through the high labour demand for cultivation as well as the possibilities of food processing. In addition, higher production and adding value to produce on site will lead to increasing incomes for producers. An increase in production will, accompanied by awareness raising activities, lead to an increase in consumption, that will reduce the devastating health effects of insufficient micronutrient intake.

This holds true for the insufficient production and consumption of vegetables in general, but also for AIV in particular. Even if exotic vegetables are replacing AIV in Africa, the over-all situation of vegetable production and consumption can be seen as underutilised. The production and consumption of vegetables in Africa is lagging far behind the world-wide average. The consumption of vegetables in SSA is less than the WHO/FAO recommended minimum intake of 200 g of vegetables/day/person. And also in the production of vegetables, Africa is bringing up the rear by producing annually app. 50 kg of vegetables per capita, which is less than half of the rate in most of the other regions of the world (FAO, 2007).

These opportunities for Africa can only be realised, if decision makers are willing to invest in improvement of vegetable production, marketing and consumption and thereby impacting significantly on the development of especially the rural and poor population. To increase demand for vegetables, promotion and raising awareness has to take place, to increase the supply, improved technologies have to be offered and propagated. These investments will have a high return in improved health status of the population as well as being a motor for economic development, thus breaking the downward trend of malnutrition and poverty in Africa.

PROMOTION OF UNDERUTILISED AIV AS ONE PATHWAY TO SUSTAINABLE DEVELOPMENT

Based on the experience in Asia and the result of conducted research, AVRDC – The World Vegetable Center, Regional Center for Africa implemented a project in East Africa, aiming to successfully reverse the downward trend in the production and consumption of AIV, by implementing various measures at the same time. As discussed above, these measures have to stipulate the demand for and the production of AIV. But to link the increasing production to the increasing demand, the market channels have to be established or improved. So the major tasks of AVRDC's project ("Empowering Small Scale and Women farmers through Sustainable Production, Seed Supply and Marketing of African Indigenous Vegetables in Eastern Africa") were to improve the productivity for the target crops, increase marketing and streamline the efficiency of the AIV sub-sector value chain as well as to increase the demand for under-utilised AIV. The project was implemented together with Farm Concern International (former FamilyConcern International) between 2004 and 2006.

AVRDC-The World Vegetable Center is an international, autonomous, philanthropic, non-profit research and development organization. AVRDC is the principal international centre for vegetable research and development. Its mission is to reduce poverty and malnutrition in developing countries through improved production, marketing and consumption of safe vegetables. Farm Concern International (FCI) is a regional market development trust developing pro-poor marketing models and strategic alliances to enhance economic growth among poor communities in East Africa. FCI market development initiatives have been benchmarked to private sector market development approaches with an aim of enhancing the competitiveness of the poor in the market place.

Project Sites

The project was conducted in two very different socio-economic and cultural settings: rural and peri-urban villages in Kiambu, Kajiado and Thika districts, Kenya within 45 kms of the capital city Nairobi, and rural villages in Arumeru District, Tanzania within 30 kms of the provincial capital of Arusha. The target areas where implementation of this project has been taking place include in Northern Tanzania: Manyire, Karangai, Olevolosi and Kiranyi villages of Arumeru district and in Kenya: Githunguri, Juja and Kikuyu Divisions of Kiambu and Thika Districts in Central Kenya, Kiserian region of Kajiado district, and other regions around Nairobi.

The Arumeru pilot sites can be characterised as sites where a limited number of households were already carrying out limited marketing of some of their produce on their own prior to the initiation of the Commercial Village Approach. In contrast, Kiambu, Thika and Kajiado District are sites where a significant percentage of households were significantly engaged in agricultural commercialization prior to initiating this project, yet the market linkages found were inefficient. Within these sub-groups, the two sites significantly differ in terms of cultural practices, altitude, levels of precipitation, and soil fertility.

In this project, there was a clear division of labour between AVRDC and FCI: AVRDC has been focusing on improving productivity of promising lines, developing and demonstrating cultivation, utilization practices and sustainable production of selected superior AIV, as well as disseminating quality base seed of target species to target farmers for promotion as well as technologies for production and processing. To improve the economic and management situation, FCI has been working and collaborating with the various players ranging from producer groups, extension officers, retail outlets and other institutions in implementation of this project, including establishing business support groups, developing market linkages and channels as well as capacity building of farmers and farmers' groups on marketing. AVRDC as well as FCI were engaged in raising consumer awareness for AIV, which was the crucial point for stimulating increased demand. In the following these different measures are discussed in detail.

Following the supply chain from production to consumption of AIV, the crucial "Elements of Success" were:

Germplasm collection and improvement, seed multiplication and dissemination

AVRDC-RCA has collected and evaluated over 1,200 germplasm accessions of 15 common AIV. Some of the AIV' lines have been purified, characterised and the cultivation and utilization practices of some promising lines/varieties have been developed, documented and disseminated.

The project multiplied and disseminated over 500 kg of seeds of the target crops and helped farmers access over 1 tonne of seeds through established seed supply systems thus ensuring that the producer groups have sufficient seed for the targeted AIV. The target crops for this project were the six most common AIV in East Africa:
African eggplant (*Solanum aethiopicum*), African nightshade (S*olanum scabrumvillosum/americanum spp*), Amaranth (*Amaranthus hypochondriacus/cruentus/blitum/dubius spp*), spider plant (*Cleome gynandra*), cowpeas (*Vigna unguiculata*) and okra (*Abelmoschus esculentum*). In addition, the project worked on and supplied the farmers with other AIV such as Ethiopian kale (*Brassicas carinata*)) Pumpkin (*Cucurbita maxima*), Fig leafed gourd (*Cucurbita ficifolia*), Sun hemp (*Crotalaria ochroleuca*) and others. A brief description of the major crops follows.

African eggplant (ngogwe in Swahili) is a very popular plant, and consumed throughout the African continent at large. Its green fruits tend to have a slightly bitter taste and in Tanzania, these are collected and cooked as a vegetable, often in tomato stews in combination with 'ugali', rice or plantains. Estimates spread widely for ngogwe yields as studies report values varying from 5-8 tons/ha (without irrigation) to 12-20 tons/ha (with irrigation) (Schippers, 2002). Recent studies at AVRDC-RCA have shown that mean fruit yields can range from 1.3 to 62.5t/ha when grown under irrigation; with yield variation depending on species with *Solanum aethiopicum* giving mean yields of 47.4t/ha while *S. macrocarpon* recorded the lowest yields (Oluoch and Chadha, 2007). Repeated fruits harvests can be obtained, sometimes within 7 days and this is a process which should be encouraged even when fruit sales do not take place as repeated harvesting tends to improve bearing capacity of the plant over time. The crop is very resistant to diseases and generally fares better under relatively humid and warm conditions (i.e. 23 to 35 degrees Celsius day time temperatures) as well as low altitudes.

African nightshade (mnavu in Swahili) is found throughout East Africa in both lowland and highland and can grow on various soil types but is believed to perform better in lowland areas that are humid, or near water sources (such as lakes) than in the more semi-arid areas since it is does not tolerate dry conditions well. Its shoots and younger leaves are boiled as a vegetable in Tanzania and are then consumed with ugali (maize or sorghum), rice or plantains. To reduce its bitter taste, it is often cooked together with amaranth. In Tanzania, juice extracted from the leaves is also used to relieve chronic conjunctivitis and related inflammations. The crop will be ready for its first harvesting five weeks from transplanting and yields may fall within 4 to 40 tons/ha, depending on the species (AVRDC, 2004; Mwai *et al.,* 2007).

Amaranth (mchicha in Swahili) is widespread throughout the lowland humid tropics. Its main use is as a cooked leafy vegetable although in Tanzania the whole plant can also be used as a medicine to treat stomach aches. It is often cooked in combination with other leafy vegetables (such as nightshade) in order to neutralise the bitterness. It is a fast growing crop i.e. in the case of the hypochondriacus variety; a first harvest can be obtained within 3-5 weeks after transplanting after which leaf cuttings can then be taken on a weekly basis. Average yields can reach 20 to 25 tons/ha with the low and higher ranges of 1.2 to 57t/ha depending on species and season. The crop grows well at relatively high temperatures (25° c day time temperature) and is fairly susceptible to various pests, diseases as well as competing weed plants.

Spider plant (Mgagani in Swahili) is one of the most important traditional vegetables in most African countries. The spiderplant is rapidly becoming popular and is no longer considered as a weed, but is most welcome as a source of food and income mostly in rural communities in East Africa. The spider plant is known for high nutritional value and is used traditionally as a medicinal plant to help mothers recuperate after delivery. Leaf yields range from 7 to 11t/ha (AVRDC unpublished, 2004).

Cowpeas (Kunde in Swahili) have long been in cultivation in Kenya and Tanzania. Numerous varieties are known which are used for their seeds. Varieties that are prostrate with long vines are mainly used for their leaves (and occasionally their young green pods) and in many places the crop is a vegetable of major importance. It is the most important pulse crop in tropical Africa, and is especially important in arid or semi-arid areas, as it is deeply rooted and tolerant to drought. The leafy vegetable varieties are grown both for direct consumption and for drying. The young tender leaves are preferred for direct consumption. The leaf yield ranges from 3 to 5t/ha (AVRDC, 2004).

Okra (Bamia in Swahili) has three cultivated species *Abelmochus esculentus, A. caillei,* and *A. manihot*. It is a crop distributed worldwide and belongs to the Malvaceae. It is an erect herbaceous crop (up to 1 to 2 m tall) grown for its fruits and have five distinct ridges. Fruits are consumed either when young and green or matured and dried, but in this case they are used as a powder added in sauces. It is a warm season crop and improved cultivars can produce 24 to 28 fruits/plant and yield up to 17 t/ha of fresh fruits and 2.5t/ha of seed with high management (AVRDC, 2004).

Ethiopian mustard (loshuu in Swahili) is a leafy vegetable common through most parts of central, eastern and southern Africa. The crop can grow both in high as well as low altitude areas but in general, performs better during relatively dry periods when there are few pests and diseases. In Tanzania, people cook the leaves and fresh shoots or will stir fry them, either alone or in combination with some other leafy vegetable and eat it with 'ugali'[1], rice or plantains. For a conventional crop, the first harvest can be obtained within five weeks of transplanting. Afterwards, leaf pruning can be done every one to two weeks (this process is also encouraged). Leaf yields can range from 6 to 30t/ha depending on the variety.

In the distribution process in Kenya, existing agro-chemical shops were engaged in the distribution process whereby farmers from the business unit are directed to stockists who have been identified and issued with seeds to sell to farmers in target areas. In Tanzania, seed distribution has occurred through the self-replicating effect. Target farmers were given seeds by AVRDC and after training in basic seed production issues, were given seeds then encouraged to produce their own after every harvest. Through these channels farmers have been able to access improved seeds and quality seeds. For sustainability of the program, farmers are also equipped with seed multiplication technology, processing and packaging technologies and this has helped some of them produce their own seeds. So far over 500kg of seeds for the indigenous vegetables have been disseminated to the farmers through the existing channels to both the target areas and several other parts of Kenya and Tanzania.

This has been due to the high demand in both formal and informal seed markets for all the major indigenous vegetables. To institutionalise seed multiplication, farmers were linked on trial bases to the Kenya Seed Company in Kenya and the Kibo Seed Company in Tanzania. Farmers were to be contracted by the companies to multiply AIV' seeds. Some farmers in the Kiambu target areas carried out some trials on African nightshade after which they found that due to the vicinity to the city, vegetable production is more lucrative than seed business. However there is a huge existing opportunity for seed production especially for rural producers who may not be in a position to compete in the leafy vegetable business. The Kenya and Kibo Seed Companies have however started producing seeds of AVRDC introduced nightshade and cowpea varieties in addition to other indigenous vegetables (amaranth, crotalaria, and spiderplant).

Production technology transfer and strengthening of extension services

Most of the farmers involved in the project had little knowledge on production technologies for AIV production and processing and thus the project conducted training, including training of trainers for group members, to disseminate appropriate technologies on appropriate land preparation techniques, manure application and soil fertility management, seed drilling and seed media mixing ratio, and general vegetable husbandry practices and farm management practices. Over 500 farmers received direct training who in turn trained over 600 other farmers, hence a multiplier effect took place reaching far more farmers than planned.

For sustainability of the technology disseminated to continue beyond the project period, the project established a working partnership with the Ministry of Agriculture and research institution officials in the two countries and who work directly with the farmers, thus giving them the necessary agronomic support during the project phase but also for the future. Training was carried out at AVRDC's Regional Center in Arusha, where progressive farmers and NARES representatives were trained on vegetable production technologies and vegetable marketing. This was to help supplement the agronomic support that the project offered to the farmers. The process of having the trainees acquire AIV production and utilization technology has made it easier for the farmers to easily assimilate the technology and constantly get to the extension officers whenever need arises. The officers have also benefited from the demonstrations and exhibitions in regards to AIV farming practice which has promoted crops which were previously viewed as weeds and for which very little had been done in the national research and training institutions. The training of trainers involved from every farmer group one trainer and these had been trained on various issues ranging from agronomic to marketing issues to supplement the groups' training and to offer training to new groups within their locality. Some of the groups who act as trainers for other groups are paid per training as a BDS provider.

Business support units

Farmers in the target areas cited various problems such as lack of reliable means of transport, exploitation by middlemen and lack of market information as major obstacles that have hampered profitability of agricultural enterprises. To overcome this the project assisted farmers in the target areas in formation of business support groups or CBO's (community based organizations) which evolved into viable business units through a model developed by FCI for this particular intervention. This model seeks to equip farmers from the targets areas with agronomic and business skills crucial for successful commercialization. Groups are mainly formed for implementation of certain agricultural technologies. The farmers in these groups were trained on production, utilization, marketing of AIV and the essence of targeting markets as a group thereby trading as a common interest block through examples of other successful groups and exchange visits.

The pro-poor market development implementation approach is based on the Commercial Villages Approach, CVA, a model aimed at enhancing the commercialization levels of villages based on clustered producer groups under a commercial village framework. Commercial Villages / Private Sector partnership is applied to for market entry and build business partnership alliances between poor communities and private sector players.

Over 28 such units of business support groups were established or reorganised in Kenya and Tanzania. Each group consists of between 15 - 30 farmers which are marketing indigenous vegetables in both formal and informal markets either directly or through linkages to intermediaries. These support units have been trained on group dynamics like successful group leadership, successful group finance management and record keeping. They were trained and assisted to conduct regular leaders' elections and development of guiding documents such as constitutions which ensure that members will abide by certain rules and adhere to a code of behaviour and safeguard farmers' money and interests.

Market linkages and channels development

The project has linked producer groups from the target areas to many outlets in both formal and informal markets. In informal markets the linkages are to small scale traders who buy at the farm gate and also at collection centres; and medium scale traders who buy from them and then sell to formal markets and to institutions. In Kenya, some of these traders then resell to informal markets at Wangige, Githunguri, Kiambu, Kangemi, Korogocho, Kawangware, Ngara, Gikomba as well as other smaller vegetable vendors located in the city estates and its environs. In Arusha, Tanzania the common sales markets are Kilombero, Central markets, Tengeru, Ngaramtoni and Shoprite chain stores for formal markets.

In the formal markets the project has linked farmers directly to or through intermediaries buying from them with the Uchumi chain stores where FCI has established a contractual agreement with the management to have the farmers under this program supply AIV. Reliable traders are now being sought who can buy vegetables from farmers and sell to Uchumi as a way of ensuring that the provision of BDS is sustainable for weak groups.

Other outlets in the formal sector that have linkages established by Family Concern are Nakumatt chain stores that get their supply of AIV either directly or through Fresh' N' Juici who supply them with much of the fresh produce. Fresh 'N' Juici is supplied by farmers under the programme directly and indirectly through a new intermediary called Rispes who outsource from Githunguri farmers groups.

Another chain store that is buying in Kenya is Tusker Mattress. Farmers have also been supplying institutions such as National Assembly Cafeteria (Kenyan parliament) every Tuesday with all of the major types of the AIV. Other markets in the formal sector that Family Concern have linked AIV farmers with are groceries such as Kairuthi eggs supplies in the city centre who supplies fresh produce also and Green Corner in Yaya centre. Most of these formal markets demand good quality supplies but buy at a better price. The formal markets are always reliable and dependable though initially they used to take little but now this is increasing at a high rate.

FCI has designed and developed a range of marketing models, which will be improved, modified and applied in this project. The models are characterised by a modified corporate and private sector approach in market access to suit poor and vulnerable farmers. Some of the models applied include; Development of Business support Groups with 10-15 members with a sales representative equipped to penetrate identified market niche's; collective product branding & labelling among farmer groups promoting the products while each member takes up the role of a marketing representative; entrepreneurs / farmer groups establish intermediary networks in various urban centres and group members bulk to meet orders and products are repackaged and / or branded according to the market requirements.

The market penetration parameters applied include; market assessments product branding, collective marketing of informal groups, market linkages, market penetration, evolution of informal groups into Business Support Groups, Business and Marketing training and in the improvement/development of commodity chains. Product development technologies utilised include; development of suitable moulds for packaging materials, design of labelling materials and bar-coding technology. Product development and/or improvement and product processing is implemented alongside product testing which uses consumer clinics and focuses group discussions as consumer research tools. The firm has conducted a wide spectrum of market assessments, developed marketing strategies and tested various marketing concepts with various development organizations and private firms. Some of the marketing concepts applied for small-scale businesses and smallholder farmers are particularly relevant to the product-growth concept which focuses on alternative growth strategies for farmers; intensification of specific areas; product development and market development.

Demand stimulation through awareness creation on production, utilization and marketing

Through awareness that the project has been carried out through the media and other promotional forums, the availability of information on the nutritive values of AIV has been provided to consumers in the target areas, leading to a boost in market demand growth.

The project has developed a number of promotional forums, campaign, exhibitions of various vegetables samples, cooking demonstrations of various AIV's recipes, distribution of recipes booklets and leaflets to both consumers and producers, held several consumer and producer awareness clinics, over 40 field forums and a major field day attended by about 200 participants. The project has also carried out 7 presentations on local radio stations in Nairobi (e.g., Kameme FM), where the audience can easily exceed 3 million listeners, through interactive forums where the audience calls or sends short messages (SMS) and answers are provided live on air. Also the project has featured in the state owned Kenya Broadcasting Corporation (KBC) where it had addressed the issue of horticultural marketing in a new program called MALI SHAMBANI. In presentations, discussion on consumers' attitude towards African leafy vegetable, their nutritive values, production process, outsourcing, cooking methods that preserves nutrients, vegetables processing and preservation methods such as blanching and drying and their cultural values has taken place.

In addition to general awareness raising campaigns, the project has organised promotion in fresh formal markets and major chain stores like Uchumi and Nakumatt in Kenya and Shoprite in Tanzania where high and middle social classes do their shopping. Recipes were displayed and tasted and materials distributed and discussed with the consumers where issues e.g. outsourcing procedure were communicated in terms of hygiene standards that the suppliers have to observe to be allowed to supply supermarkets and sources of such produce. Other categories of information supplied included nutritive value and cooking methods.

Finally, several documents have been developed to raise AIV production and consumer awareness. Some of the publications or promotional materials produced include leaflets or fliers, production manuals, banners and posters.

INTERVENTIONS FOR AND PROMOTION OF UNDERUTILISED AIV LEAD TO SUCCESS

The consequences of all these interventions are that farmers in the target areas started to appreciate farming of indigenous vegetable crops as a commercial business enterprise with demand driven scheduled production. The business is running so well that the farmers are even reducing the cultivated land under other crops to expand their production and marketing of AIV.

Especially in Kenya, the project was very successful, whereas in Tanzania success was limited. The above described interventions through the project led to substantial economic impacts, especially in Kenya (ETC East Africa, 2006). Five hundred farmers were organised in business support groups and 3,000 additional farmers had access to and adopted AIV farming as a business enterprise. Sales in Nairobi and peri-urban markets rose from less than 31 tonnes per month in 2003 to over 600 tonnes of AIV per month in 2006. This increase was only possible due to improved production, marketing and promotional efforts led by the project. In Kenya, AIV worth KShs. 80 million (UK £ 0.63 million) and KShs. 150 million (UK £ 1.10 million) were sold in informal and formal markets respectively, translating into KShs. 3.8 million (UK £0.03 million) per group of 20-30 members. Production levels of Amaranth (29.6 t/ha) and Nightshade (23-32 t/ha) in target areas in Kenya increased significantly. High production created an opportunity for household consumption and sale of AIV with income generated used to address diverse livelihood needs. The AIV farming proved to be a fast income earner due to short growing periods and low production capital input requirements.

The success of the project in Tanzania was significantly lower than in Kenya. The main reasons for limited success were:

1) The slow pace of group formation in part due to a lack of prior experience of collective action for commercialization among the participants;
2) The culture of the major ethnic group in the target area of not eating vegetables and their lack of entrepreneurial experience;
3) The widespread perception in North Tanzania of AIV in urban markets being weeds and food for the poor;
4) Drought, pest (red spidermites) and disease (verticillium wilt) attacks causing 50% and 40% losses of nightshades and African eggplant, respectively;
5) Inadequate linkages to formal markets, as development of these linkages depends on successful group formation; and
6) The customers in the modern supermarket of Arusha are significantly different to the customers of the supermarkets in Nairobi. In Nairobi, the supermarkets are frequented by the high and the middle-income group, whereas in Arusha, Shoprite's customers are to a very large extent expatriates from all continents.

The sale of AIV in the Arusha region increased significantly during the project period, although more on the informal and fresh market than in the supermarket.

The reason for the over-all success of the project, with certain limitations in the Tanzanian target areas, is the simultaneous implementation of all different elements in all three major areas of the supply chain: at production, marketing as well as the consumption level. Only by improving and facilitating the different processes on all levels, the courage and innovation of the farmers to cultivate or increase their cultivation of AIV, the readiness of the formal market and modern suppliers to partner for marketing AIV as well as consumers interested in buying and hence increasing the demand for AIV, was rewarded.

It was necessary to improve the productivity of AIV and to enable farmers to buy good quality seed of AIV, if AIV production is to be able to compete with other commercialised crop production. This was done through AVRDC's efforts of collecting, evaluating and selecting promising lines of AIV as well as multiplying good quality seed and encouraging seed companies to multiply and sell AIV seed. In addition, AVRDC successfully trained farmers in modern, more efficient and effective production and processing technologies for AIV, which were developed and demonstrated.

AIV farming has proved to be one of the most rapid sources of income generation due to the short growing period of vegetables and less capital and/or input requirement for production. The return on investment is very high compared to other crops and market demand currently is higher than supply. Inquiries on regional and export markets have been made by some exporters and have created a high possibility of full commercialization and an upsurge of production with new opportunities for both fresh and dried AIV.

After all, AIV have become a new growth industry for farmers around major urban centres like Nairobi. Fuelled by new varieties that yield well and a public promotion campaign to boost consumer awareness of these vegetables, hundreds of farmers have been given new livelihood options.

For instance, the cultivation of African eggplant (*Solanum aethiopicum*) as fruit and a leafy vegetable is expanding in Tanzania because of its economic and nutritional importance. Research carried out at AVRDC-RCA has led to the development and identification of several promising lines, notably DB3 and AB2. The production and seed distribution of these two lines has transformed the communities at Manyire near Arusha, Tanzania.

Not only do production technologies (including modern seed) need to be disseminated to and by the farmers, but it is also necessary to improve economic and management situation of farmers. FCI conducted successfully relevant training on business and marketing issues, but also established business support groups, which are the backbone for the whole commercialization of AIV production by farmers. Based on successful activities of the business support groups, reliable market linkages and channels could be developed with the help of FCI.

Evolution of farmer groups into viable business support units has also proved to be one of the greatest tools of harnessing the benefits of overcoming such challenges and threats that rural smallholder farmers face and thus can now compete effectively with medium and large scale farmers.

The evolved groups have so far been able to sell their vegetables to informal markets like Tengeru, Ngaramtoni, Kilombero, central markets and intermediaries in Tanzania; while in Kenya; the groups have been able to sell their products to chain stores, institutions, green groceries and many informal markets in the Nairobi and in Kiambu, Kajiado and Thika District (Wangige, Kiambu, Githunguri, Kiserian, Ngong, and Juja) of Central Kenya. These business support units have been able to establish product bulking and grading through establishment of common collection centres from where they record delivery of vegetables to the stores. The vegetables are kept in well ventilated structures before delivery to the markets with hired vans (pickups).

These linkages have been made possible by some marketing models that were used to design models, relevant to all the market players. The farmer groups have found a new reliable business opportunity in the AIV where due to the fact that these vegetables do not require substantial inputs the profit margin is higher than for most other horticultural produce and have a ready and growing market. This has resulted, to many farmers increasing the land under indigenous vegetables and reduction of land under other crops. The traders have found another reliable business after realization that the market demand is very high.

The innovation of partnership between high profile chain stores (supermarkets), institutions and groceries has enabled small scale producers to participate in highly competitive horticultural business which has been the preserve of the businesses controlled by medium and large scale farmers. The intervention also serves as an avenue to pass on appropriate rural participatory technologies to these communities.

Finally, as a spill-over effect of the project, other products like beetroot, strawberries, Chinese and head cabbages, kale, and Swiss chard commonly grown by farmer groups along with the indigenous vegetables have benefited from similar linkages, whereby the farmers have accessed the markets they supply with indigenous vegetables.

It is as important as the improvements on the production and marketing level are, without the increase of demand for AIV the whole project would have failed. Only through raising consumer awareness for AIV, increased demand for AIV has been stimulated, sustaining the increased productivity of AIV production and marketing.

The demand for African leafy vegetables has grown tremendously in both the urban and rural areas indicating a high potential in the target areas. The market growth rate is among the fastest in agricultural produce at 135% in Kenya although still lower in Arusha, Tanzania. This shows that African leafy vegetables can fully be commercialised in East Africa and indeed on the African continent and is a ready and reliable source of vital micro-nutrients for a malnourished society and as an income source for smallholder farmers. With the market demand rising faster than the supply of AIV due to intense consumer campaigns, this has led to increased need to continue promoting production of AIV which meets less than 60% of the current demand.

This has caused a great impact where vegetables have appreciated by all income levels improving the AIV market image earlier considered to be a poor man's vegetable. There has been a major impact through awareness creation using nutritive facts available about AIV, reducing the negative attitude leading vulnerable groups to access a cheap source of essential micro and macro nutrients.

There seems to be a multiplier effect duplicated in the informal markets where a survey shows that there are more indigenous vegetables in the informal markets than there used to be due to extensive promotions and awareness creation that has been carried out in formal and informal markets. The formal market promotions and acceptance in this market segment has exercised a market behavioural influencer role to change perceptions of informal market consumers and caused a tremendous growth in the informal markets.

Eventually, with capacity building of NARS officials and other service providers (incl. supporting seed companies to start selling AIV), the downward trend of the utilization of indigenous vegetables in East Africa has been reversed, at least for the time being in the urban / peri-urban area in and around Nairobi and to a lesser but still significant extent in and around Arusha.

The Ministry of Agriculture in the target areas has embraced indigenous vegetables as a very desirable programme and is advising their farmers to adopt it and use the introduced marketing models to sell these vegetables and even other products that can use the channels and opportunities developed over time. Thus the program presents an appreciable level of sustainability if the identified gaps are filled.

This new opportunity on commercial farming of African indigenous vegetables has spread far and wide with farmers who have heard of the intervention through presentations and frequent appearance on local radio FM stations and market consumer awareness due to increased shelf space in the past two years. Most communities benefiting from this project funded by the Maendeleo Agricultural Technology Fund solely rely on farming for their livelihood. After introduction of indigenous vegetables, production as a business opportunity, and enhancing rural -urban linkages for market access, there has been a reawakening of interest on AIV for food security and as a reliable source of income for both subsistence needs and other needs.

The two-year project to increase AIV cultivation and effectively link AIV producers to markets has been very successful. The commercialization of AIV gives an opportunity for small scale farmers to improve their incomes, nutrition and dietary diversity. The technologies disseminated through the project have been of great benefit to farmers and NARES. The approaches and methods used to disseminate both production and marketing technologies have also been very useful.

African indigenous vegetables were on a downward path, following the typical development of inferior produce and the prevalent attitude of being food for the poor. However, through raising awareness on the consumer side, facilitating and improving the market linkages as well as improving production and production inputs, AIV are becoming a lucrative source of income for poor farmers selling to wealthy urban consumers.

ARE THERE LESSONS TO BE LEARNED FROM THE RE-UTILIZATION OF INDIGENOUS VEGETABLES IN EAST AFRICA?

Although the described project successfully re-introduced indigenous vegetables in East Africa, it is not a blue print for all under-utilised crops to become utilised (again). Still, there are some general lessons, which will be applicable for the (re-) introduction of under-utilised crops into specific markets. These lessons can be grouped according to the supply chain and starting with some general lessons:

General lessons

- Only by tackling all 3 main parts of the supply chain of AIV, did success become apparent. It was necessary, to increase productivity of AIV, to improve management and business skills of farmers as well as building up business groups to increase bargaining power but also to guarantee reliable quality and quantity over time. In addition to productivity and business skills at farm level, stimulating demand increase was essential for the success of the project. Not only was intervention at all three levels necessary for success, but it was also vital that various players in the value chain providing vital BDS were involved and partnered, i.e., farmer groups, extension officers, outlet management, intermediaries, and seed companies & stockists.

Technology lessons

- Adoption rate of technologies and varieties differ from one region to another and appears to be culture specific. The adoption rate amongst the predominantly Masai community in the Arusha target areas has been very low compared to the adoption rate amongst the Kikuyu community in the Nairobi environment. The improved nightshade line SS52 has been adopted faster by consumers in Kenya compared to Tanzania. Improved African eggplant lines, however, have not been adopted in Kenya while in Tanzania the adoption rate has been extremely high and increasing fast. Finally, there is need to put more efforts in the follow up of groups to enable them to maintain cohesion and become more commercially inclined, especially in Tanzania. Any innovation can only be relevant to target communities after being harmonised with existing systems and gradually allowed to replace other systems.
- One bottleneck of technology adoption is the availability of and access to good quality seed in the informal and formal seed market. As long as availability and quality of seed is not guaranteed, commercialization of a (new / under-utilised) crop will not easily take off.
- The inclusion of okra as a target crop in the project was not well thought out. Okra is a warm season crop and performs dismally in cool regions. All the target areas in Kenya and Tanzania are cool regions and despite our best efforts, okra production has been relatively low as the crop could not flower. In addition, the market demand for okra has been very low in both countries leading to loss of interest in production by the farmers.
- To receive and deliver orders to supermarkets and informal markets, farmers and their groups have been using mobile phones for communication. This has changed the way farming as business is conducted in Tanzania and Kenya and has impacted on linkage between farmers and markets. In Tanzania where middlemen still play a crucial role, the use of mobile phones allows them to move from farm to farm picking the agreed volumes of produce from farmers at farm gate level. In Kenya, supermarkets can directly communicate with farmer groups and indicate to them how much produce they need. The use of ICT is thus very important in marketing of produce efficiently.

Group dynamics

- Adoption time of group building and other social activities as part of the project may differ according to the culture of participants but also their history.
- AIV is very suitable produce to use for development of women at group and individual level. Women are the main players in vegetable production and it was possible to empower them for ownership of the produce and income.
- AIV are usually grown on a small scale. The small scale groups have a very good opportunity to compete with medium and large scale producers especially due to short maturity period of the AIV which can be as fast as 5 weeks. The labour intensive level of large scale production can reduce the acreage involved with such short duration crops. This favours small scale growers.
- For smallholder farmers to compete effectively with large companies and large scale farmers they need to have adequate capacity and take advantage of collective sales and scheduled production that can lead to continuous supplies.

- Organization of farmers into business support groups is a tedious process. The development of these groups in Tanzania has been slow. It has taken time for members of the groups to trust each other and start working as a cohesive unit. The two year time period of this project phase was not sufficient to get completely new farmer groups to start working together as effective business support units. The lesson learnt is that for a project with such a limited time frame, it is important to co-opt already existing groups in the project so they start producing and supplying vegetables to the markets right away.

Business skills and efficiency
- Factoring (providing credit for advance payments to farmers while awaiting payments from supermarkets, transport, market levies etc) and market quality guarantee can help small-scale farmers penetrate formal markets.
- The use of groups lowered marketing costs and raised volumes supplied to formal markets.

Capacity building
- Building the institutional capacity of farmer groups (leadership, business skills, record keeping, creation of specific sub-committees etc.) is important for sustaining group activities, including legal registration for commercially-oriented groups.

Footnote
[1] 'Ugali' is a starchy rich paste made from boiling maize meal until it forms a dough-like substance.

Acknowledgements
This project was funded by Maendeleo Agriculture Technology Fund - MATF (Gatsby Trust and Rockefeller Foundation) and implemented by AVRDC – The World Vegetable Center and Family Concern (now: Farm Concern International).

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7

Small scale processing and marketing of underutilised fruits: case study of Amla in India

T. Gajanana, I.N.D. Gowda and B.M.C. Reddy

The Indian Institute of Horticultural Research, Bangalore, India, under the aegis of the International Centre for Underutilised Crops (ICUC), trained the officials of Bharathiya Agro-Industries Foundation (BAIF), a non-government organization (NGO), on small scale processing and marketing of underutilised fruits in August 2004. As a result, small scale processing units had been established at the village level in Karnataka, Maharashtra and Gujarat in India for processing underutilised fruits like amla, tamarind and jackfruit into different products. A survey was undertaken after six months of training to evaluate the processing and marketing of underutilised fruit products. The results revealed that small scale processing of amla into raw pickle was found profitable with a net profit of Rs.8/kg of raw pickle. The cost of processing of amla into hot pickle worked out to Rs.50.04/kg of pickle produced. With a price of Rs.60/kg, the processors could realise a net profit of Rs.9.96/kg by preparing amla pickle. The processor's margin was observed to be 19.92 per cent. The cost of producing one bottle (500 ml) of amla squash worked out to Rs.15.01 and with a price of Rs.40/bottle, a bottle of squash could realise a profit of Rs.24.99.

The market survey in Hassan district markets (Karnataka state) indicated that underutilised fruit products like amla pickle were sold by retailers in small quantities. While wholesaling of these products was not found feasible, some retailers expressed their willingness to sell with some conditions: samples to be given, payment after sales, a margin of 20-25 per cent and small sized packets. There are conditions which need to be fulfilled to have markets for the products of small scale processing units. The market survey in Pune markets in Maharashtra state indicated that underutilised fruit products like amla pickle, amla squash and amla supari (digestive amla) were already there in the markets though their share was very small. Retailers were willing to market the products of the units with the conditions: samples to be given, good sales after consumer reaction; good quality with reasonable price; small sized packets (200-250 g) with a profit margin of 25-35 per cent. The market survey in Valsad district in Gujarat state indicated the presence of underutilised fruit products like pachan amla (digestive amla), ber powder, salted ber and tamarind candy under different brand names (Oswal, Khelkar, frootlet etc). These accounted for 6-10 per cent of wholesale trade and 11-20 per cent of retail trade indicating thereby the existence of markets for underutilised fruit products. Despite this small share, these products had made their presence felt in the market.

The consumer survey in Pune and Valsad markets indicated that by and large, consumers accepted the quality and price of underutilised fruit products. They preferred amla supari in small sized (10-15 g) sachets in a 100g polythene pouch. However, there was a need to improve labeling. The consumers believed that the label should list the

contents, ingredients, best before date, manufacturing date and medicinal value of the product along with the price

INTRODUCTION

India enjoys a prominent position in the pomological map of the world. The range of weather conditions in this country provide suitable conditions for growing of a variety of fruits. These fruits are available in abundance and also in different seasons. This has resulted in limited scope for expansion of other minor fruits though they are nutritious, and are the main source of livelihood for the poor. Most of the underutilised fruit of the tropics are often available only in local markets and practically unknown in other parts of the world. A large number of these fruits have the ability to grow under adverse conditions and are also known for their therapeutic and nutritive value. There is a constant market demand all over the world for nutritious and also delicately flavoured new food products. Consumers today are becoming increasingly conscious of the health and nutritional aspects of their food. The tendency is to avoid chemical additives and synthetic foods and obtain therapeutic effects and nutrition from natural resources. Underutilised tropical fruits have an important role to play in satisfying these demands. Many of these fruits are highly perishable and difficult to store in the fresh form. Some of them are not easy to eat out of the hand. A few are not acceptable as a fresh fruit, because of high acidity and/or a strong astringent taste. However, all these fruits have unlimited potential in the world trade in their processed form. This will provide an opportunity for consumers all over the world to enjoy these tropical fruits in the form of processed products. Apart from processing, market potential and energetic campaigning it is necessary to create awareness and consciousness among producers and consumers of the demand for underutilised tropical fruits. Hence, there is a need to concentrate on research efforts on diversification and popularisation of such underutilised fruit crops. In order to achieve this goal, there is a need to create a demand for such fruit crops in domestic and international markets. This, to some extent, can be facilitated through developing suitable processing and marketing of underutilised fruits.

Keeping the above in view, market research has been initiated in three resource centres of Bharathiya Agro-Industries Foundation (BAIF), a non-government organization, located in three different states namely, BIRD_K, Tiptur, Karnataka, Central Research Station (CRS), BAIF, Urali Kanchan, Pune, Maharashtra and DHRUVA-BAIF, Kaparada, Gujarat. Training of the officials of BAIF from these centres had been organised under the aegis of the International Centre for Underutilised Crops (ICUC), UK, Indian Institute of Horticultural Research (IIHR) and BAIF at IIHR Bangalore during August 3-6, 2004 on *small scale processing and marketing of underutilised fruits*. These officials had in turn trained the women self help groups (SHG) in their respective centres and community processing units have also been established in different villages. In addition to production of underutilised fruit products, markets for these products had to be identified and linkages with potential markets had to be established. The specific objectives of market research are:

- Identify the marketable products from underutilised fruit species like amla;
- Identify the existing marketing channels for amla products;
- Identify the potential markets and market related problems for amla products;

- Work out the economics of small scale processing of amla.

DATA AND METHODOLOGY

The data on equipment used for processing, cost of raw material, cost of ingredients used in processing amla products were collected from the respective community level processing units. Using the amortisation technique, monthly establishment cost was worked out. Based on the quantity sold and the price realised, gross returns and net returns were estimated. A market survey was conducted in the local and district markets in the vicinity of the community level processing units in the respective resource centres. For BIRD-K, Hassan district market was selected for the market survey. For CRS, Pune, Pune market was selected. Kaparada, Dharmpur local markets and Valsad district market were selected for the DHRUVA resource centre. The products sold by the wholesalers and retailers were enumerated and the share of the different underutilised fruit products like pickles, jams, squash, chunda, chutney etc in the respective markets was estimated. Similarly, the share of different brands in respective markets was also estimated. A consumer survey of underutilised fruit products produced by the respective community level processing units was conducted by resource centres in the local markets.

RESULTS

Resource Centre, BIRD-K, Tiptur

Small scale processing of amla

After undergoing training on small scale processing of underutilised fruits at IIHR, Bangalore (jointly organised by ICUC, IIHR and BAIF), six officials of BIRD-K have, in turn, trained women SHG members in the area and have been able to establish a community village level fruit processing unit in Balehalli. The processing unit has so far produced two amla products namely, Amla Hot Pickle and Amla Raw Pickle besides one tamarind product, Tamarind Tokku (Chutney) and of late, the processing unit has also started processing jack fruit as chips and papad.

Market survey for underutilised fruit products

Pickles market: Among pickles, citron (32%), mixed (29%), mango (25%) lemon (9%), amla (4%) and karvanda (0.5%) were found to be popular in the retail market (Table 1).

Table 1. Share of different types in the retail pickle market, Hassan

SlNo	Types	Share (%)
1	Amla pickle	3.90
2	Karvanda	0.43
3	Citron	32.39
4	Mango	25.35
5	Lemon	9.21
6	Mixed	28.71
	Total	**100 (72.29)**

Note: Figures in parentheses indicate total quantity sold in a month in kg.

Retailer's margin: On an average, the retailers sold about 72.29 kg of different brands of pickles in a month. The retailers' margin ranged from 10 to 13 per cent for Mother's and MNP, 16 per cent for Priya. The retailers' margin for locally popular brands of Krupa and LMP was 60 to 70 per cent. The margin was around 48 per cent for the A-1 brand of pickles.

Consumer attitudes with regard to product brands

- A pet jar of 300 g was preferred by urban consumers while villagers preferred small packets of 100-250 g;
- There is a preference for good quality and reasonable price by village consumers;
- Local brands Krupa and LMP were preferred by the latter;
- Urban consumers preferred branded and relatively costly pickles like Priya and Mother's.

Conditions for selling new brands/products – Amla pickle

- Samples to be given to test the consumer preference;
- Payment after sales of the products;
- A margin of more than 16 per cent is required;
- Pickles should be cheaper as the target group is mainly of villagers.

Consumer survey: Regarding pickles, most consumers stated that they buy mango and lime pickles from the market. However, pickles of underutilised fruits like citron, amla, karvanda and amtekai (ambada – pickle is prepared when the fruit is tender) are prepared in their home during the season and hence are the market.

Resource Centre, CRS, BAIF, Uralikanchan,

Small scale processing of amla

Amla is available at CRS, BAIF, and Urali Kanchan was the main source of raw material for community processing of amla at the village level. However, in order to supplement raw material, about 500 kg of amla was procured from Rajasthan. Amla was processed into six products namely Amla Candy, Amla Squash, Amla Murabba, Amla Pickle, Amla Supari and Amla Mukhshudhi (Mouth Fresheners).

Marketing of Amla products

Marketing channels: CRS, BAIF has facilitated the marketing of amla products produced by community processing units through a cooperative of Women SHG namely Sankalpa Streewadi Sahakari Sanstha (SANKALPA) and the products are sold under the brand name of **SANKALPA**. In addition, other cooperative retail outlets such as **Vrindavan** and **Savithri** have also been used for marketing amla products. The marketing channels used by the Producers (Processors) of amla are as below:

1. Producer (Processor) → Village SHGs
2. Producer (Processor) → Sankalpa (Coop) → Consumers
3. Producer (Processor) → Sankalpa (Coop) → Retailer → Consumers
3.1 Producer (Processor) → Sankalpa (Coop) → Vrindavan Outlet (Retailer) → Consumers

3.2 Producer (Processor) → Sankalpa (Coop) → Savithri Outlet (Retailer) → Consumers

Sankalpa: Sankalpa Streewadi Sahakari Sanstha (Sankalpa Women Cooperative Society) is a cooperative of women SHGs. Naturally processed herbal and other products - Herbal Tea Powder, Nirgundi oil, face pack, hair oil, body pack, tulsi powder; food products - papad semiya malt, chivda, chutneys and masalas; allied products like white phenyl, incense sticks, liquid soap, scent, room fresheners, broom and chalk sticks produced by SHG women are sold through this cooperative. Of late, processed underutilised fruit products like amla candy, amla pickle, amla squash, amla murabba, amla supari and amla Mukhshudhi (mouth freshener) are also sold through this outlet under the brand name 'SANKALPA'. Sankalpa charges a commission of 15 per cent on the products sold through its outlet.

Vrindavan: It is an outlet of BAIF, Pune. The products of Vasundhara in Gujarat and Rajasthan and those of Sankalpa are sold through this outlet. An agreement has been reached between Sankalpa and Vrindavan according to which the Vrindavan outlet charges a commission of 7.5 per cent for the products of Sankalpa.

Savitri: It is an outlet of Savitri Mahila Audyogik Sahakari Sanstha (women entrepreneurs' Cooperative Society) which sells the products of all women associations. Sankalpa being the cooperative of women SHGs, its products are also sold through this outlet and Savitri charges a commission of 5 per cent on all the products sold.

Other channels being explored
Producer (Processor) → Sankalpa → Private Retailers (Bakeries/provision stores/Tea Or Sugar Depots) →Consumers

Market survey for underutilised fruit products in Pune
A survey was undertaken in Urali Kanchan and Pune city to ascertain the potential market for underutilised fruit products in general and for amla and tamarind products in particular. Both wholesalers and retailers were contacted for the survey. However, pickles, murabba, candy and juice were sold mostly on a retail basis only and thus, a total of 12 retailers dealing in pickles, squash, murabba, candy and concentrates were interviewed in Pune town with the help of a questionnaire. Bakeries, tea/sugar depots and provision stores were retailers of these items in the survey area.

Pickle market
Popular brands: Pravin, Kamadhenu, K-Pra**,** Sankalpa, Maharaja, Nisarga, Bedekar, Mother's recipe, Savitri and Vrindavan are the popular brands of pickles producing mango, lime, amla, chillies, karvanda, bitter gourd and mixed pickles.

The share of different brands of pickle in the retail market: On an average, 96.95 kg of pickle was sold in a month by retailers. Pravin was the preferred brand (52.99%) followed by Kamdhenu (16.50%), Maharaja (10.83%), Vrindavan (4.53%) and Bedekar (4%). Other brands in the market are K Pra, Mother's recipe, Nisarga, Savitri and Kasthuri (Table 2a).

Table 2a. Share of different brands in the retail pickle market (%), Pune

SlNo	Brands	Share (%)
1	Maharaja	10.83
2	Pravin	52.99
3	Kamadhenu	16.50
4	Bedekar	4.00
5	Mother's Recipe	2.32
6	Nisarga	1.93
7	K Pra	3.22
8	Sankalpa	1.55
9	Vrindavan	4.53
10	Savitri	1.18
11	Kasthuri	0.97
	Total	**100.00 (96.95 kg/m)**

The share of different types of pickles in the retail market: Mango leads the pickle market with more than 63 per cent of the market**.** Mixed pickle (mango, lime, and chillies) ranks second with around 16 per cent followed by amla pickle (13.02%), Chillies (2.57%) and Karvanda (1.60%) (Table 2b). With regards to packing, a 200g standee pouch was the preferred packaging used by the retailers.

Table 2b. Share of different types in the retail pickle market (%), Pune

SlNo	Types	Share (%)
1	Mango	63.02
2	Lime	2.95
3	Chillies	2.57
4	Amla	13.02
5	Karvanda	1.60
6	Mixed	15.86
Total		**100.00 (96.95 kg/m)**

Retailers' margin: Retailers' margin varied across the type of retailers as well as the products sold. The margin ranged from 5per cent to 15 per cent in the case of cooperative retail outlets such as the Sankalpa, Vrindavan and Savitri outlets. The margin of private retailers was 15-20 per cent for Pravin brand products (pickles), 25 per cent for Maharaja Brand products (amla and tamarind) and 20% for Kamadhenu brand pickles. The margin was up to 30 per cent in the case of some retailers irrespective of the brand or products sold. Pickles are sold in 200 g, 250 g and 350 g plastic packets. Larger quantities of 500g and 1kg were sold in plastic containers by retailers.

Squash market

Amla, pineapple and orange squash are sold in the market. Sankalpa and Maharaja were the popular brands of amla squash sold by the retailers. Amla squash is sold in 500 ml and 650 ml bottles and pineapple and orange squash are sold in 700 ml bottles.

Other underutilised fruit products markets
Other underutilised fruit products like amla candy, amla murabba, supari, mouth freshener and tamarind products e.g. tamarind concentrate, tamarind panipuri masala are being produced by women SHG of Sankalpa and Maharaja (Narmada Food Products) and the Sankalpa products are sold only through Sankalpa, Vrindavan and Savitri outlets. Some retailers are selling very small quantity of tamarind products.

Consumers' attitude about the products: Consumers buying from retailers held the view that packaging and sealing should be improved. The standee pouch was observed to be good for pickles and amla candy while a plastic bottle was preferred for murabba and squash.

Conditions for sale of new brand/product: For new products like amla pickle, murabba, squash and tamarind products like concentrate, private retailers offered to sell these products under the following conditions:

- Samples to be given first;
- Payment after the sale of the products;
- Quality should be good and the price should be reasonable, Size of packet should be small (200 - 250 g);
- A margin of 25% - 35% should be given on each new product;
- Weekly supply is better and a minimum of 10 kg/week should be supplied.

Consumers' survey
A consumer survey was undertaken in Urali Kanchan and Pune market. The results of the survey are presented below:

Amla pickle: The product is sold in 200 g and 1 kg packets which were liked by the consumers. The quality observed to range from good to excellent. Nearness to the house, preference for small sized packets and shop having all the consumable items are some of the attributes for marketing amla pickle through the Sankalpa Out let in Uralikanchan.

Amla Supari: The consumption of supari was popular on journeys and in summer. Small packets of 50-100 g were preferred by consumers. Availability of the product close to home, good quality, good taste and crispness were important attributes for marketing amla supari. It is interesting to note that consumers were willing to pay 5 per cent more for amla supari which speaks of the good demand for it.

Amla murabba (jam): Consumers attributed the medicinal property of amla and excellent quality in terms of taste, colour and thickness as reasons for preferring amla murabba. However, non-awareness, non-availability of amla supari in nearby shops may pose problems in marketing it. Amla murabba sold in 250 g bottles appeared to be accepted by the consumers.

Amla candy: Excellent quality in terms of taste and small packets of 100g, 5 piece packets, and nearness to home were the attributes for successful marketing of amla candy.

Amla squash: Good quality in terms of sweetness, thickness, bright colour, right price and packaging in 500 ml bottles enhanced consumption of amla squash. However, the colour of the label was observed to be too dull, while the license No. needed to be put on the label.

DHRUVA- BAIF, Kaprada, Gujarat

Market survey in Dharampur and Valsad markets
Three wholesalers and six retailers were contacted in the Dharmapur market. In Valsad district market, four wholesalers and seven retailers were contacted and the required information was collected. It is interesting to know that underutilised fruit products like Pachan amla (Amla Supari) – Shankar and Oswal brands, Swadist Imli (Tamarind Candy) - Sonali and Sagar brands, Bore Koot (Ber Powder) - Rukso and Oswal brands are also sold by retailers and wholesalers of Dharmapur along with pickles, jams, syrup etc. indicating thereby a potential market for underutilised crop products of the Community Processing Facility at Panas. These products can be used for comparisons with the output of the facility. The market survey in Valsad district market showed that Salted Ber, Bore Koot (Ber Powder), Imli Candy (Tamarind Candy) mixed pickles, jams and juices were the products marketed by wholesalers and retailers in the market.

Dharampur and Kaparada Taluka market
The wholesale market: The underutilised fruit products market: Amla products like whole amla in brine, Pachan amla, amla supari and tamarind products like Imli sauce, Swadist Imli (Imli candy), and Bore koot (ber powder) were sold by wholesalers. Underutilised fruit products accounted for 5.94 per cent of the wholesaler's trade in Dharampur market (Table 3a).

Table 3a. Share of different types in the wholesale market, Dharampur (%)

SlNo	Types	Share (%)
1	Pickles	94.06
2	Underutilised fruit products	5.94
	Total	**100.00 (179.32 kg)**

Popular brands of underutilised fruit products: Oswal, Shankar and Rukso brands of pachan amla, Ahar brand of imli sauce, Tarun and Kelkar brands of bore koot (ber powder) were the popular brands of wholesalers.

Wholesaler's margin: Wholesaler's margin ranged from 9 per cent for the Rasraj brand to 18 per cent – 20 per cent for Vrindavan pickles, and 20 per cent for other brands.

The retail market
A total of six retailers dealing in pickles, squash, murabba, candy and concentrates were interviewed in Dharampur town with the help of a questionnaire. Bakeries and provision stores were the retailers of these items in the survey area.

Underutilised fruit products market: Katti mitti imli (Tamarind candy), karvanda/kerda pickle, pachan amla (amla supari), bore koot (ber powder) are the major underutilised fruit products sold by the retailers. The underutilised fruit products accounted for 20.51 per cent of the retailers' trade in Dharampur market (Table 3b).

Table 3b. Share of different types in the retail market, Dharampur (%)

SlNo	Types	Share (%)
1	Pickles	79.49
2	Underutilised fruit products	20.51
	Total	100 (119.23 kg)

Popular brands of underutilised fruit products market: Frootlet (Trimoorthy foods), Rasraj kerda pickle, Shankar pachan amla, Kelkar bore koot are the major brands traded by the retailers.

Retailers' margin: Retailers' margin varied across the type of retailers as well as the products sold. The margin ranged from 5% - 6% for cashew kernels, 15% to 25% for amla products, 20%-30% for pickles in case of cooperative Vrindavan retail outlets. The margin of the private retailers was 15-20% for Vrindavan brand pickles, 15% for Rasraj pickles, 10%-15% for Nilon's pickles. For underutilised products like pachan amla, ber powder and imli sauce the margin was up to 20 per cent.

Consumers' attitude to the products: Consumers buying from the retailers believed that the standee pouch was good for pickles and a plastic bottle was preferred for amla chunda and syrup.

Conditions for sale of new brand/product: For new products like amla pickle, murabba, squash and tamarind products like concentrate, private wholesalers and retailers offered to sell these products with the following conditions:

- Samples to be given first;
- Small sized packs preferred;
- Payment after sale of the products;
- Quality should be good and the price should be reasonable, Size of packet should be small (200 - 250 g);
- A margin of 20% - 25% should be given on each new product;
- Weekly supply is better and a minimum of 10 kg/week should be supplied.

Valsad district market

Retailers

Seven retailers dealing in pickles, jams, amla, ber and tamarind products in the retail market of Valsad city were interviewed for the market survey.

Underutilised fruit products market: Amla morabba (Darthi brand), karvanda pickle, Swadist Imli (Sagar brand), salted ber (HR), ber powder (Kaka), pachan amla (Oswal brand) are the underutilised fruit products traded by retailers. Underutilised fruit products accounted for 11.38 per cent of the retail trade in the Valsad district market (Table 4).

Table 4. Share of different types in the retail market, Valsad (%)

SlNo	Types	Share (%)
1	Pickles	88.72
2	Underutilised fruit products	11.38
	Total	100 (42.89 kg)

Retailers' margin: In the pickle market, the margin ranged from 20-21 per cent, for Mother's, 18-28 per cent for Vrindavan, 20-22 per cent for Pasand, Pravin, 18-20 per cent for Rasraj and 25-30 per cent for Nilon's. In the jam market, the margin was 9-10 per cent for Kissan, 10-15 per cent for Noble. For pachan amla, salted ber and imli candy, the margin was in the range of 25-30 per cent.

Conditions for sale of new underutilised fruit products

- Samples to be given;
- Sale after consumers' favourable response;
- Credit sale;
- Quality should be good;
- Minimum 20% - 25% margin;
- A small sized packet (100 g) is preferred.

Consumer survey

Amla supari: DHRUVA sold amla supari in 10-15 g sachets which consumers preferred. Colour and taste were found to be good. However, the 10-15 g sachet needed to be in 100 g polythene pouch. There was a need for improved labeling. Consumers believed that the label should list the contents, ingredients, best before date, manufacturing date and medicinal value of the product along with the price.

Economics of small scale processing and marketing of underutilised fruits at the community village level

After undergoing training on small scale processing of underutilised fruits at IIHR, Bangalore jointly organised by ICUC, IIHR and BAIF, officials of BAIF have, in turn, trained women SHG members in the area and have been able to establish community village level fruit processing units in several villages. Processing units had produced amla products in addition to those tamarind and jack fruit. Economic feasibility of small scale processing of amla products was assessed and the results are presented in Table 5.

Economics of small scale processing of Amla into Raw Pickle: It may be observed from the table that the processor has to vest Rs.35.11 to produce a kg of raw pickle. The net profit was Rs.7.89/kg with a price of Rs.43/kg and the profit margin of the processor was 22.5 per cent.

Economics of small scale processing of Amla into Pickle (Hot): On average about 25 kg of amla was processed into pickle every day. As may be seen from the table, the cost of processing of amla worked out as Rs.50.04/kg of pickle produced. With a price of Rs.60/kg, the processors could realise a net profit of Rs.9.96/kg by preparing amla pickle. The processor's margin was observed to be 19.92 per cent.

Economics of small scale processing of Amla into squash: On an average**,** 25 kg of amla was processed into squash per day. From the data collected from processors, economics of squash preparation was worked out and the results of the analysis are presented in Table 5. It may be noted from the table that the cost of producing one bottle (500 ml) of squash worked out to Rs.15.01 and with a price of Rs.40/bottle, a bottle of squash could realise a profit of Rs.24.99.

Table 5. Economics of small scale processing of amla into different products at Community Village level

Particulars	Underutilised fruit products		
	Amla pickle (Raw)	**Amla pickle (Hot)**	**Amla squash**
Total quantity prepared (kg/bottles)	208.00	500.00	5000.00
Gross returns (300 kg @ Rs.40/kg)	8944.00	36000.00	200000.00
Cost of processing (Rs)	7303.60	30024.18	75064.18
Net returns (Rs)	1640.40	5975.82	124935.82
Cost of production (Rs/kg/Rs/bottle)	35.11	50.04	15.01
Price realised (Rs/kg)/(Rs/bottle)	43.00	60.00	40.00
Net profit (Rs)	7.89	9.96	24.99

CONCLUSIONS AND RECOMMENDATIONS

BIRD-K, Tiptur, Karnataka

Processing of amla was found to be profitable. However, at present products are marketed through BAIF and other channels ought to be explored.

The market survey indicated that a market does not exist for underutilised fruit products in the local Tiptur market. However, in the Hassan district market, underutilised fruit products like citron pickles, amla pickle, tamarind paste and jack fruit chips are sold by retailers in small quantities. In both the markets, wholesaling of underutilised fruit products was not found feasible but some retailers expressed their willingness to sell under conditions such as samples to be given, payment promptly after sales, a margin of 20-25 per cent and small sized packets. Accordingly, conditions have to be fulfilled for developing a market for the products of small scale processing units.

Consumer surveys have indicated that underutilised fruit products are acceptable. However, the 'Gramasiri' brand label is not attractive and hence needs to be redesigned and the label should contain details on manufacturing date, 'consume by' date, ingredients, license No. and price.

CRS, Pune, Maharashtra

At present, underutilised fruit products produced by community village level small scale processing unit are sold through Sankalpa cooperative society under the brand name of 'SANKALPA'. However, once the capacity of the processing unit is expanded and greater quantities of the products are produced, Sankalpa may not be able to market the entire production. Hence, alternate market channels have to be explored.

The market survey of underutilised fruit products in Pune indicated that underutilised fruit products like amla pickle, amla squash, amla supari and tamarind products like concentrate, pani puri masala are already offered in the Pune market though their share is very small. Maharaja (Narmada Food Products) appears to be the major competitor for the products of the community level processing unit.

Retailers are willing to market products of the unit with the following conditions:

- Samples to be given and after consumer response, the products should be salable;

- Good quality and reasonable price;
- Small sized packets of 200-250 g with a margin of 25-35 per cent.

The above conditions should be met for marketing of products through the retailers like bakeries and tea depots.
By and large, the consumers accepted the quality and price of underutilised fruit products produced by the small scale processing units. However, the label was observed to be dull and needs improvement to be made attractive.

DHRUVA-BAIF, Kaparada, Gujarat
The underutilised fruit products of the community processing unit are sold through the well established brand of 'VRINDAVAN' of Vasundhara Cooperative Society located in Lachhakadi, Vansda which has been in existence for the past 15 years.

The market survey in Dharmapur taluk and Valsad district indicated that underutilised fruit products like pachan amla (digestive amla), ber powder, salted ber and tamarind candy are already in the market under different brand names like Oswal, Khelkar, and Frootlet etc. These account for 6-10 per cent of the wholesale trade and 11 - 20 per cent of the retail trade in Dharampur and Valsad markets respectively indicating thereby the existence of the market for underutilised fruit products from amla. Hence, Vrindavan branded products have to compete with Oswal and Shankar brands of pachan amla, Ahar and Frootlet brands of tamarind sauce and candy, Tarun and Khelkar brands of ber powder. The share of the underutilised fruit products is small but these products have made their presence felt in the market. If Vrindavan branded products are to be sold through the retailers, the following conditions need to be fulfilled:

- Samples to given to assess the consumer response;
- Small sized packets are preferred;
- Credit sale to be allowed;
- Good quality and reasonable price with a margin of 20-25 per cent.

The quality of the products should meet the Food Products Order (FPO) licensed quality specifications. DHRUVA-BAIF should ensure this. The consumer survey indicated that amla supari prepared by the community processing unit appeared to be good but depending upon the requirement the packaging needed to be improved, the label should be attractive and it should list ingredients, best before date, medicinal value of the product and the price. Small sized packing especially in small sachets of 10-15g packed in 100-200 g polythene pouches is preferred by the consumers.

Acknowledgements
The authors wish to thank Dr Nazmul Haq, Former Director, ICUC, UK; The Director, IIHR, Bangalore; Dr J.N. Daniel, Chief Scientist, BAIF; Mrs.Jayalakshmi, Ms.Poornima, Ramesh, BIRD-K, Tiptur, Karnataka; Dr P.K. Kulakarni, Ms.Surekha Labade, Sri.Shivatare, CRS, BAIF,Uralikanchan, Maharashtra; Sri.Rakesh Tandel, Sunil Savade, Keyur, Manoj, BAIF-DHURVA, Kaparada, Gujarat for their help and cooperation during the project period.

8

Consumer perceptions and determinants in purchasing fresh and processed tropical fruit products: an exploratory study

S. Sabbe, W. Verbecke and P. Van Damme

The introduction of new tropical fruits and their products in the market place will only be successful if we understand how consumers perceive these products, make product choices and build up consumption and purchasing intentions. In this respect, we conducted exploratory research in order to gain insight into the motives underlying consumers' decision-making process in the purchase of tropical fruits and their products. The research consisted of three parts: (1) the influence of individual and environmental factors, and socio-demographic characteristics on the intention to purchase tropical fruits and products was investigated by means of a descriptive survey (n=290); (2) the impact of sensory experiences on purchasing intention was evaluated by a descriptive survey combined with sensory testing of five fresh tropical fruits (n=281) and five processed tropical fruit products (n=290); and (3) perceived motives and barriers, and the influence of nutrition and health claims on the purchase intention of tropical fruits were assessed through two focus group discussions (n=15). Important findings are that pleasure-seeking seems to be the major motivation for tropical fruit consumption, both for fresh and processed products. On the other hand, unfamiliarity with the fruits and their perceived high price are important limiting factors. However, sensory experience is the single most important factor in product acceptance: when product taste does not match sensory expectations, general acceptance and hence purchase intention of the tropical fruits and products will be lower.

INTRODUCTION

In Europe, consumers' demand for tropical fruits and their products is expanding due to increased health consciousness (FAO, 2003; Centeno, 2005), population growth of ethnic minorities in Europe (von der Linden, 2004; CBI, 2005), and through international travel and global communication (Centeno, 2005). The food industry is also making greater use of tropical fruits as ingredients for a wide assortment of food products in order to respond to consumers' growing interest in healthy products and new flavours and tastes (Kortbech-Olesen, 1996). Nonetheless, numerous fresh and processed tropical fruit products are quite unknown to many consumers and are likely to remain so unless familiarization through sensory exposure and the subsequent build-up of positive experience-based attitudes towards these products occurs. In order to overcome this initial hurdle and achieve product acceptance followed by successful market introduction, it is of primary importance to gain insight into the various factors influencing consumers' choice and consumption behaviour.

Consumers' decisions either to eat fruit or not are the result of complex interactions between personal preferences, food properties and environmental factors (Kamphuis *et al.,* 2006). With respect to personal factors, many studies emphasise socio-demographic characteristics as important determinants of fruit intake and report that older age groups, urban people and higher educated people eat more fruit (Turrell *et al.,* 2002; Mitchell, 2004). Also higher incomes typically induce increased expenditure on fruit products (Diop and Jaffee, 2005). Baker and Wardle (2003) found that, although men eat fruit generally less frequently than women, attitudes and preferences towards fruits differ very little between both genders. Additionally, several studies underline the relationship between personal motivations, past behaviour and product-related experiences or product familiarity, as well as beliefs and attitudes towards a healthy diet with fruit intake (Kearney *et al.,* 2000; Kvaakik *et al.,* 2005). Hearty *et al.,* (2007) indicated that individuals with positive attitudes towards healthy eating show a larger intake of fruits. Moreover, in their study describing factors affecting food choice with respect to fruits and vegetables, Pollard *et al.,* (2002) mentioned that product familiarity leads to the development of attitudes towards fruit and vegetable intake and hence influences subsequent behavioural intention.

Apart from personal characteristics, consumers also rely on various product attributes before deciding whether or not to buy fruit or fruit products (Brunsø *et al.,* 2002; Kamphuis *et al.,* 2006; Poole *et al.,* 2007). In order to make a purchase decision, consumers develop quality expectations about a product based on different product attributes which are traded off against each other. However, some product attributes, such as sensory ones, cannot be ascertained before purchasing. After a choice has been made, consuming the product will lead to quality experience as consumers will evaluate the sensory properties of the product as well as the other attributes that created expectations (Behrens *et al.,* 2007). The match or mismatch between quality expectation and quality experience (confirmation / disconfirmation) determines consumers' satisfaction and hence repeated purchase (Deliza, 1996; Grunert, 2002; Brunsø *et al.,* 2002).

Numerous studies mention sensory characteristics (particularly taste), health considerations and pleasure-seeking factors as the most prominent motivators for fruit consumption and hence subsequent purchasing intention (Dixon *et al.,* 2004; Verbeke, 2006; Enneking *et al.,* 2007; Poole *et al.,* 2007). Tuorila and Cardello (2002) assessed consumer responses to an off-flavour in fruit juices and revealed that liking is a very important predictor of consumption and that consumption may be not repeated if the first impression of taste is poor. Also Deliza *et al.,* (2003) cited that foods are unlikely to be accepted if consumers do not like the flavour.

Various studies also underline health considerations as a frequently mentioned reason behind food choices (Brunsø *et al.,* 2002; Grunert, 2006; Verbeke, 2006). Although health-related qualities of a product are rather invisible, nutrition and health claims have become an established way of communicating the healthiness of a food product to the consumer (van Trijp and van der Lans, 2007). Consumers are quite open to a wide range of nutrition and health claims. However, the extent to which these are considered as credible or acceptable and thus influencing purchase intention differs (Urala *et al.,* 2003; Niva, 2006). Claim credibility perceptions are mainly dependent on the claim type and the specific claim-carrier product combination. Some studies mention intrinsically healthy products (e.g. fruit juices) as credible carriers for claims

(Balasubramanian and Cole, 2002). Other studies point in the opposite direction and indicate that enrichment of foods, which are perceived as naturally healthy is not regarded as truly enhancing the health benefits of the food product (Bech-Larsen and Grunert, 2003; Niva, 2007). Furthermore, van Kleef *et al.,* (2005) mentioned that consumers look at nutrition and health claims differently when their health status changes. Experiencing health problems makes people more aware and involved and influences their receptiveness to information addressing those relevant health issues.

The interplay between taste and health within the food choice process is rather complex. Consumers are constantly vacillating between eating for health or for pleasure (Tuorila and Cardello, 2002; Niva, 2007). Several studies indicate that consumers will not sacrifice sensory pleasure in order to achieve a healthy diet. For example, Luckow and Delahunty (2004) indicated that consumers' acceptance of a product is based on taste rather than on health claims, for they would not expect unpleasant flavours to be markers for health benefits. Also Verbeke (2006) reported that most consumers are not willing to compromise on taste for eventual health benefits in the case of functional foods.

Besides sensory and health considerations, which are found to be prominent factors, consumers' fruit choice is also driven by numerous other product attributes such as brand, convenience, price, availability, packaging, etc. (Batt, 2003, Deliza *et al.,* 2003; Enneking *et al.,* 2007; Poole *et al.,* 2007).

Furthermore, several studies mention a positive effect of socio-environmental factors such as social support from family, friends and co-workers on fruit intake (Steptoe *et al.,* 2004; Kamphuis *et al.,* 2007). Also situational factors, such as moment and place of purchase, may influence consumers' behaviour during the purchasing stage of fruits and fruit products (Meiselman, 1996; Grunert, 2006).

The complex interaction between different factors influencing consumers' decision to eat fruit has been widely described in literature. Though, little research has been done on this topic with respect to tropical fruits and derived products. Most research about this food category focuses on trade-related aspects, nutritional properties, production methods, and processing and packaging issues. Research related to consumers' perceptions and decisions to eat tropical fruit is scarce. Nonetheless, when launching new tropical fruits or derived products, it is important to understand how consumers perceive these products, how they make product choices and how they build up purchasing and consumption intentions. The scarcity of insight in consumer decision-making process towards the growing share of tropical fruits forms the rationale for this research.

MATERIALS AND METHODS

In order to gain insight in consumers' decision making processes towards the purchase of tropical fruits and derived products, we performed three exploratory studies.

Study 1

The first study investigated the influence of individual factors (product familiarity, general attitude and beliefs), environmental factors (social norms) and socio-demographic characteristics on the intention of a person to purchase fresh or processed tropical fruit products (Sabbe *et al.,* 2007a).

Data were collected through a questionnaire with close-ended questions. Questions dealt with topics related to product familiarity, beliefs, general attitude, social norms and purchasing intention, and were separately assessed for fresh and processed tropical fruit products, respectively. The questionnaire also included questions about socio-demographic characteristics.

The questionnaire was used during an exhibition (Agriflanders) in Ghent (Belgium), held in January 2007. Respondents (*n*=290) were selected by means of convenience sampling and the obtained data were analysed using SPSS 12.0. The gender balance was 54.8% male and 45.2% female. Mean age was 39.9 years with a standard deviation of 14.5 years. More than one quarter of the respondents (27.4%) had travelled outside Europe in the last two years.

Study 2

The second study assessed the impact of sensory experiences after specific tropical fruit consumption on consumers' general expectations formed before tasting (Sabbe *et al.,* 2007b). Data were collected through a questionnaire, combined with consumer sensory tests. Before tasting, consumers' general expectations about tropical fruits and their intention to purchase these fruits were measured by evaluating multiple product attributes (i.e. quality, special, attractive, taste, nutritious, safety and healthy). After tasting, the same attributes were used to evaluate the tested product, and the subsequent purchasing intention was again assessed. In this way, we recorded consumers' general expectations about fresh and processed tropical fruit products before tasting and consumers' specific experience after tasting the test products.

Respondents were selected through convenience sampling. In total, 281 questionnaires which included consumers' sensory tests of five fresh tropical fruits, i.e. cherimoya (*n*=55), dragon fruit (*n*=54), mangosteen (*n*=56), persimmon (*n*=60) and tree tomato (*n*=56)[1], and 290 questionnaires integrating sensory tests of five processed tropical fruit products i.e. açaí juice (*n*=60), baobab juice (*n*=56), berrycactus jam (*n*=59), cashew apple juice (*n*=59) and tamarind jam (*n*=56)[1], were analysed by means of SPSS 12.0.

Study 3

The third study was performed in order to gain insights into perceived motives and barriers, and to evaluate the impact of health and nutrition claims when purchasing tropical fruits (Sabbe *et al.,* 2007c).

A qualitative approach was chosen for this study. Two focus group discussions, with a total of 15 participants, were carried out in Ghent (Belgium) in May 2007. One group consisted of seven women aged between 25 and 40 years whereas the other one included eight women between 50 and 65 years. All recruited respondents were open-minded towards tropical fruits and had some knowledge about this fruit category. Within each group, there was a balanced mix (i.e. light versus heavy users) of tropical fruit users and consumers of tropical fruit juices.

Prior to the focus group discussions, a discussion guide was developed with the main objective of identifying motives and barriers for the consumption and purchase of fresh tropical fruits and tropical fruit juices. Attention was given to nutrition and health claims as possible motivators for tropical fruit juice consumption. The guide consisted of instructions for the discussion procedure and described the structure and topics that had to be discussed. A professional research agency assisted in conducting the focus group discussions: they recruited the participants and facilitated the group discussions. The sessions were videotaped with participants' permission and transcribed. A qualitative analysis of the transcripts was subsequently performed.

RESULTS

Role of individual, environmental and socio-demographic characteristics

Consumers' *familiarity* with tropical fruits was assessed by their knowledge, usage and past experience and was found to be significantly higher for processed tropical fruit products than for fresh tropical fruits. However, product familiarity varied and certainly depended on respondents' knowledge with respect to the different tropical fruit species and their product categories. In fact, Figure 1 indicates that, with respect to knowledge, a distinction could be made between common and exotic tropical fruit. The first group contains tropical fruits (i.e. pineapple, coconut, passion fruit, mango, avocado, litchi, carambola and papaya)[1] that were known by more than 70% of the respondents whereas the latter one includes fruits (i.e. persimmon, tree tomato, dragon fruit and guava)[1] unknown to more than 60% of the respondents. Furthermore, the different tropical fruit product categories (juices, yoghurt, jam and canned) seem all to be well-known (Figure 2), although we could expect that consumers' knowledge within each product category will vary depending on the type of tropical fruits being processed in it.

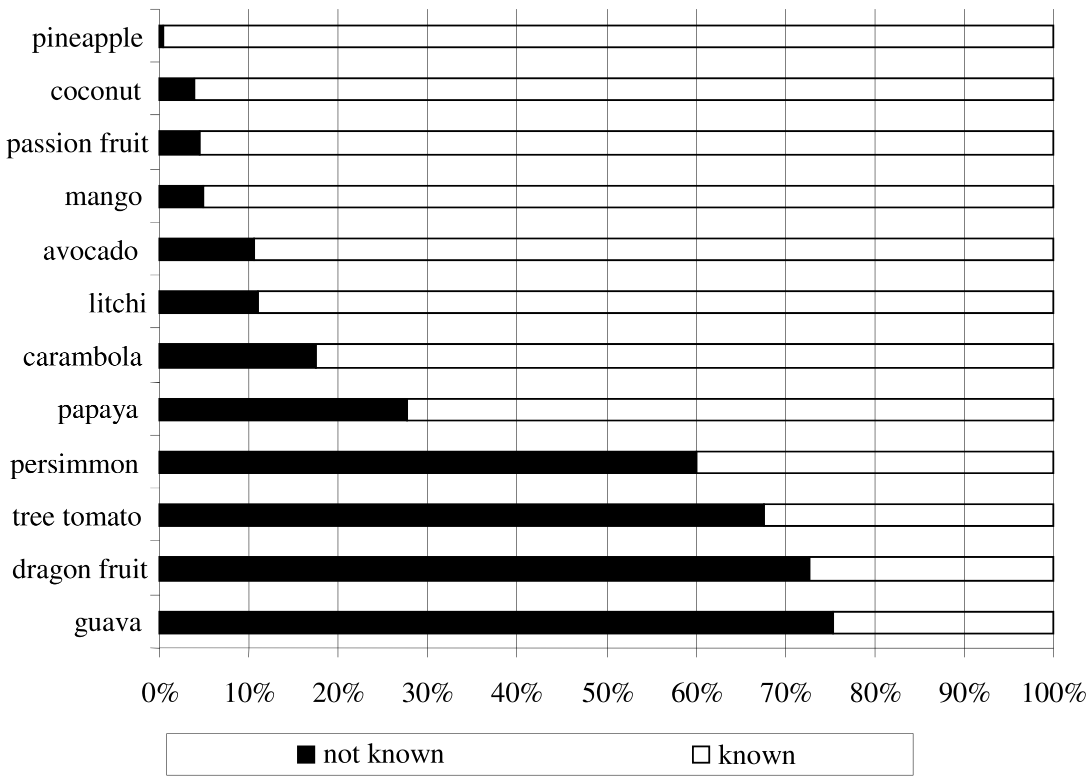

Figure 1. Consumers' knowledge of 12 different fresh tropical fruits species

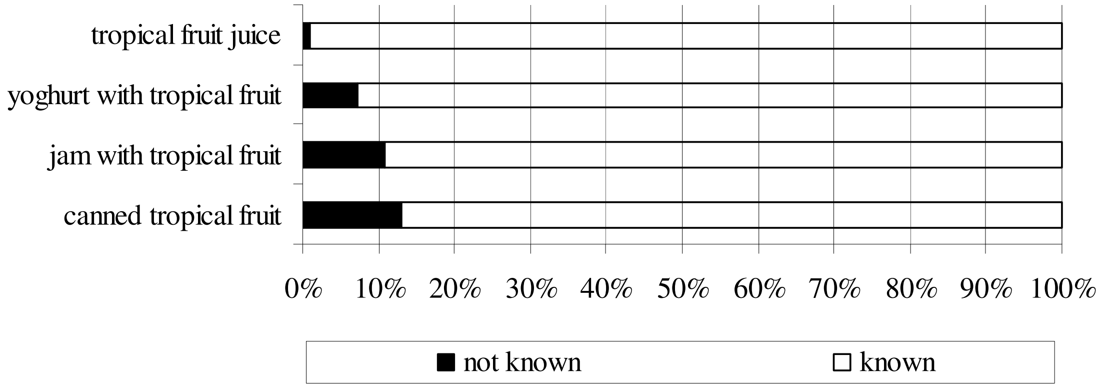

Figure 2. Consumers' knowledge of four product categories containing tropical fruits

A general positive attitude towards tropical fruit consumption among respondents, which is significantly higher towards fresh than towards processed tropical fruit products, was revealed.

Consumers' beliefs with respect to tropical fruits and derived products were measured by evaluating multiple product attributes (Figure 3). The different product attributes, with the exception of the attribute 'cheap', received positive scores for fresh fruits as well as for processed tropical fruit products. Consumers hold stronger beliefs that fresh tropical fruits are 'special', 'attractive', 'healthy', 'nutritious' and 'good tasting' in comparison with these beliefs expressed for processed tropical fruits. On the other hand, compared to their beliefs related to processed tropical fruits, respondents associate fresh tropical fruits with being 'expensive', less 'easily available', lower in 'quality' and less 'sustainable'.

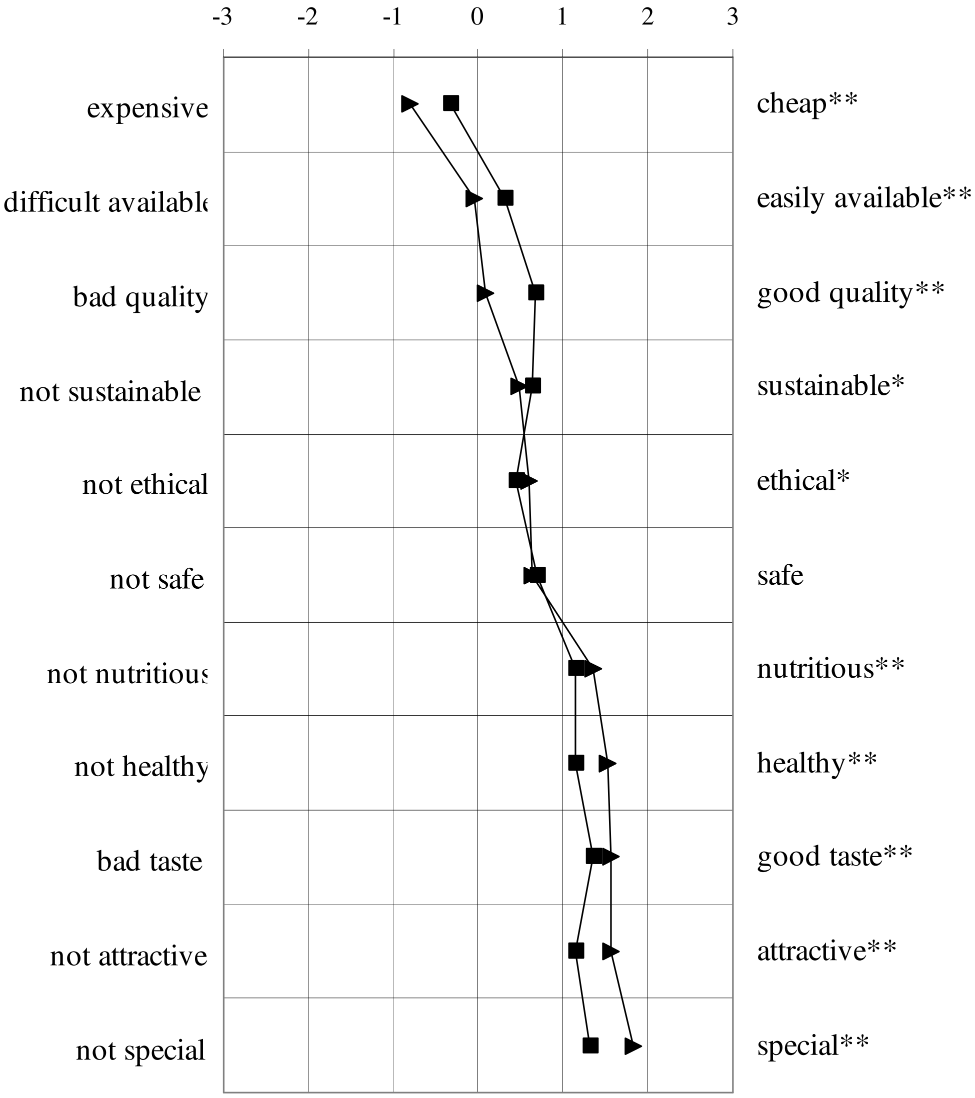

Figure 3. Attribute profiles of fresh and processed tropical fruits: average attribute ratings (*n*=290). Legend: ▲= fresh tropical fruits; ■ = processed tropical fruit products
* $p < 0.05$; ** $p < 0.01$

In order to assess the underlying dimensions that constitute consumers' belief in tropical fruits, a factor analysis of product attribute beliefs was performed. With respect to fresh tropical fruits, the factor analysis revealed three factors explaining 63.9% of the variance. With satisfactory composite reliability coefficients three constructs were composed: a credence attribute beliefs-construct, containing the credence attributes 'sustainable', 'healthy', 'ethical', 'safe' and 'nutritious'; a special attribute beliefs-construct, including the attributes 'attractive', 'good taste' and 'special' and a search attribute beliefs-construct, enclosing the search attributes 'cheap' and 'easily available'. The attribute 'quality' was not assigned to any of the factors, which suggests that 'quality' can be regarded to a considerable extent as an overarching concept. With respect to processed tropical fruits, an exploratory factor analysis was also conducted but no meaningful constructs could be identified. The high heterogeneity of processed tropical fruit product categories used in this study may explain the lack of consistency in terms of reported beliefs. However, the analysis revealed two main factors; one in which the attribute belief for 'attractive' loaded high and the other with a high factor loading for 'easily available'.

The *social norm* refers to the possible influence from partner, children, family, friends and colleagues at work on consumers' tropical fruit consumption. Factor analysis, explaining 70% of the variance in the original data, revealed three dimensions. The first factor contains the variables 'friends', 'colleagues' and 'family' and is labelled as the construct 'social environment'. On the second factor, the item pertaining to the impact of 'children' loads high and is further referred to as 'children'. 'Partner' loads high on the third factor.

Finally, a stepwise linear regression was used to assess the impact of individual characteristics (product familiarity, general attitude and beliefs), social influences (partner, children and social environment) and socio-demographic factors as predictors of the intention to purchase fresh and processed tropical fruit products.

The regression model indicated product familiarity, children and the special attribute beliefs-construct as significant and positive determinants on the intention of purchasing fresh tropical fruits (Table 1). On the other hand, familiarity with processed tropical fruit products, general attitude and the belief attribute 'attractive' were found to be significant predictors in the purchasing process of processed tropical fruit products (Table 1).

Table 1. Stepwise multiple regression with purchasing intention of fresh and processed tropical fruit products as dependent variable

Variable entered	Estimate β	SE	*t*-statistic	*p*-value
Fresh tropical fruits (*n*=290); R^2adj=0.454**				
Product familiarity	0.675	0.057	11.85	0.000
Children	0.168	0.069	2.43	0.016
Special attribute beliefs-construct	0.172	0.086	2.01	0.045
Processed tropical fruit products (*n*=290); R^2adj=0.498**				
Product familiarity	0.714	0.070	10.23	0.000
General attitude	0.400	0.085	4.70	0.000
Attribute belief 'attractive'	0.188	0.071	2.63	0.009

** $p<0.01$

Furthermore, with respect to socio-demographic characteristics, this study revealed that, both for fresh and processed tropical fruit products, females and respondents who had travelled outside Europe have a higher purchasing intention than males and those who had not travelled. In addition, respondents older than 55 years claimed to have a higher intention of purchasing fresh tropical fruits than respondents aged between 25 and 40 years, and respondents living in urban areas have a stronger purchasing intention of processed tropical fruits, compared to those living in rural areas.

Role of sensory experiences

General expectations consumers have about fresh and processed tropical fruit products were not systematically confirmed after tasting the selected fresh and processed tropical fruit products. Expectation confirmation largely occurred after tasting cherimoya and persimmon and after tasting berrycactus jam and cashew apple juice. Expectation disconfirmation occurred for mangosteen, tree tomato and tamarind jam. As adults generally prefer sweet tastes, pleasant smells and tend to reject bitterness and sourness (Messer, 1989), it was expected that consumers' expectations would not have been fulfilled after tasting mangosteen, tree tomato and tamarind jam because of their predominantly sour taste. The low sugar-to-acid ratio, yielding a poor sensory quality for dragon fruit, can explain the observed expectation disconfirmation with respect to taste after consuming this fresh fruit. Expectation disconfirmation also occurred for açaí juice and baobab juice. Unfamiliarity with new and unknown exotic flavours, as is the case with açaí and baobab juices, also seem to lead to disconfirmation of taste expectation as respondents could not refer to already known and established tastes and flavours.

When general expectations about taste were not confirmed after consuming the considered fresh or processed tropical fruit, a simultaneous decrease in the rating of some other non-sensory attributes was observed. If taste expectations were not fulfilled, respondents considered most of the tested tropical fruit as less 'nutritious' and less 'healthy' after its consumption. In addition, expectation disconfirmation with respect to taste resulted also in a decrease in perception of the tasted fresh tropical fruit as being something 'special' and 'attractive'. With regard to the tasting of the processed tropical fruit products, a similar relationship between disconfirmation of the attributes 'taste' and 'attractive' was observed. Furthermore, disconfirmation with respect to taste was mostly reflected in a decrease in purchase intention after consuming the fresh or processed tropical fruit products. Apparently, consumers deduce other (non-sensory) quality attribute expectations from sensory experiences.

In this study, taste experience was shown to greatly influence acceptance of fresh and processed tropical fruit products and hence consumers' satisfaction. Disconfirmation of sensory expectations, mostly accompanied by a decrease in beliefs about tropical fruits' health and nutritional benefits after tasting, leads to consumer dissatisfaction and is translated into a lower intention to purchase the tasted tropical fruits or their products.

Role of motives and barriers, and nutrition and health claims

A key message from this third study is that pleasure-seeking or hedonism appears to be a major stimulus for purchasing tropical fruits, both in fresh and processed form. In fact, the most important motivations with respect to the purchase of tropical fruits and tropical fruit juices are consumers' impulsive need for indulgence, and the festive and special character (in terms of taste, attractiveness and colour) of the fruits and their juices. Other important motivations for consuming fresh tropical fruits are that these are perceived as having a special taste and being healthy. Some respondents also believed that fresh tropical fruits contain other vitamins and minerals than local, native fruits. With respect to tropical fruit juices, different exotic fruit combinations and their convenience in usage and consumption are - besides their perceived special taste and festive character - important motivations for their purchase and subsequent consumption. In line with consumers' growing demand and search for natural and healthy products (Fulker, 2001;

von der Linden, 2004), it was not surprising to find that freshly squeezed tropical fruit juices are preferred to concentrates and nectars. Their naturalness, perceived healthiness and convenience are convincing factors for purchasing these juices.

The perception of fresh tropical fruits as being expensive, together with a lack of knowledge and unfamiliarity with them, form the main barriers to their purchase. For many less well-known fresh tropical fruits (e.g. dragon fruit, kumquat, mangosteen, rambutan and tree tomato)[1], respondents mentioned being unable to judge the overall quality of the fruit due to lack of knowledge and concrete judgement criteria in terms of taste, usage, conservation, etc. Disappointment can thus occur more easily during consumption. The mismatch between expectation and experience, combined with the perceived high price, will negatively influence consumers' future purchases of fresh tropical fruits. With respect to tropical fruit juices, unfamiliarity mainly influences consumers' purchase decision. Most respondents buy tropical fruit juices containing a mixture of known and unknown tropical fruits but tend to reject juices containing mainly unknown tropical fruits. Here, lack of knowledge with respect to taste, combined with high price form the main barriers.

In summary, respondents consume tropical fruit juices for the sensory sensation. Health reasons do not form the main motivation for tropical fruit juice consumption. Though, nutrition and health claims do seem to influence consumers' purchasing decision. In fact, when discussing diverse tropical fruit juices carrying different claims, the participants constantly referred to the complex interaction between eating for pleasure and health.

From the group discussions it became apparent that people are searching for pleasure and healthfulness in terms of 'natural' and 'unprocessed' as they mentioned to attach importance to nutrition claims such as 'no additives', 'no preservatives', 'no colorants', 'no added sugars', etc. The respondents considered fruits to be healthy and furthermore subsequently health promoting in a very natural way. Enriched or fortified tropical fruit juices (e.g. added with calcium and vitamin D) were not easily conceptualised as truly enhancing the health benefits of the product by the participants. Moreover, the discussants stated that the fragile balance between health and pleasure could easily be disrupted, especially when the juices carry claims confronting consumers with illness, emphasising the prevention of diseases or having medicinal-related associations. Tropical fruit juices are then no longer considered as juices which are consumed for their indulgence character, but more as a medicine. However, respondents mentioned that they are not looking for curing properties in tropical fruit juices. They all declared to seek medical support in cases of illness. On the other hand, people with special health needs (e.g. vegetarians, diabetics) are more aware of nutritional and health claims and will thus be more responsive to those claims addressing their specific needs.

DISCUSSION

This exploratory research suggests that a substantial market potential for sales growth of tropical fruits and derived products exists. Indicators are consumers' positive general attitude towards tropical fruits and their beliefs that these fruits are nutritious, healthy, tasty, attractive and special. An important drawback pertains to the existing unfamiliarity with this fruit group as a lot of fresh and processed tropical fruits are still quite new to many consumers. The introduction of fresh and processed tropical fruit products in the marketplace will only be successful if the voice of the consumer is completely understood. Therefore, the identification of the underlying needs that determine consumers´ purchasing behaviour is essential.

Pleasure-seeking behaviour is found to be a major drive for tropical fruit consumption. Consumers mainly purchase fresh tropical fruits and their juices for their indulgent, festive and special character. But the interplay between taste and health considerations on tropical fruit consumption cannot be neglected. Sensory experiences play a predominant role in consumer satisfaction. A decrease in health and nutrition beliefs was observed when a disconfirmation with respect to taste occurred. Taste disconfirmation also led to a lowering in the perception of tropical fruits as being ‘attractive’. Repeated purchase intention and consumption is determined more strongly by confirmation of taste expectations, rather than by perceived health and nutritional benefits and search attributes such as ‘attractiveness’.

Although health considerations do not form the main motivation for tropical fruit consumption, it seems that nutrition and health claims on tropical fruit juices do influence consumers’ purchasing decision. However, it has to be stressed that there exists a complex relationship and fragile equilibrium between eating for pleasure and eating for health. With respect to tropical fruit juices, people are searching for pleasure and healthfulness in terms of ‘natural’ and ‘unprocessed’ as they consider tropical fruits inherently healthy and naturally health promoting. On the other hand, tropical fruit juices carrying claims with disease- or medicine-like representation evoke quite negative responses in individuals who do not have health problems as the juices will risk association with medicinal products, to the detriment of their indulgent character. Hence, purchase intentions are likely to decline.

Product familiarity is found to be a prominent determinant when purchasing tropical fruits, both for fresh and processed tropical fruits. Especially for those tropical fruits that are less well-known, consumers do not dispose of concrete quality judgement criteria. As they do not know what to expect in terms of taste, usage, preservation, etc., disconfirmation of expectations and subsequent disappointment might occur after consumption. Combined with the perceived high prices, this is likely to have a negative impact on future purchasing intentions. The same can be assumed for tropical fruit juices for which unfamiliarity with respect to taste and the price form the main barriers to purchase.

But, unfamiliarity and lack of knowledge with new tropical fruits and derived products can be overcome. As taste is a predominant factor in the purchase of tropical fruits, consumers should be given the possibility of tasting the fruits and their products, for example through taste sampling or demonstrations at the place of purchase. Furthermore, straightforward communication about health benefits, usage (e.g. in recipes) and preservation issues as well as information about judgement criteria can become a useful tool by making consumers familiar with tropical fruits.

CONCLUSION

Consumers’ decision to purchase tropical fruits, both in fresh and processed forms, is mainly determined by their taste, familiarity and price. Besides, health considerations and the attractiveness of tropical fruits cannot be neglected in consumers purchasing process. Perceptions about these latter attributes, however, are influenced by the flavour of the tropical fruits and derived products.

Interesting as the results might be, this research has some limitations. The main limitations are linked to the research methods used and more specifically, their qualitative nature. Therefore, findings are preliminary and can neither be extrapolated to the overall Belgian population, nor to populations in other European countries. The insights generated by this qualitative research will form the basis for developing hypotheses for further quantitative survey research with large and representative samples of tropical fruit consumers.

Acknowledgements
This exploratory research was performed within the European Sixth Framework Program and fits into the PAVUC project (Producing added value from under-utilised fruit crops with high commercial potential), under contract number FP6-2003-INCO-DEV-2-015279. The financing of the work by the European Union for this research and more specifically by Chiquita fresh BVBA for the third study is gratefully acknowledged. More information about the project can be found on www.pavuc.soton.ac.uk.

Footnote
[1] açaí (*Euterpe oleracea* Mart.), avocado (*Persea americana* L.), baobab (*Adansonia digitata* L.), berrycactus (*Myrtillocactus* spp.), carambola (*Averrhoa carambola* L.), cashew apple (*Anacardium occidentale* L.), cherimoya (*Annona cherimola* Mill.), coconut (*Cocos nucifera* L.), dragon fruit (*Hylocereus* spp.), guava (*Psidium guava* L.), kumquat (*Citrus* spp.), litchi (*Litchi chinensis* Sonn.), mango (*Magnifera indica* L.), mangosteen (*Garcinia mangostana* L.), papaya (*Carica papaya* L.), passion fruit (*Passiflora* spp.), persimmon (*Diospyrus* spp.), pineapple (*Ananas comosus* (L.) Merr.), rambutan (*Nephelium lappaceum* L.), tamarind (*Tamarindus indica* L.), tree tomato (*Cyphomandra betacea* C. Martius ex Sendtner)

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9

Sowing seeds of success: commercial farmers' perspective

J. Moffett

A new political environment, the reality of climate change, an awareness of Peak Oil and rapidly changing terms of trade resulting from globalisation, required a commercial farming operation in South Africa to re-evaluate its farming practices and product portfolio, to develop and adopt new approaches and to successfully reposition the farm. An integrated, diversified and dynamic approach has led to better utilisation of the crops grown on the farm - both traditional and novel/underutilised. Making use of available research and development at the institutional level, as well as engaging in private/public/community partnerships, has generated positive results – both financially and for the wider community.

INTRODUCTION

Kirklington Farm has, since 1911, been owned, managed and worked by the same families. Situated in the picturesque Eastern Free State of South Africa, near the town of Ficksburg, the area has a temperate climate: summer (November to March) temperatures fluctuate between 10°C and 36°C and winter (May to August) –15 C to 25C. Rainfall, occurring predominantly in the summer months, averages 650mm per year and with an altitude of 1700m above sea level and with a large range of soils, makes this area ideal for the cultivation of a variety of crops including large and small grains, oilseeds, fruit, vegetables and livestock. The farm weathered the changes in agricultural practices from manure and bone meal to lower input farming in the 1990's when the sustainable approach was expanded upon to include organic and biodynamic methods and by 2006 was farmed wholly organically on 1000 hectares generating positive returns economically, environmentally and socially. I need to apologise for the, at times, disjointed nature of the paper, a result of taking a complex and highly integrated, diversified, live 3D image and converting it to a plain 2D format. I am alone responsible for any misunderstandings or misinterpretations.

BACKGROUND

Following World War II, Kirklington experienced the Green Revolution and for a period of three decades crop yields doubled and even trebled, however the honeymoon was not sustainable and from the 1970's Green Revolution practices were causing a number of seriously negative outcomes namely, degraded soils, chemically resistant weeds, insects and diseases; polluted ecosystems and humans; nutritionally unsound commodities and relentlessly shrinking financial margins. See Figure 1.

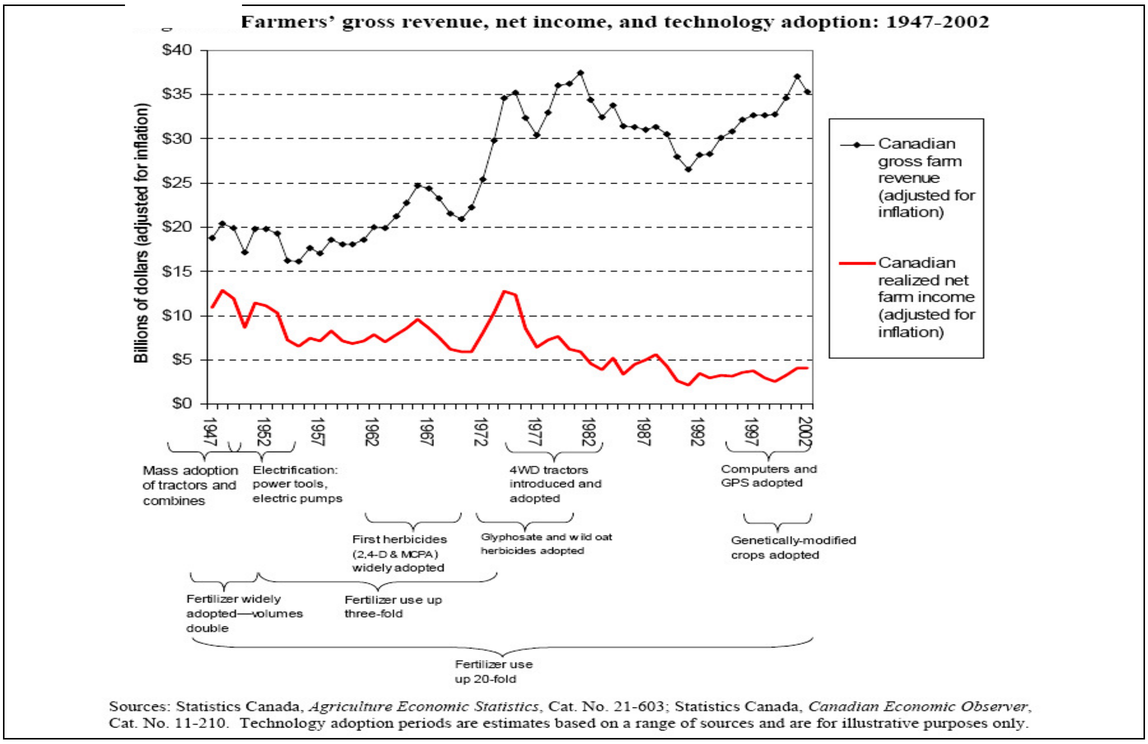


Figure 1. The Impact of Green Revolution Technologies on Farm Income.

The Brown Revolution, driven by the agrochemical and seed industries, was introduced to Kirklington in the 1980's with the mix of crops remaining much the same, i.e. maize, wheat, sunflower, grain sorghum in rotation and beef cattle and sheep. Despite these new technologies and increases in chemical fertilisers and poisons which increased yields, net profits continued their downward spiral. Supported by government subsidies and practicing low input sustainable agriculture (LISA), Kirklington survived into the 1990's, but climate change in the form of unseasonable extreme droughts and floods coupled with democratic elections and a new government introducing globalisation and withdrawing subsidies, meant a new course had to be charted for survival of the whole farm organism.

When researching Kirklington financial records I found a definite reversal in terms of trade during the previous decade: the economics of chemical farming were changing for the worse and producing commodities was becoming increasingly risky without a concomitant increase in return. Input prices were rising continuously, driven by agri-industry corporations' predatory pricing policies. For example, in the seed market five major seed firms now produce over 80% of the crop seed sold internationally. They are Monsanto, DuPont, Dow, Syngenta and Bayer[1]. Similar concentrations of power in the fossil fertiliser and poisons industries existed with large areas of cross holdings, partnerships and agreements. At the farmers' gate stood the same faces, but this time buying the farmers' produce at continuously declining prices. We were not alone in our dilemma; globally farmers were experiencing comparable problems (See Figure 2). Finally I realised, chemical farming is "violent" farming, based on a system of unremitting exploitation of all factors of production, which is linear, short-term focused and unsustainable. Figure 3 maps the stylised conventional industrial agriculture model including the inputs and raw outputs; the reliance on external capital and information and the degradation of the most important resource, the soil. This is a far cry from the example nature gives.

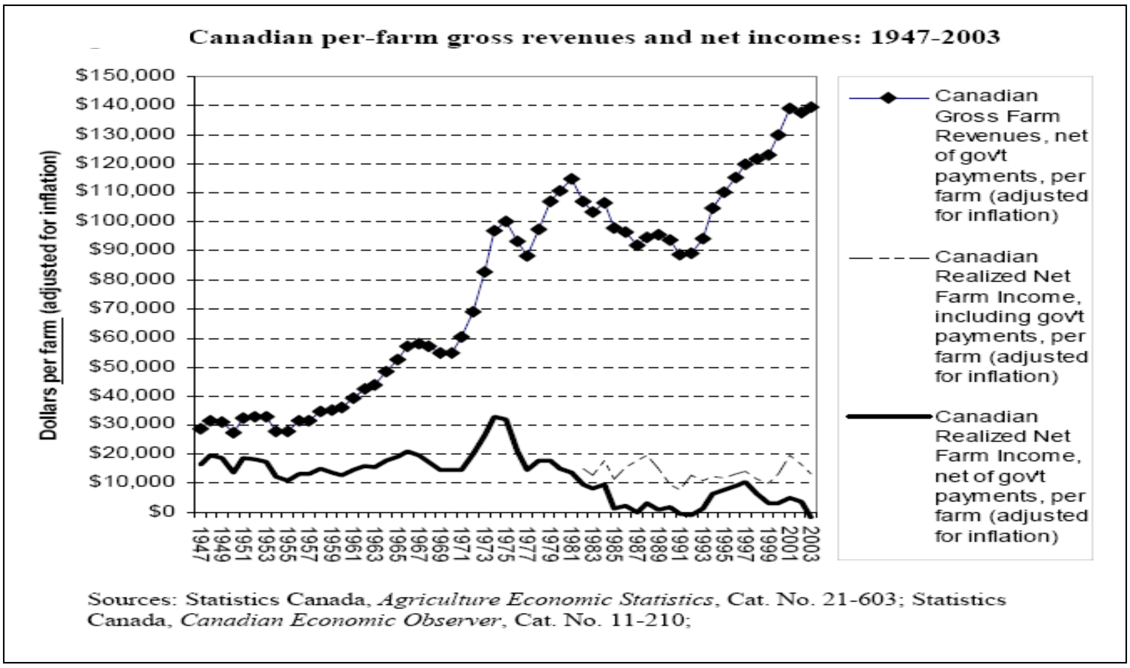


Figure 2. Net Farm Incomes Declining

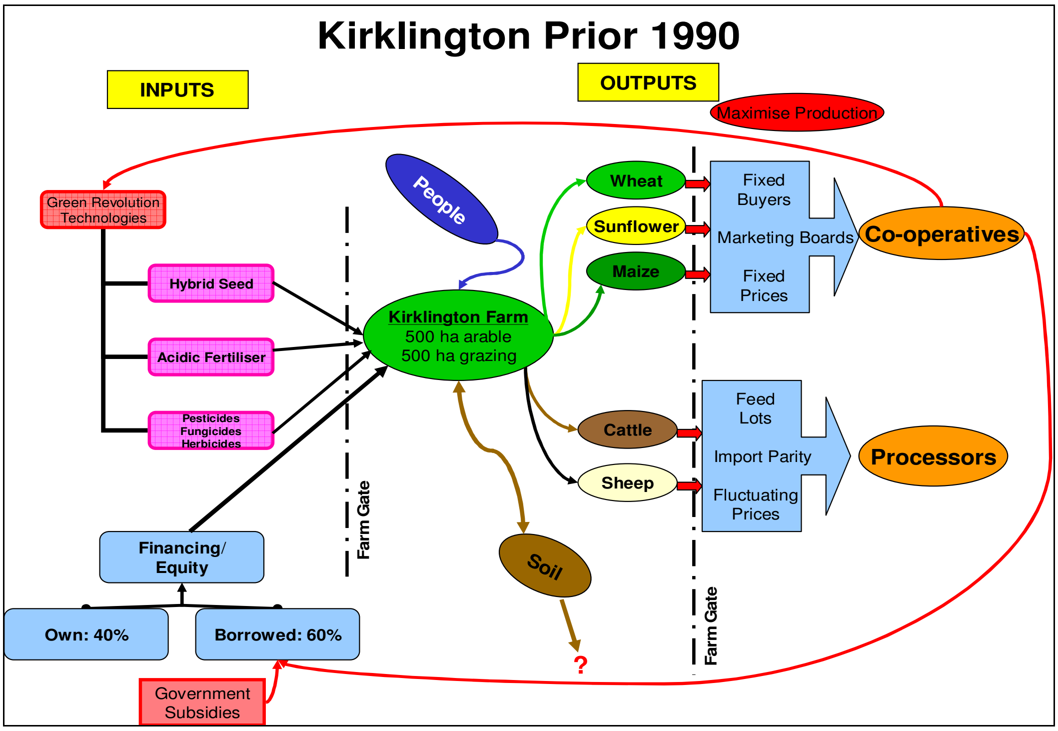


Figure 3. Kirklington Production up to the 1990's

Travelling in the USA in 1988/89 provided me with an insight into the potential of commercial organic and biodynamic family farming which promised the possibility of reversing the negative trends by producing a higher value product (nutritionally and financially) at a better price with a long-term reduction in costs. Wider research (see quote below) indicated that profitable and sustainable commercial organic farming was feasible and desirable with accompanying benefits for the community (employment, local healthy food and the multiplier effects of money retained in the local economy) and ultimately spiritual fulfilment especially in the realm of bio-dynamics.

"In 1989, the National Research Council of the USA National Academy of Sciences issued a highly significant report on "Alternative Agriculture" which was defined as **a system of food and fibre production that applies management skills and information to reduce costs, improve efficiency, and maintain production levels through such practices as crop rotations, proper integration of crops and livestock, nitrogen fixing legumes, integrated pest management, conservation tillage, and recycling of on-farm wastes as soil conditioner: and biofertilisers**. The report encouraged the collective adoption of these practices by U.S. farmers as the best alternative to the continued and intensive use of chemical fertilisers and pesticides which have often impaired the quality of our soil, water, and food.

Again, in 1993 the National Academy of Sciences left no doubt as to these earlier concerns when the National Research Council released a report on "Pesticides in the Diets of Infants and Children" which concluded that people in this age group could be at considerable health risk from consumption of foods containing pesticide residues.

Both of these reports have raised considerable speculation about the future of our chemical-based agricultural production system. A growing consensus of consumers, environmentalists, legislators, and many farmers is that our current farming practices will have to change considerably to achieve a significant reduction in pesticide usage in U.S. agriculture. The ultimate goal of sustainable agriculture according to the National Research Council, and other sources as well, is **to develop farming systems that are productive, profitable, energy conserving, environmentally sound, conserving of natural resources, and that ensure food safety and quality.** Consequently, the leading question that U.S. farmers are asking is, "How can I make these changes, reduce my chemical inputs, and achieve an acceptable level of economic and environmental sustainability?" A successful transition from chemical-based farming systems to a more sustainable agriculture will depend largely on what farmers do to improve and maintain the quality of their agricultural soils. Indeed**, soil quality is the "key" to a sustainable agriculture**. Not surprisingly, the alternative agricultural practices advocated by the National Research Council are mainly those that can improve and maintain soil quality. Experience has shown that the transition from conventional agriculture to nature farming or organic farming can involve certain risks, such as initially lower yields and increased pest problems. Once through the transition period, which might take several years, most farmers find their new farming systems to be stable, productive, manageable and profitable without pesticides"[1].

The agriculture I envisaged and wanted to create had to depend more on knowledge and understanding of nature, including human nature, and less on capital and access to technologies developed to extract wealth from the user, and by focusing on the four pillars of sustainable business: social, environmental, financial and spiritual, I would be maximising the Quadruple Bottom Line (QBL) and successfully achieving our goals. Education, skills and experience were the immediate challenges, however having had no formal chemical agricultural training, I found it easier to realise organic farming works, making the learning process faster than usual.*" Free your brain and your behind will follow" Farmer Tom Frantzen, USA ATTRAnews USA*[2].

Based on these ideas, facts and ongoing research we decided to pursue the organic way with an organic and precautionary approach based on the Precautionary Principle (see Information Box 1): slowly- to learn and live the "new" initiative- the starting point being the soil and its neglected and underutilised crop, soil life, followed by seed, and so up the growth chain to the final edible crop.

Box 1. The Precautionary Principle

1. Scientific uncertainty should not automatically preclude regulation of activities that pose a potential risk of significant harm (Non-Preclusion PP).
2. Regulatory controls should incorporate a margin of safety; activities should be limited below the level at which no adverse effect has been observed or predicted (Margin of Safety PP).
3. Activities that present an uncertain potential for significant harm should be subject to best technology available requirements to minimise the risk of harm unless the proponent of the activity shows that they present no appreciable risk of harm (BAT PP).
4. Activities that present an uncertain potential for significant harm should be prohibited unless the proponent of the activity shows that it presents no appreciable risk of harm (Prohibitory PP). From ".wikipedia.org/wiki/Precautionary_principle"

MATERIALS AND METHODS: THE SILENT REVOLUTION

"To be sustained over a short term, the enterprise must be profitable; to be sustained over a long time period, the management of the natural resources such as soil and water must be considered." ATTRAnews ibid.

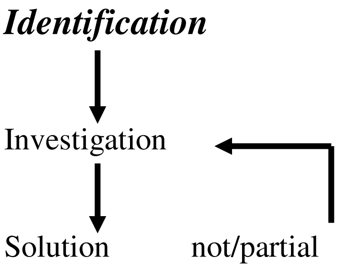
The conversion period was finally stretched over 10 years in order to accommodate the timely and costly research, experimentation, trials and market developments which were virtually non-existent in South Africa while government agricultural departments were pursuing the elusive industrial agriculture model.

At the outset the decision to grow crops, which had a history at Kirklington, organically, meant a reduction in risk of inevitable experimental failure, financial loss and critique from across the fence. Based on successful trials, the market would be investigated for an offset point for the crop and simultaneously a search for new and underutilised crops would occur followed by research and development.

A holistic method of experimentation introduced many variables requiring an open mind and tolerance for failure and unpredicted success. The identification of critical inputs and research areas including seed, soil and soil life, fertiliser and bio-fertiliser, cultivation techniques, pest, weed, disease and harvesting led us to reading numerous books, scientific papers and liaising with institutions (e.g. Small Grain Institute of the Agricultural Research Council) technical colleges and universities (e.g. Free State and

Stellenbosch) including overseas institutions (e.g. Elm Farm Research Centre, UK). Many problems came up and were solved by following the format in Table 1 below.

Table 1. Technical Problems: Process and Solutions



Identification	Investigation	Solution
Information on organics, soil, soil life	Enquiries ex farmers, internet, advisors, institutions, universities.	Old Farmers handbooks; new books; internet; farmers; farm walks; advisors; institutions.
Regulations	Search as above	Internet; farmers; certifiers
Market for in-conversion	Contact traditional markets, farmers markets,	Retailers; farmers markets Municipal markets.
Inputs: seed, fertilisers, machinery	As above and own resources	Internet; farmers, advisors, own planning
Technical experience	Industry info.	Trial & error; costly industry information
Training	None	In house
Irrigation	Industry	Trial & error; costly industry information
New technology	Magazines, internet, farmers, advisors	Trial and intuition.
Weeds, pests & disease	As above	Least cost option of present equipment and resources or borrow, lease.
Value adding	Market, farmers, advisors, internet, magazines	Thorough research and development.

Upon reaching a critical point of knowledge confidence, practical trials were commenced where factors such as cultivation effect on weeds, on germination time, incidence of pests and different methods of control and the harvest quantity and quality were monitored and recorded. These factors are listed below.

Objectives and parameters used and measured during trials of old and new crops

Soil

Objective: To transform the soil from a disease inducing to a disease suppressing state; get the soil alive with earthworms and other soil life; improve nutrient status and water absorbing capacity.

Parameters: cultivation type (e.g. plough, minimum till); effect on soil (soil life, structure, organic matter, water retention capacity); effect on seed germination; outcome on weeds and pests; effect on harvesting.

Seed
Objectives: To identify suitable crops, cultivars and varieties for successful cultivation.
Parameters: time & rates of application; inoculants- microbial and chemical (permitted); depth of planting and placement; mixed & strip crop seeding.

Fertiliser
Objective: To determine the optimal type and application method(s) of fertiliser and biofertiliser.
Parameters: type (precision &/ broadcast); rate; depth of application; relation of application to seed; green manure; post emergence fertilising and foliar feeding.

Pests, weeds and diseases
Objective: To establish the best method of control.
Parameters: daily/weekly monitoring; critical thresholds for action; action type (organic poison, microbial exclusion, farm remedies, cultivation); catch crops, intercropping, strip cropping and weeds as indicators of soil structure and nutrient status.

Equipment
Objective: To identify the implement best suited for the job.
Parameters: conventional; adapted, new.

Harvesting
Objective: To determine the effectiveness of the previous parameters.
Parameters: yields; quality, time.

The First Trials
A conventional dry land crop, asparagus, lent itself to organic production rather easily with manageable production problems and became a good organic cash crop in the short term.

Peach and apricot trees, planted conventionally, though using some organic techniques (e.g. manure, lime-sulphur), were targeted for conversion in 1991.The following 5 years were an organic experiment on 11 hectares of fruit, applying as many of the above objectives and parameters. The focus was the soil: initially large quantities of composted sheep manure were broadcast (up to 40 tons/ha per annum) to combat nitrogen deficiencies as indicated by yellowing leaves. Pernicious scale was dealt with by spraying milk (lactic acid) but was replaced with much cheaper effective micro-organisms EM. See Information Box 2 below on EM. Early season aphid infestation was sprayed with a mixture of khakibush/Mexican marigold (Tagetes minuta) extract and molasses; again EM replaced this remedy with EM fermented plant extract (EMFPE) based on khakibush, garlic and chilli. The inter row area was tilled to provide a fire break and reduce competition from grasses and weeds for moisture and nutrients, however as the soil status improved over time, this area was allowed to grow and mown occasionally, becoming a habitat for many predators (spiders, ladybirds, birds and snakes).

Over the years the soil improved dramatically as soil samples indicated the presence of large quantities of earthworms and other soil fauna and flora. The final results were pleasing with above industry average yields and brix (sugar) levels allowing us to gain access to the German baby food market. Subsequently the increasing factory production costs and high cost of transport forced us to change our marketing strategy and focus on the local market through a "pick-your-own" plan where buyers picked and transported their own fruit enabling us to generate good profits shared with the fruit manager.

My choice to use EM as opposed to various other similar products was based on the concept of "appropriate technology", i.e. a technology which is effective, efficient, economical and safe, i.e. it satisfies the precautionary principle. I have not found another source of mo's which can compete with EM. For example the EM application cost per hectare per year on the orchard is R200 (US$29).

Box 2. What is EM?

As an alternative to agrochemicals (i.e. chemical fertilisers and pesticides), Professor Teruo Higa, developed the concept and technology of Effective Microorganisms (EM). EM has been shown to be effective in replacing agrichemicals, especially when applied in combination with organic amendments. EM is a mixed culture of aerobic and anaerobic beneficial, naturally-occurring, microorganisms that can be applied as inoculants to enhance the microbial diversity of soils and plants which, in turn, can improve soil health and the growth, yield and quality of crops. (Higa and Wididana, 1991a). EM contains predominant populations of lactic acid bacteria, yeasts, actinomycetes, photosynthetic bacteria and other organisms that are mutually compatible and co-exist in liquid cultures. Higa and Parr, 1994.

Parallel to the fruit project, trials on other traditional conventional and underutilised crops were conducted on 3,5 hectares and included: wheat, maize, sunflower, rye, triticale, grain sorghum, barley, spelt, soyabeans, cowpeas, vegetables (potatoes, butternut, radish, sweet corn, fine beans, mange tout) green manures and forage crops (serradella, Japanese radish,).

Through the biodynamic and organic network we embarked on medicinal and essential oil plant trials which were grown in separate fields as these required long term analysis.

Pasture trials were and are conducted in situ where a field is identified for pasture establishment. Trials with pasture mixes (livestock salad bars including poor man's lucerne, serradella, *Eragrostis curvula*, Smuts finger grass, rooi grass (*Themeda triandra*), chicory, sheep's burnet, yarrow and dandelion) as opposed to monocrop pastures, are a work in progress.

Experiments with organic remedies for the livestock, cattle and sheep, proceeded with the aim of doing away with poisons, and ranching toxin-free, rather than specifically directed at achieving organic status. Diatomaceous Earth (DE. See Information box 3 below) was identified as a non-chemical anthelmintic added to livestock feed and also applied externally for control of lice, ticks and flies. EM was also tested as an additive to water and feed to improve the animals' health.

Box 3. What is Diatomaceous Earth?

"Diatomaceous earth consists of the remains of fossilised marine algae namely diatoms. The product is mined and reduced to powder form. This powder acts as tiny pieces of glass that tear the shells of insects and other arthropods." The Control of Internal Parasites in Ruminants. Jean Duval, agronomist, M.Sc. January 1994. Ecological Agriculture Projects, McGill University (Macdonald Campus),Ste-Anne-de-Bellevue, QC, H9X 3V9 Canada.

RESULTS AND DISCUSSION

During the initial years of trial and error, the conventional side of the farm, particularly livestock, provided seed finance for the experiments until viability was established (commercial production) or discontinuation.

Regular and continual, recorded observation supported by intuition was vitally important. I initially ignored that "little voice", as being unscientific, but I soon learnt it was one of the most powerful tools I had, freely at my disposal, to use and the number of times it has literally "saved the day" are too numerous to mention. In all my networking and advice I strongly advise the use of intuition.

Once success with a trial crop was achieved both financially and productively, larger scale planting was embarked upon, dependent on market requirements, i.e. we never planted a crop that was not sold (off farm and/or on farm) beforehand.

The search for markets occurred simultaneously with the trials and successes in order that upon a crop coming "online" it could be sold 100%. This 100% objective generally required value adding.

Example of R & D: Organic Rye and Rye Flour

Rye was identified as a promising crop to grow commercially and process as flour as none (both conventional and organic) was produced in South Africa for human consumption. A retailer partnered with us to provide a ready market on completion of trials and commercial harvest. Rye had for many years been grown as green forage for livestock in the dry winter months and had shown itself to be hardy and robust, resistant to aphids and rust, producing at least 2 tons/ha when allowed to grow to maturity for seed.

Treatments

Soil preparation included two methods: (1) traditional mouldboard plough and attached harrow and (2) chisel plough and harrow. Both systems applied effective micro-organisms (EM) via sprayers to the soil during the operation.

Chemically untreated seed was precision planted with inoculation of EM (i.e. soaked in a dilution of 1:100 $H2O$ for 30 minutes to provide prophylactic protection against soil pathogens) and without on each of the two soil prep methods at a depth of 10 mm at a rate of 25 kg/ha, apart and above the drilled fertiliser (4 cm and 10 cm).

Fertiliser in two forms was applied: a commercially available organic fertiliser (Talborne Prescription Mix Fertiliser) at recommended rates of 200kg/ha and farm composted sheep manure inoculated with EM at 10 000kg/ha. The former was split applied with seed drilling on half of (1) and (2) and the compost before soil preparation on the remaining halves of (1) and (2). See Table 2 below.

Foliar feeding of EMFPE occurred twice on the 8 replicates of 0.37 ha, providing disease and pest protection simultaneously (competitive exclusion). Being a winter crop, weeds were not a problem particularly in the ploughed section, though weeds were more active in the chisel ploughed part, but did not pose an economic threat. (Note: weeding of small grain winter crops has become necessary in some years or fields where weed seed banks are high; a combine harvester head reel tines mounted on a frame worked effectively at removing 80-90% of weeds at the stooling growth stage). Harvesting of each of the 8 trials was separate and then compared.

Table 2. Layout of Field Trial Rye.

Field Trials: Rye							
Mouldboard Plough with EM (MBP)				Chisel Plough with EM (CP)			
Seed with EM		Seed only		Seed with EM		Seed only	
COF	Compost	COF	Compost	COF	Compost	COF	Compost
EMFPE Spray overall							

COF = Commercial Organic Fertiliser
EM = Effective Micro-organisms
EMFPE = EM Fermented Plant Extract

Observations and Results

The MBP plots exhibited more even germination due to a finer and moister seedbed. This factor was discounted in years of good autumn rains when the CP method was as effective in even germination (even plant growth is necessary if blind-harrow weeding at a later stage is required).

Germination of the EM treated seed was two days ahead of the untreated seed. The EM seedlings were thicker and more robust than the untreated. This confirmed research of the beneficial effects of EM on seeds and seedlings in terms of protection from soil borne pathogens and the positive impact on growth through provision of nutrients and other beneficial substances such as hormones, enzymes, vitamins and lactic acid.

The seedlings planted with drilled COF were greener than the applied compost plots initially indicating that the fertiliser was more available. By the time of stooling, the plants were more uniform in colour. In terms of cost the drilled COF was less expensive as one less field operation was required, but the farm produced compost was cheaper as a fertiliser. The decision became one determined by time, availability and quantity of the two fertilisers.

The EMFPE spray had a visual impact in terms of increased vigour, growth and colour.

Good spring rains meant sufficient moisture for seed maturity and the MBP plots at harvest yielded 2500 kg/ha compared to the 2300 kg/ha of the CP plots. There were not significant differences in yield between the treated and untreated seed. The quality of seed of all plots was good and on milling the flour proved to be good enough to replace imported rye flour.

An economic assessment of the input costs indicated that the compost plots were more expensive, at R500/ha for compost whereas the COF cost R400/ha and coupled with the lower yield meant the COF method was financially the better option. However, it is important to note that the impact of compost on soil health was far greater adding organic matter and micro fauna and flora which benefits would be longer term and not readily measurable immediately. (1US$ = 7 Rand). Storage of the reaped seed was initially in large silos where pests (weevil and flour moth larvae) became a problem, solved by packing in 50 kg bags and treated with DE which mechanically kept the pests at bay.

Together with organic wheat and later maize and barley, rye was stone milled on farm in a new plant adding significant value to the raw crops. By-products of the process were used for the livestock.

Current Activities

"Love what you do; live with intention; always learn; don't forget to play." Organic Salad Producer .ATTRA USA

Our present basket of products and output has evolved and changed as the market and our expertise has developed. Looking at Figure 4: Kirklington 2007, which logs as many of the activities, actions, products, and factors outside the farm gate, the noticeable difference with the pre 1990 farm chart are the huge number of extra activities taking place; in particular the recycling of energy as far as possible and reducing the energy leaving the farm. At the core of the farm organism are people who drive and give direction to the farm based on respect for nature. Information, knowledge and experience are indicated and by following the flow of the chart the successful outcomes are seen. There are still significant inflows from outside the farm, but some are necessary and others are under the spotlight to reduce. The huge value and premium we put on networking, making new friends and exchanging thoughts and knowledge is not emphasised, however it is probably the most essential aspect of all the important parts of the whole organism in constant flux.

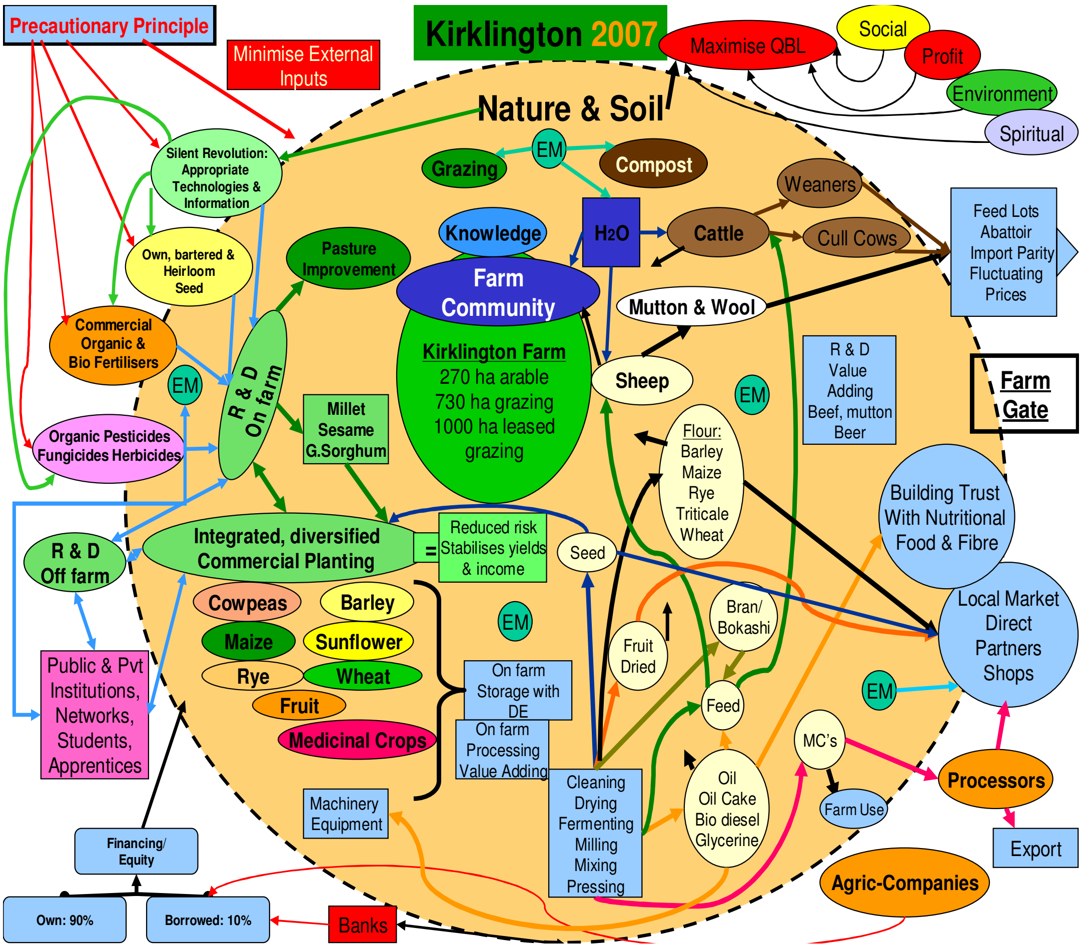


Figure 4. Kirklington 2007: activities, actions, products, and factors outside the farm gate

Asparagus: A Past Cash Crop

Dramatic changes have seen the South African asparagus market become almost totally organic, with the largest asparagus producer in the Western Hemisphere being organic and selling organic into the conventional market. As a small producer we climbed out when the big fish arrived and looked for other products to produce and sell. This experience subsequently applied to fresh vegetables we produced for a retailer.

Our lesson: the ability to transform as market forces change is fundamental to success and the age-old adage: increasing diversity lends stability and reduces risk, has come back into its own.

Livestock

The cattle and sheep enterprises are operated extensively on four farms (two leased) utilizing low-input organic methods to provide the market both local and urban with quality weaners and lamb/mutton/wool. Feed is 100% outdoor grazing on veld (natural pasture), planted pasture and planted forage supplemented with protein and carbohydrate licks in the dry winter months.

Diatomaceous earth (DE) was identified as a non-chemical anthelmintic and added to livestock feed and also applied externally for control of lice, ticks and flies and complemented with the application of EM5, an EM derivative producing esters which disrupt external parasites' digestive systems.

The inclusion of EM and derivative, Bokashi (EM fermented bran) in the drinking water, feed and licks promoted better feed conversion and enhanced microbial life in the stomach enabling better health and returns on feed (see Table 3).

Table 3. Winter Production Lick Kirklington

				KG
Ingredient	**R/kg**	**kg**	**Cost**	**%**
Oil Cake	1.30	50.00	65.00	6
Sulphur	2.22	5.00	11.10	1
P12	2.67	75.00	200.25	9
Salt	0.40	175.00	70.00	20
MaizeMeel	0.60	450.00	270.00	51
Feed lime	0.33	50.00	16.50	6
Bokashi	2.00	25.00	50.00	3
DE	3.00	20.00	60.00	2
MEM	2.00	25.00	50.00	3
Total		**875.00**	**R 792.85**	
Cost/kg			**0.91**	
RDI & Cost		**0.65**	**0.59**	
Cattle	**Bulls**	**Cows**	**Calves**	**LSU's**
Kirk	5.00	80.00	27.00	90
Pbg	6.00	191.00	16.00	205
Swlte	0.00	58.00	0.00	58
				353
Sheep	**Rams**	**Ewes**	**Lambs**	**LSU's**
Kirk	13.00	650.00	280.00	157
			Total	**510**

The sheep are corralled nightly on old straw where the combination of manure, straw and EM creates an immediately available organic fertiliser which is recycled onto the arable lands without composting, providing nutrients, structure and mo's to the soil. Maize and sunflower oil cake, grown and processed on the farm, are available in the dry winter months as part of their ration providing protein, carbohydrates and nutrients, further recycling and adding value to farm products and by-products. Note: compost was made from the sheep "waste" for a number of years in windrows 30 meters by 4 meters by 3 meters using a front end loader, water and EM, however, the experience with EM in Thailand indicated that composting was not necessary as the EM suppressed most pathogens (e.g. E.coli 0157) and fixed volatile nutrients rapidly, and so we discontinued the expensive compost program.

New interest in organic meats from speciality outlets indicates a new market where value adding will be necessary allowing the capture of more of the value chain in the livestock cycle.

Cash Crops: Barley, Rye, Wheat, Triticale and Sunflower
Table 4 - Kirklington Organic Farm Production 2004/5 - provides details of crops, land number and size, application and date thereof, yield and expected yield.

Table 4. Kirklington Organic Farm Production 2004/5

Kirklington Organic Farm Production 2004/5						
Crop	**Land**	**Size**	**Month**	**Application**	**Reaped Yield**	**Expected 2004/5**
Fruit:	K9	11	Jan	Cattle Manure Compost @ 2 tons/ha		
Apricot			Feb	Cattle Manure Compost @ 2 tons/ha	5 tons	10 tons
Peach			Dec	Sheep Manure Compost @ 5 tons/ha	30 tons	50 tons
			2*mnth	EM fermented plant extract(FPE) @ 1 liter/ha + 300l H2O		
				Weed control: mechanical mowing & sheep in winter.		
			June	Spray EM FPE		
Wheat	K18	20	Jun-04	Seed: own @ 25 kg/ha with EM		40 t
				Talborne Organic Prescription Fertiliser Mix @ 100 kg/ha		
				Weed control: mechanical combine harrow		
				Pest control & foliar feed: EM FPE @ 2L/ha + 300l H2O		
	K24	26	Jun-05	As above		55t
Rye	K18	20	Jul-04	As above		40 t
	K8(a)	3	Jul-05	As above		6t
	K7	7	Jul-05	As above		14t
Sunflower	K18	20	Sep-04	Sunflower seed: own @ 2,5 kg/ha		20t
				Talborne Organic Prescription Mix @ 100 kg/ha		
				Weed control: mechanical sweep & rolling harrow		
				Pest control & foliar feed: EM FPE @ 2 L/ha + 200l H2O		

Sunflower	K31	9	Sep-04	Talborne @ 100 kg/ha		7t
				Seed: own at 3kg/ha		
				Weed control: mechanical sweep& rolling harrow		
				Pest control & foliar feed: EM FPE @ 2L/ha + 200l H2O		
White Maize	K8(a)	2,1	Nov-04	Conventional untreated seed @ 8kg/ha plus EM Sheep Manure @ 20t/ha		6,3t
Yellow Maize	K24	4	Nov-04	Conventional untreated seed @ 8kg/ha plus EM Sheep Manure @ 20t/ha		12 t
				Weed control: mechanical rolling harrow & sweep		
				Pest control & foliar feed: EM FPE @ 2L/ha + 200l H2O		
Soya Beans	K18	5	Dec-04	Own seed @ 50kg/ha Sheep manure @ 5t/ha treated with EM		5t
Dry Beans	K8(a)	2	4-Dec	Own seed Plus EM Sheep manure @ 5t/ha treated with EM		2t
				Weed control: mechanical sweep		
				Pest control & foliar feed: EM FPE @ 0.5l/ha + 200l H2O		

Cereals entail more intensive farming involving expensive inputs trialled over a number of years and continuously tweaked on the land (changed, improved, increased or discontinued) to improve yields, reduce costs and influence the bottom lines. For example, the inclusion of EM into the planter drilling units enabled us to place EM with the seed and fertiliser providing even greater microbial life in the growing-soil zone which had the positive spin-offs of less disease and higher levels of nitrogen fixing allowing reduction in commercial fertiliser application (for small grains the fertiliser was reduced from 200 kg/ha COF to 100 kg/ha supplying 7 kg/ha of N. The final harvested yield was 1700 kg/ha with a protein content of 13% in a drought year when average yields for the district were 1500 kg/ha).

As part of the growing program, crop rotations and strip cropping are practiced depending on the weather, particularly rainfall and time of seasons. A normal year had allowed us to strip plant sunflower and soyabeans with fishmeal and mo's inoculated into the soil, in rows of four. Two cultivations with a rolling harrow simultaneously kept weeds at bay and applied EM and a good growing season allowed us to reap a decent crop of 1000kg/ha soyas and 1200kg/ha sunflower seed realising a good profit as inputs were low.

Barley, rye, wheat, maize, soya beans, dry beans and triticale are stored on-farm and stocks are drawn as the market or farm demands either as various grades of flour or whole grain; packaged in 12,5kg and 25kg bags the grains and value added products are despatched by courier countrywide. Various retained seed for our own use for planting is stored separately with DE and wormwood (*Artemisia afra*).

Increased production of organic sunflower was investigated and trialled as for the winter crops, though market size and pricing differed in terms of higher price (100%) and much smaller volumes. Planting using an adapted Monosem precision vacuum planter which concurrently accurately placed COF and EM inoculated seed alongside, followed by a spreading of diatomaceous earth on the surface (cutworm & beetle deterrent), enabled rapid and accurate planting. The same system applied to other large seeds: maize, cowpeas, soya beans and lupins.

Sunflower is stored on-farm, cleaned, pressed or decorticated (dehulled), filtered, packaged in 5 to 25 litre containers and despatched to local distributors, shops, processors and consumers.

The increase in the price of oil with news of Peak Oil added significantly to input costs in crop production and the feasibility of a larger oil press and bio-diesel converter were investigated. The numbers made sense and these were purchased having a capacity of producing 900 litres per day, well in excess of our peak daily requirements. The by-product of oil cake and glycerine are utilised on farm in livestock feed and cleaning machinery respectively.

The arable soil at Kirklington has improved over the 17 years I have farmed and the proof is in the more stable yields and improved quality of crops. Looking into the soil itself shows varying results depending on that particular soil's history. The orchard soil, for example, has shown dramatic improvement in terms of structure, organic matter, humus and life. This shows up in the earthy smell given off when digging under the trees; the huge numbers of macro soil life (earthworms, beetles, spiders, and centipedes), the tilth and in the sweetest fruit with virtually no pest damage.

The arable lands are not as robust and healthy, but improvements in structure due to discontinuance of fossil fertilisers and poisons, requiring less mechanical disturbance and the use of EM manure, organic fertilisers and bio-fertilisers have made a significant contribution: the soil
pH is rising without additions of lime. Soil life is noticeable, especially when working the land when earthworms appear before and after planting.

Generally the growth of the soil and its crop of life is satisfying and continues to move in the right direction.

Fruit: Apricots and Peaches

As explained above, external factors (exchange rate and processing costs) have changed the marketing of fruit from export orientated to local and urban. The orchard has matured and with gentle management, including limited pruning, prophylactic sprays, slow harvesting and value adding, is now a cash cow. Weather still plays a major role in primary production (drought, hail & frost) and after harvest practices (drying fruit). To combat drought we continue mulching the tree drip lines with grass bales (*Eragrostis curvula*) and thinning the immature fruit more heavily while hail is steered away using Basotho cultural methods. We have found that spraying an EMFPE with a predominance of pine needles provides protection against frost for the swelling buds.

Medicinal Crops
The potential for certified organic medicinal plants looks promising and 15 hectares have been planted providing work for 30 local women.

Essential Oils
A trial of roses for extraction of rose oil for the fragrance industry was started in 2005 in partnership with an international firm specialising in organic and biodynamic perfumes.

Forage crops: Green Feed, Japanese radish, Cowpeas
The production of sheep and the rotation of crops in the organic production plan require the farm to grow various winter and summer feeds for on-land utilization. These are low input crops geared at achieving maximum forage per hectare in order to convert sunlight to feed to beef and mutton and thereby adding significant value to the original inputs. The benefits of rotation, sheep manure and nitrogen-fixing plants are valuable by-products of this process.

Soil, Grass and Environment
The main objective of organic farming is to grow the soil. Based on this premise the farm organism is not only naturally geared to accomplish this, but also managed to continually improve this natural tendency.

Experience at Kirklington has shown the improvement in grass growth and palatability by following this goal. The same applies to arable lands converted to pastures as to natural veld/pasture.

Present practices include broadcasting EM manure (livestock manure inoculated with effective micro organisms), spraying EM during rain or soon after at rates of up to 100 litres multiplied EM per hectare, reseeding mono-culture pastures by drilling in mixtures of legumes, herbs, broadleaf plants and grasses as mentioned above and high impact grazing on the lines of mimicking indigenous wildlife feeding patterns.

Livestock grown on good pasture or veld is more thrifty and able to weather parasite pressures economically.

Ultimately the whole farm environment has improved and continues to recover, substantiated by the return of fauna and flora previously thought lost to the farm. The most prominent is birdlife, especially raptors which are so necessary for the balance in Nature. Guinea fowl flocks are numerous and are excellent indicators of pests in newly planted fields, where they scratch for grubs and beetles.

People
All people at Kirklington have benefited by the conversion to organic family farming in areas such as health, wealth, learning, experience and wisdom. A marked reduction in sick days was a measurable benefit, moreover we all felt better without the toxic chemical loads we absorbed during the years before abandoning the industrial conventional system. This meant we were able to increase our personal work load benefiting us and the farm. Most of our food for the farm community is farm produced and fresh, either raw or processed just prior to consumption. The benefits of non toxic food, higher vitamin content of freshly ground flours contribute to the Quadruple Bottom Line. It is our vision to continue this process.

Research and Development
This vital area continues to enjoy significant attention in terms of new, underutilised and lost crops such as sesame, millet, sorghum, hemp, black velvet bean and flax. The application of biodynamic principles has been conducted over many years and now gathers momentum in a more regular fashion.

Challenges

Creativity is the most underutilised tool in the toolbox and at Kirklington is becoming a standard part of the process in dealing with the ups and downs that have been many and continue to appear as the playing field changes. Major stepping-stones now facing us, organic farmers and chemical farmers are land reform, the cost of oil and globalisation.

Land Reform
We have discussed this issue at length within the farm community and recognise the political need and aspirations. Our approach, as with all things organic, is slow and cautionary. The technical details of ownership, entities and who benefits have become secondary factors and we feel will come into their own over time. The most important facet is the ability to farm successfully, sustainably and happily.

Our idea is to build managerial and ownership capacity slowly through mentorship over a number of years or for as long as we feel it is necessary until the farmer feels confident to continue solely or as partners.

The concept of LISA is paramount to all areas in this approach.

Cost of Oil
Despite many conflicting opinions, our research and feeling is that this is one of the most important factors to manage in the short, medium and long term.

The Kirklington experience has undoubtedly shown the importance of living as far as possible within the available on-farm energy resources, for to stray from this goal entails endangering the QBL.

The impact of increasing oil prices is felt throughout the farm organism and we are actively pursuing policies to reduce the impact and multiplier effects.

These include bio-diesel (sunflower) mentioned above, solar and gas (methane) energy for heating, cooking and weeding, animal traction, on-farm engineering (lathes, motor rebuilding and blacksmithing) and brainstorming.

Globalisation
This field is like a kaleidoscope, ever changing with dark areas which are pitfalls for the unwary. We have had to continuously modify, change and transform our marketing strategies to remain in the market. This has been planned and managed successfully.

The greatest challenge is the impact of the global village and industrial organic. Our immediate response has been to reduce our risk in faraway markets and increase our presence in local markets. Rebranding our products is one consideration we are implementing (e.g. "Family Farm Grown").

DISCUSSION AND RECOMMENDATIONS

Today's industrial agriculture based on the green and brown revolution technologies (fossil fertiliser, genetically modified seeds and toxic poisons) is recognised to be totally unsustainable and is fundamentally different to sustainable agriculture in that it substitutes capital for labour and off-farm technology for management whereas sustainable agriculture is based on knowledge of how to work with nature and not dominating her.

It is clearly apparent that commercial (and subsistence) farmers face seemingly insurmountable problems, in particular, their source of seed. Corporate seed merchants are geared to short-term profit maximisation and monopolisation and as such their interests (patenting seeds) and farmers' interests are not compatible. As we have discovered, the greatest need among today's and tomorrow's farmer is cost-effective, appropriate technology seed which "requires an agriculture which is holistic and integrative, not specialised or segmented. It is dynamic and site specific (terroir), not standardised and routine. It is interdependent and management intensive, not management extensive and centralised in control. The farm is clearly biological rather than mechanical in nature"[1].

Cost effective, appropriate technology seed is one of the many inputs desperately needed by farmers to replace the industrial input model. In order to achieve this, seed and other inputs need to be locally based, developed and conserved in farmers/community/government partnerships (FCGP) and internationally protected where the rights to the seed genes are held in the public domain and not removed and patented by multinational corporations.

Resembling a well integrated, diversified farm, the FCGP would need to go beyond just seed, but operate locally and beyond, networking with as many interested researchers, farmers and community members as possible, providing practical, easily understandable information and seed for trials and commercial growing.

Knowledge of other inputs and outputs would complement the work of the FCGP seed business, including place-based management practices from successful farms that reduce costly inputs to serve as models for change including focusing on research and development on biologically-based pest and disease management and capturing best practice data for future use.

To developing comprehensive market information enabling farmers to make informed crop and marketing decisions and assisting in developing closer, more trusting and synergistic relationships with retailers and consumers and regulators which would be FCGP value adding.

The FCGP would provide farmers with tools to compile directories of food systems, biofuels and carbon-based waste products to better understand relationships between crop production, food consumption, energy and nutrient production and supply assistance with formation of farmer/community based cooperatives.

Reorganising regulatory agencies along these lines in order to complement the preceding processes would be integral to the FCGP's role.

Finally, establish programs to link students with farms and new farmers with mentoring older farmers.

CONCLUSION

The transformation of Kirklington into a highly diverse, stable and integrated unit has been exciting, daunting, frustrating and satisfying. The starting point was the recognition and acceptance of the problems and challenges facing commercial farming locally and globally, principally farming inputs, seed and fertiliser, followed by thorough research and networking to find solutions and pursue established goals. On-farm research and development yielded successes and also required changing goals or parameters where failure was apparent, followed by commercialisation of the crop, value adding and sale to trusted consumers or partners. Topics of present importance include inputs, land reform, continuing research of bio-diesel and globalisation. The farm as an organism has grown and matured, yet the process continues.

"Guns are too callous, bombs too ruthless, and knives too blunt to cut the darkness of these times. Our activism demands a poetry that holds out for nothing less than poesis- a participation in the beauty of making and re-making reality." Alistair McIntosh, Love and Revolution, pp 11.

Footnotes

[1] The Next Agricultural Revolution. Revitalising family-based agriculture and rural communities. Dr William Heffernan, Ph.D., Professor Emeritus, University of Missouri, Rural Sociology, USA.

[2] "Beneficial and Effective Micro-organisms for a Sustainable Agriculture and Environment". Dr.Teruo Higa, Professor of Horticulture, University of the Ryukyus, Okinawa, Japan and Dr James F. Parr, Soil Microbiologist, Agricultural Research Centre, US Department of Agriculture, Beltsville, Maryland, USA. International Nature Farming Research Centre, Atami, Japan, 1994.

[3]ATTRA*news* is the newsletter of ATTRA - National Sustainable Agriculture Information Service is managed by the National Centre for Appropriate Technology (NCAT), US Department of Agriculture.

[4] Dr John Ikerd, Professor of Agricultural Economics at University of Missouri. The Next Agricultural Revolution. Revitalising family-based agriculture and rural communities.

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10

Traditional versus exotic vegetables in Tanzania

G. Kedling, I.S. Swai and D. Virchow

Traditional vegetables have been important from time immemorial to meet the nutritional needs of Tanzanian people. However, with the modernisation of agriculture and the beginning of a market economy, exotic vegetables with a potential for the main domestic and export markets became increasingly important. Furthermore, agricultural research has concentrated mainly on exotic rather than traditional vegetables. Therefore, the World Vegetable Center (AVRDC-RCA) and partners launched a project on "Promotion of Neglected Indigenous Vegetable Crops for Nutritional Health in Eastern and Southern Africa (ProNIVA)".

One part of the project focuses on the production, collection and purchase of traditional in comparison with exotic vegetables. For this purpose 291 women farmers in three different districts of Tanzania were interviewed during both the dry and rainy seasons. Besides being produced by farmers many traditional vegetables are gathered from the wild or fallow land where they grow spontaneously. The ratio of produced to collected vegetables per women farmer varies and is lowest in rural, semiarid Kongwa (dry season 0.88; rainy season 0.73), intermediate in rural, humid Muheza (1.13; 0.97) and highest in peri-urban, semiarid Singida (2.40; 0.81). As the two semi-arid districts Kongwa and Singida show high differences it is assumed that climatic conditions have less influence on collecting vegetables but rather the rural or peri-urban location of villages, including the opportunities of finding and collecting traditional vegetables in the wild.

When the production of traditional vs. exotic vegetables is compared the ratio is highest in Kongwa (dry season 11.42; rainy season 33.60), intermediate in Muheza (7.64; 13.50) and lowest in Singida (3.23; 6.69). While exotic vegetables are cropped to a low extent by all interviewed farmers they are especially unimportant during the rainy season when wild vegetables are abundant. Similarly, the ratio of purchased traditional vs. exotic vegetables is highest in Kongwa (1.8), intermediate in Muheza (1.5) and lowest in Singida (0.6) during the rainy season.

Although traditional vegetables are still collected and cultivated to a certain extent, the data from this study show that with on-going urbanisation, collection as well as the production of traditional vegetables is decreasing. For further development, it seems that in urban and peri-urban regions traditional vegetables only have a chance to survive if demand for traditional vegetables is increasing by promoting awareness of traditional vegetables.

This study is supported by Eiselen Stiftung Ulm, Germany and the Federal Ministry for Economic Cooperation and Development, Germany.

INTRODUCTION

In Tanzania, vegetables are typically grown on a rather small scale (Mwasha 1998). However, horticultural crops usually generate higher income per unit area and represent an alternative for farmers with too small cultivable land to provide adequate livelihood from field crops. Furthermore, vegetables are an efficient source of micronutrients, both with respect to unit cost of production and per unit of land as it was found in different Asian countries (Ali and Tsou, 1997). While vegetables were considered as luxury products and of secondary importance in Tanzania for a long time and the government gave priority to cereals production, recently a rapid increase in fruit and vegetable production has occurred due to the revival of economic growth and liberalisation of non-traditional export products. However, the ten most important vegetables produced in terms of yield in 1995/96 were cabbage, tomato, onion, garden pea, amaranth, Chinese cabbage, eggplant, carrots, cauliflower and, finally, okra (Mwasha, 1998). Thus, only two traditional vegetables were included, namely amaranth and okra. Consequently, a displacement of traditional vegetables through exotic ones already took place in Tanzania and exotic vegetables are highly favoured.

In fact, the Green Revolution – as far as the conservation of biodiversity is concerned – has intensified the erosion of indigenous and traditional plant varieties and for a long time, the genetic variability of these indigenous and traditional plants and their wild relatives have received minimal attention in research and development. However, now, as there appears some interest in the indigenous knowledge system, traditional plant species and farmers' knowledge of how to manage, select and breed them have been partially replaced by modern agriculture (Slikkerveer, 1995).

Unfortunately, only few important crops get more attention through the development of appropriate varieties and agronomic research, while there is a tendency for the rarely cultivated crops to disappear (Schippers, 2002). With the onset of the market economy and modernisation of agriculture in Africa, attention has been given to crops that offer a potential for export. As a result, exotic vegetables have become more prestigious than traditional vegetables and conventional agronomy has, to a large extent, concentrated on conserving the genetic resources of exotic rather than indigenous or traditional vegetables. Consequently, the latter are threatened with extinction as they have to compete for attention with the much more popular exotic vegetables (Maundu *et al.,* 1999). Another reason for a decline in traditional vegetable usage is that the indigenous knowledge on their production methods, preservation, use and nutritive value is not systematically transmitted anymore from one generation to another (Anonymous, 1998). Furthermore, urbanisation has also led many growers to prefer introduced vegetable crops.

The neglect of traditional vegetables is not reasonable at all as these vegetables are especially important to the countries of sub-Saharan Africa, being better adapted to the environment than the introduced commercial vegetables. Furthermore, traditional vegetables represent cheap but quality nutrition for large parts of the population in both rural and urban areas (Chweya and Eyzaguirre, 1999). In fact, almost all of these vegetables are good sources of micronutrients including iron and calcium as well as vitamins A, B complex, C and E and, for example, amaranth contains a multiple of these nutrients compared to green cabbage (IPGRI, 2003).

As traditional vegetables play such a vital role, their genetic diversity must be conserved and enhanced. Species domestication, crop improvement, and plant introduction usually takes place in traditional home gardens, which are important in terms of production of food, spices, medicine and other essentials, comprising unique and, sometimes, rare genetic diversity of our crop plants as well as some of their wild relatives (Engels, 2002). Thus, home gardens as micro-environments containing high levels of species and genetic diversity, are important for *in situ* conservation of a wide range of plant genetic resources (Eyzaguirre and Watson, 2002), i.a. traditional vegetables. In this study the term “traditional vegetable” (TV) is used for indigenous or exotic vegetable species which, due to long use, have become part of the culture of a community.

This study is associated with a project on „Promotion of Neglected Indigenous Leafy and Legume Vegetable Crops for Nutritional Health in Eastern and Southern Africa“ (ProNIVA), which was launched by the Regional Centre for Africa of AVRDC – The World Vegetable Center (AVRDC-RCA) and partners. So far, through the ProNIVA project it was found that especially poor households rely more on traditional vegetables than wealthy households (Weinberger and Swai, 2006). Traditional vegetables further contribute to food security during food shortages and as they can be produced with low inputs they, consequently, have low capital risk (Weinberger and Msuya, 2004). However, traditional vegetables should not be seen as pure subsistence crops. They definitely have the potential for commercialisation and some of them can already be found in supermarkets and convenience stores (Weinberger and Msuya, 2004). Thus, they do compete with exotic vegetables and the research question which will be discussed in this paper is if exotic vegetables replace or rather complement traditional vegetables. The differences between various agro-ecological zones and different levels of urbanisation shall be examined likewise.

MATERIALS AND METHODS

Research was carried out during June and July 2006 (dry season) and November and December 2006 (rainy season) in three different districts of Tanzania. These districts are located in different agro-ecological zones and characterised by a different level of urbanisation (Table 1). The districts of Muheza and Kongwa equal each other as the visited villages can all be classified as rural. Likewise, Kongwa and Singida have common features as they are both located in a semi-arid agro-ecological zone in Central Tanzania while Muheza is situated at the coast.

Table 1. Characterization of research districts

District	Singida	Kongwa	Muheza
Location in Tanzania	Central Tanzania/ Central Semi-Arid Lands	Central Tanzania/ Southern Maasai Steppe / Arid Lands	Northern coastal areas /Northern Coast
Mean annual rainfall (mm)	200-400 (semi-arid)	500-1000 (semi-arid/humid)	1000-1200 (humid)
Altitude	1100 – 1300m (high)	500 – 1200 m (medium to high)	150 – 1200 m (low to high)
Soils	plateau soils; loam with good drainage	red earth; loam with good drainage	loamy sand with imperfect drainage
Natural vegetation	woodland/ brushland	woodland	savannah, woodland
Location	peri-urban	rural	rural
Population density	30-49 p/km^2 (medium)	30-49 p/km^2 (medium)	> 100 p/km^2 (very dense)

Source: Hathout, 1983; Anonymous, 1998; Anonymous, 2007

In each district 6 villages were visited and 20 women per village interviewed. However, during the second survey in November and December not all women were available and finally only 291 out of 360 women could be interviewed repeatedly (79 in Kongwa, 98 in Muheza and 114 in Singida, respectively).

Each of the participating women was interviewed individually and asked besides general questions on her person, household and wealth parameters, different questions on vegetable production and consumption. Questions on vegetable production which were analysed for this study were:

- Which vegetables (exotic and traditional) do you produce at the moment in your homegarden?
- Which naturally growing vegetables do you gather at the moment?
- Do you buy any vegetables at the moment (this time of the year)? If yes, which vegetables do you buy at the moment / at this time of the year?

RESULTS

Vegetable types cultivated in farmers' fields or gardens and collected from the wild or fallow land vary both between districts and seasons. While in Kongwa district cowpea leaves are most important as a cultivated vegetable in both seasons, in Muheza district wild cucumber and sweet potato leaves are cropped by most farmers during dry and rainy season, respectively. In contrast, sweet potato leaves are of particular importance in Singida not during the rainy but dry season, while most farmers favour cassava leaves in the rainy season (Table 2).

Table 2. Traditional vegetables cultivated during dry and rainy season in three districts of Tanzania and percentage of women cultivating

Kongwa				**Muheza**				**Singida**			
Dry season		Rainy season		Dry season		Rainy season		Dry season		Rainy season	
TV	%	TV	%	TV	%	TV	%	TV	%	TV	%
Cowpea lvs *Vigna unguiculata*	71	Cowpea lvs *Vigna unguiculata*	65	Wild cucumber *Cucumis* sp.	84	Sweet potato lvs *Ipomoea batatas*	83	Sweet potato lvs *Ipomoea batatas*	60	Cassava lvs *Manihot esculentus*	61
Wild cucumber *Cucumis* sp.	57	Pumpkin lvs *Cucurbita* sp.	61	Sweet potato lvs *Ipomoea batatas*	70	Pumpkin lvs *Cucurbita* sp.	79	Okra *Abelmoschus esculentus*	49	Sweet potato lvs *Ipomoea batatas*	43
Sweet potato lvs *Ipomoea batatas*	28	Amaranth lvs *Amaranthus* sp.	29	Cassava lvs *Manihot esculentus*	64	Amaranth lvs *Amaranthus* sp.	72	Wild cucumber *Cucumis* sp.	43	Amaranth lvs *Amaranthus* sp.	36
Amaranth lvs *Amaranthus* sp.	25	Sweet potato lvs *Ipomoea batatas*	27	Amaranth lvs *Amaranthus* sp.	61	Cowpea lvs *Vigna unguiculata*	56	Amaranth lvs *Amaranthus* sp.	38	Pumpkin lvs *Cucurbita* sp.	32
Okra *Abelmoschus esculentus*	23	Okra *Abelmoschus esculentus*	15	Cowpea lvs *Vigna unguiculata*	61	Cassava lvs *Manihot esculentus*	49	Cassava tree lvs *Manihot glaziovii*	19	Wild cucumber *Cucumis* sp.	21

Source: Survey conducted by AVRDC, 2006. N= 120 female participants per district (360 overall). Note: Ivs = Indigeneous vegetables.

Again, different vegetable types are collected from wild and fallow land in all districts especially during the dry season (Table 3). During the rainy season mainly amaranth is favoured as a vegetable gathered from the wild by all farmers in Muheza and Singida districts, while in Kongwa the vegetable 'Mhilile', a *Cleome* sp., is most often collected by farmers.

Table 3. Traditional vegetables collected during dry and rainy season in three districts of Tanzania and percentage of women collecting

Kongwa				Muheza				Singida			
Dry season		Rainy season		Dry season		Rainy season		Dry season		Rainy season	
TV	%	TV	%	TV	%	TV	%	TV	%	TV	%
False sesame *Ceratotheca sesamoides*	86	'Mhilile' *Cleome* sp.	56	Bitter lettuce *Launaea cornuta*	93	Amaranth lvs *Amaranthus* sp.	100	Wild simsim *Sesamum angustifolium*	70	Amaranth lvs *Amaranthus* sp.	100
'Mhilile' *Cleome* sp.	59	Wild simsim *Sesamum angustifolium*	49	Black jack *Bidens pilosa*	72	Bitter lettuce *Launaea cornuta*	91	False sesame *Ceratotheca sesamoides*	51	False sesame *Ceratotheca sesamoides*	77
Amaranth lvs *Amaranthus* sp.	44	Cassava tree lvs *Manihot glaziovii*	37	Amaranth lvs *Amaranthus* sp.	50	Black jack *Bidens pilosa*	83	Amaranth lvs *Amaranthus* sp.	15	Wild cucumber *Cucumis* sp.	57
African spiderplant *Cleome gynandra*	43	African spiderplant *Cleome gynandra*	35	African nightshade *Solanum* sp.	45	Jute mallow *Corchorus olitorius*	59	African spiderplant *Cleome gynandra*	5	African spiderplant *Cleome gynandra*	29
Cassava tree lvs *Manihot glaziovii*	15	Baobab tree lvs *Adansonia digitata*	32	Jute mallow *Corchorus olitorius*	44	African nightshade *Solanum* sp.	57	Jute mallow *Corchorus olitorius*	4	Wild simsim *Sesamum angustifolium*	23

Source: Survey conducted by AVRDC, 2006. N= 120 female participants per district (360 overall)

The percentages, showing how many farmers cultivate or collect a certain vegetable, indicate that slightly more farmers cultivate traditional vegetables during the dry compared to the rainy season. Contrariwise, more farmers collect traditional vegetables during the rainy season as they grow more spontaneously and are more abundant than during the dry spell.

This relationship is similar for the exotic vegetables which are cultivated in all districts to a greater extent during dry than during rainy season. It is noticeable that overall only few farmers cultivate exotic vegetables compared to traditional ones. However, in the peri-urban Singida district much more farmers raised exotic vegetables in their gardens than in the rural Muheza or Kongwa districts. Tomato and white cabbage, for example, was cultivated by 27% and 28% of farmers, respectively, in Singida during the dry season, while only 12% and 6%, respectively, cropped these vegetables in Muheza and even only 8% and 3%, respectively, in Kongwa district (Table 4).

Table 4. Exotic vegetables cultivated during dry and rainy season in three districts of Tanzania and percentage of women cultivating

Kongwa				**Muheza**				**Singida**			
Dry season		Rainy season		Dry season		Rainy season		Dry season		Rainy season	
EV	%	EV	%	EV	%	EV	%	EV	%	EV	%
Tomato *Lycopersicon esculentum*	9	Chinese cabbage *Brassica pekinensis*	4	Common bean *Phaseolus vulgaris*	19	Tomato *Lycopersicon esculentum*	13	*Tomato Lycopersicon esculentum*	32	Chinese cabbage *Brassica pekinensis*	17
Chinese cabbage *Brassica pekinensis*	3	Swiss chard *Beta vulgaris* subsp. *cicla*	1	Tomato *Lycopersicon esculentum*	18	*Chinese cabbage Brassica pekinensis*	7	White cabbage *Brassica oleracea convar. capitata*	28	Tomato *Lycopersicon esculentum*	8
White cabbage *Brassica oleracea* convar. *capitata*	3	Tomato *Lycopersicon esculentum*	1	Swiss chard *Beta vulgaris* subsp. *cicla*	11	Eggplant *Solanum melongina*	6	Chinese cabbage *Brassica pekinensis*	9	Swiss chard *Beta vulgaris* subsp. *cicla*	5
Common bean *Phaseolus vulgaris*	3	-		White cabbage *Brassica oleracea* convar. *capitata*	8	Swiss chard *Beta vulgaris* subsp. *cicla*	6	Swiss chard *Beta vulgaris* subsp. *cicla*	6	White cabbage *Brassica oleracea convar. capitata*	3
Swiss chard *Beta vulgaris* subsp. *cicla*	1	-		Eggplant *Solanum melongina*	3	White cabbage *Brassica oleracea convar. capitata*	2	Eggplant *Solanum melongina*	5	Eggplant *Solanum melongina*	3

Source: Survey conducted by AVRDC, 2006. N= 120 female participants per district (360 overall)

If the number of vegetables cultivated on average by one farmer is compared to those collected from the wild there seem to be not many differences on the first glance (Figure 1).

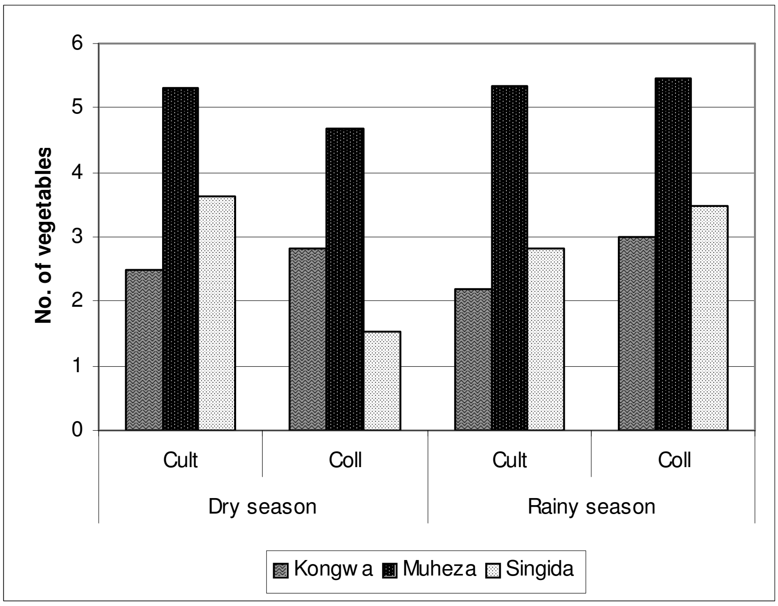

Figure 1. Vegetables cultivated and collected during dry and rainy season in three districts of Tanzania

It can be seen that in all districts not only more farmers cultivate vegetables but also slightly more different vegetable types are cultivated during the dry than during the rainy season. Fewer vegetables are collected during the dry than during the rainy season. However, if the ratio between cultivated and collected vegetables is calculated per district it shows clearly that, irrespective of the season, more vegetables are gathered from the wild than grown in farmers gardens in Kongwa district. While in Muheza this ratio nearly always equals one, it is high during the dry season in Singida but below one during the rainy season (Table 5).

Table 5. Ratio between cultivated vs. collected and traditional (TVs) vs. exotic vegetables (EVs) during dry and rainy season in three districts of Tanzania

District	**Ratio Cultivated : Collected**		**Ratio TVs : EVs**	
	Dry season	**Rainy season**	**Dry season**	**Rainy season**
Kongwa	0.9	0.7	11.4	33.6
Muheza	1.1	1.0	7.6	13.5
Singida	2.4	0.8	3.2	6.7

When traditional vegetables are compared to the exotics there is a considerable difference in the number of types cultivated by farmers (Figure 2). In all districts exotic vegetables are grown to a less extent and especially so during the rainy season. Clearly, most exotic vegetables are produced during the dry season in the peri-urban Singida district where much more farmers seem to be involved in exotic vegetable growing than in the two other rural districts.

If the ratio between traditional and exotic vegetables is calculated it clearly shows that in relation to traditional, exotic vegetables are becoming increasingly important in Singida district, to a lesser extend in Muheza and are rather unimportant in Kongwa district (Table 5).

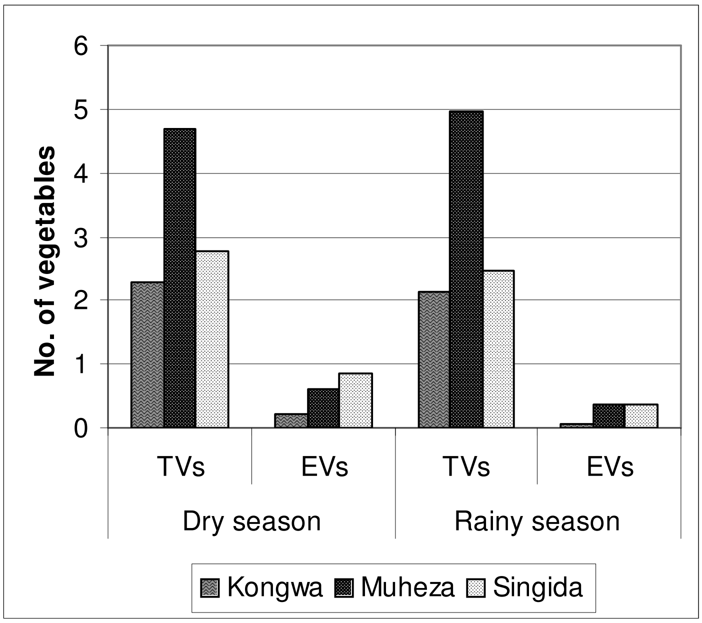

Figure 2. Traditional and exotic vegetables cultivated during dry and rainy season in three districts of Tanzania

In general, in Muheza district much more different traditional vegetable types are cultivated and collected by one farmer than in the other two districts. On average, between 4 and 6 vegetables are produced or collected per farmer in Muheza, while it is only between 2 and 3 types in Kongwa and between 1 and 3.5 types in Singida district. Thus, vegetable diversity in the humid Muheza district is much higher compared to the other semi-arid districts.

Besides vegetable production and collection this study also allocated data on farmers' behaviour of buying additional vegetables. It was again differentiated if traditional or exotic vegetable types were purchased and the average number of vegetables purchased per farmer calculated (Table 6). Also the ratio of traditional and exotic vegetables bought was generated and the so far existing pattern of the three districts was confirmed. In the peri-urban Singida district more exotic vegetables were purchased unlike in rural Muheza where slightly more traditional types were bought by farmers. In rural Kongwa, nearly double the number of traditionals compared to exotics was purchased and, consequently, exotic vegetables were of less importance in this district.

Table 6. Average number of traditional and exotic vegetables purchased by one farmer during rainy season and ratio between traditional vs. exotic purchased vegetables in three districts of Tanzania

District	TVs	EVs	Ratio TVs : EVs
Kongwa	2.2	1.2	1.8
Muheza	1.7	1.1	1.5
Singida	0.9	1.4	0.6

DISCUSSION

Currently, only 150 plant species are used and commercialised on a significant global scale, while there are an estimated 7,000 species that play an important role especially for poor people in developing countries (ICUC, 2007). At the same time, a nutrition transition is affecting especially people living in urban and peri-urban settings. Thereby, even among the poorest in sub-Saharan Africa, it was observed that large proportions of the population are shifting away from traditional plant-based diets that are rich in fruit and vegetables and towards a dietary pattern rich in calories provided by animal fats and sugar and low in complex carbohydrates (Popkin, 2002).

In this study it was shown that in the researched districts of North-Eastern and Central Tanzania still more traditional than exotic vegetables were cultivated and collected and, thus, local and indigenous knowledge on these traditional plants is still available. However, different numbers of vegetables were cultivated during dry and rainy season. This is natural for wild and spontaneous growing vegetables as they rely on rainfall. In Zimbabwe, for example, it was also noticed that wild and semi-wild vegetables were only consumed during two month (December and January) when they were available (Benhura and Chitsaku, 1992). However, it would be preferable to achieve a year-round vegetable production so that fresh vegetable products can be provided throughout the year. A decline in vegetable supply during one season would be a food security concern especially for the very poor (Gockowski *et al.,* 2004). Changing from fresh to dried products, e.g. vegetables, can also be a health concern as it was observed in South Africa, where dietary problems such as diarrhoea occurred. This weakens the health of community members and it is suggested to grow fresh products even during dry season using recycled water (Vorster *et al.,* 2007), thus, to ensure a year-round availability of fresh vegetables.

As wild vegetables still seemed to play an important role for peoples diet in both rural Muheza and Kongwa districts, but also in peri-urban Singida during the rainy season, they should not be neglected in future research and development. On the one hand, wild food plants are often used during food shortages and casually. On the other hand, rural communities and especially children depend on wild food for some essential dietary components, such as vitamin C (Maundu, 1995). To maintain wild vegetable resources, it is not only important to save indigenous knowledge but also to preserve the habitats where wild food plants occur. These habitats are e.g. forests or swampy areas but also bush and fallow land. Since many wild vegetables occur alongside staple crops in fields, at field boundaries, along roadsides, in gardens and garden fallows and are sometimes also called 'weeds' (Price, 2003), one should carefully think about changing an agricultural system from extensive to intensive, e.g. starting to apply herbicides. With the introduction of exotic vegetables usually the production systems are changed which additionally can influence the availability of traditional wild vegetables.

In peri-urban areas, such as villages close to Singida town in the present study, exotic vegetables are becoming more and more important compared to traditional vegetables. It was noticed already in the 1980's that urbanisation in developing countries not only modifies patterns of staple food consumption but affects the use and availability of food items such as traditional vegetables, wild grain, fruits and leaves, small livestock, game and gathered products of animal origin. These changes are expected to narrow the food base as well as to have a negative impact on nutrition (Delisle, 1990). In the peri-urban Singida district not only exotic vegetables were gaining importance but at the same time collected wild vegetables were loosing importance, especially during the dry season. Thus, this district presented the typical pattern including the respective changes of urbanisation.

Yet, it is also suggested that urban and peri-urban dwellers usually have a more diverse diet, including more fruits and vegetables, which is due to several factors such as the availability of storage facilities and a wider variety of foods in urban markets. While vegetable consumption was found to be always higher in urban compared to rural areas in different African countries, it was also observed that vegetable consumption increases as income increases (Ruel *et al.,* 2005). Obviously, only those who can afford it will have better access to a diverse and varied diet in urban than in rural areas. At the same time, urbanisation will distance more people from primary food production and will have a negative impact on access to and availability of a nutritious diet containing enough vegetables, especially for the urban poor (WHO, 2003).

It is generally believed that the introduction of exotic vegetable varieties in Africa contributed to the decline in the production and consumption of African indigenous vegetables (Smith and Eyzaguirre, 2007). Some literature states that declining use of traditional vegetables is due to declining availability (Okeno *et al.,* 2003; Adedoyin and Taylor, 2000), while others argue, that traditional vegetables are quite available especially during the rainy season, e.g. in Nigeria, but were among the least consumed foods (Maziya-Dixon *et al.,* 2004). Thus, conserving traditional plants themselves is only one part of the story, while it is just as well important to maintain traditional knowledge on advantages of these crops and how to use, prepare, store and consume them.

It was shown in this study that exotic vegetables replace rather than complement traditional vegetables in the researched districts of Tanzania. Differences in adaptation of exotic vegetables was mainly observed between villages with different levels of urbanisation and seemed to be less or non dependent on agro-ecological zones and climatic conditions. In a changing world, i.e. with urbanisation, there will be a downward trend and loss of traditional vegetables: like Singida is today in terms of availability and production of traditional and exotic vegetables, Muheza will be tomorrow and Kongwa the day after if urbanisation is persistent.

Still, success stories of rising popularity of traditional vegetables are known from other African countries. In Kenya, for example, farmers even started to reduce the cultivated land under other crops to expand their production and marketing of traditional vegetables (Virchow *et al.,* 2007). Similarly, in South Africa wild traditional vegetables were more and more cultivated in homegardens, thereby rapidly becoming cash crops (Jansen van

Rendsburg *et al.,* 2007) and in such a way popular that most consumers would like to eat them more often (van den Heever and du Plooy, 2007).

Thus, there is an opportunity for traditional vegetables to become a popular and important food (again) - even in Tanzania. Definitely, the whole production chain must be targeted and farmers, as well as retailers and consumers sensitised and supported. Appropriate technologies for production, processing and marketing are needed, business support groups have to be established, market linkages and channels developed and consumer awareness for traditional vegetables raised (Virchow *et al.,* 2007). The outcome of all these efforts will impact many different people - farmers, retailers, consumers - and gives a chance to especially small-scale and poor vegetable growers. At the same time, it will influence many different areas of life of people, namely occupation, income and wealth, dietary health and nutrition. Consequently, rising production and consumption of traditional vegetables, though not the key to all problems, will contribute to the overall well-being of people in Tanzania.

Acknowledgements

The authors would like to thank very much all participating farmers, the horticultural extension workers in the different districts, AVRDC-RCA and HORTI Tengeru staff, as well as students and staff from Sokoine University of Agriculture, Morogoro. Outstanding support by Prof. Dr. John Msuya as well as financial support by BMZ/GTZ, DAAD and Eiselen Foundation is gratefully acknowledged.

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11

A donor's perspective

Jean-Marc Leblanc

IFS was founded by scientists for scientists as one of the first organizations to explicitly address the needs of young scientists in developing countries. The IFS Programme was conceived in the 1970s as a response to the brain drain: unfavourable conditions in scientific institutions in these countries resulted in the migration of many of the most promising young researchers. IFS created an alternative by offering competitive research grants with some supporting services and occasional workshops.

A MEASURABLE IMPACT

During the 33 years of the Programme to date, some 4,000 grantees (of which 30% are women) in 100 countries have received almost 6,000 research grants. The impact of this programme has been documented in detail in IFS publications, particularly the MESIA series (Monitoring and Evaluation System for Impact Assessment) 1. Here it will suffice to mention a few key issues relevant to the scientists and socio-economic development in their countries:

Establishing a science career- IFS support is focused on young scientists and many receive continuous support over a period of several years (the grant is renewable twice). During this period they are able to establish their careers.

Key persons in national science institutions- Many former IFS grantees have assumed leadership positions in universities, research institutions, government agencies and civil society where they have broad influence on national and regional science education and policy. The successful career development achieved by many IFS grantees contributes to national efforts to secure a sustainable base for research initiatives in these critical research areas.

Scientific productivity- Bibliometric studies show that IFS grantees publish their research results both nationally and internationally. The studies also show that IFS support often coincides with an increasing level of scientific productivity by the grantee.

Increasing the stock of knowledge relevant to the sustainable management of biological and water resources- Research undertaken by IFS grantees has resulted in a variety of outputs including reports, publications, new technologies, patents and commercial products. Importantly, projects have resulted in the transfer to society (policy and decision makers, NGOs, donor projects) of knowledge achieved through research allowing issues related to the sustainable management of natural resources to be dealt with in a more informed manner.

LOOKING FORWARD: 2006 - 2010

A considerable part of IFS support over the years has been provided to talented young scientists in the Middle Income Countries. In the past decade, however, many of these countries have invested heavily in research infrastructure, national research funding mechanisms and development of national post-graduate research training programmes. For this reason the role of IFS in these countries is changing. Although IFS will continue to collaborate with these countries and support their young researchers, the provision of grants is no longer top priority.

The situation described above opens up opportunities for IFS to concentrate its support and focus more on young scientists in countries which have not made similar investments in their research infrastructure. These are mainly the Least Developed Countries and many Low Income Countries. Some Low Income Countries such as China, India and Brazil are giving high priority to the development of national scientific and higher education systems. For this reason they will not be a priority for IFS, even though young researchers in these countries will continue to remain eligible for IFS support. IFS will now give priority to young researchers in Least Developed and Low Income Countries with vulnerable scientific infrastructures. In this document, these countries are referred to as IFS Priority. An updated list of IFS priority countries and other eligible countries is available on the IFS website. www.ifs.se

JUSTIFICATION AND GOALS FOR THE FIVE YEAR PROGRAMME

The Context: Research for Development

The role of Science and Technology is of the utmost importance for meeting sustainable development goals. This has been stated in the UN Millennium Declaration in 2000, the UN Summit on Sustainable Development in 2002, and as a joint statement from international scientific organizations to the UN General Assembly in 2005. "Scientific skills" are necessary to "unlock the potential of innovation and technology to accelerate economic growth" and permit entry to the global economy, according to the UN Africa Commission.

The scientific capacity needed to achieve economic growth and sustainable development goals can only be marshalled by investing in, and strengthening, science capacity in the developing countries themselves. The first requisite is nationally-based, sustained and productive communities of scientific practitioners. Researchers from the North and from the Diaspora can help but are no substitute.

It is not possible in any country to achieve sustainable development without technologies, scientific applications, practices, and policies that are developed with local conditions in mind. To achieve sustainable development goals, science capacity must be capable of carrying out holistic approaches to finding solutions. These approaches require communities of scientific practitioners who can, through multidisciplinary and interdisciplinary projects, address issues that have complex ecological, socio-cultural, technological, political and economic dimensions.

However, achieving sustainable development is not only a question of addressing local and national issues appropriately. Indeed, in today's globalised world, there is a clear international context to many of the priority research areas relevant to poverty reduction and sustainable development – climate change and biodiversity are just two examples. Gaining a clear picture of the complex issues at stake and possible ways they can be addressed requires contributions from scientists around the world including the perspectives of those in low-income countries. This in turn requires competent researchers in these countries that have the capacity to interact with and contribute to international research initiatives.

Constraints to Scientific Research in Vulnerable Environments

Scientific capacity exists in developing countries, and local scientific communities are engaged in research that has meaningful development impact. Nevertheless, more investment is necessary if local capacities are to begin to overcome the substantial constraints that they face.

An IFS Impact Study 2 showed that the main perceived constraint to pursuing meaningful scientific research is the lack of funds and consequently the lack of adequate research equipment.

THE FIVE YEAR PROGRAMME FRAMEWORK

The core components of the IFS programme during 2006 – 2010 are:

- a competitive research grant scheme and
- capacity enhancing support adding value to the grant scheme

The grant scheme has been instrumental in transforming an academic degree holder into a scientist who can plan, conduct and report a research project independently. The capacity enhancing support (see below) represents a new initiative in response to changing needs and priorities. It will be systematically developed and introduced during the Five Year Programme period.

IFS support will continue to be provided to individuals. However, interdisciplinary and multidisciplinary research will be encouraged by facilitating the formation of research groups and operational networks. Grantees conduct their research in their own countries as employees or affiliates of national scientific institutions. These institutions benefit directly from IFS grants through access to equipment purchased by IFS, and through other young scientists being exposed to the quality research conducted by IFS grantees.

The Grant Scheme

IFS functions similarly to a research council for a specific target group. The established core component of the IFS programme will continue to be the competitive grant scheme that focuses on individuals - promising young scientists – who conduct research into the sustainable utilisation, management and/or conservation of biological and water resources.

The grant, a maximum of USD 12,000, can be used for the acquisition of equipment and other research tools as well as for fieldwork and experiments. Because it can be renewed twice the successful grantee can be supported with a maximum amount of USD 36,000.

From 2002 to 2005 IFS awarded on average 230 grants per annum. The target for this Five Year Programme period is an increase to between 250 and 300 grants annually.

The Capacity Enhancing Support

In countries with vulnerable scientific infrastructure, promoting scientific research is not only a matter of providing research funds but also of further nurturing enabling environments characterised by high quality academic supervision, training opportunities and interaction with other scientists.

To further increase the impact of the IFS Grant Programme in such countries, IFS will systematically introduce capacity enhancing support for grantees. A selection of activities is being developed. It is based on IFS' accumulated experience in helping young scientists in IFS priority countries. These activities will add value to the grant scheme by providing the missing critical elements of the academic environment needed by any researcher to carry out good quality research.

The support will be made available either as funding for a grantee to participate in a single Capacity Enhancing Activity (CEA) or as a package of activities for a grantee to take part in throughout the duration of his/her research project. As of 2006, IFS will offer individually designed Capacity Enhancing Packages (CEP) to an increasing number of grantees based in low income countries with vulnerable scientific infrastructure. The opportunity for grantees themselves to propose relevant activities for strengthening their own capacity is an important feature. The grantee will have primary responsibility for selecting relevant activities and IFS will advise and, in some cases, put requirements, on the inclusion of specific capacity enhancing activities in the package. The final decision will be made by IFS.

The capacity enhancing support (through CEA and CEP) will make it possible for grantees to participate in training workshops, attend thematic workshops, seminars, conferences and courses as well as receive mentorship support during their research period. In this way it will help them to establish themselves nationally and internationally.

Ideally all grantees will benefit from the capacity enhancing support. When funds are limited preference will be given to grantees in IFS priority countries.

Over time the range of capacity enhancing activities being offered to grantees is expected to grow and a 'course catalogue' of such activities will develop over the Five Year Programme period. IFS will not organise all these activities. On the contrary, IFS will take every opportunity to arrange workshops and courses jointly with other organisations. IFS will also offer grantees the opportunities to participate in workshops and courses organised by partner institutions. In addition, IFS will market components of the capacity enhancing support and conduct courses requested by donors and other organisations.

A brief overview of capacity enhancing activities is presented below. Some are not stand-alone components but are expected to be selected in combination with others. A catalogue of different types of capacity enhancing activities to be offered by IFS will be available at the IFS secretariat.

Mentorship

IFS will identify grantees whose research initiatives are likely to benefit significantly from contact with a mentor who can offer specialist advice at strategic stages during the research work. Mentorship will mainly be conducted by email. It can also include an occasional visit to the institution of the mentor.

Participation in scientific meetings and visits to well equipped laboratories
IFS can provide travel support to enable grantees to participate in scientific meetings, especially towards the end of the research period when they have produced research findings. Papers may be included in the conference proceedings. This will also provide grantees with opportunities to exchange views with scientists working on related issues and build up their national and international contacts and networks.

Travel support to visit a well equipped laboratory in the region can also be provided. Here grantees can receive training and utilise advanced instruments which are not available in their home laboratories.

Conceptualizing and Preparing Research Proposals
IFS has developed a course module in research project conceptualisation and proposal preparation. It is aimed at selected IFS applicants whose proposals were promising, but, in the competitive context, were not successful. Participating applicants will, through interaction with resource persons and their peers, be given an opportunity to improve their research project proposals.

Access to Scientific Literature
IFS will, together with partners, arrange training workshops on how to access electronic library resources including the acquisition of full text online journals, databases and document delivery.

Statistical Methods and Experimental Design
This course will cover descriptive and inferential statistics as well as experimental design as a planned interference in the natural order of events. Through lectures and discussions it will strengthen grantees statistical reasoning and increase their understanding and interpretation of statistical results. It will also help them choose an appropriate experimental design as an essential part of their research strategy.

Good Laboratory Practice
This workshop will present and discuss the main components of Good Laboratory Practice (GLP) as described in internationally agreed documents. GLP is a quality control system concerned with the organizational process and the conditions under which non-clinical health and environmental safety studies are planned, performed, monitored, recorded, archived and reported.

Training Workshops
Training workshops consist of different modules. These modules can be combined to form a workshop appropriate for the specific problems facing grantees.

Scientific Methodologies
Training workshops in research methods will be arranged to present and discuss how to develop and execute scientific research. The training contains lectures on the fundamentals of empirical scientific inquiry including hypothesis, objectives, research plan and statistical methods.

Preparing Scientific Presentations
This workshop aims to improve the skills needed to develop and deliver a good oral presentation and to create a poster. These skills are of value when preparing a seminar in graduate school or organising a dissertation defence.

Writing and Publishing Scientific Papers
IFS will arrange workshops on writing and publishing scientific papers. These will cover the reasons for publishing, the principles and practice of scientific editing and publishing, the content of scientific papers and preparation techniques. One immediate output of the workshops will be a usable manuscript generated by each participant for submission to a reputable journal.

Development of Equipment Policy
In past years several workshops have been arranged by IFS addressing hands-on service and repair of equipment. IFS will strengthen its collaboration with networks dealing with equipment policy issues. It will, for example, in collaboration with partners, develop training courses that focus on how to develop/improve and agree on policies and guidelines for "purchasing, service and maintenance of scientific equipment" at the university level.

Thematic workshops
Workshops will be arranged to provide training in specific scientific fields. These workshops can include issues such as the following: the scientific state of the art and new scientific findings; research planning and strengthening of scientific capacity; how to operate development needs in terms of research questions etc.

Mobilizing Networks and Groups
Alumni Groups: At the request of current and former grantees IFS will help start up alumni groups at the country level and connect these to IFS Affiliated organizations. Alumni groups will, *inter alia,* help their younger colleagues to conceptualise research projects.

Interdisciplinary Research Groups: Meetings will be arranged targeted at IFS-supported researchers who have formed or intend to form a research group. At these the Research Group Coordinator will have an opportunity to present the holistic outline of the group project and the research group participants can then present their individual projects. These presentations will be followed by discussions on how the individual projects complement each other and contribute to the common goal. Such discussions will allow participants to improve their project design. IFS will also make resources available to facilitate communication among research group members during the research period.

Thematic Networks: IFS will assist thematic operational networks to facilitate communication among researchers

Networks concerned with Scientific Equipment: IFS will continue to support and facilitate the development of scientific equipment networks with the aim of increasing the availability of well functioning equipment.

Awards
An award scheme has proven to be an important incentive to young researchers. For this reason, IFS will continue to give awards to outstanding grantees and former grantees each year.

The Five Year Programme has been developed in consultation with our stakeholders during 2005 and early 2006. These meetings made it clear that IFS enjoys a resounding endorsement for its professional and comprehensive work with young scientists in developing countries. However, an additional message also clearly emanated from these meetings: namely that, in addition to the grant, there is a need to strengthen the scientific skills of young scientists, especially in the more vulnerable environments, and IFS clearly has a role to play here. They recommended that IFS back up its current grant programme with additional activities that provide scientific counselling in order to increase research success.

IFS has taken these recommendations fully into account in this Five Year Programme. We will focus even more on young researchers in low income countries with vulnerable scientific research infrastructure. These are our priority countries and the major recipients of IFS grants. The enormous need for providing more than just the research grant is becoming increasingly apparent. Many young scientists are working under great difficulties and the new strategies outlined in this document will, we hope, address these challenges in an effective manner.

In these IFS priority countries, the most urgent challenges to be addressed by scientific research are related to central issues in the fight against poverty. These include weak farming systems which have low agricultural productivity and generate low income and high post harvest losses. Other central issues in the fight against poverty include poor nutrition and hunger, unsafe drinking water, poor sanitation, and environmental degradation. IFS supports young scientists who are interested in conducting research on these issues. The IFS programme is thus in line with the United Nations Millennium Goals and can make an important contribution to poverty alleviation.

IFS makes a difference not only for the individual scientists but also at the national and the international level.

For more than three decades IFS has provided competitive research grants to promising young scientists. The new feature of this Five Year Programme is provision of capacity enhancing activities offered as additional support to grantees working under difficult circumstances. These capacity enhancing activities include a variety of components which are often lacking for these young scientists: mentorship, thematic workshops, methodology courses, scientific paper writing workshops, help to access scientific literature, and support to attend scientific meetings.

During the assessment of applications, IFS Advisers and Secretariat will identify grantees that would benefit from specific support activities. The grantees will have the possibility to propose activities best suited for their own research career development. IFS advisers and former grantees will also function as resource persons in the capacity enhancing activities carried out.

Providing IFS grants to young researchers in low income countries with vulnerable scientific infrastructure together with additional support in the form of capacity enhancing activities will help them to become established scientists and to contribute to poverty reduction and sustainable development.

SUCCESS, FAILURES AND LESSONS LEARNED - FOOD AND NUTRITIONAL CROPS: CASE STUDIES

12

Diversity of small millets germplasm in genebank at ICRISAT

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The family *Poaceae* includes an estimated 8000 species belonging to some 600 genera. Species of *Poaceae* (=grasses) occur in habitats across all countries that support the growth of flowering plants. Their use as food grains and feed for livestock make them very relevant to human survival. Among them, 35 species belonging to 20 genera are known to have been domesticated. Of these, eight species that have small seeds are used essentially as food crops in their respective agro-ecosystems. These include finger millet [*Eleusine coracana* (L.) Gaertn.], foxtail millet [*Setaria italica* (L.) Beauv.], Proso millet (*Panicum miliaceum* L.), little millet (*Panicum sumatrense* Roth. ex Roem. & Schult.), barnyard millet [*Echinochloa crusgalli* (L.) Beauv. & *Echinochloa colona* (L.) Link], kodo millet (*Paspalum scrobiculatum* L.), teff [*Eragrostis tef* (Zucc.)] and Fonio millet (*Digitaria exilis* Stapf. & *Digitaria iburua* Stapf.). Small millets are also called minor millets, however, considering their nutritive values it would be more appropriate to call them nutritious millets. Of the eight crop species, ICRISAT was requested to assume the responsibility of germplasm assembly, characterization, documentation and conservation of the first six of these crops, and hence this paper confines itself to these six small millets.

Small millets are mainly cultivated in arid, semi-arid or montane zones as rainfed crops in South Asia, China, CIS countries and several countries in Africa. Small millet crops are together cultivated on 18-20 m ha with a production of 15-18 m tons (Prasada Rao *et al.,* 1987). Small millets are often grown under adverse soil and weather conditions compared to other crops. They have always been crops of drought-prone areas, but give reliable harvests, though these could be lower than from other crops. Information about the crops and germplasm related activities with the ICRISAT collections are discussed in this paper.

ABOUT THE CROPS

Finger millet (*Eleusine coracana)*

This is cultivated for human food in 14 countries of Africa and five countries of South Asia on over 3.5 m ha annually (Upadhyaya *et al.,* 2006a). Finger millet was domesticated about 5000 years B.C. in Eastern Africa (possibly Ethiopia) and introduced into India as a crop about 3000 years ago (Hilu *et al.,* 1979). The closest wild relative of finger millet is *Eleusine coracana* subsp. *africana* (Kennedy-O'Byrne) Hilu & de Wet. *Eleusine coracana* subsp. *africana* is a native to Africa. These two taxa (finger millet and subsp. *africana*) are tetraploids (2n=36) with basic chromosome number x=9. These subspecies hybridise where they are sympatric in Africa and derivatives of such crosses often occur as weeds in cultivated fields.

Finger millet is an annual grass, erect, about 100 cm tall, profusely tillering and producing aerial branches. Plants invariably lodge. The inflorescence is a whorl of 2-8 digitate, straight or curved spikes of 1-32 cm length (Table 1), about 1.3 cm broad, with about 70 spikelets arranged alternatively on the rachis, each containing 4-7 seeds, seed weight being 2-5 g per 1000 seeds. Seeds are nearly globose, reddish-brown to nearly white in colour. Finger millet has a wide range of seasonal adaptation and can be grown in lands almost at sea level (parts of Andhra Pradesh and Tamil Nadu –India) to about 2400 m.a.s.l. in hills of Uttrakhand (India) and Nepal, and similarly at high altitudes in Uganda, Kenya and Ethiopia. On average, finger millet yields one ton ha^{-1} grains, but its reported yield potential is up to 3.7 t ha^{-1} in Ethiopia (Mulatu & Kebebe, 1993), 4.3 t ha^{-1} in Uganda (Odelle, 1993), 4.8 t ha^{-1} in India (Bondale, 1993), and 6.1 t ha^{-1} in Zimbabwe (Mushonga *et al.,* 1993).

Finger millet seeds are consumed in a variety of forms, such as unleavened bread (roti), thin or thick porridge, fermented porridge; and also extensively used in brewing. Finger millet food has high biological value. Seed protein content is about 7.4%, which is comparable to that of rice. However, some lines have as much as 14.2% protein (Iyengar *et al.,* 1945-46). Finger millet seeds are particularly rich in tryptophan, cystine, methionine, and total aromatic amino acids compared to other cereals. The seeds are exceptionally rich in calcium containing about 0.34% in whole seed compared with 0.01 – 0.06% calcium in most cereals (Kurien *et al.,* 1959). The seeds are also rich in iron containing 46 mg kg^{-1} (Serna-Saldivar & Rooney, 1995), which is much higher compared to wheat and rice.

Table 1. Summary of germplasm characterization data and economic traits of small millets

Trait	Finger millet		Foxtail millet		Proso millet		Little millet		Kodo millet		Barnyard millet	
	Range	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Days to flowering	50-120	80.4	32-135	53.5	26-50	34.5	39-138	58	51-112	77.5	27-90	46.1
Plant height (cm)	30-240	100.7	20-215	110.1	27-133	59.3	50-240	113	30-97	54.8	29-235	83.1
Basal tiller (no.)	1-70	5.2	1-80	7.5	1-32	3.9	3-46	14.6	2-48	15.2	1-44	6.5
Flag leaf blade length (mm)	100-750	358.1	30-520	284.7	29-380	222.3	60-560	247.2	24-440	183.5	50-420	198.3
Flag leaf blade width (mm)	5-20	12.6	5-40	20.2	6-130	19.4	5-160	38.8	5-15	7.7	5-40	18.4
Peduncle length (mm)	18-450	215.4	80-500	299.6	32-400	180.9	60-480	189.6	-	-	20-520	151.3
Exsertion (mm)	10-800	112.9	10-360	162.4	50-320	99.7	80-280	31.1	-	-	50-280	64.8
Inflorescence length (mm)	10-320	93.1	10-390	163.1	34-400	193.1	27-500	282.2	20-160	64.3	13-280	144.7
Seed size (g 1000-seeds-1	2.6			1.86		4.7-7.2						
Special trait	Drought resistant	Highly nutritious			Short duration		High fat				Highly nutritious	
	High iron											
	High calcium											

Foxtail millet (*Setaria italica)*

Foxtail millet was first domesticated in the highlands of Central China; remains of the cultivated form are known from the Yang-Shao period dating back some 5000 years. Comparative morphology suggests that foxtail millet spread to Europe and India as a cereal crop soon after its domestication (Prasada Rao *et al.,* 1987). *Setaria viridis* is a possible ancestor. The cultivated species and the progenitor have 18 somatic chromosomes (2n=18). Three races namely, *moharia, maxima,* and *indica* are recognised. Race *moharia* is common in Europe, Southeast Russia, Afghanistan and Pakistan. Race *maxima* is grown in Eastern China, Japan and Korea and has been introduced into the USA. It also occurs in Nepal, Northern India and Georgia (of the former USSR). Race *indica* is found in remaining parts of India and Sri Lanka.

Foxtail millet is an annual grass and variable in its morphology. Plants range from single-stemmed to highly tillered. The average plant height is little over 1.0 m but can reach 2 m. Panicle length varies from 1-39 cm (Table 1) and diameter from 1.5 to 3 cm. The central rachis is often weak, so panicles droop. By contrast, some varieties in China are single-stemmed and with a height as tall as 150 cm. Leaves are 30 to 35 cm long and 1.5 to 3 cm wide. Panicle length varies from 12 to15 cm and width 4 to 6 cm. Seeds are small (2-3 g 1000 seeds^{-1}) and generally light cream coloured. Seeds are nutritious, with protein, fat and minerals contents comparable to wheat (Mangala Rai, 2002). Foxtail millet is adapted to temperate regions although found in the tropics. It has a broad range of maturity, from 70 to 120 days.

Proso millet (*Panicum miliaceum)*

Domestication of proso millet probably occurred in Manchuria (de Wet, 1986). It was probably introduced into Europe about 3000 years ago. After this date, proso millet was introduced to the Near East and India (Zohary & Hopf, 1988). Presently proso millet is important in Northwest and Northeast China and CIS countries. In India, proso millet is cultivated in Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Uttar Pradesh, Maharashtra, Orisa and to a limited extent in foothills of Himalaya. It is cultivated in Bangladesh (Majid *et al.,* 1989) and is of minor importance in drier parts of Sri lanka (Ponnuthurai, 1989). The chromosome number have been reported to be 2n=36, and 2n=72 in some of the Indian races (Bor, 1960).

Proso millet is an annual grass, adapted to temperate and subtropical parts of the world. It is a highly variable crop. Plant height can range from 27 to 133 cm, panicle length 3 to 40 cm (Table 1), seed weight 5 to 9 g 1000-seeds^{-1}. Seeds are generally oval-shaped and of varied colours: white cream, yellow, orange, brown and black. Proso millet accumulates higher dry matter in the reproductive parts as compared to wheat, maize and sorghum. Proso millet has a high water use efficiency (Hulse *et al.,* 1980), though this is not because of drought resistance but due to its short growing season. The plant has a shallow root system and does not grow well under water stress, or under excessive moisture. Crop maturity varies from 60 to 90 days depending on varieties.

Little millet (*Panicum sumatrense)*

Little millet has its progenitor in *Panicum psilopodium.* This is cultivated across India, Nepal and Western Myanmar. The chromosome number of little millet have been reported to be 2n=36 (Bor, 1960). Sub-species *P. psilopodium* is distributed from Sri Lanks to Pakistan and eastward to Indonesia. Of the cultivated *species*, two races, *robusta* and *nana* are recognised. *Robusta* is cultivated in Northwestern Andhra Pradesh and parts of Orissa where it crosses with race *nana*. Plants in race *nana* vary from 60 to 70 cm in height. The inflorescence is 14 to 15 cm long, erect, open, and highly branched. These branches sometime droop at maturity. Plants of race *robusta* are 50 to 240 cm tall. The inflorescence is 3 to 50 cm long (Table 1), open or compact, and highly branched. It is a primarily self-pollinated crop with up to 3.5% cross-pollination.

Kodo millet (*Paspalum scrobiculatum)*

Kodo millet was domesticated in India, almost 3000 years ago. The species is found across the Old World in humid habitats of the tropics and subtropics. The chromosme number is reported to be 2n=40 (Hiremath & Dandin, 1975). Crossing readily occurs between cultivated and weedy races, and seed from hybrids is harvested along with those of the sown crop, racial differentiation is not distinct despite years of cultivation in India (de Wet, 1986). As a wild cereal, it is harvested in West Africa and India. In India, it is widely spread from Tamil Nadu and Kerala in the south to West Bengal and Rajasthan in the north (de Wet, 1986). Kodo is grown to a limited extent in Bangladesh (Majid *et al.,* 1989).

As a commercial crop, kodo millet is grown only in India. Plant height varies from 30 to 97 cm and produces many basal tillers, ranging from 2 to 48. The inflorescence is small, 2 to 16 cm long (Table 1). It matures late compared with other small millets. It is highly self-pollinating; florets generally remain closed during the flowering period. The grains occur in a hard husk, making debranning difficult. The crop is drought tolerant and often cultivated on marginal soils. Kodo millet grains are consumed as food, though, nutritionally, these are poor. On average, kodo millet grains have 8.3% protein, 1.4% fat, and 2.6% minerals.

Barnyard millet (*Echinochloa crusgalli* and *E. colona*)

Two species of *Echinochloa* are grown as cereals, i) *E. crusgalli* is a native of Eurasia and was domesticated in Japan some 4000 years ago; ii) *E. colona* occurs widely in tropical and subtropical areas and was domesticated in India. Both species are fairly similar and have the same chromosome number (2n=54; hexaploids), but hybrids between them are sterile. *E. colona* differs consistently from *E. crusgalli* in having smaller spikelets with membranaceous rather than chartaceous glumes. Simply put, *E. colona* is awnless whereas *E. crusgalli* has awned glumes. *E. colona* is cultivated in India in Madhya Pradesh, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Bihar and in the foothills of Himalaya. Plants of *E. crusgalli* are erect, growing up to 235 cm tall (Table 1), leaf blades are linear with a broad round base gradually tapering to a fine point, panicles are 13 to 280 mm long and 5 to 25 mm wide. The spikelet head is windmill-shaped, short and stiff awned. Plants of *E. colona* are reddish-purple or green with a reddish base. Inflorescences are usually erect, rarely drooping and awnless spikes.

Echinochloa species are drought resistant and also capable of withstanding water logging. Generally yields are low: 300-600 kg ha^{-1} of grains, and a straw yield of around 1000 kg ha^{-1}. Active plant breeding research at the agricultural universities in Karnataka, Tamil Nadu and Uttrakhand (India) has resulted in release of a number of varieties, yielding up to 3 tons of grains and 7 tons of fodder per hectare. Grains are nutritious, having 11.6% protein, 5.8% fat and 4.7% minerals (Mangala Rai, 2002).

GERMPLASM ASSEMBLY AT THE ICRISAT GENEBANK

The major donors of small millet germplasm to ICRISAT are listed in Table 2 and have contributed 5977 samples. Subsequent to this, geographical representation in the collection was reviewed and attempts were made to secure new germplasm from hitherto under-represented areas, and 2459 germplasm samples were collected from farmer's fields through 60 missions. Most of these missions were organised for other crops; however, small millets were also collected. Of these, only four missions, one each in India and Zimbabwe, and two in Uganda were organised with greater emphasis of collecting small millet germplasm. The current status of small millet germplasm in the ICRISAT genebank is given in Table 3.

Table 2. Major donors for small millets germplasm to ICRISAT genebank

Donor organization	Number of accessions
ICRISAT, Zimbabwe	1440
Rockefeller Foundation, USA	1255
Hill Crop Improvement Programme, Dolakha, Nepal	733
Royal Botanical Gardens, Kew, UK	634
Tamil Nadu Agricultural University, Kovilpatti	530
University of Illinois, USA	475
National Bureau of Plant Genetic Resources, Regional Station, Akola	469
ICARDA, Syria	441

Table 3.Germplasm assembly of small millets in ICRISAT genebank

Country/Crop	**Finger millet**	**Foxtail millet**	**Proso millet**	**Little millet**	**Kodo millet**	**Barnyard millet**	*Total*
Afghanistan		30	16				46
Australia			2				2
Bangladesh			2				2
Burundi	15						15
Cameroon	8	8		3		1	20
China		60	2				62
Egypt						1	1
Ethiopia	31	1					32
Germany	1		12				13
Hungary		10	10				20
India	1364	978	69	459	656	447	3973
Iran		6	9				15
Iraq			2				2
Italy	7						7
Japan			1			164	165
Kenya	946	9	1				956
Korea, Republic of		52	73				125
Lebanon		33	1				34
Malawi	252	1	1			2	256
Maldives	4						4
Mexico	1	2	13				16
Myanmar		6		2			8
Nepal	780	21	6				807
Nigeria	19						19
Pakistan	1	29	41			11	82
Senegal	5						5
South Africa	1	3					4
Sri Lanka	18	14	2	1	2		37
Syrian Arab Republic		119	35	1		2	157
Taiwan		28					28
Tanzania	42						42

Turkey		26	49				75
Uganda	959						959
Ukraine			4				4
Former USSR		67	121			16	204
UK	14	4	4				22
USA	6	25					31
Other countries	4	3	9			2	18
Unknown	181		358			97	636
Zambia	136						136
Zimbabwe	1154						1154
Total	5949	1535	842	466	658	743	10193

GERMPLASM CHARACTERIZATION

Small millet germplasm accessions were planted in batches over the years (1974-2006) at ICRISAT, Patancheru, India for seed increase and botanical and agronomic evaluation and characterization. ICRISAT-Patancheru is located at 18^0N and 78^0E, at an altitude of 545 m, and about 600 km from the sea. Annual rainfall is about 750 mm, most of which occurs from June to September. Germplasm accessions were sown on red soils (alfisols), on ridges 60 cm apart, each accession occupying a single row of 4 m length, spacing being 60 x 10 cm. Basal doses of 20 kg nitrogen and 50 kg phosphorus ha^{-1} were applied, with 45 kg nitrogen ha^{-1} as top dressing. In all the years, sowings were made towards the end of July (20-31 July). Irrigation and hand weeding were carried out when necessary. The crop was reasonably free from any disease or insect damage and no chemical sprays were applied.

Data was recorded of qualitative (description in discrete classes) and quantitative (continuous variation) traits. However, the set of descriptors differed from one species to another. Ten descriptors that were common between them were: days to 50% flowering, basal tiller number, plant height (cm), flag leaf blade length (mm), flag leaf blade width (mm), flag leaf sheath length (mm), peduncle length (mm), panicle exsertion (mm), inflorescence length (mm) and seed size. During field evaluation, accessions were also classified into botanical races. A brief summary of characterization data is given in Table 1.

GERMPLASM REGENERATION, CONSERVATION AND SAFETY BACKUP

Regeneration

The need for regeneration of an accession is triggered by one of the three criteria: (1) accessions that had reached a minimum level of seed stock or viability (<75% germination); (2) accessions required for medium-term storage (MTS) and/or long-term storage (LTS); and (3) germplasm repatriation when needed.

Conservation

Seed must be cleaned and dried to a minimal seed moisture content, before storing in cool and dry conditions with regular monitoring of seed health. In the ICRISAT genebank, the seeds of the entire collection are stored in aluminum cans at 4^0C, 20–30% RH for MTS.

The germplasm accessions are also conserved in LTS (-20^{0}C) after packing in vacuum-sealed aluminum foil pouches. Before packing, the seeds are dried to about 5% moisture content in a walk-in-drying room (100 m^3 size; 15^{0}C and 15% RH) facility. By July 2007, 87% of the total germplasm collection had been transferred into the LTS facility.

Recently conducted seed health monitoring of seeds conserved for 10–25 years (MTS) indicated greater than 75% seed viability for the majority of accessions. Accessions with declining seed viability (less than 75% seed germination) are regenerated as a priority and the old stock is replaced with fresh seeds. Most of the accessions showing low germination had been held in MTS for more than 25 years . Seed is also evaluated for diseases and treated with appropriate agrochemicals where possible before regeneration.

Safety back up

ICRISAT's agreement with the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) requires safety duplication preferably at –18°C. We have established a safety backup of 7622 small millet germplasm accessions (4580 finger millet, 1039 foxtail millet, 628 kodo millet, 521 proso millet, 479 barnyard millet and 375 little millet) at the ICRISAT genebank at Niamey, Niger. The remaining accessions will be transferred in due course.

DEVELOPING CORE, MINI-CORE AND COMPOSITE SETS TO ENHANCE UTILIZATION OF GERMPLASM

Developing core collections

One of the reasons that plant breeders are using less basic germplasm in research is the lack of information on traits of economic importance, which often shows high genotype x environment interactions and requires replicated multilocational evaluations. This is a very costly and resource-demanding task owing to the large size of the germplasm collections. To overcome this, our research now focuses on studying the diversity of germplasm collection and developing "core collections", which are about 10% of the entire collection, but represent almost the full diversity of the species. From the germplasm collection in the ICRISAT genebank, we have already developed core collections of sorghum, pearl millet, chickpea, pigeonpea and groundnut and also of finger millet (622 accessions, Upadhyaya *et al.,* 2006a) and foxtail millet (155 accessions, Upadhyaya – unpublished data).

The finger millet core collection (622 accessions), along with three control cultivars, was evaluated in a replicated trial during the 2004 rainy season. Data was recorded for five qualitative and 15 quantitative traits. The data analysis indicated significant genotypic variance for several traits including grain yield and days to flowering. We identified 25 accessions which were better or similar to control cultivars for grain yield and early maturity. Cluster analysis on these accessions based on the first five principal components indicated that the selected accessions were diverse (Fig. 1). Similarly, the core set of foxtail millet germplasm accessions (155) along with four control cultivars was evaluated during the 2005 rainy season. Data was recorded on 14 qualitative and 11 quantitative traits. We identified 25 accessions, which were better or similar to control cultivars for grain yield and early maturity. Cluster analysis of these accessions based on the first five principal components indicated that the selected accessions were more diverse than the control cultivars (Fig. 2). Identification of these superior and diverse accessions could be useful in developing cultivars with broad genetic base, high yield and early maturity in finger millet and foxtail millet.

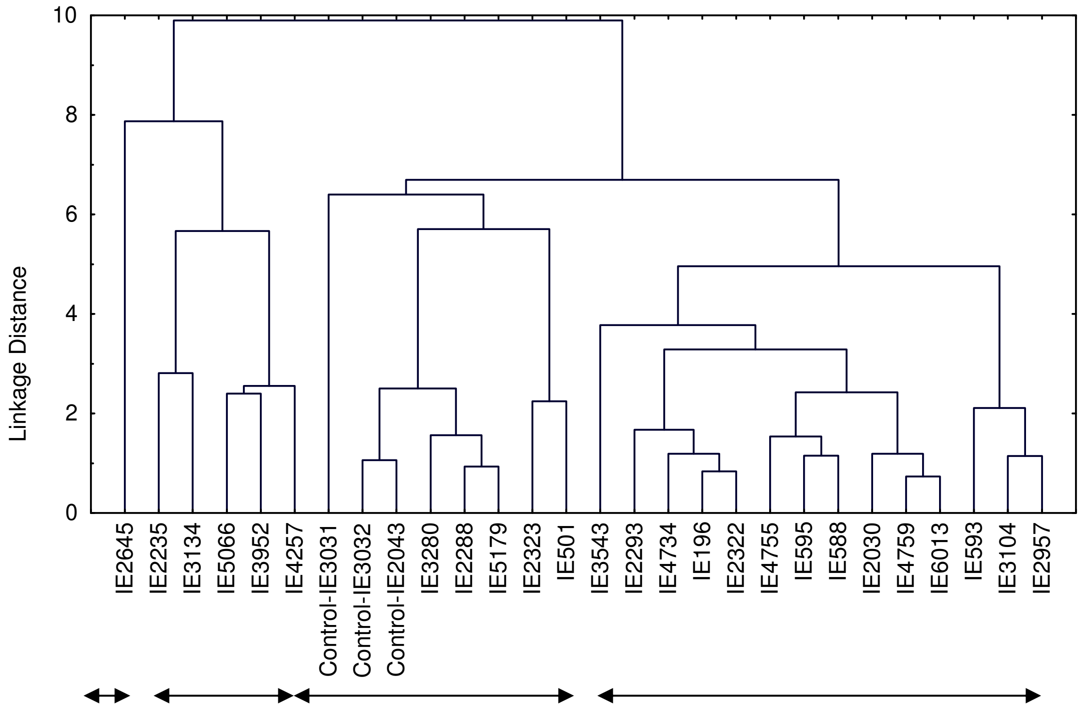

Figure 1. Finger millet dendogram based on first five principle components of 25 accession and three control cultivars

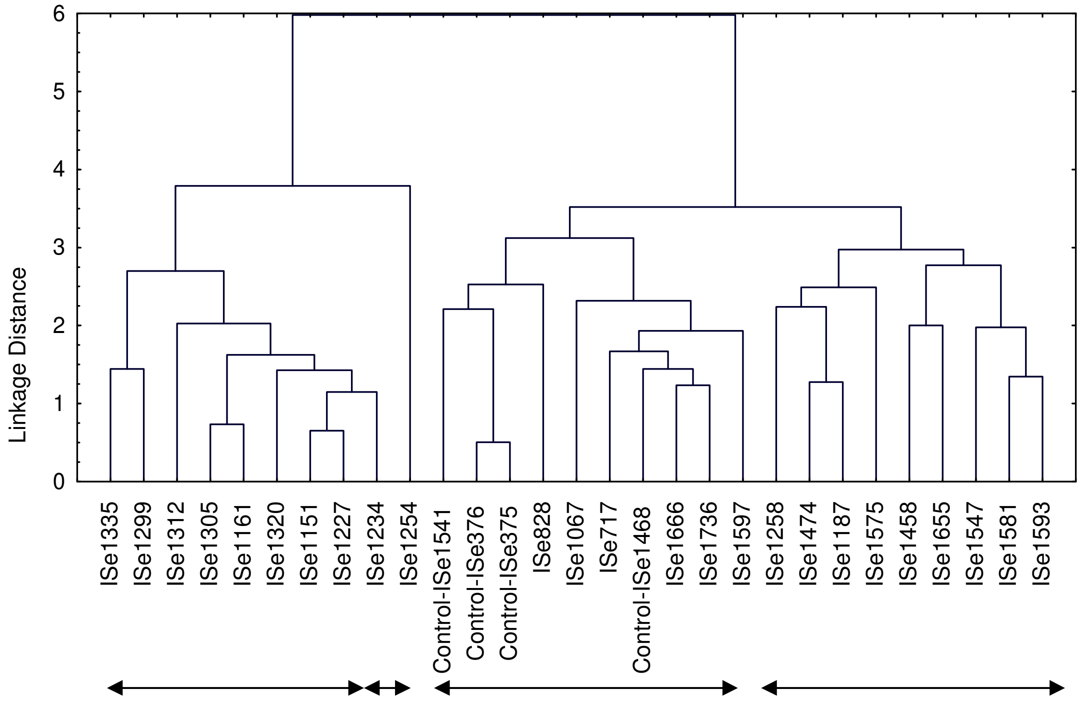

Figure 2. Foxtail millet dendogram based on first five principle components of 25 accession and four control cultivars

Developing mini-core collections

When the size of the entire collection is very large, even a core collection may become unwieldy for evaluation by breeders. To overcome this, ICRISAT scientists developed a seminal two-stage strategy to develop a mini-core collection, which consists of 10% accessions of the core collection (and hence only 1% of the entire collection) (Upadhyaya & Ortiz, 2001). This mini-core collection still represents the diversity of the entire core collection. The first stage involves developing a representative core collection (about 10%) from the entire collection using all the available information on origin, geographical distribution, characterization and evaluation data of accessions. The second stage involves evaluation of the core collection for various morphological, agronomic, and quality traits, and selecting a further subset of about 10% accessions from the core collection. Standard clustering procedure should be used to separate groups of similar accessions at both stages. At ICRISAT, we have already developed mini-core collections of chickpea consisting of 211 accessions (Upadhyaya & Ortiz, 2001), groundnut (184 accessions; Upadhyaya *et al.,* 2002), pigeonpea (146 accessions; Upadhyaya *et al.,* 2006b), finger millet (65 accessions), and foxtail millet (46 accessions) (Upadhyaya – unpublished data).

Development of composite collection

With the support of the Generation Challenge Programme, ICRISAT has developed composite collections of finger millet consisting of 1000 accessions (Upadhyaya *et al.,* 2005) and foxtail millet consisting of 500 accessions (Upadhyaya *et al.,* 2006c). These composite collections will be genotyped using 20 SSR markers. The data generated will be used to define the genetic structure of the global composite collection and to select reference accessions (300 of finger millet and 200 of foxtail millet) representing maximum diversity for the isolation of allelic variants of candidate gene(s) associated with beneficial traits. It is then expected that molecular biologists and plant breeders will have opportunities to use diverse lines in functional and comparative genomics, in mapping and cloning gene(s), and in applied plant breeding to diversify the genetic base of breeding populations, which should lead to the development of broad-based elite breeding lines/cultivars with superior yields and enhanced adaptation to diverse environments.

FUTURE PLANS

In the future, we will examine gaps in germplasm collection and attempt to fill them either by germplasm exchange or through fresh exploration. Focus will be on assessment of the germplasm for usefulness in crop improvement. Core and mini-core subsets of germplasm will be evaluated at diverse locations to identify trait specific diverse parents for various agronomic and nutritional traits. Molecular characterization of mini-core collections to identify trait specific germplasm lines, and reference sets of finger millet and foxtail millet will be enhanced to add value to the germplasm accessions. The reference sets will be evaluated more systematically and data published for the benefit of researchers.

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13

Ancient underutilised pseudocereals - potential alternatives for nutrition and income generation

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Pseudocereals were extensively used in Middle America during prehispanic times. The native word to define them was *huautli* and referred to both, *Amaranthus* and *Chenopodium* seeds. Ancient Aztec, Maya and Purhépecha cultures used *Amaranthus hypochondriacus*, *A. cruentus* and several species of *Chenopodium* for consumption as vegetables (*quelites*) and as cereals. The tradition of their culture has prevailed in some areas which despite enduring marginal conditions are at the same time an important reserve of germplasm and a source of indigenous knowledge, recently surveyed under sponsorship of Sistema Nacional de Recursos Fitogenéticos (SINAREFI) which aims at collecting germplasm and systematising growing practices. Studied communities were the mestizo towns of Opopeo and Huiramangaro pertaining to the municipalities of Villa Escalante and Pátzcuaro Michoacán. *Amaranthus hypochondriacus* land race Azteca cv. Chía blanca, *Chenopodium berlandieri* ssp. *nuttalliae* cv. Chía roja and *A. hypochondriacus* land race Mixteco cv. Chía negra are the species cultivated. Two crop systems were characterised: a) *Milpa*, which is practiced in plains, consisting of growing cultivars Chía roja and Chía blanca in association with corn, squash and in some cases beans, and b) *Mogote*, which is a modification of the slash and burn system, enabling the use of areas inadequate for traditional farming practices. Pseudocereals yields range from 17.5g to 111.9g per plant. A wide variation between genotypes is noted, a fact that, together with optimal cultural practices gives possibilities for selection and improvement. Protein contents ranged from 13.15% to 17.95%. From the farmers' point of view, growing pseudocereals in association brings them the possibility to obtain several foodstuffs along the year with average yields of 1 ton/ha of corn and 1.2 ton/ha of pseudocereals, all of which improves their revenue by more than 200%, obtaining also a nutritious food. Within the studied communities 'Chía blanca' is used to prepare, sweets known as *alegrías*, *tortillas* and *atoles*. 'Chía roja' and 'Chía negra' are employed to prepare *tamales*, locally known as *chapatas*. Communities studied, face problems of unemployment, migration and malnutrition, however, if provided with adequate economic and technical support, pseudocereals seem to be a good solution to such problems as has been demonstrated by several organizations working in communities located in the states of Oaxaca, Puebla and Querétaro, where adequate selection of cultivars, efficient growing techniques, organisation and integration in small agroindustries have proven to be successful.

INTRODUCTION

Traditional farming systems in Mexico are based mainly on the use of local genotypes of staple crops such as corn and beans as well as landraces of domesticated and semidomesticated plants, all of which are grown in association to improve both income and diet of peasants inhabiting regions with marginal agricultural conditions. These traditional farming systems can be traced back to ancient cultures. *Chinampa* was developed by the Aztecs; the so called *solar* farming method by the Mayan civilization and *milpa* has been practiced among Mesoamerican peoples since prehispanic times. All these systems promoted biodiversity by using several plant species which in turn satisfied food and housing requirements (Altieri, 1999).

Nowadays there are regions where these traditional farming systems are still practiced however diverse factors such as mechanization, use of alien varieties and agrochemicals, changes in land usage and migration have all contributed to gradual decrease of these traditional methods, and consequently of the germplasm diversity (local land races, semidomesticated and wild edible plants). Among valuable germplasm are pseudocereals such as genera *Amaranthus* or *Chenopodium*, which, like true cereals, are rich in starchy materials, which can be used in the producion of flour, bread and noodles.

Pseudocereals were staple crops in Aztec times and according to the Mendoza Codex, seeds of *Chenopodium spp* and *Amaranthus spp* known jointly as *huautli*, formed a substantial part of the tributes paid to Emperor Moctezuma, amounting to nearly 7,000 tons, a quantity exceeded only by the three major crops: maize, beans and chilli (Hunziker, 1952). Pseudocereals were important not only from a socio-economic point of view but also in religious practices and it was for this reason that Spanish conquerors forbade *huautli* growing. This, added to introduction of Old World crops, contributed to their gradual decline (Iturbe, 1994).

However in some distant rural areas, pseudocereals in association with corn, beans and squash, are still grown. Traditions, remoteness, the need of food and income alternatives, as well as scarcity of economic resources have all contributed to preserve these prehispanic forms. However as young people migrate to urban areas, the remaining old peasants find it increasingly difficult to produce and sell these crops, some of which face the danger of extinction. This paper aims at presenting the current status of pseudocereals cultivation in the Mexican region known as the Purhépecha high plateau.

MATERIALS AND METHODS

Description of the region

The studied areas comprised two communities located in the State of Michoacán, Opopeo within the municipality of Pátzcuaro and Santa María Huiramangaro, in the municipality of Salvador Escalante (Figure 1). Pátzcuaro is located at 19°31' North and 101°36' West, at an altitude of 2,140 metres above sea level (masl). Climate is temperate with summer rainfall [C(w)]. Annual rainfall is 983.3 mm and temperatures range from 9.2 °C to 23.2 °C. Its most important water reservoir is Pátzcuaro Lake. Mixed forests of pine, oak, cedar, spruce and juniper grow within this region. Ejido de Santa María Huiramangaro, is located at 19°30'57'' North and 101°45'42'' West, at 2,263 masl. This village has 2628 inhabitants, providing 586 to the economically active population (INEGI, 2000; CIESEM 2001a).

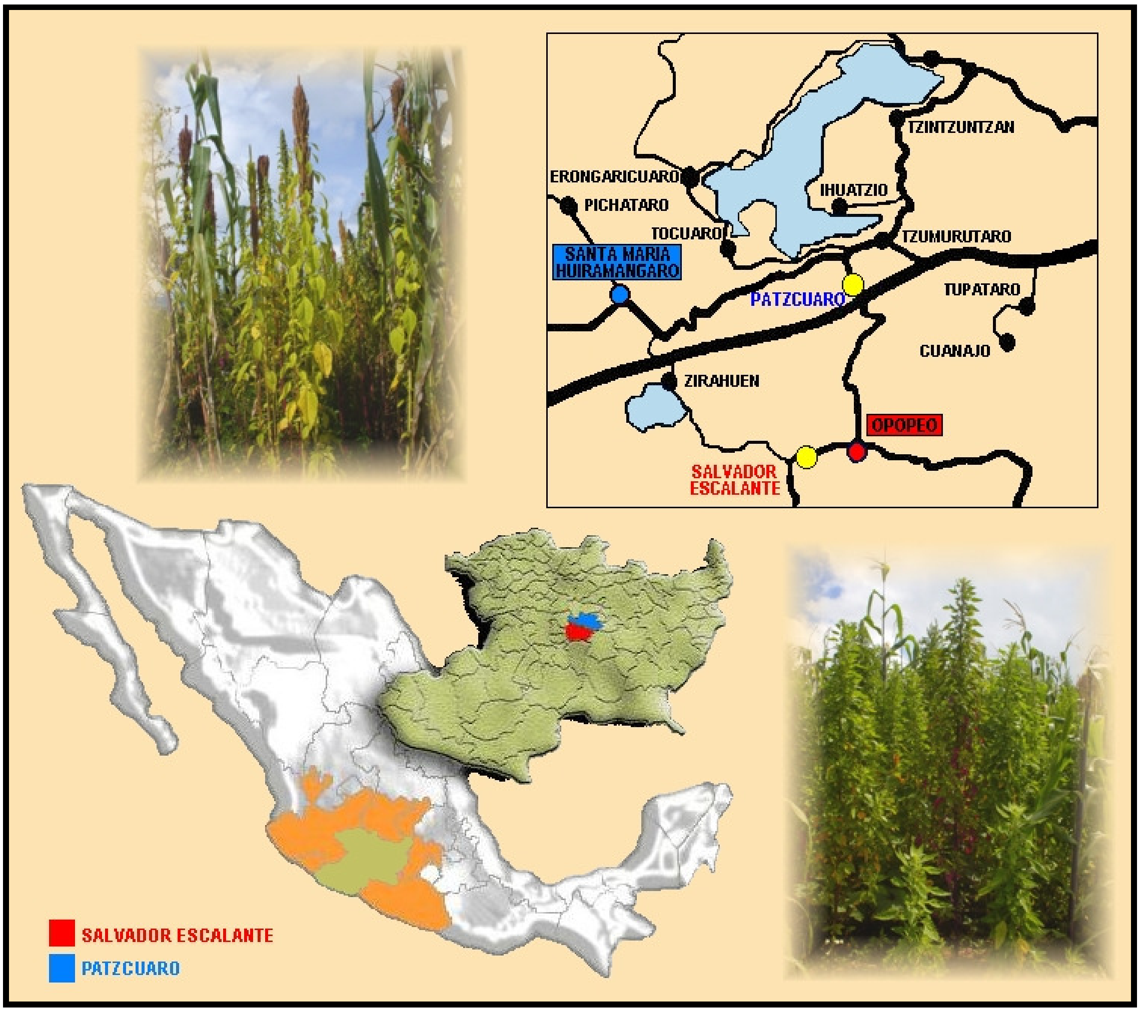

Figure 1. Geographical location of Opopeo and Huiramangaro, Michoacán, México.

Salvador Escalante municipality is located 19°24' North and 101°38' West, at 2280 masl and comprises regions with two types of climate, temperate with summer rainfall and tropical (Aw). Annual rainfall is 780.4 mm and temperatures ranges from 5.4 to 24.1°C. Major water resources are the lakes Zirahuén and Cutzitan. In this region forests of pine and oak grow together with tropical flora like *parota* (*Enterolobium cyclocarpum*), *ceiba* (*Ceiba speciosa*), *tepeguaje* (*Leucaena iveruienta*), *guaje* (*Leucaena esculenta*) and *cirián* (*Crescentia cujete*) (CIESEM, 2001b). Opopeo the second community studied belongs to this municipality and is located 19°24'43'' North and 101°36'18'' West at an altitude of 2,240 masl with a total population of 8,380 inhabitants with 2,214 economically active, devoted to agriculture, cattle-raising, carpentry, commerce and services (INEGI 2000).

In these two communities several representative plots were selected to follow up the whole process of pseudocereal growing in close cooperation with peasants to obtain first hand information about their cultural practices. In Ejido de Opopeo, four plots were selected, three of them grown under the *milpa* system. Two of them have humic andosol: (Th), and the remainder, haplic phaeozem (Hh), the other plot is grown under the *mogote* system and has a lithosol (I) soil type.

In Santa Maria Huiramangaro two plots were selected as representative of pseudocereal growing systems, both of them with the andosol humic soil type.

Agro climatic characterisation

To perform the agroclimatic characterisation, the geographic location was established by means of GPS Garmin eTrex Summit equipment and with this data information related to climatic conditions, vegetation, type and soil use was obtained from charts E14A21 and E14A32 published by Instituto Nacional de Geografía e Informática (INEGI 2000, 2001). To complete climate characterization of studied communities information on temperature (medium, minimum and maximum), rainfall and evaporation was obtained from the meteorological station number 665 located at Morelia, Michoacán.

Figure 1 shows that average monthly temperature ranges from 15.4°C to 17.4°C, with an annual rainfall from 1,000 to 1,200 mm. This figure also shows that the favourable period for plants ranges from the second half of May to the end of September and beginning of October, because rainfall exceeds evaporation.

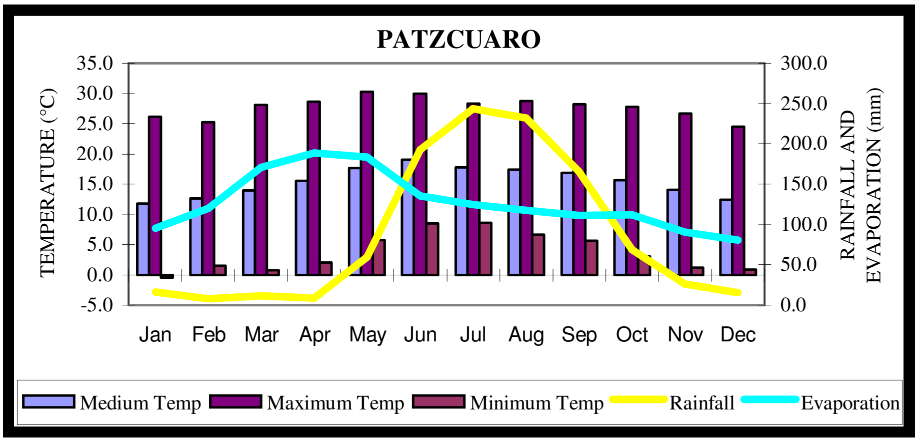

Figure 1. Temperature, rainfall and evaporation in Pátzcuaro, Michoacán.

Current status of pseudocereals within the region

In order to establish pseudoceral production status within the region, semistructured surveys were conducted among peasants and rural authorities, at the same time and to obtain first hand information regarding growing practices, direct participation in land preparation, sowing, weeding, harvesting, winnowing, processing of pseudocereals products and marketing.

An ethno botanic exploration methodology described by Hernández (1971) was applied. Interaction with the studied community began by contacting peasants directly in their plots, at home or in community assemblies where reasons for this study were thoroughly explained, inviting them at the same time to collaborate with the project. To obtain information related to indigenous knowledge of growing techniques and pseudocereal use, an observational approach was applied, with the aid of qualitative techniques such as open, semistructured interviews and participative observation.

Information was also obtained at the regional market place (*tianguis*) interviewing merchants, and taking notice of buyers preferences. At peasants' homes a participative strategy was followed regarding *chapatas* preparation, threshing, cleaning and seed storage. During field exploration specimens were collected which after botanical identification were stored at the Herbario Nacional (MEXU).

RESULTS

Pseudocereals are generally grown in association with corn, squash, and occasionally also with beans. In this multicrop system, corn and beans are sown in the same place, so that the former plants support the latter growth, which in turn helps to improve soil due to its nitrogen fixation capacity. Squash with its broad leaves covers the soil, protecting it form rainfall and sun thus diminishing erosion, evaporation and weed growth. Multi-crop systems bring about other benefits such as variety of harvested products per growing cycle, more labour occupation during the growing cycle and better land use.

Description of cultivated pseudocereals

Within the region three cultivars of pseudocereals are grown, one belongs to *C. berlandieri* subsp. *nuttalliae* (cv. Chía roja) and two belong to *Amaranthus hypochondriacus*: cv. Chía blanca from the landrace Azteca and cv. Chía negra of the land race Mixteco.

Chenopodium berlandieri subsp. *nuttalliae* cv Chía roja

Morphological characterisation: 'Chía roja' (Figure 2) is an erect herbaceous plant with a prominent, angular, red and branched stem with green, yellow and purple pigmented stripes (Figure 3). Average number of branches ranges from 32 to 41. It has polymorphic leaves, lanceolate and rombic with indented margins with 3-12 indentations. Lower leaves are mostly green, however in some cases red or purple leaves are also found (Figure 4). Panicles are terminal and amaranthiform with intermediate density but occasionally there are plants bearing a compact panicle. In some cases before maturity panicles exhibit red colour and upon maturity colour changes to purple (López, 2005) (Figure 5). Other morphological characteristics are presented in Table 1. One outstanding distinctive trait of this cultivar is a total absence of saponins, bitter compounds present in seeds of cultivars such as Huauzontle or other species of the genus like quinoa (Ch. Quinoa) (De la Cruz *et al.,* 2007).

Table 1. Additional morphological characteristics of cv Chía roja *(Chenopodium berlandieri* subsp. *nuttalliae)* grown in Opopeo, Michoacán.

Descriptor	**Type/Value**
Pigmented axils	Absent
Intensity of stem colour	Clear, Intermediate or dark
Branch position	Oblique
Ratio length/width in upper leaves	2.29-2.54
Ratio length/width in lower leaves	2.23-2.35
Maximum length of leaves (cm)	7.2-8.9
Maximum width of leaves (cm)	3.1-3.8
Maximum length of petiole (cm)	3.8-4.6
Panicle colour intensity before maturity	Medium
Colour intensity of panicle at harvest	Clear or intermediate

Figure 2. *Chenopodium berlandieri* subsp. n*uttalliae* cultivar Chía roja.

Figure 3. Stems of *Chenopodium berlandieri* subsp. n*uttalliae* cv Chía roja

Figure 4. Leaves of *Chenopodium berlandieri* subsp. *nuttalliae* cv Chía roja.

Figure 5. Inflorescence of *Chenopodium berlandieri* subsp. *nuttalliae* cv. Chía roja

Seed characterization: Seeds of ‘Chía roja’ are sharp cornered, slightly flat with smooth margins (Figure 6). Diameter ranges from 1.5 to 1.7 mm, average thickness is around 0.95 mm, average weight ranges from 0.14 g to 0.48 g per 100 seeds, and density is 0.66 g/ml to 0.76 g/ml. Colour is red- purple exhibiting variability which according to the RHS Colour Chart corresponds to charts 59A and B, 185A and B, and 60 B (Royal Horticultural Society, 2001). Seed yield is on average of 31 g per plant.

Figure 6. Seeds of *Chenpodium berlandieri* subsp. *nuttalliae* cv. Chía roja

Amaranthus hypochondriacus land race Azteca cv. Chía blanca
Morphological characterization: 'Chía blanca' is an erect herbaceous, branched plant with a green or yellow green prominent cylindrical angular stem, and yellow or yellow green stripes (Figure 7). Leaves exhibit polymorphism, ovate, green or yellow green and with in dented margins. Panicle type is terminal and amaranthiform with density intermediate and compact. Prior to maturity panicle colour ranges from orange, to purple or green and at harvesting it may be green-yellow or yellow. Additional morphological traits are presented in Table 2.

Table 2. Additional morphological characteristics of *Amaranthus hypochondriacus,* land race Azteca cv. Chía blanca

Descriptor	**Type/Value**
Pigmented axils	Absent
Intensity of stem colour	Clear
Main branches	30
Branches position	Oblique
Ratio length/width in upper leaves	1.99-2.05
Ratio length/width in lower leaves	1.88-2.07
Maximum length of leaves (cm)	12.4-18.7
Maximum width of leaves (cm)	6.5-9.5
Maximum length of petiole (cm)	7.1-12.0
Panicle colour intensity before maturity	Medium, clear
Panicle density	Intermediate, compact

Figure 7. *Amaranthus hypochondriacus* land race Azteca cv. Chía blanca

Seed characterisation: Seeds of ‘Chía blanca’ (Figure 8) are round lenticulate with smooth margins, diameter is around 1.3 mm, thickness 0.9 mm, 100 seeds weight 0.075 g and average density is 0.98 g/ml. Colour is beige, corresponding to chart 161 and intensity A, B and C (Royal Horticultural Society, 2001). Average seed yield in grams per plant is 27.4.

Figure 8. Seed and popped seeds of *Amaranthus hypochondriacus* land race Azteca cv Chía blanca.

Amaranthus hypochondriacus land race Mixteco cv. Chía negra
Morphological characterisation: ‘Chía negra’ is an erect herbaceous plant with a prominent branched, cyilindric, angular stem, greenish-yellow or red in colour with

yellow stripes (Figure 9). Leaves are green, polymorphic ovate without pigmented axils and with entire margin. The panicle is amaranthiform, compact and terminal, and colour before maturity is green, orange or purple. Upon ripening colour becomes green or yellow varying in intensity. Other morphological traits of are presented in Table 3.

Table 3. Additional morphological characteristics of *Amaranthus hypochondriacus,* land race Azteca cv. Chía negra

Descriptor	**Type/Value**
Pigmented axills	Absent
Intensity of stem colour	Clear
Main branches	28
Branches position	Oblique
Ratio length/width in upper leaves	1.95
Ratio length/width in lower leaves	1.91
Maximum length of leaves (cm)	21
Maximum width of leaves (cm)	11.5
Maximum length of petiole (cm)	8.6
Panicle colour intensity before maturity	Medium and dark
Colour intensity of panicle at harvest	Medium and dark

Figure 9. Plant and panicle of *Amaranthus hypochondriacus* land race Mixteco cv. Chía negra.

Seed characterisation: Seeds are rounded and lenticulate, with entire smooth margins (Figure 10). Average diameter is 1.3 mm, thickness 0.9 mm and density of 0.92 g/ml, weight of 100 seeds is 0.08 g.

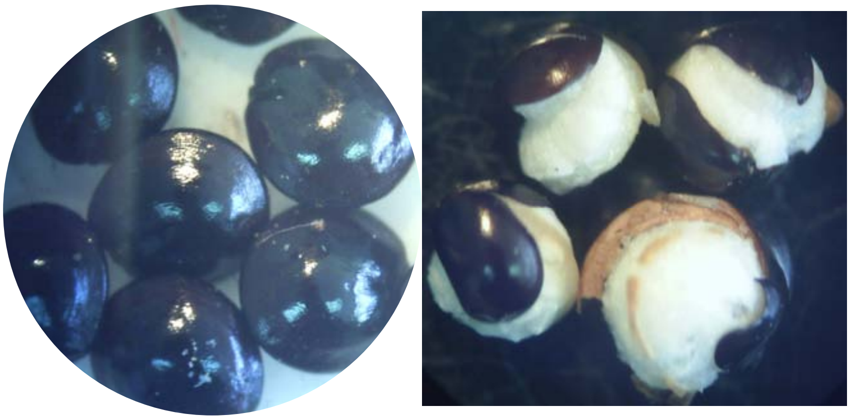

Figure 10. Normal and popped seeds of 'Chía negra' *(Amaranthus hypochondriacus* landrace Mixteco)

Growing systems
Pseudocereals are cultivated under a traditional rainfall multicrop system and grown in association with corn, squash and occasionally beans. Basically two systems can be found: *milpa* and *mogote*.

Milpa
The *Milpa* system is used in plots located in plains or areas with moderate slope. Animal traction is used (horses or oxen). An individual guides the ploughing yoke, another follows sowing three corn seeds per step, another one sows pseudocereal and squash seeds mixed with either cow manure or chemical fertiliser and finally someone covers the seeds using another plough (Figure 11). Cultural practices (weeding, thinning) are performed manually. Figure 12 shows plants under a multi-crop system.

Figure 11. Sowing corn in association with pseudocereals

Figure 12. Pseudocereals grown under the *milpa* system. a) 'Chía blanca' b) 'Chía negra' and 'Chía roja' c) 'Chía roja', corn and squash.

Mogote

Mogote is a slash and burn growing system and is an ancient practice almost extinct nowadays (Figure 13). Hills or high slope lands with naturally occurring broad leaved vegetation, shrubs of *Quercus spp.* and *Alnus jorullensis* are employed for this system. Land preparation begins during Spring by cutting down and burning native plants. Upon establishment of the rainy season, corn and pseudocereal seeds are sown directly on burned vegetation ashes by means of a wooden instrument which digs holes allowing insertion of seeds, called *coa* (meaning digging stick). When only pseudocereals are grown, seeds mixed with manure are spread by hand without covering. Weeding is performed manually and in multicrop system harvest is sequential: squash is harvested during August, fresh ears of corn (*elotes*) in September, pseudocereals ('Chía roja', 'Chía blanca' and 'Chía negra') are harvested in December, and dry corn in January (Pérez *et al.,* 2005).

Figure 13. *Mogote* system of growing. Native plants are chopped and burned and pseudocereals grow among ashes and stones.

Harvesting

Harvesting must be done on time to avoid losses due to excessive grain shedding because of dehiscence and also to avoid seed browning, especially in the case of *Chía roja* whose seeds tend to loose their brightness. A sickle is used for cutting panicles when they reach physiological maturity (according to a growers' saying, "when the seeds are opening their eyes"). Panicles are allowed to dry on the plot or in a shed (Figure 14). Once dried, panicles are threshed by hand and winnowed to obtain clean seed to be used at home or sold in the market (Figure 15).

Figure 14. Ripen ‘Chía roja’ (left). Panicles of pseudocereals drying in the open air (right).

Figure 15. Threshing of the seeds by hand (left) and cv Chía roja and Chía blanca seeds ready to use or to be sold in the market

Uses of pseudocereals

People from the studied communities, use amaranth (‘Chía blanca’) to prepare sweets known as *alegrías* and with ‘Chía roja’ or ‘Chía negra’ they make *chapatas*. *Alegrías* are round sweets prepared with popped seeds of ‘Chía blanca’, mixed with non refined melted sugar (Figure 16). *Alegrías* preparation is a family based agroindustry which allows peasants to obtain an additional income. Five small or three big *alegrias* are sold for $10. *Chapatas* are a sort of *tamales* (a lump of corn dough, prepared by mixing cornmeal with equal parts of ground ‘Chía roja’ or ‘Chía negra’ seeds and sugar all of which is wrapped in corn husks (*totomoxtle*) and steam cooked. Three *chapatas* are sold for $10, in the traditional market (*tianguis)* of Pátzcuaro (López, 2006).

Figure 16. *Alegrías* prepared with 'Chía blanca' (left) and *chapatas* prepared with corn dough, 'Chía roja' flour and sugar (right).

Economic aspects and yield

Yield estimation under the *milpa* system, is 1 ton per hectare for corn and 700 kg per hectare for pseudocereals. Considering the ratio benefit/cost multicrop systems give a ratio of 2.5 in comparison to a corn monocrop (ratio 1) (Pérez *et al.,* 2005).

Thus multicrop systems favour diversification of the impoverished, rural regions inhabitants' diet, generating at the same time products which through simple processing techniques (sweets, tamales etc.) bring an additional income to peasants who may obtain products even when climatic conditions are adverse. If the first half of the year is good peasants can harvest squash and sweet corn, if there are no early frosts a grower can harvest 'Chía roja', 'Chía blanca' and 'Chía negra' and if all the year is good also corn. The price per kilogram of *Chías* ranges from $25 to $35.

Regarding nutritive value, samples of 'Chía blanca', 'Chía roja' and 'Chía negra' collected from the studied region yielded protein and lipid contents ranging from 13.1% to 17.9%; and 3.6% to 4.9% respectively (De la Cruz *et al.,* 2006). More detailed studies concerning essential amino acids contents and balance are presently under way.

Pseudocereals as an alternative crop to diminish malnutrition and improve social well being in impoverished regions

Nowadays in rural areas of Mexico malnutrition reaches 40% of the population. In some states like Puebla, Morelos, Tlaxcala, Distrito Federal, Estado de México, Oaxaca, Queretaro and Michoacán, San Luis Potosí, Guanajuato and Durango efforts are made to solve the problem by promoting the cultivation of pseudocereals, mainly amaranth. For instance in Oaxaca amaranth growing is promoted through governmental and non governmental organizations as an alternative to facing problems of malnutrition and unemployment. An example of such efforts is "*Puente a la salud comunitaria*" involving 1,500 women in 16 different rural communities, which promotes talks about nutrition, cookery demonstrations with recipes to prepare amaranth dishes, all of which aim at convincing peasants to grow amaranth in backyard orchards or in *milpa* (PUENTE, 2006). So far this effort has increased amaranth consumption from one to three times a week in 70% in families of the communities (Figure 17).

Figure 17. Promoting familiar orchards, growing and consumption of amaranth is an activity that “Puente a la salud comunitaria” and other organizations perform in Oaxaca, México.

Workshops that teach inhabitants to prepare sweets, biscuits, powdered beverages, snacks, etc., are also organised everywhere within the region, in order to show peasants how to improve opportunities for generating extra income by providing local markets with a diversity of amaranth products, thus contributing to nutrition improvement and profitable economic activity (Figure 18). Similar efforts are made by other governmental and non governmental institutions in other regions, as in the case of the organisation “Mexico Tierra de Amaranto” which besides promoting growing and consumption of amaranth in marginal rural areas of Querétaro, has established links between peasants and food processing factories to ensure markets for amaranth production (SAGARPA, 2007).

Figure 18. Amaranth cooking demonstrations and processing workshops allows to increase consumption and to get extra income from amaranth growing in Oaxaca, México.

Amaranth is also grown in some rural areas of Mexico City mainly in Xochimilco as a single crop under the *chinampa* system and in areas like Tulyehualco where a great range of amaranth products are processed on a family scale. In Tehuacán, Puebla, the “Cooperativa Quali” is promoting growing and processing of amaranth as a means to help rural communities to meet nutrition and economic problems (QUALI, 2007). Production of amaranth, the most important pseudocereal grown in Mexico reached 2922 tons in 2005 with the most important producers located in the states of Puebla, Tlaxcala, Distrito Federal, México, Oaxaca and Guanajuato (SIAP, 2007).

Nowadays when subsistence agriculture faces serious challenges such as migration of inhabitants of rural areas to cities, malnutrition and poverty it is important to promote production and marketing of amaranth and of the two other pseudocereals presented here ('Chía roja' and 'Chía negra') to give alternative crops to encourage peasants to remain in their native communities, to improve nutrition and last but not least to produce higher economic returns.

CONCLUDING REMARKS

Multicrop growing systems such as those practiced in the regions studied are being re-evaluated taking in account that space and time combinations can make for more efficient use of natural resources (soil, water, air and solar radiation) giving to peasants the possibility to diversify production improving also nutritional status (Casanova *et al.,* 2005). Nowadays, when commercial agriculture, characterised by high inputs of agrochemicals, machinery and use of monocrops has a negative impact on the environment and biodiversity, multicrop systems such as those that remain in the region studied are considered as a sustainable alternative to preserve biodiversity and to obtain products and by-products that can help satisfy demands for food, feed, and fuel from rural communities (Bray, 1974).

Important factors which support preservation of the multicrop system here reported are that inhabitants of the communities studied are of mestizo origin and have preserved traditions belonging to the original *Purhépecha* culture regarding agricultural practices and food consumption. Moreover, another socio-economic factor is that communities are located in a region where subsistence agriculture is practiced and peasants have no access to credit or to inputs such as agrochemicals and machinery having in consequence no influence of the "green revolution".

Milpa and *mogote* systems favour the use of family labour in activities such as sowing, weeding, threshing, winnowing and preparing products which is positive in regions where employment is scarce and there are no economic resources to hire labour. Communities studied are located in a mountainous region where thin and stony soils with pronounced slopes prevail, making them unsuitable for commercial agricultural practices. In turn practice of small scale traditional systems is favoured, promoting biodiversity and conservation of germplasm.

Socio-economic factors threaten these systems because the lack of development perspectives pushes young generations out of the communities abandoning plots and reducing possibilities of conservation of traditional knowledge and germplasm. To reduce this problem an integral approach has to be designed to promote growing, use, transformation and marketing of native pseudocereals to have a positive impact on the socio-economic status of rural marginal communities. This effort needs to be supported by the collection, characterisation, conservation and improvement of these neglected crops making use of such technologies as hybridisation, *in vitro* culture, molecular markers etc., taking in account the requirements of growers, consumers and processors through a participative approach.

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14

Role of Bambara groundnuts (*Vigna subterranea*) in cropping systems in Western Kenya

D.O. Andika, M.O.A. Onyango and J.C. Onyago

The Bambara groundnut (*Vigna subterranea*) is an Indigenous African crop that has been cultivated in Africa for centuries. It is a highly nutritious plant which plays a crucial role in people's diets and is currently grown throughout Africa. It has been reported as one of the indigenous food crops found in western Kenya that has a potential for reducing food and nutritional insecurity. Despite its usefulness in terms of nutrition and improvement of soil fertility, it remains one of the neglected crops by the scientific community and is commonly referred to as a poor man's crop. The main objective of this study was to evaluate the role of Bambara groundnuts (*Vigna subterranea*) in cropping systems in Western Kenya. Structured questionnaires and survey checklists were used in the study to determine the extent of use of Bambara groundnuts in the cropping systems in the region. The Bambara crop is mainly grown during the short rains between September and December. Its production area per household has been diminishing over the years since the late 1980s, until recently; it is now being taken up as a short rains crop. Over 75% of farmers grow Bambara groundnuts as an intercrop with cereals mainly maize and to a small extent sorghum and millet. Knowledge of the crop remains low and marketing opportunities of the crop need to be developed.

INTRODUCTION

Legumes are widely used for food, fodder, shade, fuel, and timber, as cover crops and for green manure. They are a feature of cropping systems (in rotation or intercropping), grazing systems, plantation systems where legume cover crops are grown in the inter-row space of tree crops such as coffee, tea, rubber and oil palm, and agro-forestry systems. They are an essential element of sustainability of any cropping system for the effective management of available resources both below ground and above ground, for example; worldwide, legumes are grown on approximately 250 million hectares and they fix about 90 million tonnes of N_2 per year (Kinzig and Socolow, 1994). Symbiotic nitrogen fixation in cropping systems in the tropics has been reported as one of the key contributions of legume crops. However, since the capacity to fix N2 is dependent upon several factors, physical, environmental, nutritional and biological, it cannot be assumed that any N_2-fixing system will automatically make a large contribution to the N cycle. Many different legume species are utilised as components of lowland and upland cropping systems. Some species are grown widely as oilseeds (groundnut and soybean) or pulses (chickpea, pigeonpea, cowpea, black gram, green gram, common bean), but often crops have localised use e.g. rice bean and Bambara groundnut. The distribution of crop legumes is generally determined by their adaptation to particular climates and environments (Rachie and Roberts, 1974; Wood and Myers, 1987).

Bambara groundnut (*Vigna subterranea* (L.) Verdc) is one of the many legumes that can provide protein and minerals and the seeds have been described as a complete food as they contain proteins, carbohydrate and lipids (Brough and Azam-Ali, 1992; Williams, 1995). Bambara groundnut is extensively cultivated in Africa at a subsistence level and is the third most important legume crop after cowpea and groundnut (Kay, 1979) and it is widely consumed in most parts of Africa including Kenya. This legume has been reported as one of the indigenous food crop found in western Kenya that has a potential for reducing food and nutritional insecurity (Musotsi, 2004; Obuoyo, 2005).

This legume can positively contribute to food security and help to alleviate nutritional problems. However, it has been classified as an underutilised crop and is only receiving more attention in the recent past (Williams, 1995; Heller *et al*., 1997). This crop is drought resistant; it tolerates poor soils and is fairly resistant to pests and diseases. Bambara groundnuts are grown in pure stands or intercropped with cereals, but owing to its neglect little has been reported on its contributions to cropping systems. Bambara groundnuts can form an excellent soil cover owing to its bunchy growth habit (Williams, 1995). Therefore the objective of this study was to evaluate the role of Bambara groundnuts (*Vigna subterranea*) in cropping systems in Western Kenya.

MATERIALS AND METHODS

Description of study area

The study was carried out in the Butere-Mumias District of Western Kenya. The district lies between longitudes 34º20' and 35ºE and latitudes 0º15' and 1ºN of the equator. The total arable land in the district is 71000 ha with an average farm holding of 2.6 ha. The total population in the district is 476,928 with 107,444 farm families. The district has varying topography with altitudes ranging from 1250m to 2000m above sea level. There are two rainy seasons in the district: the long rains start in February and end in July with the peak in May; and the short rains begin in September and end in December. The driest months are December, January and February. The mean annual rainfall is 1750mm. The district has high temperatures all the year round with slight variations in mean maximum and minimum ranges of 23ºC to 32ºC and 11ºC to 13ºC, respectively. The major soil types in the district are classified as deep moderately deep acrisols and ferrasols. They are well drained, moderately deep to deep, dark yellowish brown to dark reddish brown, friable sandy clays to clay with an acidic humic top soil.

Establishment of cropping systems and role of Bambara groundnuts

A transect study along the Buyangu – Butere road, which is the main road in the district employing stratified sampling was used to determine the cropping systems as well as the role played by Bambara groundnuts. Five farms on the right side of the road were evaluated at 1 km intervals. Observation checklists and structured questionnaires were used to obtain the information. 120 checklists were completed and used to evaluate cropping systems and the role of Bambara groundnuts in the district.

RESULTS AND DISCUSSION

Different cropping systems are practiced in the Butere-Mumias District of Western Kenya. Intercropping was the dominant system with 54% of respondents practicing it in the long rains (Figure 1). Crop rotation was the second most practiced cropping system followed closely by sole cropping and monoculture. Agro forestry and strip cropping are practiced to some extent with fallow cropping being the least practiced cropping system.

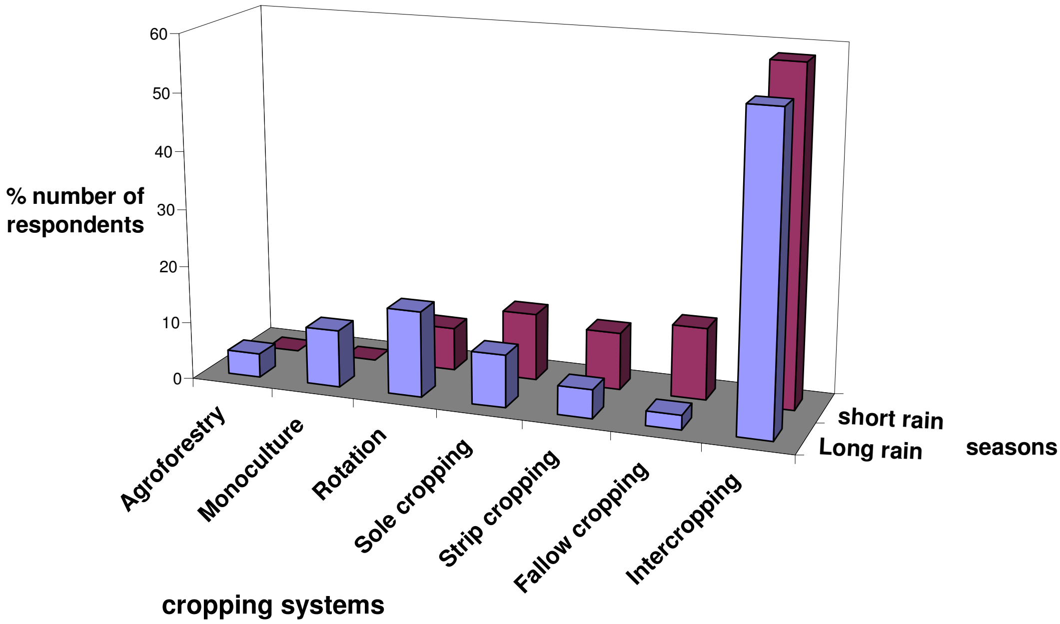

Figure 1. Cropping systems practiced in Butere-Mumias District during long and short rain seasons

The main crop grown during the long rainy season is maize (*Zea mays*). Maize is mainly intercropped with legume crops which are well known to the farmers in the region (Figure 2). The bean (*Phaseolus vulgaris*) is the dominant legume intercropped with maize in the district (Figure 3), followed by cowpea (*Vigna unguiculata*), Bambara groundnuts, groundnuts and soybeans, in that order of preference. It was observed that millet (*Eleucine coracana*) was the only other cereal grown in the long rains and that it was intercropped with Bambara groundnuts. Some farmers were observed to be intercropping two cereals such as millet and maize.

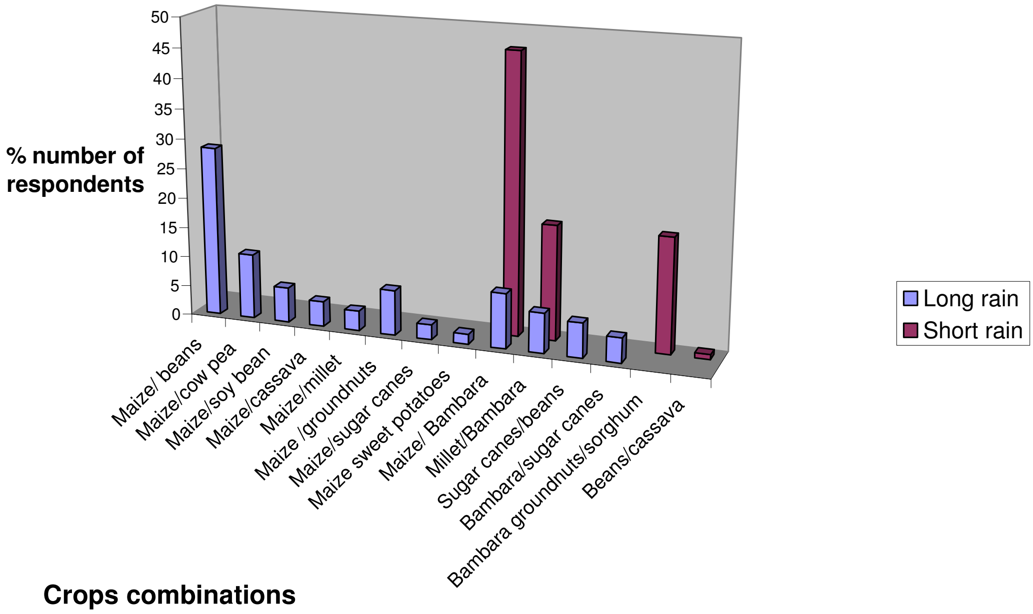

Figure 2. Crop combinations in intercropping systems during long and short rain seasons in Butere-Mumias District

Figure 3. Maize and beans intercrop during the long rain season in one of the farmer's fields

To most farmers the ultimate objective of growing crops is to obtain high yield with minimal chances of crop loss (Oniang'o, 2001). Therefore the choice of cropping system is very crucial since most of the agricultural production in this region is determined by natural climate. Intercropping, i.e. the growing of two or more crops simultaneously on the same piece of land in separate rows, offers a number of advantages which include; increased crop density, crop diversification, mitigating risks due to weather aberrations, optimal use of basic resources such as moisture, light, and nutrients and insect and pest control (Jensen, 1996). This offers a possible explanation for the wide use of this system during the main production season as was clear from the results that most of the farmers practice some kind of intercropping irrespective of crop combination.

According to the results from intercrop crop combinations, information from farmers varies. According to Willey (1979) interspecific competition occurs during intercropping and therefore choice of the most compatible intercrop crops is the key to a successful system. The crops should be able to utilise resources from different ecological niches (Shennan, 1992). Any kind of intra-specific competition should be minimised (Snaydon and Harris, 1981).

These results agree with Francis (1986), who reported that, intercropping of grain legumes with cereal crops is common in the tropics. The range of crop combinations and sowing practice is numerous and ranges from mixed cropping, in which many species are sown in a field, to organised rows or strip cropping. The combination of crops is determined by the length of growing season and environmental adaptation, but usually early and late maturing crops are combined to ensure efficient utilization of resources during the growing season. Generally legumes such as cowpea, pigeonpea, groundnut, chickpea and Bambara groundnuts are intercropped with maize, sorghum or millet. Differences in the competitive abilities of the component crops for soil-N can result in stimulation of N_2-fixation (Rerkasam *et al*., 1988).

Monoculture in the district is due to cultivation of sugar cane as a cash crop. During initial stages of growth of sugar cane it is intercropped with either beans or Bambara groundnuts (Figure 1). After establishment, sugar cane forms a dense canopy which does not permit intercropping for four to five years when it is in the field. Strip cropping is used in the district to prevent soil erosion and promote moisture conservation.

The scenario during the short rains is not much different from that in the long rains apart from the kind of crops grown (Figure 2). Intercropping systems predominate, followed by fallows and sole cropping respectively (Figure 1). Most of the farmers grow Bambara groundnuts intercropped with maize while others intercrop it with millet and sorghum (*Sorghum bicolor*) (Figure 2).

The short rainy season is characterised by relatively modest rainfall which occurs for a short period between late September and December. Farmers therefore tend to grow crops that are considered hardy and can mature under low rainfall. Bambara groundnuts have been described as a drought tolerant crop (Williams, 1995), able to yield in such conditions. Similarly millet and sorghum are drought tolerant crops. The use of Bambara groundnuts in the short rainy season guarantees soil cover limiting soil erosion. Symbiotic nitrogen fixation of approximately 106 N kg/ ha has been reported in Bambara groundnuts (Williams, 1995). Most of this nitrogen is made available to crops in the next season. Farmers have reported yield increases in maize and sorghum on fields previously producing Bambara groundnuts (Williams, 1995).

Some farmers left their land fallow during the short rainy season (Figures 1 and 2). This is partly attributed to climatic during the short rainy season as well as lack of farm inputs. Therefore the land is left until the long rains which commence in late February. This fallow cropping system is also considered as a method of replenishing soil nutrients fromthe previous cropping cycle.

Bambara groundnuts are also grown as a sole crop during the short rains (Figures 4 and 5). From the results in Figure 4, most farmers grow legume crops during this season as pure stands. Most of these legumes have short growth cycles and therefore have the ability to utilise the available resources within a short time and produce some yield (Lemon *et al*., 1990).

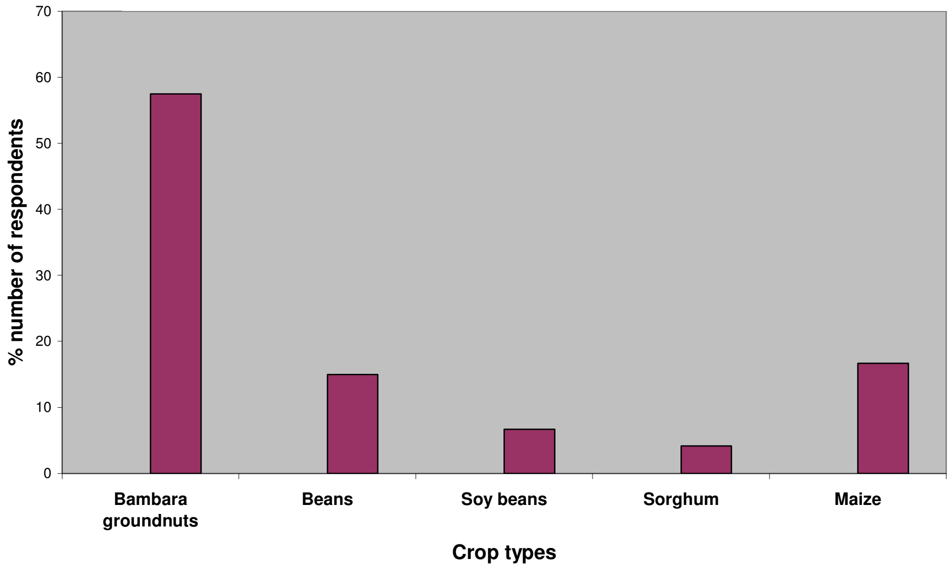

Figure 4. Crops grown in sole cropping during short rain season

Figure 5. Pure stand of Bambara groundnuts during the short rainy season in a farmer's field

The legumes commonly used in the district were ranked according to different uses (Figure 6). Bambara groundnuts were considered to be an excellent soil cover followed by beans. Similarly they were considered the best legume in terms of utilising water in cropping systems. Beans were ranked the best in improving the growth of companion crops in the intercrop system. In terms of yield, beans and Bambara groundnuts were ranked as the highest yielding legumes. Bambara groundnuts were mainly grown for the market sale while beans and the cowpea were mainly grown for domestic consumption.

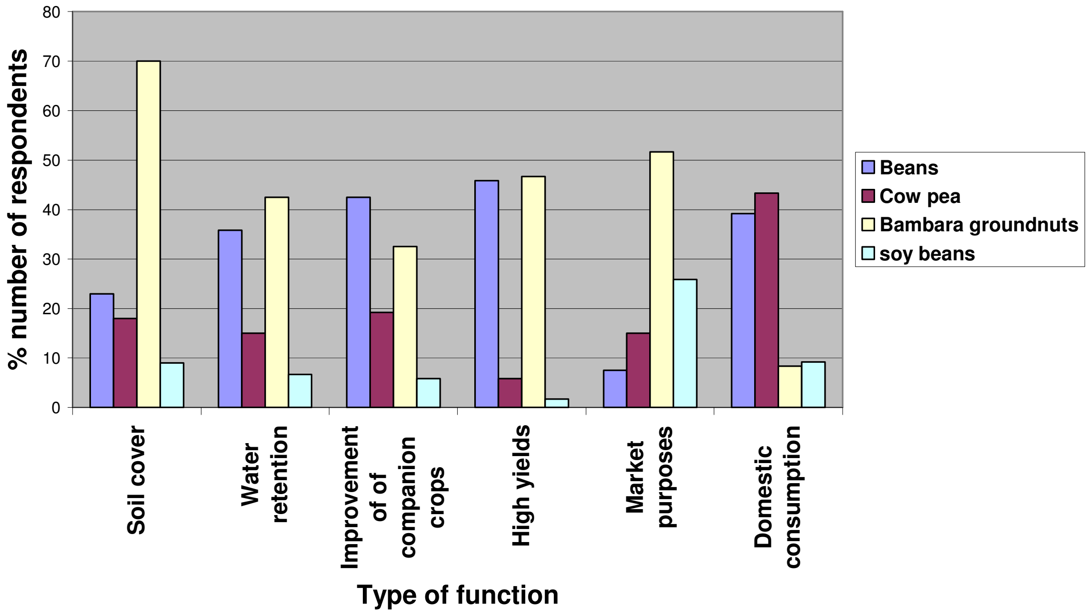

Figure 6. The functions of different legumes in nutrition, the economy and cropping systems

Bambara groundnuts have a bunched growth (Figure 7), which enables it to form an excellent soil cover (Williams, 1995). According to Williams (1995), cover crops make a fundamental contribution to the stability of the cropping system. They have direct and indirect effects on soil properties as far as capacity to promote increased biodiversity in the agro-ecosystem. In regions where smaller amounts of biomass are produced, such as dry areas and eroded soils, cover crops are beneficial as they protect the soil during fallow periods, mobilise and recycle nutrients, improve the soil structure and break compacted layers and hard pans, permit a rotation in a monoculture and can be used to control weeds and pests. This enables it to reduce the effect of direct sunlight on soil resulting in low evaporation rates from soil (Lal *et al*., 1991). This possibly explains why Bambara groundnuts are widely grown during the short rain seasons in the district. Due to the high nutritional value of Bambara groundnuts, most of the growers' sell their produce at competitive prices in the nearest markets. This makes it an income generating crop for most farmers who undertake its production.

Figure 7. Bambara ground nuts with its soil covering characteristics

CONCLUSIONS AND RECOMMENDATIONS

Bambara groundnuts play a key role in cropping systems and the livelihood of many farmers in Butere-Mumias district. It is used in soil conservation as a soil cover, for moisture retention and improvement of soil nutritional status through symbiotic nitrogen fixation. The Bambara groundnut is chiefly grown in the short rainy season, a time at which it yields well and is highly marketable. Cropping systems in the district are highly diverse but intercropping predominates.

Acknowledgements

DAAD for financial assistance, Maseno University for providing enabling environment to conduct this research and IFS for sponsoring my participation in the symposium.

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15

Aerial Yam: a potential underutilised crop for the resource-poor people of Bangladesh

Abul Kalam Azad, Mian Sayeed Hassan and Md. Abdur Razzaque

Air potato Yam or Aerial Yam (*Dioscorea bulbifera* L.) is an underutilised tuber crop in Bangladesh. It has been grown in some part of Bangladesh. Air potato has potential to grow all over of Bangladesh particularly in the homestead. It is used as a vegetable. The crop is rich in carbohydrates, sodium and potassium. The crop can partially supplement the staple food of Bangladesh during times of food scarcity. The return of the crop is very good while the investment is low. Thus, it can play a vital role in poverty alleviation. Selection of a high yielding variety and seed multiplication are necessary to expand the crop all over Bangladesh. Adaptive research will help to expand this potentially valuable underutilised crop. The extension and popularisation of this underutilised crop would promote income generation of the farm families.

INTRODUCTION

Air potato Yam or Aerial Yam (*Dioscorea bulbifera* L.; Figures 1-3) is an underutilised tuber crop in Bangladesh (Figure 4). The crop is produced mostly in the homestead. But because of its high yield and market potential it can be popularised as a commercial crop. The crop can play a vital role in poverty alleviation.

Figure 1. Seedling of aerial potato

Figure 2. Creepers in dead and horizontal support

Figure 3. Bearing creeper of aerial yam

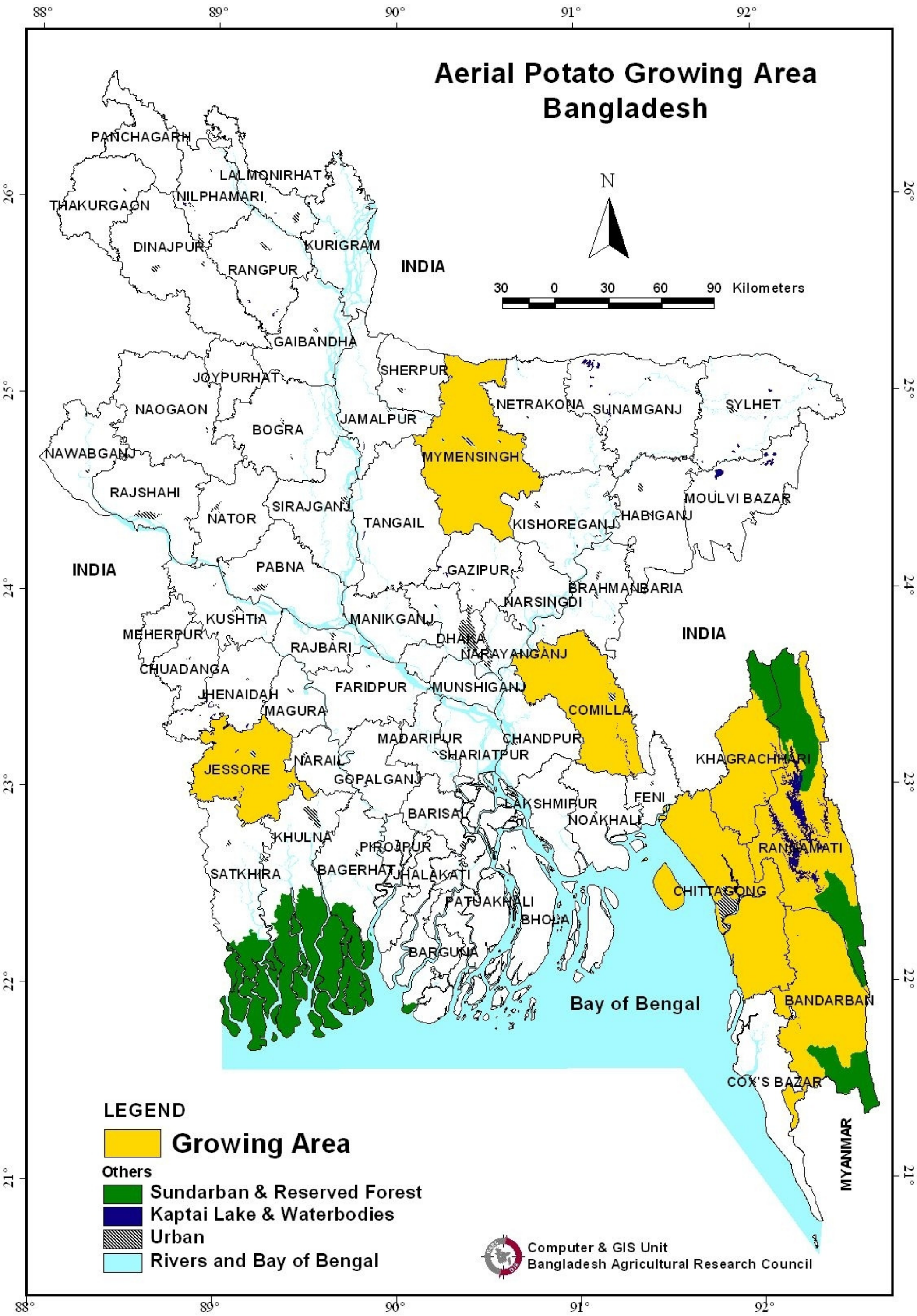

Figure 4. Aerial potato growing area: bangladesh

USES

The bulbils and underground tubers are used as vegetable. It can be mashed or cooked with meat or fish. It can also be cooked with rice to make a mixed vegetable-rice dish.

NUTRITION

The bulbils and the tubers are rich in carbohydrates. However, other nutrients are also available in the bulbils and underground tubers (Table 1).

Table1. Nutritive value of Aerial potato (per 100 g edible portion)

Sl. No.	Nutrients	Underground tubers	Aerial tubers (bulbils)
1.	Carbohydrates (g)	16.4-31.8	18.0
2.	Fat (g)	0.20-0.40	0.20
3.	Protein (g)	1.4-3.5	1.40
4.	Fibre (g)	0.40-10.0	1.2
5.	Water (%)	65-81	79.4
6.	Calcium (mg)	12-69	40
7.	Phosphorous (mg)	17-61	58
8.	Iron (mg)	0.70-5.20	2.0
9.	Sodium (mg)	8-12	-
10.	Potassium (mg)	294-397	-
11.	B-carotene (mg)	0-10	-
12.	Thiamine (mg)	0.01-0.04	-
13.	Riboflavin (mg)	0.01-0.04	-
14.	Niacin (mg)	0.30-0.80	-
15.	Ascorbic acid (mg)	4-18	-
16.	Calories	71-135	78

PRODUCTION AREA

The Aerial yam has been grown in the district of Chittagong, Chittagong Hill Tract, Comilla, Jessore and Mymensingh. Farm research trials showed that the crop can be produced in upland soil all over the country.

PLANT CHARACTERS

Aerial yam produces large bulbils in the air and small tubers underground (Figures 5 and 6). The plant is a creeper and needs live or dead support for cultivation. The oval shape bulbils of 100-1500 g are produced in the aerial canopy. A plant can produce a hundred bulbils.

Figure 5. Mature bulbul of aerial yam

Figure 6. Underground tubers of aerial yam

CULTIVATION

Well-drained light soil is suitable for cultivation of *Dioscorea*. The plant is propagated by stem cutting or small bulbils. Tiny bulbils of previous years are used for propagation. The propagules are planted in pit of 50x50x50 cm in March-April. Compost, Triple Super Phosphate (TSP), Muirate of Potash (MP) are mixed with soil at least 15 days ahead of planting. Dead plant support or live plat support like fruit and forest trees are used for its cultivation. Generally used live supports are jackfruit, jamun, coconut, arecanut, mango, ber and guava.

FERTILISER DOSE

The recommended dose of manure and fertilisers are: Compost 3- 5 kg, Urea 90-100 g, TSP 90-100 g and MP 70-90g for each pit. The crop is tolerant to major diseases and pests.

INTERCROPS

The live support fruit trees can produce good crops every year. Short duration vegetables such as red amaranth, Indian spinach and kang kong can be grown at the early stage of its cultivation when it is grown under open condition. The crop can be intercropped with bitter gourd, bottle gourd, sweet gourd in the horizontal support (*Macha*).

YIELD

The crop is harvested 8-10 months post-planting in October to December. A vine can produce 10-14 kg if it is grown on a dead support in the open. Per hectare yield is 25-30 tons. A vine can yield 2-5kg when grown on a live support.

ECONOMIC VALUE

The crop is highly profitable to cultivate. The cost of cultivation depends mostly on the cost of support. Taka 46.00 can be earned by spending taka 7.5 per vine if it is produced on *Moringa sp*. The cost:benefit ratio was estimated at about 6:1 in that species. The cost of production can be minimised if a live support is used.

POVERTY ALLEVIATION

There are about 1.40 million homesteads in the country, to which cultivation could be extended. This will help in meeting the demand for vegetables from farmers. Every homestead of Bangladesh is composed of a good number of fruit and forest trees which are suitable for cultivation of *Dioscorea.* The crop may partially supplement the staple food as it is rich in carbohydrates. It can be produced by minimal land and investment, and gain higher returns. The crop is suitable for income generation for farm families. Therefore, the crop has great potential to alleviate the poverty of resource poor people of Bangladesh.

CONCLUSION

Cultivation of aerial potato gives a high dividend to farmers. The expansion of this crop depends on seed availability at farm level. Therefore, seed multiplication and distribution to the farmer are very important for its promotion in initial extension activities. Research initiatives on the crop are also important for variety selection and technology support to the farmers. The extension and popularisation of this underutilised crop should be initiated for income generation of the farm families.

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16

Collection and characterisation of germplasm of some underutilised plant species in Pakistan

Zahoor Ahmad, S. Hussain, M.S. Iqbal, M. Irfan, N. Rehman, A. Jamal, A. Qayyum and A. Ghafoor

Bearing in mind the importance of underutilised crops in crop diversification, and the little research and development work carried out on these crops, the germplasm of *Nigella sativa* (109 accessions), *Plantago ovata* (107 accessions), *Sesamum indicum* (216 accessions), *Ricinus communis* (78 accessions), *Cyamposis tetragonoloba* (116 accessions), *Linum usitatissimum* (102 accessions), *Crotolaria juncea* (112 accessions), *Vigna unguiculata* (215 accessions), *Phyllanthus amblica* (20 accessions) and *Tamarindus indica* (24 accessions) were collected and characterised during 2003-2006 for various morphological and agronomic traits under two projects funded by Pakistan Agricultural Research Council under the Agricultural Linkage Program and Southampton University, UK. The germplasm collected has been characterised largely on characters contributing to yield. High genetic variability for quantitative traits in *Nigella sativa, Plantago ovata, Ricinus communis, Sesamum indicum* and *Cyamposis tetragonoloba* was recorded. There was low variability in *Tamarindus indica* and *Linum usitatissimum* within the germplasm characterised. Based upon evaluation data, elite germplasm lines particularly for yield were identified. The seeds of 4 accessions of *Nigella sativa* showing high yield potential were multiplied and distributed to farmers. In *Phyllanthus emblica*, three clones namely Desi, Shisha and Banarasi are mainly found in Pakistan. The Desi clone is collected from the wild, while Shisha and Banarasi are vegetatively propagated. The fruits from Shisha clones are used in pickles and Banarsi with large fruit size are preserved and processed for various uses.

INTRODUCTION

Due to wide variation in geography, altitude, soil and climate, a variety of crops ranging from tropical to temperate are grown in Pakistan. During the last 3-4 decades due to shortage of food, major emphasis was given on the improvement of basic staple crops like wheat, rice and maize, but also on cash crops like cotton and sugarcane. Research and development activities on major crops resulted in substantial yield increase during the last 3 decades. With achievement of self sufficiency in major food crops, efforts are now made with the objective to rescue and improve those crops (mostly minor and under-utilised) neglected by research and development. These minor and underutilised species have now been accepted as an integral part of the daily life of local communities. These species may be local staples for food/feed, fiber but are considered minor, although they have high potential (Padulosi *et al.*, 2002). These minor species mitigate seasonal shortages of major staples, and are used in intercropping and mixed cropping systems. These are less susceptible to biotic and abiotic stresses and require little input (Haq *et al.*, 1998). Despite the important role of under-utilised crops in the life of local communities, there have been few efforts to preserve their germplasm and improvement. In a national workshop on “Under-utilised Crops of Pakistan” held in May, 1998 and a national seminar on “Medicinal Plants Research and Development” in July, 1999, the following species based upon factors like nutrition, food security, primary health care, income generation, potential for development, multipurpose use, ease in cultivation were prioritised for research, conservation and development.

METHODS

The germplasm of the targeted under-utilised species (*Nigella sativa* L., *Plantago ovata* L., *Linum usitatissimum* L., *Sesamum indicum* L., *Cyamposis tetragonoloba* Taub., *Ricinus communis* L., *Trigonella foenum-graceum*L., *Phyllanthus amblica* L. and *Tamarindus indica* L.) was collected from farmers' fields, breeders and local markets. The germplasm collected was characterised and evaluated at the National Agricultural Research Centre, Islamabad. For characterization, germplasm was planted in a 5m row depending upon the crop sowing season. Crop specific cultural practices were followed during the evaluation. The plant descriptors varied from crop to crop but common characters were days to flowering, days to maturity, plant height, yield per plant or row, biomass yield, 100-seed weight, etc.

For selected genotypes, SDS-PAGE analysis was carried out to assess diversity at the molecular level. SDS-PAGE of total seed protein was carried out in a discontinuous buffer system according to the method of Laemmli (1970). The gels were rinsed with Coomassie Brilliant Blue (CBB) and then destained till the background become transparent (Masood *et al*., 2003). The data recorded were analysed statistically and means, standard deviation and heritabilities were calculated. Heritability was estimated as the ratio between genotypic and phenotypic variance (Singh and Chaudhry, 1985). The data were also analysed by numerical taxonomic techniques using cluster analysis (Sneath and Sokal, 1973) with Statistica and SPSS for windows packages (SPSS, 1996; Statsoft 2001).

RESULTS AND DISCUSSION

The germplasm of different species was collected from various ecologies of Pakistan. Collections were made either from farmers' field or local markets and breeders. Some germplasm accessions of *Plantago ovata* and *Sesamum indicum* were also imported from USA and Japan. The total material collected belonging to 12 species is given in Table 1.

Table 1. Germplasm collected of underutilised crops

S.No.	Name of Plant Species	No. of Accessions Collected
1.	*Cyamposis tetragonoloba* Taub	116
2.	*Nigella sativa* L.	109
3.	*Plantago ovata* L.	107
4.	*Sesamum indicum* L.	216
5.	*Linum usitatissimum* L.	102
6.	*Ricinus communis* L.	78
7.	*Trigonella foenum-graceum* L.	71
8.	*Hibiscus connabinas* L.	36
9.	*Phyllanthus amblica* L.	20
10.	*Tamarindus indica* L.	24
11.	*Vigna unguiculata*	215
12.	*Crotolaria juncae* L.	112
	Total:	**1216**

Germplasm Characterization and Evaluation

a) *Cyamopsis tetragonoloba*:

One hundred and sixteen accessions of *Cyamopsis tetragonoloba* were evaluated. High genetic variability was recorded for the traits pods per plant, plant height, biomass and harvest index. Low variability was observed for number of branches per plant, pod length, number of seeds per pod and 100 seed weight (Table2).

Table 2. Summary statistics of *Cyamopsis tetragonoloba* germplasm

Traits	Mean ± SE	σ	Range	
			Min.	Max.
Number of Branches per Plant	7.69±0.31	3.32	0.60	16.60
Number of Pods per Plant	25.61±1.31	14.11	7.40	70.80
Pod Length (cm)	5.20±0.09	0.92	3.49	10.43
Number of Seeds per Pod	7.68±0.06	0.64	5.53	9.13
Biomass (g)	94.58±3.19	34.36	20.00	212.00
Plant Height (cm)	71.47±1.12	12.07	46.80	110.80
Seed Yield (g)	18.08±0.75	8.03	6.37	54.23
Harvest Index (%)	22.35±1.23	13.24	4.60	70.00
100 Seed Weight (g)	3.28±0.04	0.44	1.82	4.30

Correlation coefficients for several traits revealed that number of branches per plant and pod length had highly significant correlation with other yield component characters (Table 3).

Table 3. Correlation coefficients between eight quantitative traits of *Cyamopsis tetragonoloba* L.

	# Brn/pt	*# Pods/pt*	*Pod L. (cm)*	*Seed/ pod*	*Bm (g)*	*Pt Ht. (cm)*	*SY (g)*	*HI (%)*
# Pods/pt.	0.446**							
Pod L.(cm)	-0.008	0.002						
Seeds/pod	-0.016	0.159	0.484**					
Biomass (g)	0.383**	0.455**	0.291**	0.083				
Pt.Ht.(cm)	0.315**	0.183	0.392**	0.323**	0.402**			
SY (g)	0.019	-0.036	-0.218*	-0.147	-0.037	0.184		
HI (%)	-0.253*	-0.285**	-0.350**	-0.197*	-0.677**	0.394**	0.645**	
100 SW (g)	-0.270**	-0.331**	0.001	-0.095	-0.250*	0.165	0.138	0.286**

*Significant,**Highly significant at P≤0.05 # pods/pt= # of pods/plant, pod L.=pod length, sds/pod= # seeds/pod, Bm= biomass, Pt. Ht.= plant height, SY=seed yield (g), HI= Harvest Index, 100 SW= 100 seed weight.

Biomass was found to have a highly significant association with plant height and a negative one with harvest index. The genetic diversity revealed by SDS-PAGE analysis showed no intra and inter accessions genetic diversity as electrophoretic seed protein profiles for all accessions were similar (Figure 1).

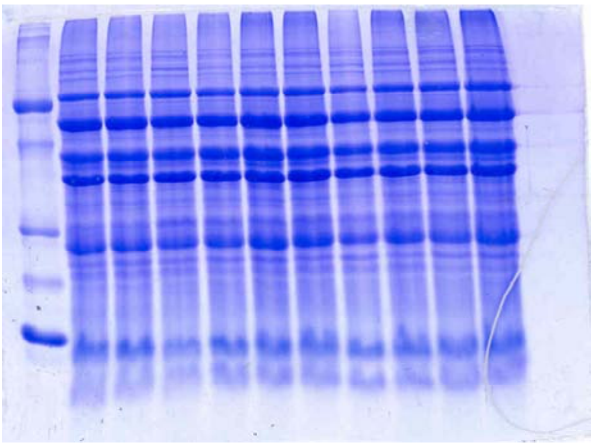

Figure 1. Electrophoregrams showing protein banding in Guar germplasm

b) *Hibiscus cannabinus*

Forty accessions of *Hibiscus cannabinus* were characterised and high variability in plant height, biomass and seed yield was recorded (Table 4). Medium to low variability was recorded for days to flowering, stem diameter, days to maturity, seed yield and harvest index indicating a narrow genetic base in available germplasm. There is need to expand germplasm collection from varied ecologies.

Table 4. Summary of Statistics in 40 accessions of *Hibiscus cannabinus* germplasm

Characters	Year 2004		Year 2005	
	Mean ± S.E	**σ**	**Mean ± S.E.**	**σ**
Days to flowering	62.46±1.07	5.877	54.46±0.738	4.723
Stem diameter (mm)	8.01±0.27	1.516	10.33±0.264	1.69
Days to 90% maturity	114.1±0.80	4.39	114.29±1.191	7.623
Plant Height (cm)	164.4±6.52	35.75	142.81±3.293	21.088
Biomass (g)	1990±291.06	1594.24	1859.756+104.199	667.197
Seed Yield	144.73±14.83	81.27	370.424+24.945	159.723
Harvest Index (%)	9.43±1.11	6.08	19.962+1.136	7.274

c) *Linum usitatissimum* L.

Thirty seven accessions of linseed were characterised. High genetic variability was recorded for days to flowering, number of capsules per plant and yield per row (Table 5).

Table 5. Basic statistics for germplasm evaluation in *Linum usitatissimum* L.

Traits	Mean± SE	σ	Range	
			Min.	**Max.**
Days to Flowering	128.22 ± 1.33	8.08	119.00	162.00
Plant Height (cm)	90.65 ± 1.56	9.51	77.20	113.40
No. of Secondary Branches	29.92 ± 1.96	11.95	14.20	69.00
No. of Primary Branches	5.28 ± 0.24	1.44	3.40	8.60
No. of Capsule	132.45 ± 7.54	45.85	53.80	247.20
Seed Yield (g/unit area)	597.23 ± 36.20	220.21	35.82	1184.56
Biomass (Kg)	2.45 ± 0.14	0.84	0.30	4.40
Harvest Index (%)	24.50 ± 0.90	5.49	11.67	37.95
100 Seed Weight (g)	0.50 ± 0.01	0.07	0.37	0.63

Other important traits like plant height, number of branches, biomass and 100 seed weight need improvement because these traits contribute to the economic yield. The data presented in Table 6 revealed varying degrees of association between nine characters under study. Days to flowering showed highly positive association with number of secondary branches (r = 0.503)** but a significantly negative association with seed yield (r = 70.410)*, thus suggesting a suitability of short duration genotypes for incorporation in breeding programs. Plant height showed a significantly positive association with biomass and 100 seed weight. The study suggests to explore more genotypes with high harvest index and more capsules per plant for developing high yielding varieties.

Table 6. Correlation coefficients of *Linum usitatissimum* L. germplasm

Traits	DF	PH	NSB	NPB	#Capsule	SY	Biomass	HI
PH	-0.108							
NSB	0.503**	-0.282						
NPB	0.093	-0.255	0.621**					
#Capsule	0.045	-0.198	0.587**	0.741**				
SY	-0.410*	0.011	-0.153	-0.084	0.065			
Biomass	-0.34**	0.398*	-0.284	-0.145	-0.122	0.829**		
HI	-0.38**	-0.474**	-0.078	0.060	0.271	0.446**	-0.068	
100 SW	-0.448**	0.434**	-0.167	-0.008	0.223	0.233	0.311	-0.061

*Significant,**High significant at P= 5 % & 1 %, respectively ; DF=Days to first flowering , PH= Plant height, NSB=number of secondary branches, NSP=number of primary branches, #Capsule= number of capsules, SY=Seed yield, HI=Harvest Index, 100SW= 100 Seed weight.

A phenogram was constructed from the Euclidean dissimilarity coefficient matrix and all genotypes were grouped in three clusters (Figure 2). In cluster 1, only one accession number 21325 collected from district Jhang was present whereas cluster 2 comprised 28 accessions. Cluster 3, comprising 8 accessions, includes germplasm collected from diverse ecologies. The SDS-PAGE analysis revealed low diversity in *Linum usitatissimum* (Figure 3). This was due to the fact that SDS-PAGE is not a powerful tool for all species particularly for intra specific variation.

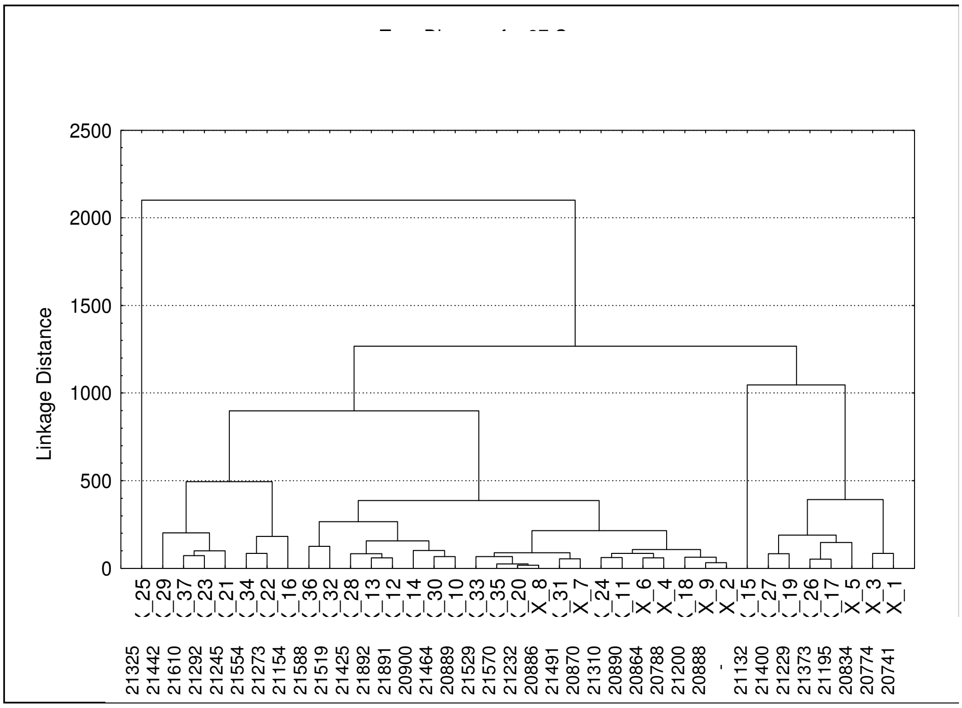

Figure 2. Phenogram of 37 accessions of *Linum usitatissimum* L. Germplasm

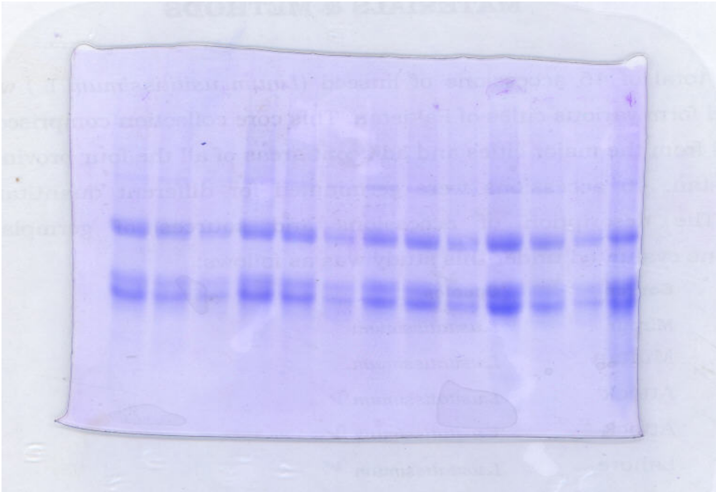

Figure 3. Electrophoregram Showing Protein Banding in *Linum usitatissimum*

d) *Nigella sativa* L.

Nigella sativa germplasm comprising 31 accessions was evaluated for qualitative and quantitative traits. High variability was recorded for plant height, days to flowering, days to maturity, capsule weight, yield, 1000 seed weight and harvest index whereas low to medium variability was recorded for other traits investigated (Table 7). The high CV for biomass, seed yield and 1000 seed weight indicated the diverse nature of this germplasm. Accessions having higher biomass, a greater number of capsules per plant, greater plant height, and harvest index (Accessions No.20567, 20654, 20663) could be potential sources used in a breeding program for higher yield.

Table 7. Statistics of 31 Genotypes of *Nigella sativa* L.

Traits	Units	Mean±SE	σ	σ^2 expressed in percent of means	Range		CV%
					Min.	Max.	
Plant Height	Cm	61.8±1.88	10.49	178.1	35.1	77.1	16.96
Days to First Flower	Days	146±2.54	14.14	136.9	125	171	9.68
Days to 50%Flowers	Days	154±2.04	11.35	83.7	138	175	7.34
Days to Maturity	Days	188±1.83	10.17	55.0	177	210	5.39
Biomass	Gram	22.67±1.48	8.23	298.8	7.96	44.75	36.31
No. of Branches	Number	7.34±0.16	0.89	10.8	5.40	9.90	12.08
Number of Capsule	Number	41.40±2.36	13.12	415.8	10.60	63.50	31.69
Capsule Length	Cm	13.12±0.29	1.64	20.5	11.18	20.63	12.47
Capsule Width	mm	9.67±0.06	0.35	1.3	8.91	10.35	3.63
Capsule Weight	Gram	7.48±0.38	2.13	60.7	2.48	12.00	28.41
Number of Locules	Number	28.86±0.39	2.17	16.3	25.1	33.2	7.51
Yield	Gram	5.36±0.44	2.45	112.0	1.47	10.64	45.68
1000 Seed Weight	Gram	3.41±0.28	1.57	72.3	1.98	8.07	45.99
Harvest Index	Percent	24.23±0.92	5.10	107.3	5.10	13.28	21.07

SE, Standard error, σ, Standard deviation, σ^2, variance, CV, coefficient of variability

The result presented in Table 8 revealed varying degrees of association between 14 characters. Seed yield showed positive correlation with biomass, number of capsules per plant, length and width of capsule, capsule weight and harvest index. Short duration plants with high number of capsules could be selected in the hybridization program.

Negative correlation of 1000 seed weight with yield and its components (biomass and capsule traits) could be broken through mutation breeding, selective diallels or back-cross techniques. Penograms based on 14 characters for 31 accessions presented in Figure 4 revealed five clusters at 50% linkage distance. The accessions in cluster 1 were short stature, early maturing but low yielding while cluster 3 and 4 comprised of accessions with high yield, late maturity and intermediate plant height. The accessions in cluster 5 had high seed weight.

Table 8. Correlation coefficients of various agro-morphological and quantitative traits of *Nigella sativa* L. germplasm

Traits	**PH**	**D1F**	**DF**	**DM**	**BM**	**NB**	**NC**	**CL**	**CWd**	**CWt**	**NL**	**Yield**	**1000-SW**
D1F	0.589**												
D50%F	0.540**	0.975**											
DM	0.215**	0.361**	0.311**										
BM	-0.054	-0.196*	-0.106*	-0.331**									
NB	0.121*	-0.086	-0.139*	0.181*	0.080								
NC	0.299**	0.134*	0.077	0.410**	0.289**	0.184*							
CL	-0.185*	-0.379**	-0.281**	-0.338**	0.551**	0.027	-0.246**						
C Wd	-0.056	-0.110*	-0.056	-0.205**	0.172*	-0.041	-0.317**	0.378**					
C Wt	0.174*	0.025	0.031	0.264**	0.538**	0.001	0.853**	0.095	-0.272**				
NL	0.362**	0.024	-0.082	0.193*	-0.185*	0.378**	0.388**	-0.131*	-0.046	0.128*			
Yld	0.068	-0.213**	-0.119*	-0.343**	0.858**	-0.003	0.203**	0.556**	0.147*	0.495**	-0.199*		
1000-SW	0.053	-0.120*	-0.124*	-0.067	-0.277**	0.100*	-0.264**	-0.087	0.025	-0.335**	0.078	-0.153*	
HI	0.369**	-0.074	-0.034	-0.099	0.144*	-0.108*	0.008	0.303**	0.037	0.178*	-0.016	0.601**	0.184*

*Significant,**High significant,***Highly significant at $P \leq 0.05$, PH=Plant height, D1F=Days to first flower, DF=Days to 50% flowers, DM=Days to maturity, NB=number of branches, NC= number of capsules, CL= Capsule length, CWd,= Capsule width, CWt= Capsule weight, NL=number of locules, Yld=Grain yield, 1000SW= 1000 seed weight, HI= Harvest Index.

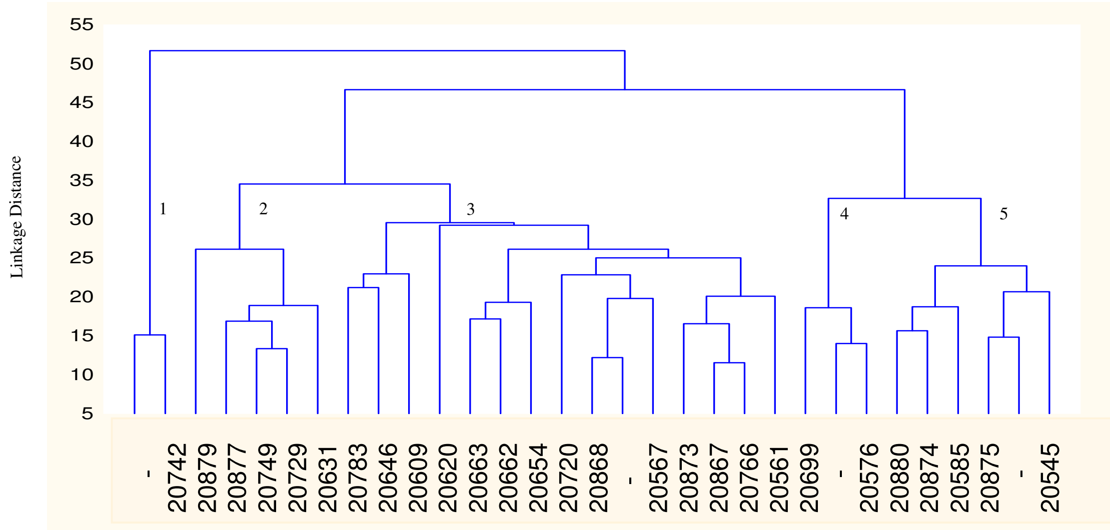

Figure 4. Phenogram of 31 genotypes of *Nigella sativa* L. germplasm based on UPGMA

Summary statistics for agro-morphological traits (grain yield per plant, biological yield, and harvest index), nutritional characters (oil, protein, carbohydrates, fibre, etc.) and mineral nutrients (Fe, Ca, Cu, Mg, ph, Mg, zn, Co, Mn, Na, P, B, K and N) are presented in Table 9. The wide range for all traits indicated the scope of simple selection from material evaluated in the study. Mineral nutrient data showed quantitative differences, Mg and Ca are highest as compared with other secondary and micro-nutrients.

Table 9. Descriptive statistics for agro-botanical traits, nutritional characteristics and mineral nutrients of *Nigella sativa* L. germplasm consisted of 36 genotypes

Traits	**Units**	**Mean ± SE**	**σ^2 % of Mean**	**Range**	**CV**
Agro-botanical plant traits					
Grain yield	Grams	5.75 ± 0.44	123.86	1.47 – 11.24	46.42
Biomass	Grams	23.98 ± 1.49	334.86	7.96 – 46.34	37.37
Harvest Index	Percent	24.52 ± 0.83	100.67	13.28 – 31.33	20.26
Nutritional characteristics					
Oil contents	Percent	31.16 ± 0.23	5.98	28.40 – 34.33	4.38
Protein	Percent	22.10 ± 0.25	10.56	19.21 –26.28	6.91
Carbohydrates	Percent	25.47 ± 0.62	53.70	14.71 – 30.80	14.52
Ash	Percent	5.07 ± 0.07	3.81	3.52 – 6.06	8.67
Moisture	Percent	5.89 ± 0.05	1.53	5.42 – 6.74	5.10
Fiber	Percent	10.52 ± 0.39	52.08	6.03 – 15.08	22.24
Hexane	Percent	0.26 ± 0.01	1.66	0.17 – 0.52	25.33
C:M (2:1)	Percent	0.38 ± 0.03	7.08	0.22 – 1.04	43.45
C:M (1:3)	Percent	0.30 ± 0.03	8.52	0.13 – 0.81	53.48
Mineral nutrients					
Nitrogen (N)	Percent	3.57 ± 0.09	8.96	1.67 – 5.56	15.83
Iron (Fe)	mg/kg	0.26 ± 0.02	4.11	0.10 – 0.74	39.51
Calcium (Ca)	mg/kg	9.13 ± 0.16	9.86	7.38 –10.83	10.39
Copper (Cu)	mg/kg	0.03 ± 0.00	0.05	0.02 – 0.03	14.77
Magnesium (Mg)	mg/kg	10.20 ± 0.09	2.66	9.40 – 11.56	5.11
Lead (Pb)	mg/kg	0.06 ± 0.00	0.58	0.02 –0.09	31.38
Zinc (Zn)	mg/kg	0.05 ± 0.00	0.57	0.01 – 0.09	34.51
Cobalt (Co)	mg/kg	0.03 ± 0.00	0.61	0.00 –0.06	45.68
Manganese (Mn)	mg/kg	0.05 ± 0.00	0.31	0.03 – 0.07	25.49
Sodium (Na)	mg/kg	0.35 ± 0.02	4.70	0.17 – 0.68	36.64
Phosphorus (P)	Percent	0.57 ± 0.01	0.19	0.50 –0.66	5.83
Boron (B)	Ppm	23.68 ± 0.99	150.47	12.78 –39.58	25.21
Potassium (K)	Percent	0.83 ± 0.01	0.85	0.63 –0.99	10.14

e) *Plantago ovata*

Plantago ovata is an important winter herb with sintgnific medicinal value and adapted to dry and marginal lands. Forty seven accessions collected locally and imported from the USA were characterised for plant height, tillers per plant, inflorescene length, 1000 seed weight and seed yield. High genetic variance was observed for tillers and grain yield, and moderate variation for plant height (Table 10). The low variability for other traits revealed a need to explore a greater range of genetic resources. Expansion of genetic variability for tillers and yield, together with plant height resulted in the appearance of a number of more productive forms. Figure 5 presents the clustering pattern of 47 accessions for 5 agronomic traits. Four clusters were observed at 50% linkage distance. Cluster 1 consisted of 13 accessions, three from Pakistan and 10 from USA, cluster 2 included 17 accessions, 12 from Pakistan, 2 from India and 3 from USA. All thirteen accessions of cluster 3, were from the USA, while cluster 4 consisted of four accessions and out of these two were from India, one each from the USA and Mexico. On the basis of cluster analysis, a clear indication was given that origin of germplasm helped in describing genetic diversity related to geographic origin Genetic diversity was related to origins/collection sites of the germplasm that indicated the potential for future exploration mission and acquisition. It is suggested that selected accessions be tested under a wide range of environments to find the best adapted cultivars to ensure good harvests.

Table 10. Basic Statistics for 47 accessions of *Plantago ovata*

Traits	**Units**	**Mean + SE**	**SD**	**Range**	
				Min.	**Max.**
Plant height	Centimeter	31.66 + 0.50	3.40	22.3	38.3
Tillers per plant	Number	16.64 + 0.150	10.07	5.6	49.7
Inflorescence length	Centimeter	3.84 + 0.11	0.72	2.7	5.7
1000-grain weight	Grams	1.72 + 0.04	0.27	1.25	2.75
Grain yield	Grams	45.39 + 3.09	21.17	8.72	96.27

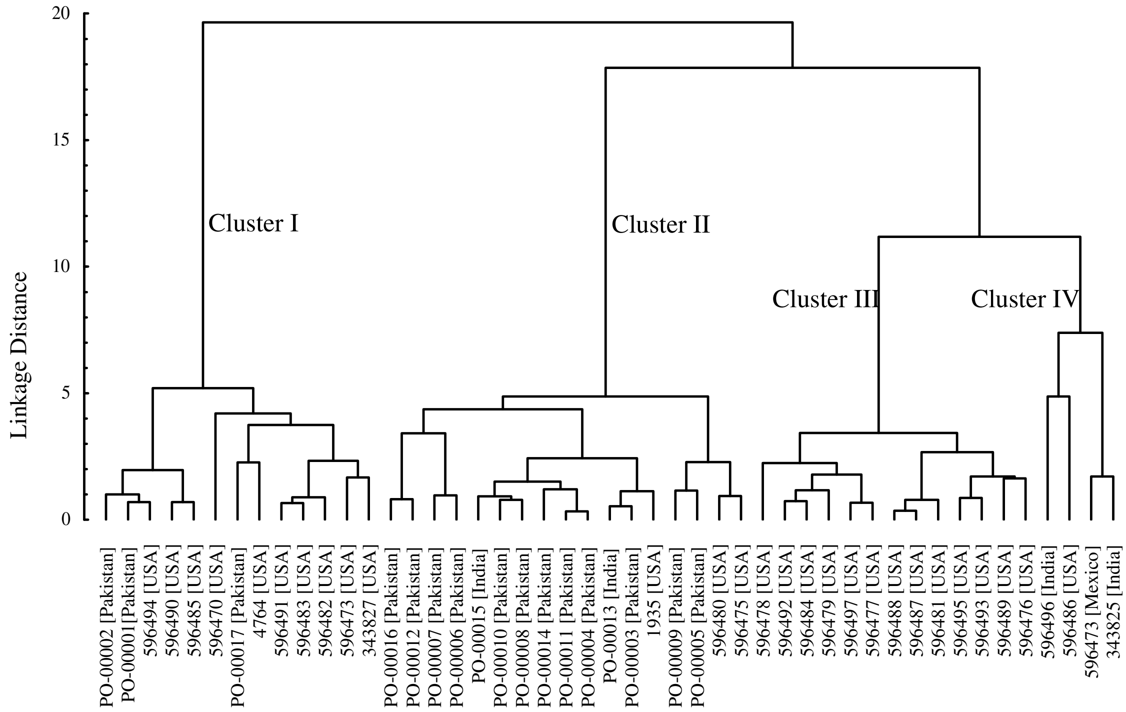

Figure 5. Cluster patter of *Plantago ovata* germplasm

f) *Ricinus communis*

Thirty three local and exotic accessions of *Ricinus communis* were evaluated for qualitative and quantitative traits and high level diversity was recorded (Table 11). Highly significant positive correlations were observed between number of spikes and plant height, number of bolls and number of spikes, number of branches and plant height, yield per plant and plant height. Highly significant negative correlation was found between hundred seed weight and yield per plant, days to first flower and plant height.

Table 11. Summary statistics on inter accession variation in Castor (*Ricinus communis*)

Name of Trait	Mean	S.E.	Mean±SE	S.D.	Var.	Min.	Max.
Plant Height	76.41	4.36	76.41±4.36	25.03	626.28	29.40	126.00
Chlorophyll Contents	37.13	0.72	37.13±0.72	4.15	17.25	27.00	43.14
Number of Spikes	2.71	0.28	2.71±0.28	1.59	2.54	1.33	9.20
Number of Bolls	43.47	6.21	43.47±6.21	35.66	1271.94	10.00	147.80
Number of Nodes	17.03	0.74	17.03±0.74	4.27	18.27	10.33	29.00
Number of Branches	4.01	0.30	4.01±0.3	1.75	3.08	2.25	9.70
Yield per Plant	21.75	3.99	21.75±3.99	22.94	526.43	1.80	100.56
Hundred Seed Weight	22.50	1.04	22.5±1.04	6.00	36.00	11.59	36.04
Days to First Flower	85.94	2.59	85.94±2.59	14.86	220.93	58.00	114.00
Days to Maturity	145.12	3.48	145.12±3.48	20.01	400.42	108.00	170.00
Oil Contents	32.45	0.53	32.45±0.53	3.03	9.17	25.88	39.26

The accessions were also evaluated for total seed proteins using SDS-PAGE and data recorded were subjected to cluster analysis (Fig.6) which revealed that evaluated germplasm has diversity independent of the origin or source as the accessions of the same origin or source may be grouped into different clusters.

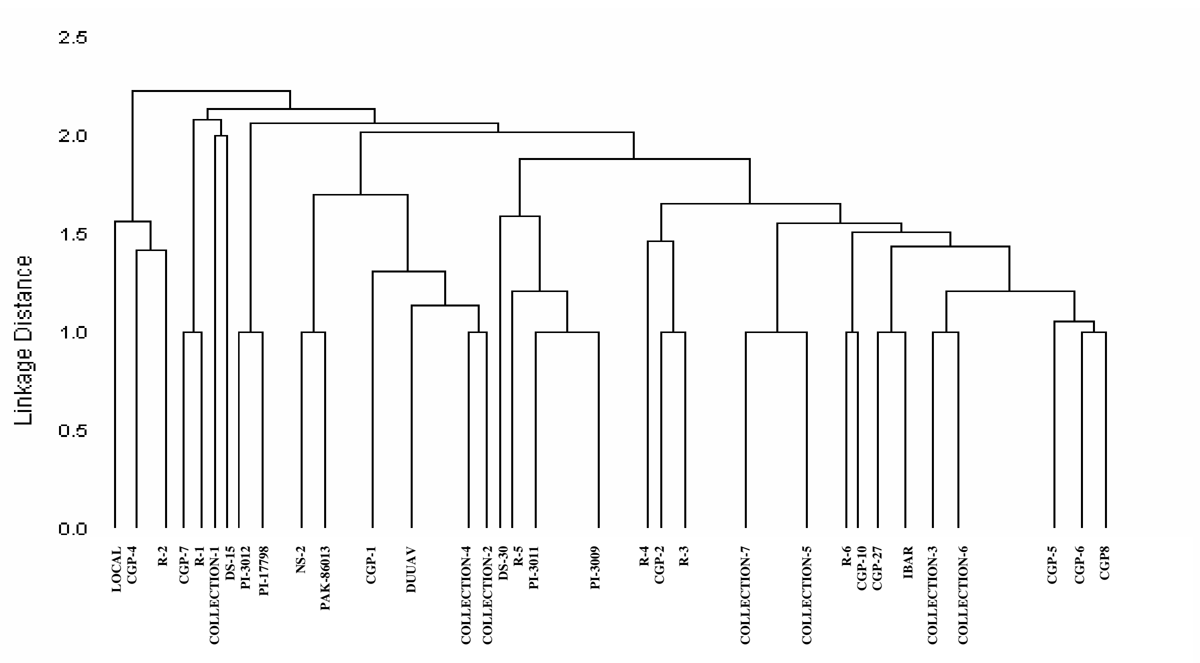

Figure 6. Dendrogram of 33 Castor accessions based on SDS-PAGE markers

g) *Sesamum indicum*

Sesamum indicum germplasm comprising 141 accessions was evaluated and high genetic variability was recorded for number of branches per plant, number of seeds per capsules, plant height, biomass and grain yield (Table 12).

Table 12. Summary statistics of 141 accessions of *Sesamum indicum* germplasm

Traits	Mean $\pm$ SE	SD	Range	
			Min.	Max.
No.of Branches per plant	48.83$\pm$1.24	14.75	5	88
Capsule length (cm)	2.36$\pm$0.03	0.32	0.49	3.86
No. of seeds per capsule	46.87$\pm$1.37	16.30	2.93	83.06
Plant height (cm)	160.39$\pm$1.39	16.58	96	199.6
Biomass (g)	327.46$\pm$13.33	158.8	50	850
Grain yield (g)	50.17$\pm$3.09	36.77	0.73	188.4
Harvest index (%)	14.77$\pm$0.61	7.29	0.36	34.66
100 seed weight (g)	0.29$\pm$0.00	0.05	0.16	0.41

SE= Standard Error, SD= Standard Deviation

A low level of genetic variability was observed in capsule length, harvest index, and 100-seed weight. A correlation table (Table 13) was compiled to compare eight quantitative traits. Biomass was found to have a highly significant correlation with number of branches per plant (0.451**), number of seeds per capsule (0.47**) whereas it was significantly associated with capsule length. Grain yield was highly significantly associated with number of branches per plant (0.266**), capsule length (0.261**), number of seeds per capsule (0.447) and biomass (0.769**). Harvest index was associated highly significantly with 100 seed weight. Harvest index interestingly showed negative correlation with harvest with 100 seed weight and capsule length. Likewise plant height was also in negative association with biomass, grain yield, harvest index and 100 seed weight, thus giving a new direction towards crop improvement for short stature.

Table 13. Correlation coefficients of eight quantitative traits of *Sesamum indicum* L.

Traits	No. of Branches/ Plant	Capsule Length (cm)	No. of Seed/ Capsule	Plant Height (cm)	Biomass (g)	Grain Yield (g)	Harvest Index (%)
Capsule length (cm)	-0.090						
No. of seed/capsule	0.157	0.446**					
Plant height (cm)	0.118	-0.006	-0.014				
Biomass (g)	0.451**	0.243*	0.471**	-0.005			
Grain yield (g)	0.266**	0.261**	0.447**	-0.150	0.769**		
Harvest index (%)	-0.053	0.192	0.231*	-0.208	0.131	0.681**	
100 Seed Weight (g)	-0.092	0.081	-0.063	-0.182	0.063	0.251*	0.305**

*Significant,**Highly significant at $P \leq 0.05$

h) *Trigonella foenum graecum*

Fifty five accessions of *Trigonella foenum graecum* were evaluated for qualitative and quantitative traits. High variability was recorded for plant height, number of pods per plant, pod length, seed yield and harvest index (Table 14). Low variability was recorded for number of seeds per pod and days to maturity. Data presented in Table 15 reveal that significant correlation exists for days to flowering with 100 seed weight and plant height with 100 seed weight, and number of pods with biomass. Evaluation data may assist selection of desirable genotypes to be used in breeding programs.

Table 14. Summary statistics of 55 accessions in *Trigonella foenum graecum*

Traits	Mean ± SE	σ	Range	
			Min.	Max.
Days to Flowering	98.2± 0.211	1.568	97	101
Plant Height (cm)	64.44± 1.108	8.216	45	81.4
Number of Pods per Plant	58.44±2.835	21.025	28	139
Number of Seeds per Pod	35.236±21.811	161.756	10.97	12.13
Pod Length	9.585±0.125	0.926	6.96	12.07
Days to Maturity	159.01±0.269	1.995	155	166
Biomass (g)	80.113±5.123	37.996	27.63	234.6
100 Seed Weight (g)	1.115±0.015	0.113	0.901	1.356
Seed Yield (g)	17.700±0.857	6.352	5.51	31.52
Harvest Index (%)	24.14 ±1.289	9.560	8.6	48.2

Table 15. Correlation coefficients between eight quantitative traits in *Trigonella foenum graecum*

	Days to flowering	Days to maturity	Plant height (cm)	No. pods/ plant	No. seeds /pod	Biomass (g)	100 seed weight (g)	Seed Yield (g)	Harvest index (%)
Days to Flowering	0.076								
Plant Height (cm)	0.025	-0.070							
Number of Pods/plant	0.013	-0.097	-0.076						
Number of Seeds/pod	-0.06	-0.068	0.205	0.097					
Pod Length	-0.102	-0.055	-0.109	0.191	0.084				
Biomass (g)	0.067	-0.068	0.055	0.336*	0.023	0.139			
100 Seed Weight(g)	0.270*	-0.060	0.347**	-0.143	-0.173	-0.059	-0.100		
Seed Yield (g)	-0.012	-0.054	-0.038	0.213	0.073	-0.074	0.536**	-0.038	
Harvest Index (%)	-0.106	-0.075	-0.097	-0.232	0.004	-0.206	-0.515	0.059	0.341**

*Significant, **Highly significant at P≤0.05

Acknowledgements

The financial support from Pakistan Agricultural Research Council under Agricultural Linkage program (ALP) and Centre of Under-utilised Crops of Southampton University, U.K. is greatly acknowledged. The authors are also thankful to scientists/staff of Plant Genetic Resources for their help in collecting and evaluation of germplasm. The cooperation of farmers for providing assess to germplasm and providing land for demonstration plots is greatly acknowledged.

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17

Ricebean: a multipurpose underutilised legume

K.D. Joshi, B. Bhandari, R. Gautam, J. Bajracharya and P.A. Hollington

Ricebean (*Vigna umbellata*) is a neglected legume regarded as a minor food and fodder crop in Nepal and northern India, and grown in range of cropping systems with maize during summer, as a sole crop in the uplands, on rice bunds or in home gardens. It is mainly grown for human consumption, though it is also used for fodder and green manure. There has been very little research or development support for this crop and farmers mainly grow landraces. There is no published literature on ricebean regarding its area coverage, production, productivity, utilisation and marketing. It is grown by subsistence farmers in a very limited scale and most of the produce is consumed at home, although there is a limited market for a short period each year. The crop contributes to household food security; several food items are prepared from ricebean, it is culturally important and is thought to have important nutritional values. Ricebean foliage and dry straw are valuable livestock feed, and when used as a green manure it improves soil fertility. This paper describes diversity in ricebean germplasm, indigenous knowledge in Nepal on ricebean, farmers' preferences and future prospects for the crop.

INTRODUCTION

Like other Vigna species, ricebean (*Vigna umbellata*) is a warm-season annual. Grown mainly as a dried pulse, it is also important as a fodder and as a green manure. The dried seeds are highly nutritious and as the protein is high in lysine they make an excellent addition to a cereal-based diet. The seeds are also high in mineral content, and in vitamins, including thiamine, riboflavin, niacin and ascorbic acid.

The presumed centre of domestication is Indo-China – it is thought to be derived from the wild form *V. umbellata* var *gracilis*, with which it is cross-fertile, and which is distributed from Southern China through the north of Vietnam, Laos and Thailand into Burma and India (Lawn, 1995; Tomooka *et al.,* 1991). Wild forms are typically fine-stemmed, freely-branching and small-leaved, with a twining habit, photoperiod sensitivity and indeterminate growth (Lawn, 1995). Flowering is asynchronous, and there is a tendency to hard seeds. In many areas, landraces which retain many of these characteristics persist, in particular with regard to daylight sensitivity, growth habit and hard seeds.

Ricebean is a neglected crop, cultivated on small areas by subsistence farmers in hill areas of Nepal, northern India and parts of SE Asia. It can be grown in diverse conditions and is well known among farmers for its wide adaptation and production even in marginal lands, drought-prone sloping areas, and flat rainfed *tars* (unirrigated, ancient alluvial river fans). It is mainly grown between 700 and 1300 m a.s.l., although in home gardens it is found from 200 up to 2000 m. There is almost no published literature on ricebean in Nepal, even grey literature with relevant information on its area and distribution and the potential of the crop is lacking. Most of the crop currently grown in Nepal is used for human nutrition, with a smaller proportion used for fodder and green manuring. Generally, ricebean is grown as an intercrop with maize, on rice bunds or on the terrace risers, as a sole crop on the uplands or as a mixed crop with maize in the *khet* (bunded parcels of lands where transplanted rice is grown) land. Under mixed cropping with maize it is usually broadcast some time between sowing maize and that crop's first and second earthing up, so ricebean sowing extends from April-May to June.

The crop receives almost no inputs, and is grown on residual fertility and moisture and in marginal and exhausted soils. Anecdotal evidences indicate that the area and production of ricebean in Nepal is declining due to the introduction of high yielding maize varieties and increasing use of chemical fertilisers, while consumption is decreasing due to increased availability of more preferred pulses in the local markets. No modern plant breeding has been done and only landraces which have low yield potential are grown. These have to compete with other summer legumes such as soybeans (*Glycine max*), black gram (*Vigna mungo*), cowpea (*V. unguiculata*), common beans (*Phaseolus vulgaris*) and horse gram (*Mactotyloma uniflorum*). Other production constraints that limit the production of ricebean include small and fragmented land holdings and declining productivity.

So far little has been done to exploit the potential of ricebean. It is well adapted to the humid tropics and does well on many soil types, but has several features that need attention before it could be widely adopted. Most varieties are highly photoperiod sensitive, and when grown in the Nepal are late flowering and have strong vegetative growth. Their twining habit makes them very suitable for use as intercrops with such species as maize, sorghum and millet, which can provide support, but also makes them difficult to harvest. Many current varieties are susceptible to shattering, and show high levels of hard seededness.

There is no institutional support either from research or from the extension services for the development and promotion of this crop. Despite this, as a legume ricebean should have an important contribution to make to mixed subsistence farming systems, it is important culturally, and is thought to possess important nutritional characteristics which could give it a major role in improved diets and food security in the areas where it is currently grown and elsewhere. This paper describes the initial work of a major initiative under the INCO programme of the European Commission's Sixth Framework Programme (FP6), FOSRIN (Food Security through Ricebean Research in India and Nepal), which aims to popularise ricebean on a wider scale, assess economic (production chain) and nutritional aspects of the crop, and evaluate the range of germplasm and indigenous knowledge available.

METHODS AND MATERIALS

Germplasm evaluation

Ricebean germplasm was collected by the Plant Genetic Resources unit of the Nepal Agriculture Research Council (NARC) from 25 districts of the country in various missions between 1972 and 1994. In April-May 2006, germplasm was also collected from 16 districts of Nepal (eight of those districts previously not covered) by mobilising two non-government organisations, the SUPPORT Foundation (8 districts) and the Rapti Agriculture Graduates Society (RAS)-Nepal (3 districts). Local Initiatives for Biodiversity, Research and Development (LI-BIRD) (3 districts), CAZS-Natural Resources (CAZS-NR) and NARC (2 districts) also collected germplasm. In total 273 ricebean accessions collected from over 30 districts in Nepal were evaluated at 2 sites in summer 2006 (Table 1, Figures 1). The process was coordinated by LI-BIRD.

Table 1. Districts and organizations involved in ricebean landraces in collection in Nepal, 1972 – 1994 and 2006

Name of district	**No. of accessions**	**Collected by**
Arghakhanchi, Baitadi, Bajura, Bajhang, Bhaktapur, Bhojpur, Dang, Dhankuta, Gorkha, Gulmi, Humla, Ilam, Jhapa, Kabhre, Kalikot, Khotang, Lalitpur, Lamjung, Mugu, Myagdi, Nuwakot, Okhaldungha, Pyuthan, Tanahun, Terhathum	117	NARC (historical)
Achham, Bajura, Baitadi, Bajhang, Dadeldhura, Doti, Darchula, Surkhet,	71	SUPPORT Foundation
Gulmi, Kaski, Palpa	48	LI-BIRD
Kabhre, Nuwakot	17	CAZS-NR/NARC
Dang, Pyuthan, Salyan	20	RAS-Nepal
Total	273	

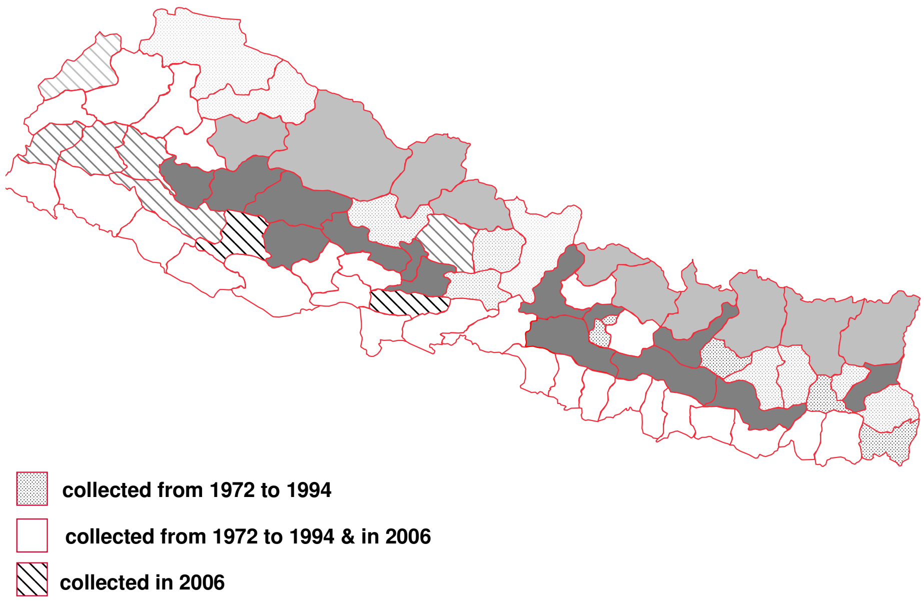

Figure 1. Ricebean germplasm collection in Nepal from 1972 to 1994 and in 2006. High hill and mountain districts are shown in light grey, mid hills in dark grey and terai in white.

Initial germplasm evaluation in 2006 was carried out at two sites; the NARC Research Farm at Khumaltar, Lalitpur (1350 m), and with farmers of the Darbar Devisthan Village Development Committee (VDC – the smallest political unit in Nepal) in Gulmi district (1500 m) in the Middle Hills (Figure 2).

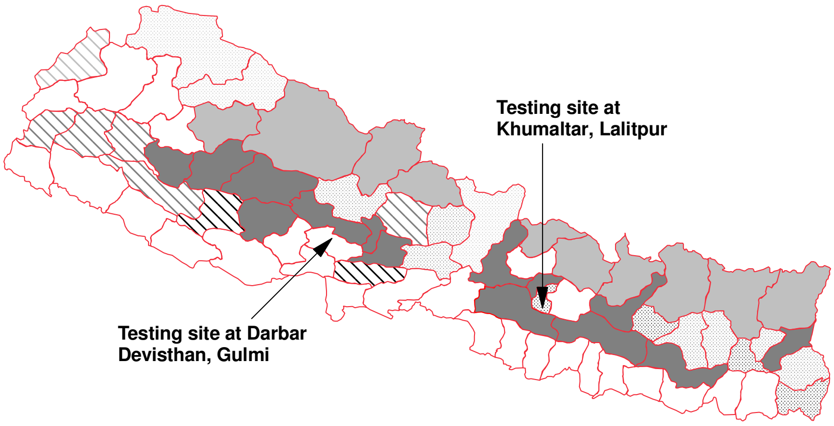

Figure 2. Ricebean germplasm evaluation sites in Nepal, 2006. High hill and mountain districts are shown in light grey, mid hills in dark grey and terai in white.

Germplasm evaluation on-station

The germplasm evaluated at Khumaltar included the historical collections (117 accessions) collected from 1972 to 1994. These were evaluated in raised single row plots of 2 m length with a spacing of 25 cm between plants. Three seeds were planted per hill and subsequently two seedlings were thinned out after the crop was fully established. The plots were managed in the same way as farmers' customary practices, and neither fertiliser nor irrigation were applied. Various agro-morphological traits were recorded at different crop growth stages (Table 2) following the "Descriptors for grain legumes and oil seed crops" (Anonymous, 1995).

Germplasm evaluation on-farm

156 germplasm accessions collected in 2006 from various parts of Nepal were planted for on-farm evaluation on 15-16 June 2006 at Darbar-Devisthan VDC in Gulmi district. Gulmi was selected for this as it represents a typical ricebean domain in the middle hills of Nepal, with predominantly sloping *bari* land (upland with big terrace risers) and low average rainfall. Another important feature of Gulmi is that traditionally farmers grow a range of legume species including ricebean in their *bari* lands, and so are very experienced in terms of indigenous knowledge related to the cultivation and utilisation of this crop. Ricebean currently occupies over 100 ha in Gulmi district (personal communication, District Agriculture Development Officer). As a result, using Gulmi would provide additional knowledge on the practices adopted by farmers for the cultivation of a range of legumes including ricebean.

The on-farm evaluation was managed by LI-BIRD. The trial was grown as a sole crop in a non-replicated observation nursery with two rows each of 4 m length (16 plants per plot). The crop was grown following farmers' customary agronomic practices, ploughing the land twice after applying farm yard manure (FYM) at a rate of 7.5 t/ha. No chemical fertilisers were used in the trial. Three seeds per hill were sown on raised beds with a spacing of 1 m between rows and 50 cm between plants. A single plant was retained after full establishment. Three weedings were done, the first 48 days after seeding (DAS), the second at 75 DAS and the third at 104 DAS (at flowering). Since most accessions were of indeterminate growth habit staking with bamboo sticks was provided at 72 DAS for all plants showing an indeterminate growth habit. A range of agro-morphological parameters were evaluated (Table 2).

Table 2. Agro-morphological parameters studied during germplasm evaluation

Germplasm evaluation	Parameters covered
On farm	Dates of planting, flowering and maturity; growth habit, plant height at maturity, flower colour, pod length, number of pods per plant, number of seeds per pod, 100 seed weight, seed colour, total grain yield per plant
On Station	Dates of planting, flowering and maturity; growth habit, yield and yield components; number of pods per plant, 100 grain weight and grain yield per plant, disease and pest reactions

Some of the germplasm collected in 2006 did not germinate due to poor seed quality or hard seededness, while several others had poor growth, and some accessions were morphologically very similar to cowpea and black gram. As a result, data were collected and analyzed from only 74 of the accessions. Because of the indeterminate growth habit, time to maturity varied greatly between accessions, and harvesting ranged from September to November. As the first year study was carried out in order to developing a suitable protocol for more detailed work in the second year, the observations were recorded only from single plants and so could not be statistically analysed.

Indigenous knowledge and relative importance of ricebean

Farmers compared ricebean with most commonly grown legumes in the area, listed by the farmers as cowpea (locally called *swosta)*, pea (*Pisum sativum*), winter bean, *Gahate simi (Phaseolus lunatus),* lentil (*Lens culinaris*) and ricebean. A comparison was made considering taste, perceived nutritional value, and various usages.

Farmers' preferred trait analysis (PTA) and preference ranking for ricebean

Ricebean is commonly known as *Jhilinge* in the area. A preferred trait analysis (PTA) was carried out with farmers of the Darbar Devisthan VDC. A total of 325 farmers including women participated in a Focus Group Discussion (FGD) arranged for this purpose, although only 21 were found to be currently growing ricebean. An additional FGD was carried out in Ilam district. The FGDs collected farmers' perceptions on cultivation, cropping patterns, seed availability, uses, specific characters, and identified various constraints associated with ricebean cultivation and marketing. A preference ranking for the most commonly grown ricebean landraces was also done. Market price was not included in the analysis as most of the produce was consumed locally.

RESULTS

Germplasm evaluation on-station

Ricebean varietal diversity: Variation for flowering and maturity between the accessions was quite high, and ranged from 61-104 days for flowering and 99-134 days for maturity. The high standard deviation indicated that accesions varied greatly for these traits, although the coefficient of variation for some of the quantitative traits was not high (7-8%) (Table 3). NPGR-05565, NPGR-06657 and NPGR-08380 were particularly early maturing. Yield and yield components showed very high variation, with some accessions very high yielding, for example NPGR-00195 (1300 g/m^2) and NPGR-05432 (1200 g/m^2). These results indicate that there is a great potential for making genetic advance through breeding or even through germplasm enhancement as these traits vary quite high.

Some of the accessions were infected with diseases and insect pests at flower initiation and pod formation. Rust, *Cercospora* leaf spot and web blight (*Rizoctonia* sps) were the major diseases recorded. These were scored, based upon damage. Web blight greatly affected the plants, with drying of foliage in NPGR-05382, NPGR-05432, NPGR-06591, NPGR-06657, NPGR-08380. The incidence of aphid infestations was also recorded. Most accessions from Illam, Bhojpur and Dhankuta were more resistant to rust, blight and *Cercospora* spots.

Table 3. Descriptive analysis of quantitative traits in ricebean landraces, Khumaltar, Nepal, 2006

Quantitative traits	**Mean**	**Range**	**Standard deviation**	**Coefficient of variation**
Leaflet length (cm)	11.7	7.0-14.3	0.89	0.08
Leaflet width (cm)	8.3	4.5-10.4	0.66	0.08
Days to flowering	87.1	61-104	9.02	0.10
Days to first mature pod	121.6	99-134	8.25	0.07
Pod length (cm)	7.7	5.3-11.6	1.38	0.19
Number of seeds per pod	6.7	5-9	0.88	0.13
100 seed weight (g)	6.8	5.2-8.9	0.77	0.11
Yield g-^{m2}	939.7	500-1300	150.87	0.15
Seed length (mm)	6.1	4.26-7.8	0.80	0.14
Seed width (mm)	3.3	2.54-3.98	0.33	0.10
Seed thickness (mm)	4.1	3.1-4.76	0.31	0.07

Promising accessions from the medium and late categories were selected for further analysis during the coming season, and for entry into mother-baby trials.

An analysis of the qualitative and quantitative data together was performed to show the genetic relationships between the accessions and their agro-ecological differentiation .High diversity was found between the accessions for most qualitative and quantitative traits, and two distinct groups were identified (Figure 3). The observed traits explained 38.4% of the total variation and showed a geographical cluster of genotypes in the western part of Nepal from the mid to the high-hills. Qualitative traits such as growth pattern, flowering behaviour and maturity were important for this clustering (Figure 3).

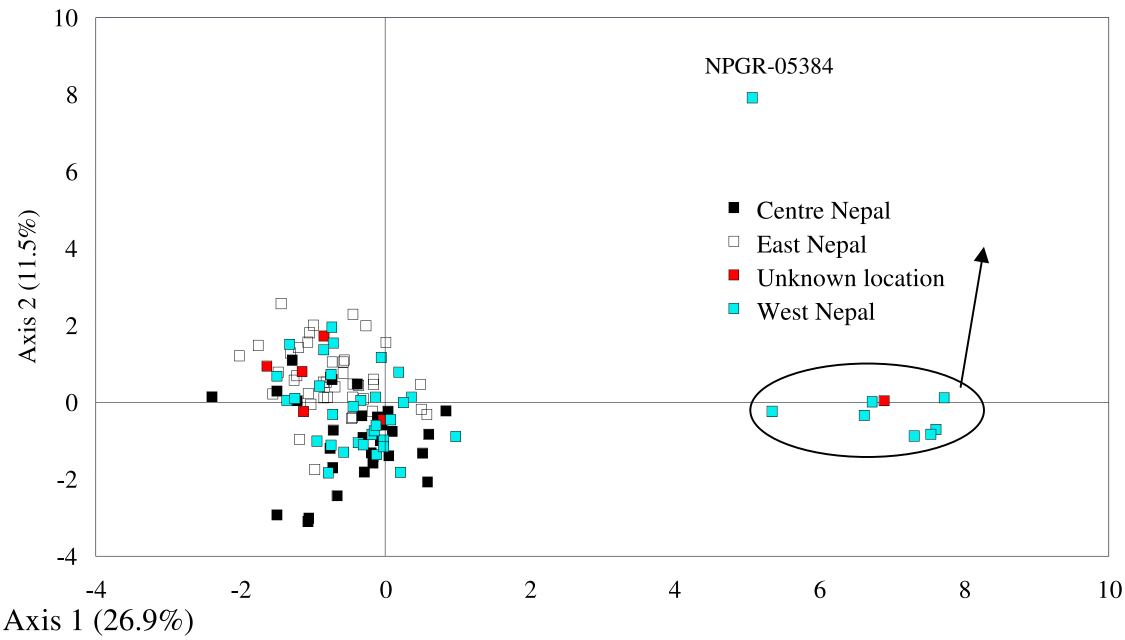

Figure 3. Scatter plot of ricebean landraces of Nepal collected from 1972 to 1994

Accessions NPGR-05384, NPGR-05386, NPGR-05388, NPGR-05435, NPGR-05436, NPGR-6591, NPGR-06725, NPGR-06756 and NPGR-07883 from high altitude sites (Humla, Mugu and Bajura) and a mid-hill site (Baitadi) were distinct and showed geographical differentiation. The important traits for this were growth pattern, twining tendency, days to 50% flowering and days to first pod maturity. All these accessions were determinate, with non-twining tendency but varied in flowering and first pod maturity, which ranged from 61-102 days for flowering and 99-134 days for maturity. Most accessions from Humla were early maturing, although a determinate accession from Mugu (NPGR-05384) was as late as the indeterminate types. Phenotypic diversity was higher for leaf pubescence (Shannon-Weaver index H = 0.67), flowering period (0.78), pod pubescence (0.77), number of seeds per pod (1.15), seed shape (0.55) and seed colour (0.50) with the overall index H' = 0.525.

In this diversity study the growth habit, duration of flowering, seed colour and size were the most important traits and showed high phenotypic diversity. Variation was observed between ricebean accessions for flowering and maturity period and for yield potential. These findings indicate great potential for improving ricebean through breeding. However, they are still preliminary and need further study before they can be confirmed.

On-farm evaluation

Ricebean accessions were evaluated in the field for phenology, yield and yield components and insect and disease reactions during the 2006 cropping season. Based upon days to maturity, 74 accessions were grouped into three major categories. The majority (48) were of medium maturity, and matured between 120 and 140 days from the time of seeding (Table 4). Only four accessions were early, while 22 took over 140 days to mature after planting.

Table 4. Category of accessions on the basis of maturity period in 2006

Maturity group	Maturity days after seeding	Number of accessions
Early	<120 days	4
Medium	120-140 days	48
Late	>140 days	22

The difference in flowering time between the early and medium groups was much wider than between the medium and late maturing groups. It is interesting that although the early maturing groups were tallest and had the most pods and seeds per pod they still gave the lowest yields. This was because all the early accessions matured during the peak rainy season, when grain filling was very poor, evident from the low seed weight of these accessions. The seeds of the late group were twice as large than the early ones, while the grains of the medium group were almost 43% larger than those of the early group (Table 5).

Table 5. Descriptive analysis of quantitative traits of early, medium and late maturing ricebean landraces, Darbar Devisthan, Gulmi, Nepal, 2006

Quantitative traits	Early		Medium		Late	
	Range	Mean	Range	Mean	Range	Mean
Days to flowering	55-79	76	75-112	91.8	95-112	98.9
Days to first mature pod	118	118	132-139	136.3	143-151	148.1
Plant height (cm)	190-212	199	119-273	186.7	129-268	195.3
Pod length (cm)	7-8.6	7.73	5.9-11.6	8.6	7-10.8	8.2
Number of pods per plant	121-353	268	58-516	241.1	35-285	158
Number of seeds per pod	7.2-8.1	7.7	2.4-9.5	6.9	4-7.2	5.9
100 seed weight (g)	4.3-7	6.1	5.3-14.3	8.7	6.6-23.4	12.2
Yield per plant (g)	47.7-161.3	86.9	26.1-274.4	103.2	27.1-170	81.1

This is important, as grain size is one of the most important parameters in terms of market price. Early maturing varieties could have a problem of small grain size, and in addition as they these will be harvested during the monsoon grain quality is likely to be poor due to low sun shine and high moisture during ripening and drying.

Out of seventy four accessions evaluated in 2006, 14 accessions from the medium group and 8 from the late group performed well for a number of economically important traits, for example number of pods per plant, grain yield and 100 seed weight. The germplasm also showed great diversity in seed colour.

A principal components analysis was carried out for the accessions collected in 2006 based on time to flowering and maturity, plant height, pod length, number of pods per plant, number of seeds per pod, 100 seed weight and total seed yield per plant. These traits showed the discrete diversity between the ricebean landraces. Unlike the historical accessions, there was no distinct clustering for the germplasm collected in 2006, although the accessions were also quite diverse for the traits analysed (Figure 4).

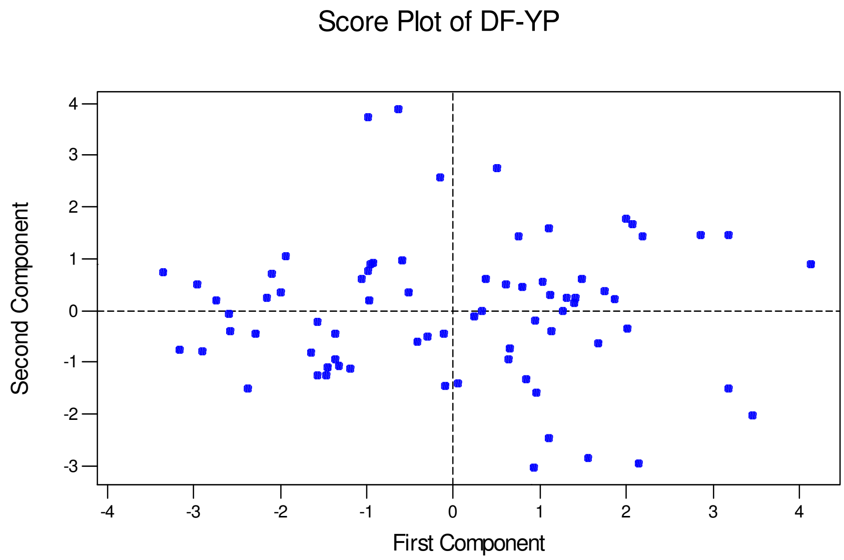

Figure 4. Scatter plot of ricebean landraces of Nepal collected in 2006

Farmer description of ricebean germplasm. Preliminary findings from FGDs in Gulmi and Ilam revealed that at least five types of ricebean are widely known. The farmers' descriptors mainly revolve round the colour and size of the grain (Table 6). *Kalo* (black) *masyang* is the most prevalent as it gives the highest yield and is also good for making *dal* (soup). *Rato* (red) *masynag* and *Thulo masyang* (large ricebean) are less common. The quality of the beans of *Rato Masyang* is not considered good, but although_*Thulo masyang* is also less common it makes good *dal* and fetches a good price. It is a climber and can reach a height of 5-6 m if grown on poles or on trees. It may yield 2-4 kg of seed per plant. The seeds are yellowish or white and nearly round and have about the same shape as cowpeas. It appears to grow at a slightly higher altitude than the other varieties.

Pahenlo masyang (yellow ricebean), found in both determinate and indeterminate forms, is grown on *khet* terraces. The indeterminate trailing type is most commonly intercropped with maize.

Ghore or Khairo (brown) has large speckled beans and can be seen growing on stakes. The plant can be quite large and probably yields more fodder than grain, but the taste is not so good and marketing is difficult as a result.

In general ricebean *dal* is not preferred over that made from other pulses due to its strong taste and pungency. Of the ricebean *dals*, *Kalo* is the most preferred, followed by *Khairo* or *Ghor,e* while *Pahenlo Masyang* is considered to be the worst for *dal* due to its pungency. Unlike other legumes, the green pods of ricebean are not eaten as they are not tasty or smooth.

Table 6. Farmers' descriptors of major ricebean types in Durbar Devisthan, Gulmi and Ilam, Nepal 2006

Local name	English translation	Farmers' distinguishing traits
Gulmi		
Rato Jhilinge	Red ricebean	Red, small to medium sized grain, medium in maturity, drought tolerant, low yield
Khairo Thulo Jhilinge	Brown and bold grain	Brown with stripes and bold grains, late in maturity, high yielding
Seto Thulo Jhilinge or Pahenlo Thulo Jhilinge	White bold grain Yellow bold grain	Bold white to yellowish grains, late in maturity, high yields
Bhadaure Jhilinge	Early small seeded	Greenish to yellowish, small grains, early maturity, low yields
Ilam		
Rato masyang	Red ricebean	It is less common
Ghore masyang	Brown ricebean	Large, brown or speckled beans, grows on stakes and plant can be quite large. High fodder yields
Pahenlo masyang	Yellow ricebean	Short determinate form grown on *khet* terraces , indeterminate larger one intercropped with maize
Thulo masyang	Large ricebean	Climbs strongly and can reach 5-6 meters if grown on poles or in trees, seeds are yellowish with some variegations

According to the farmers, no ricebean landraces have yet been lost from the village although the area, production, productivity and consumption of ricebean is said to be declining each year. In some parts of Nepal, ricebean is only grown on the edges of fields or on terrace risers including one row within the maize field. If grown in the main field, the trailing vines can cause maize to lodge, so reducing the maize yield. In some areas, ricebean is increasingly mixed with sorghum, which supports it better than maize.

Indigenous knowledge of ricebean on food and cultural values

Ricebean is known by several vernacular names, e.g. *Masyang, Jhilinge, Siltung*, and *Guruns.* It has multiple usages, and most parts of the crop are used for different purposes. For example the grains are used for making various kinds of food items (Table 7), in particular *dal*, *Biraula*, *Batuk* and *Masaura*. *Biraula* is a snack made of soaked ricebean either fried or steamed. *Batuk* is a deep fried cake made from the paste of black gram or ricebean or other legumes, made by crushing soaked grains of the legumes. *Masaura* is a kind of nugget made from the legume paste mixed with the chopped stalk of taro, preserved over several months and eaten in the form of curry with potato and other vegetables. Ricebean is also consumed as a snack, for example with roasted maize, and is eaten with local alcoholic drinks. It also has cultural importance, being used in local feasts or social gatherings as curry and in the form of snacks.

Table 7. Common uses of ricebean in Nepal with their importance

Plant part	Order of importance	Common uses	Preferred traits	Preferred landraces
Grain	1	*Dal,* curry, *Biraula, Batuk, Masaura, Khichadi (*rice and a legume cooked together: the proportion of rice is always more than of the legume), green pods for vegetable; snacks of various kind	Bold grains, higher yield, medium maturity, non-shattering determinate to semi determinate type, tasty, tolerant to high intensity of rainfall during early flowering stage	White large, brown large in terms of yield and grain size, taste but lack on other traits
Green foliage	2	Livestock fodder	Indeterminate type with luxurious vine growth, late maturity	Any late maturing, indeterminate landraces
Green foliage	3	Green manure	Indeterminate type with luxurious vine growth	Any late maturing, indeterminate landraces
Dry straw	4	Livestock feed		

There are some contradictions in farmers' opinions regarding the best season for eating ricebean. It is perceived to be a *cold* food, unsuitable for consumption during winter, particularly for children and old people, although in many parts of the country it is consumed during winter. However, framers from central Nepal confirmed that ricebean is mostly consumed between February and June (hot/warm season). People can consume it up to August provided when they think it is reasonably hot orwarm. It is definitely considered as a cold food and not consumed during winter or on a cold day or even on a rainy day during summer. In the same area the transaction of ricebean (sale or exchange) is also closely linked with consumption pattern, which occurs between December to May. It will be really difficult to find ricebean in the villages after the planting season, you may be lucky if you did find in the market!

Ricebean is also known to cause flatulence and is believed to cause gastritis, although the reasons behind this are unknown. Some of these issues need further validation through more detailed studies and nutritional analysis of the crop. Farmers also emphasised the need for research on the chemical composition and nutritional value of ricebean in order to develop it and promote its wider cultivation and use

Farmers also have an opinion on the value of different ricebean landraces for different purposes. For example *Seto Thulo* (white large) and *Khairo Thulo* (brown large) are considered the best for food, while landraces with a luxurious vegetative growth with indeterminate vines, that mature late and yield high biomass are preferred for fodder..Both *Seto Thulo* and *Khairo Thulo* were identified as suitable for fodder purpose (Table 7). Fodder yields are important in Nepal, where livestock play a major role in the farming system. For green manuring and soil improvement, farmers preferred landraces with many broad leaves and more vines and medium to late maturity, although they did not mention any specific landrace by name.

Preference ranking of ricebean against most commonly grown legumes in the area

The most commonly grown legumes in the areas where ricebean is grown are cowpea (*swosta)*, pea, winter bean, *Gahate simi (Phaseolus lunatus),* lentil and ricebean. Farmers ranked cowpea as the best, followed by pea in terms of taste, nutrition and common use value. Ricebean and *Gahate simi* were both ranked as the third most important legumes (Table 8). Lentil, another most common legumes, was not ranked in the top three.

Table 8. Farmers' preference ranking for common grain legumes at Darbar Devisthan, Gulmi, Nepal, 2006

Commonly grown legumes	Taste[†]	Nutrition	Used as *dal*[§]	Total	Farmers' overall preference ranking
Rice bean	3	4	3	10	3
Cowpea	1	2	1	4	1
Gahate simi	4	3	3	10	3
Pea	2	2	2	6	2
Winter bean	6	3	5	14	5
Lentil	5	5	4	14	5

[†] Rankings are based on the scores where lowest score is best and highest is worst, [§]*dal*/soup is most common use value of legumes in the area

Preferred trait analysis and preference ranking of ricebean in Darbar Devisthan

From the discussion it was found that around 80% farmers in the area grow ricebean, either on a small scale either fodder or green manure, or on a slightly larger area for grain and fodder as an intercrop with maize. The average land under ricebean was below one *ropani* (500 m^2) per household.

Farmers always preferred a ricebean variety with high grain and good fodder yield potential. Most gave equal importance to grain and fodder yields while selecting the variety, due to the importance of livestock in the farming system. Farmers emphasised the softness and palatability of the fodder by the animals. Grain colour did not seem to be of particular importance in the preference ranking. For market purposes, the farmer-preferred traits were:

- Bold seed size
- Good taste
- Attractive grain quality
- Uniformity (no varietal mixtures)

Farmers did not prefer early accessions due to their low grain yield and very small grain size: these mature during the peak rainy season (August-September) and have a higher number of chaffy pods. However, as such genotypes may not be appropriate as commercial varieties they may have an important role as parents for breeding programmes to reduce the maturity period of ricebean. There has also been little effort so far to exploit the options offered by short duration ricebean varieties to allow shor-duration winter crop to be grown on residual moisture after the ricebean harvest in September.

Landraces with bold (large) grain, medium maturity and semi-determinate growth habit are always preferred by farmers over fodder yield (Table 9), but landraces or varieties with such traits are not available.

Table 9. Preference ranking of ricebean landraces in Nepal†

Traits	***Rato* (Red)**	***Seto Thulo* (White bold)**	***Khairo Thulo* (Brown bold)**	***Bhadaure***
Yield potential	1	1	2	3
Grain type	2	1	1	3
Grain colour	3	1	2	3
Maturity	1	3	3	2
Shattering	2	2	2	1
Pod size	2	1	1	3
Drought tolerance	4	1	2	3
Taste	4	1	2	3
Market potential	4	1	2	3
Rainfall tolerance	2	3	3	1
Total	24	16	20	25
Rank	III	I	II	IV

† Rankings are based on the scores where lowest score is best and highest is worst

Farmers in Gulmi distinguished the following important traits for ricebean when grown for food, and ranked them in the following order of preference:

1. Higher grain yield (bold seed and more pods).
2. Determinate growth habit with erect plant type
3. Synchronization in maturity of upper and lower pods of the same vine
4. Suitable for intercropping and mixed cropping
5. Medium duration (second to third week of October) and semi determinate growth habit for good fodder yield
6. Good taste and nutritional value for human health, e.g. easy to digest
7. Tolerant to drought
8. Tolerant to high rainfall during flowering
9. Low shattering
10. Disease and pest tolerance

Farmers in Gulmi ranked *Seto Thulo* as the most preferred landrace overall, followed by *Khairo Thulo, Rato* and *Bhadaure* (Table 9).

The farmers would adopt several varieties to match specific niches in the farming systems. They have clear preference for larger, bold seeded varieties with determinate growth, giving more grain and fodder yield and a plant type which is suited for growing as an inter or mixed crop with maize, sorghum or on terrace risers. Farmers ranked these landraces according to their important features. Farmers also provided positive and negatives attributes of most common types of ricebean in Gulmi (Table 10). This analysis of their existing landraces indicated that farmers might be interested in improving the taste and eating quality, grain yield, maturity and growth habit of landraces suitable for intercropping with maize, if they could also provide a reasonable fodder yield.

Table 10. Farmers' description of positive and negative traits of landraces

Name of landraces	Positive traits	Negative traits
Rato Jhilunge (red ricebean)	Somewhat tolerant to heavy rain during early flowering stage, maturing at proper time (3rd -4th week of October)	Not so tasty, coarse grain, lower yield
Khairo Thulo (brown large)	Tastier than red, better yield, good fodder yield	Late maturing (3rd week of November)
Seto Thulo (white large)	Tasty, soft, high yielding grains, better fodder yield	Late maturing (3rd week of November)
Bhadaure (early and small grained)	Early maturing (3rd week of September), other crops can be grown after its harvest on the same land	Low grain and lower fodder yields, matures with maize making difficult to harvest

Ricebean marketing

Ricebean is not generally grown for commercial purposes, and there are no established markets. However, it is sold in local markets, and is often exchanged between farmers in the villages. In the study area, only 10-20 % of ricebean-growing farmers sold it either informally or in the local market. The price obtained ranged between EUR 0.29 to 0.51 per kg.

On-going studies and future prospects

We intend to carry out a systematic germplasm evaluation in four locations in 2007, using a proper protocol. The selected landraces are considered as the core collection, and some will be evaluated in mother and baby trials. As the early genotypes mature in September this could open up the option of growing short duration winter crops on residual moisture. Secondly, short duration accessions could be very valuable resource as the potential parents, especially through breeding to introduce some earliness into preferred late accessions. These genotypes will be planted as a non-core collection, and the seed will be maintained.

Although farmers have some landraces with good yield potential these do not exactly match their preferences in terms of the overall combination of traits (particularly growth habit and duration). Priority areas for the farmers are developing improved varieties, developing the market, and a better understanding of the chemical composition and nutritional quality of ricebean in order to promote it more widely. We will organise organoleptic tests for the most preferred common landraces, which will help strengthen the role of ricebean in the farming systems. If possible, we will also carry out a nutritional study of ricebean fodder, and raise awareness about it among the community, both activities also suggested by the farmers.

Acknowledgements

This document is an output from the FOSRIN (Food Security through Ricebean Research in India and Nepal) project funded under the INCO programme of the European Commission's 6th Framework Programme. The views expressed are not necessarily those of the EC. We are grateful to the many farmers in Gulmi, Ilam and other districts of Nepal who provided germplasm or participated directly or indirectly in the various activities of the project. We thank the other partners in the FOSRIN project for their help and support. Special thanks go to the staff of LI-BIRD and NARC Khumaltar who conducted the various research activities, and to the SUPPORT Foundation and RAS-Nepal for collecting germplasm.

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The challenge of introducing new and underutilised crops in intensive systems: three successful cases in Argentina

Cristian Desmarchelier, Graciela Ciccia, Hugo Golberg and Jorge Alonso

INTRODUCTION

Argentina is noted for its export-oriented agricultural sector, and intensive production of commodities such as cereals, soybean, corn, and sunflower, which have become an important part of the nation's economy. Intensive farming practices involve large fields, large inputs (pesticides, fertilisers, etc), and a high level of mechanization. However, in recent years several environmental drawbacks have also been pointed out for these practices, including pollution, loss of soil fertility, and depletion of biodiversity. It is for this reason that, as in other regions of the world, the scientific and economic interest in new/underutilised crops is increasing rapidly in our country.

The present paper attempts to describe three case studies of new/underutilised crops that are being introduced successfully in Argentina in recent years, and at present are at different stages of production and/or research. These include "Amaranth" (*Amaranthus* spp. - Amarantaceae), "Congorosa" (*Maytenus ilicifolia* - Celastraceae), and "Wormwood" (*Artemisia annua* - Asteraceae). All three species have economic importance from different perspectives.

ANCIENT FOOD CROP FOR NEW ECOSYSTEMS: THE CASE OF "AMARANTH"

Background

"Amaranth" is the common name used for several species belonging to the genus *Amaranthus* (Amaranthaceae), a shrub that grows throughout several regions of Mexico, Central America, and the Andean countries of South America (Figure 1). The seeds of "amaranth" have been considered edible for centuries in many parts of the continent, and the plant has been treated as a crop amongst the most important pre-Hispanic cultures in some countries such as Mexico and Peru, mostly due to the high content of protein and iron in the seeds. Lately, the medicinal importance of this so called "pseudo-cereal" has also increased due to the fact that the lectins present in the plant have shown to be important markers of malignant colon processes. It is also important to mention that some studies have shown cholesterol-lowering and antibacterial properties in the plant (Alonso and Desmarchelier, 2005).

Figure 1. *Amarantus* spp.

But “amaranth” is an important grain due to its nutritional properties. The protein content ranges from 12% to 17%, and the amino acid profile is well balanced with a high content of essential amino acids. By comparison, other grains only contain up to 8% of protein and the amino acid balance is poor. Native to Central America and to the tropical Andes of South America, “amaranth” was domesticated by Mayas and Incas (Fomsgaard, 2007). However, its use has been in decline since the European Conquest in the 15th Century. In recent years, the Food and Agriculture Organisation of the United Nations (FAO) and World Health Organization (WHO) have made a big effort in collecting existing knowledge about “amaranth” cultivation and preparation of “amaranth”-based food to make it available to a broader public. A range of scientific publications is available as well, which presents important results on the content of nutrients and anti-nutrients in “amaranth” seeds and leaves, on the properties of its proteins, on the beneficial composition of the fat in “amaranth” grains and on its resistance to drought stress and insect attacks (Fomsgaard, 2007).

Malnourished children and adults living in rural areas need much better access to protein–rich food supplies. Thus, several projects throughout Latin America are now focussing on the production of this crop, notably in Mexico, Peru, Nicaragua, and more recently, in Argentina. At present, the use of “amaranth” is being introduced successfully in regional primary health care systems in Argentina. This has occurred in the frame of a larger project known locally as “Cultivando la Salud” (or “Cultivating Health”, in English) (Alonso *et al.,* 2006), a joint venture between the Argentine Association of Phytomedicine (AAF) and the Centre for Educational Orientation (COE) of Italy. The project, mostly funded by the Italian Government, is focused not only on health issues, but also has a strong productive component, with a special emphasis on the production and distribution of phytomedicines, as we will see latter in this manuscript.

Our experience in Argentina – Buenos Aires

One field experiment was conducted during 2005 in order to investigate optimal conditions for growth of *A. caudatus* var. Centenario in a suburban area of the city of

Buenos Aires, Argentina. The experiment was conducted in a field provided by the Local Development Centre of the Malvinas Argentinas City Council, in the province of Buenos Aires, Argentina. Previous soil analysis performed at the School of Agriculture of the University of Buenos Aires indicated favourable chemical and physicochemical conditions for crop introduction in the previously mentioned area (data not shown).

The aim of the experiment was to determine the most effective method for obtaining plants in the field, taking into account certain factors such as soil texture, direct sowing or transplanting, and plant population density, during the initial stages of production. The trial was conducted under natural and biodynamic conditions, and all cultural activities were performed following a biodynamic calendar (Lievegoed, 1998). Seeds of *A. caudatus* var. Centenario were kindly provided by the Programme for Cereals at the Agrarian University in La Molina, Lima, Peru. The experiment consisted of a pilot test in order to determine the response of "amaranth" to certain factors such as latitude and soil in the relevant district. As a first step, germination capacity was tested, showing values higher than 90%. Two sowing methods, two soil textures, and three densities were investigated. Furrows were prepared 50 cm apart, and treatments consisted of the following: a) direct sowing and transplant; b) sandy loam (35% sand, 65% loam), and loam; c) distance between plants of 50 cm, 35 cm, and 15 cm. The experimental overview is presented in Table 1 and Figure 2.

Table 1. Experimental overview for the plots of *A. caudatus* in the District of Malvinas Argentinas, Province of Buenos Aires.

SECTOR A	12	11	10	9	8	7	6	5	4	3	2	1
SECTOR B												

Figure 2. Seedlings of *A. caudatus* obtained at the District of Malvinas Argentinas, Province of Buenos Aires.

The following indicators were observed throughout the experiment for a time period of 90 days: date of emergence, height of the plant, and general plant health. Both pots and field were sown on the same day. In the case of direct sowing, after 30 days from sowing, excess plants were removed according to the distance required between plants. In the case of transplants, seeds were previously sown in pots (Figure 3) and seedlings were transplanted into the field after 30 days, when the seedlings had at least five leaflets. Significant differences for the mean values where determined by using the Student's *t*-distribution method, at a significance level of 0.05. The results observed over 90 days indicate that there are significant differences in the growth of plants obtained by direct sowing and transplanting, with a higher growth rate in the latter (Figure 4 and 5). No significant differences where observed, however, in the growth rate of plants in different soil textures, or at different densities. However, higher rates of plant death or loss where observed for the case of direct sowing (Figure 6). Regarding aspects of health, the plants were only attacked by common ants.

Figure 3. Experimental plot with *A. caudatus* at the District of Malvinas Argentinas, Province of Buenos Aires.

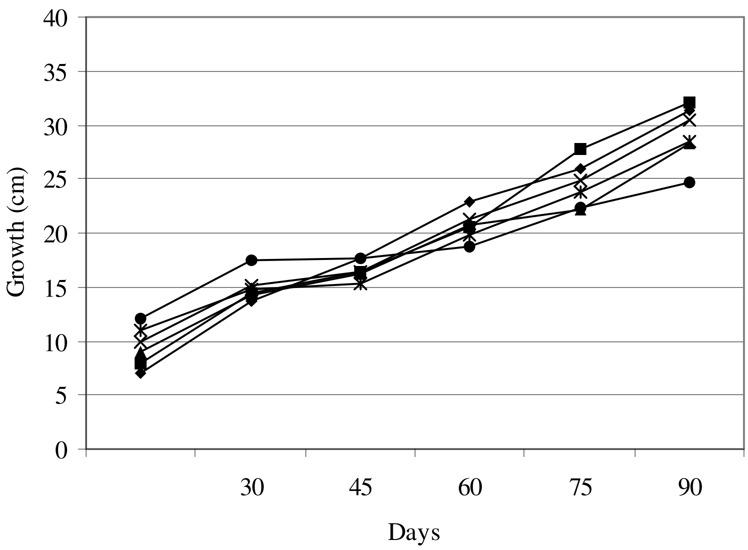

Figure 4. Results observed during initial 90 days in the growth of plants of *A. caudatus* obtained by transplant. No significant differences where observed between different soil textures and densities.

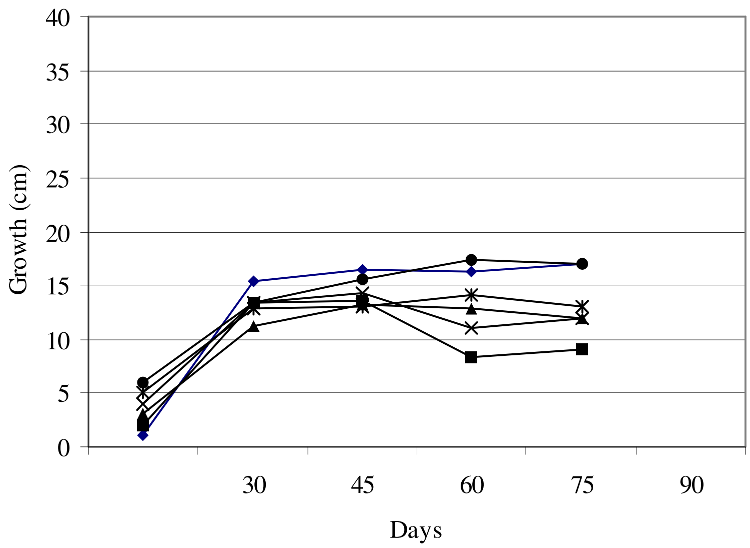

Figure 5. Results observed during initial 90 days in the growth of plants of *A. caudatus* obtained by direct sowing. No significant differences where observed between different soil textures and densities.

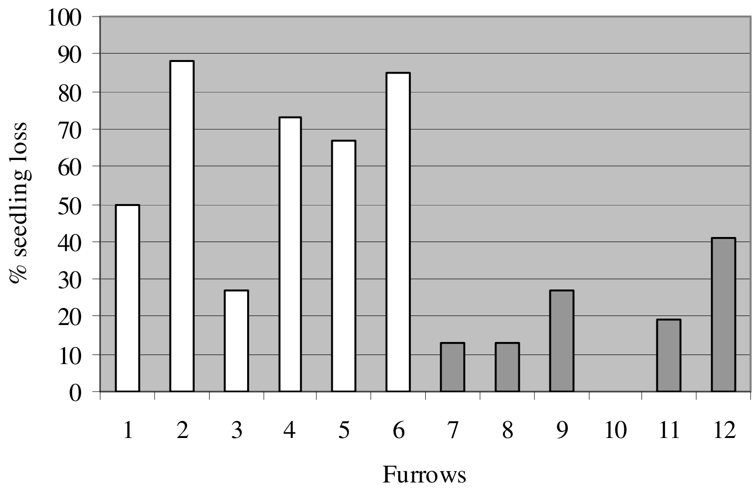

Figure 6. Rates of plant death in different furrows with direct sowing (□) and transplant (□).

Our experience in Argentina – Santa Fe

As in the case of other regions of Argentina, our experience in the Province of Santa Fe (Pietronave and Junco, 2006) suggests that "amaranth" is also adaptable to the plains that are characteristic of our country, where production is taking place at present. During the year 2006, and in the frame of the project mentioned above, 20 ha of the species *A. mantegazzianus* Passer. were cultivated in the district of Reconquista, in order to produce seeds of this pseudo-cereal for human consumption. Cultivation was performed following the biodynamic principles of organic farming. As a first step, germination capacity was tested in two separate assays, showing values that ranged between 90 and 100%. Based on these results, sowing in the field was the second step, which was performed using direct-sowing techniques, with a substrate or vehicle, due to small size of the seeds. The distance between furrows was 70 cm, and 4-6 plants per linear metre, yielding a plant density of 70,000-100,000 pl/ha. The best time of the year for sowing “amaranth” (Southern Hemisphere) is between the last days of September and the first days of November. In the case of our experience in Reconquista, the second half of October gave the best results.

Three different systems were tested: 1) monoculture; 2) corn-“amaranth” combination; 3) sorghum-“amaranth” combination. The results obtained suggested that both combinations yielded better results than monoculture, mostly due to the fact that the deleterious effects of weeds and pests where lessened due to increased biodiversity, and that the protective effects of one crop upon the other were more important. It should also be mentioned that using two or more crops within one productive system can reduce economic risk in a significant manner.

Once the panicles matured (mid March) they where harvested manually by cutting 10 cm below the structure, and immediately stored for drying (maximum 12% moisture content) and further threshing. The drying process took approximately 15 to 30 days, depending on climatic conditions, and threshing was performed mechanically. Yields obtained ranged from 156 to 411 kg/ha (average 330 kg/ha), although it is believed that using irrigation systems, these yields could reach 1,000 kg/ha.

It is interesting to point out that, during the period of production of “amaranth” in Reconquista during 2006, soybean fields were strongly affected by a seasonal drought, thus losing an important percentage of production. However, “amaranth” plants were hardly affected by this, thus reinforcing the idea that, if the demand for “amaranth” grows in the future, this crop could be used as a buffer product in combination with commodity crops, reducing in this way economic risks.

The distribution of “amaranth” flour is planned for several regions of the country, such as the case of the district of Malvinas Argentinas, in the Province of Buenos Aires, where the effects of its inclusion in the diet of urban low-income children are being studied. This experience has been initiated in May 2007, and we expect to come to conclusions later in the year.

RAW MATERIALS FOR DEVELOPMENT OF NEW BOTANICALS: THE CASE OF “CONGOROSA”

Background

Maytenus ilicifolia (Celastraceae) (Figure 7), also known by the vernacular name of “congorosa” (Spanish) and “espinheira santa” (Portuguese), is a medicinal plant native to Southern Brazil, Paraguay, Bolivia, Uruguay, and North-Eastern Argentina. Although used against a wide range of ailments throughout the region, its greatest use is in the treatment of gastritis, gastric ulcers and related conditions. This has led scientists in the region to focus most of their research efforts on the evaluation of “congorosa” in this aspect, and to-date there is adequate pharmacological, preclinical and clinical information in order to suggest that this species may be used as an effective and safe anti-ulcerogenic agent (Alonso and Desmarchelier, 2005). Due to the fact that this plant is collected from the wild, its domestication in our country has become of extreme importance.

Figure 7. *Maytenus ilicifolia* (Celastraceae)

A number of pre-clinical studies performed in animals have shown that "congorosa" extracts have anti-ulcerous activity in vivo when administered orally (Carvalho *et al.,* 1997; Jorge *et al.,* 2004; Souza Formigoni *et al.,* 1991). In the models described, gastric ulcers were previously induced by indomethacin, and/or physical stress, and the anti-ulcerous action observed was similar to that obtained for ranitidine and cimetidine, two conventional drugs used in the treatment of gastric ulcers. Similar results were also observed when the extracts were tested in a model that measures gastric secretion in an in vitro frog-isolated gastric mucosal preparation (Ferreira *et al.,* 2004). In all cases, the results obtained were accompanied by an increase in volume and pH of gastric secretions. These results indicate a systemic action for the active principles present in the extracts or plant. Based on the pre-clinical results described, clinical studies have been performed in order to determine the antiulcerogenic activity of "congorosa" in human patients. One study (Geocze *et al.,* 1988) was performed during a 28 day period with 23 patients suffering high levels of non-ulcerative dyspepsia, gastritis and gastric pain. Thirteen patients received a treatment consisting of one daily capsule containing 200 mg of a lyophilised aqueous "congorosa" extract. The remaining 10 patients received a placebo. The group that received "congorosa" showed a substantial clinical improvement, when compared to the placebo group. Patients treated with "congorosa" extract did not show side effects. These results suggest that it will be important to adjust doses, and increase days of treatment and the number of patients in future studies.

Although it has been stated that the triterpenes, mainly friedelin (Figure 8) and friedelin-3-ol are the main compounds responsible for the activity described (Oliveira *et al.,* 1992; Pereira Soares *et al.,* 1992), some further studies also suggest a synergic action of triterpenes as a whole, together with condensed tannins belonging to the group of catechin, flavonoids and tetrasaccharides (Leite *et al.,* 2001; Oliveira *et al.,* 1992; Martins *et al.,* 1997). Regarding the mechanism of action, several studies indicate that an inhibition in the proton pump could be involved in the process, since this is a common final stage in the regulatory pathways of gastric secretion. Antioxidant and anti-inflammatory activity, also observed in some of “congorosa”´s active principles, could also be involved in the process (Jorge *et al.,* 2004).

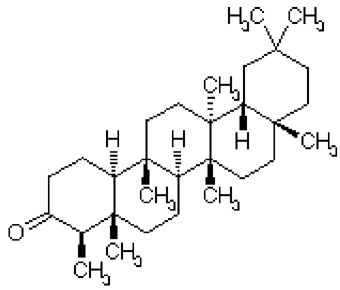

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Figure 8: Friedelin, an active triterpene present in leaves of “congorosa”

Our experience in Argentina

At present, the use of “congorosa” has been introduced successfully in regional primary health care systems. As in the case of “amaranth”, this is also occurring within the “Cultivando la Salud” project, and paying special attention to all stages that lead to manufacturing phytomedicines, including collection of wild species and cultivation of domesticated plants, production of extracts as by products for the manufacture of phytomedicines, and high quality standards of finished products (Figure 9). Thus, compliance with national health policy requirements is a must when it comes to distribution of phytomedicines within the local health care system. The cycle is not complete until medicines reach the community, usually through prescription by health professionals that receive training for this purpose, also provided by the project.

Figure 9. Herbal medicines produced within the project “Cultivando la Salud”

In the particular case of “congorosa”, the standardised dry extract of the leaves is provided in the form of tablets, which are manufactured in a national laboratory using plants obtained from the wild, collected in a sustainable manner thanks to previous inventories of this natural resource. However, expectations on the growth in use of “congorosa” are high for the future, due to the wide potential of the market on one hand, and to the high efficacy of the product on the other.

This fact has brought about an issue regarding the danger of sustainability of the natural resource, and recently new measures are being taken from the private sector in order to ensure availability of homogenous and standardised material for the future. Thus, and as a first step, a pilot project for the agronomic production of “congorosa” has been initiated in the province of Misiones, where the plant grows wild. The pilot project is being held as a joint venture between a private pharmaceutical company and a local association of farmers. These activities are taking place under the guidance and coordination of the Argentine Association of Phytomedicine, which is following the guidelines of previous experiments in Southern Brazil, at the University of Campinas, Sao Paulo (Melillo de Magalhâes, 2000).

Thus, and in an initial stage, the association of farmers mentioned above is in the process of producing seedlings that will be transplanted later in 2007 to a field belonging to the pharmaceutical company. Seedlings have been obtained from seeds, and are of slow growth, taking up to six months before they can be conveniently transplanted in the field. This process will take place during the summer in the Southern Hemisphere. The density of plants will be of 4,000 plants/ha. Once the plants reach a height of at least 50 cm (which can take up to two years) harvest will be initiated once or twice a year, by cutting off leaves that grow beyond that height. During a period of two years, plants will be grown using GAP and specific indicators (both agronomic and phytochemical) and monitored in order to better understand the behaviour of “congorosa” as a crop in our country.

CHINESE PLANT FOR THE LOCAL PHARMACEUTICAL INDUSTRY: THE CASE OF “WORMWOOD”

Background

“Wormwood” (*Artemisia annua* L. - Asteraceae) (Figure 10), a native shrub to China and other areas of the Eastern Asia, is a source of the sesquiterpene lactone artemisinin, a precursor of several chemical agents that have become of increasing importance for the production of antimalarial agents within the pharmaceutical industry (Heemskerk *et al.,* 2006). This species can also be found growing throughout other temperate areas of the World, such as Europe, USA and South America, where it is also known as “annual wormwood”. Traditionally, “wormwood” is used in the treatment of several ailments such as malaria and fever, and also for loss of appetite, indigestion, gastrointestinal problems, and gallbladder disorders, amongst others (Heemskerk *et al.,* 2006; WHO, 2006).

Figure 10. *Artemisia annua* (Asteraceae)

Although several secondary metabolites have been reported in “wormwood”, perhaps the most interesting from a pharmaceutical point of view include the essential oil and those belonging to the sesquiterpene lactone endoperoxides group. The later are represented by artemisinin (Figure 11) and artemisinic acid, a chemical precursor of the former. Artemisinin is a peroxide-bridged sesquiterpene lactone compound which has no N atom, unlike quinine class anti-malarial drugs. The characteristic peroxide lactone structure is indispensable for anti-malarial activity, and artemisinin derivatives that include the referred structure such as artesunate, artemotil and artemether have been widely validated from a clinical point of view in the treatment of malaria (Hanes and Vouiller, 1994; White, 1994). These compounds have become an alternative in areas where the disease has become highly resistant to other treatments such as chloroquinine and sulfadoxine-pyrimethamine. All the artemisinin compounds induce more rapid reduction of parasitaemia than other antimalarial drugs, indicating a direct effect on ring forms (White, 1994).

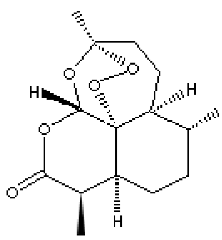

Figure 11. Artemisinin

Recent estimates of the global malaria burden have shown increasing levels of malaria morbidity and mortality throughout the world, and in particular reflecting the deterioration of the malaria situation in Africa during the 1990s. In response to increasing levels of antimalarial resistance, since 2001 the World Health Organisation (WHO) has recommended that all countries experiencing resistance should use combination therapies instead of conventional monotherapies; preferably antimalaria medicines in combination with artemisinin derivatives, also known as artemisinin-based combination therapies (ACTs) for falciparum malaria (WHO, 2006). Therefore the world market for products including artemisinin derivatives is now growing rapidly, and the demand for artemisinin and supply have increased in recent years.

Our experience in Argentina

Fundación Mundo Sano (FMS) is a non-profit organisation whose objectives are to encourage research, foster technological innovation, and promote education for health in Argentina. FMS has particular expertise in working on epidemiology and vector control in transmissible diseases such as leishmaniasis, malaria, dengue, and Chagas disease. In the particular case of malaria, and since 2006, FMS has been involved in the implementation of the first pilot project for the agronomic production of "wormwood" and industrial extraction of artemisinin in Argentina. The aims of the project are to become of public interest, to solve cost transparency issues, and to follow WHO guidelines regarding production of artemisinin.

In the particular case of the agronomic production of "wormwood", and as a first step, FMS has implemented experimental plots in two different locations of the country, in order to determine if latitude (day length), temperature, and soil quality affect biomass production and artemisinin content in a significant manner. Thus, two different hybrids were tested at two latitudes: 35°S and 25°S. The hybrids tested (germplasm) were provided by Mediplant (Switzerland) and reported to contain different relative contents of artemisinin (F1 = 1.3%; F2 = 0.9% in dry leaves).

As a first step, and due to the fact that direct sowing is not effective for agronomic production of "wormwood", nursery seedlings 6 weeks prior to transplanting were produced in the field, and following the guidelines provided by Mediplant (2006). Nursery production was carried out during the months of spring (September-November), and seedlings were ready for transplanting during the first week of December, 2006.

Each plot (geographical location) consisted of 2,000 plants, divided in two sections: one section with 1,000 F1 hybrid plants, and one section with 1,000 F2 hybrid plants. Distance (density) between plants was set at 80 cm (Figure 12), and no treatment with fertilisers or herbicides was performed during the period of vegetative growth. During a period of 20 weeks, plants were harvested every 14 days in 3 replicates of n=10 plants each, dried according to standard procedures (Figure 13), and the following variables were measured: plant height, and biomass production (or tons of dry leaves per hectare). Flowering time was also monitored, since it has been stated that harvest should be done just before this process begins, mostly due to the fact that biomass (artemisinin-containing leaves) and content of artemisinin may decrease drastically once the flowering process is initiated (WHO, 2006). Significant differences for the mean values where determined by using the Student's *t*-distribution method, at a significance level of 0.05.

Figure 12. Field of *A. annua*, 30 days from transplant

Figure 13. Drying of *A. annua*

The results obtained suggest that there are no significant differences between both localities regarding biomass production (Figure 14). Significant differences were observed, however, between the yields of leaves for hybrids F1 and F2, suggesting that F1 should be more recommended for production in future. Regarding flowering time for each locality, a two week difference was observed in favour of latitude 27°S. In fact, flower buds were observed at this latitude during the first week of March, while at 35°S flowering did not start until the third week of the month. These results are in line with the fact that “wormwood” is a short day plant, thus flowering earlier in regions or latitudes closer to the tropics (Kumar *et al.,* 2004; Laughlin, 1994).

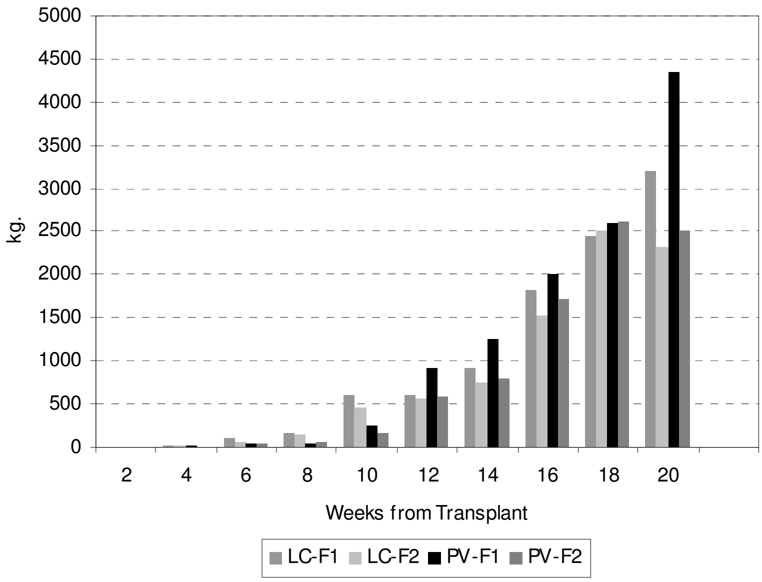

Figure 14. Estimated yield of dry leaves (kg.) per hectare of *A. annua*, for two hybrids (F1 and F2) harvested at two different latitudes (LC = 35°S, and PV = 27°S).

These results indicate that, in Argentina, agronomic production of *A. annua* is perfectly feasible, suggesting that the biomass yields can easily reach those mentioned by Mediplant (2006). However, further studies are in process in order to determine if there are any differences in the content of artemisinin between plants grown at the two different latitudes.

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19

The potentials of African yam bean (*Sphenostylis stenocarpa* Hochst. Ex. A. Rich) in Nigeria: character distribution and genetic diversity

B.D. Adewale, O.B. Kehinde, B.O. Odu and D.J. Dumet

The prominence of the economic and genetic resources of African yam bean (AYB) in Africa is declining, thus necessitating urgent rescue processes to prevent imminent extinction. In order to assess potentials and limitations of crops for improvement, the evaluation of intra-specific variability of the crop was carried out. A morphological characterization study was conducted on eighty accessions of AYB, collected from the Genebank of the International Institute of Tropical Agriculture. The genetic divergence in the 80 genotypes, mostly indigenous to Nigeria was examined by principal component analysis (PCA) and hierarchical cluster analysis involving sixty-two qualitative and quantitative characters. The total genetic variation observed among genotypes was explained by 58 axes of the PCA, with the first three axes accounting for 40.37% of total variation. The first principal component was highly loaded with tuber characteristics, the second distinguished genotypes with long pods and heavier seeds. The discriminatory feature of the third component was pigmentations. The hierarchical cluster analysis classified all the eighty genotypes into five groups on the basis of the average distance between clusters at 1.00 point of inflection. Pigmentation of the stems, branches, petioles and peduncles with plant type, days to first anthesis, leaf length and width distinguished variables in the field. Pod weight, number of locules per pod, number of seeds per pod, seed weight per pod, seed length and the tuber characteristics distinguished genotypes after harvest. It was established in this study that the eighty genotypes exhibited high and significant ($P \leq 0.05$) variances for most of the quantitative traits. This study suggests that AYB has a vast gene pool for character-based selection for breeding and improvement programmes.

INTRODUCTION

African yam bean (AYB) belongs to the family Fabaceae, subfamily Papilionoideae, tribe Phaseoleae, sub tribe Phaseolinae and genus: *Sphenostylis* (Okigbo, 1973; Allen and Allen, 1981). It should not be confused with *Pachyrhizus* spp, a South American and a more popular tuberous legume which in many literatures is referred to as yam bean, Mexican yam bean, Jicama etc... African yam bean (*Sphenostylis stenocarpa* Hochst. Ex. A. Rich.) Harms, is a tuberous legume indigenous to tropical Africa.

The centre of diversity of the crop is wide, encompassing major parts of west and central Africa and some parts of east and southern Africa. Despite its adaptability to a range of climatic conditions in Africa, it is still referred to as a minor or lesser legume (Rachie and Robert, 1974). However, its importance in African food culture (Okigbo, 1973; Potter, 1992; Klu *et al.,* 2001) will make the above description inadequate.

Therefore, it is more appropriate to describe the crop in its present status as an underutilised, underexploited and or a neglected legume until it receives proper research attention. The hard seed coat which makes for long cooking times and the presence of some antinutritional factors (Okeola and Machuka, 2001) may be major constraints discouraging research.

The majority of past research studies on AYB have been on its food value with the material available. Very little has been recorded of the biology, morphology, agronomy and genetics of the crop. It is noteworthy that where research efforts have been made, very few (less than five) genotypes, mainly classified on the basis of the seed coat colors were used. Obiagwu, (1997) remarked that most indigenous leguminous species have not been appropriately classified or studied. Results from so few genotypes cannot be considered conclusive as they lack genetic variability.

The protein content in AYB seeds compares well with the WHO/FAO recommendation (Betche *et al.,* 2005). AYB whose seeds are exceptionally nutritious (Rachie, 1973) is significant among other tropical African legumes: producing edible pulses and tubers. Its contribution in improving the lives of the people in Africa and Nigeria is still uncertain, but extremely relevant.

The lack of the knowledge of the genetic variability of germplasm had been implicated in the relatively limited progress in the improvement of pulse crops (Ramanujam, 1975). This study aims at improving the understanding the of variability of AYB accessions and the distribution of differentiating characters in the life span of the crop; in order to establish the potentialities of the crop.

MATERIALS AND METHODS

To ascertain the distribution of AYB in Africa and especially in Nigeria, an extensive literature review of research works on the crop was carried out. Details are given in Figure 1 and Table 2.

Eighty genotypes are described in Table 1. These were obtained from the genebank Unit of the International Institute of Tropical Agriculture (IITA), Ibadan. They were grown on ploughed, harrowed and ridged plots in an IITA experimental field (860 m^2) in Ibadan. The layout was ten plants per genotype in a single row, to minimise environmental variations; at the rate of one plant per hill at a spacing of 1 m by 1 m apart. NPK fertiliser was applied, essentially following the recommendations of Togun and Olatunde (1998). Insects were controlled with insecticides at two weeks interval during the flowering period.

Table 1. Representative codes and origins of the eighty genotypes of African yam bean

S/N	Genotypes	Codes in Dendrogram	Origin
1	TSs1	AT01	Nigeria
2	TSs2	AS01	Nigeria
3	TSs3	AT02	Nigeria
4	TSs4	AT03	Nigeria
5	TSs6	AS02	Nigeria
6	TSs7	AS03	Nigeria
7	TSs8	AS04	Nigeria
8	TSs9	AT04	Nigeria
9	TSs10	AS05	Nigeria
10	TSs11	AT05	Nigeria
11	TSs12	AT06	Nigeria
12	TSs13	AT07	Nigeria
13	TSs16	AT08	Nigeria
14	TSs18	AT09	Nigeria
15	TSs22	AT10	Nigeria
16	TSs23	AT11	Nigeria
17	TSs24	AT12	Nigeria
18	TSs27	AT13	Nigeria
19	TSs30	AT14	Nigeria
20	TSs31	AT15	Nigeria
21	TSs32	AT16	Nigeria
22	TSs33	AT17	Nigeria
23	TSs36	AS06	Nigeria
24	TSs38	AT18	Nigeria
25	TSs39	AS07	Nigeria
26	TSs40	AS08	Nigeria
27	TSs44	AT19	Nigeria
28	TSs46	AS09	Nigeria
29	TSs47	AS10	Nigeria
30	TSs48	AS11	Nigeria
31	TSs49	AT20	Nigeria
32	TSs50	AS12	Nigeria
33	TSs53	AT21	Nigeria
34	TSs55	AS13	Nigeria
35	TSs56	AT22	Nigeria
36	TSs57	AT23	Nigeria
37	TSs58	AS14	Nigeria
38	TSs59	AT24	Nigeria
39	TSs60	AS15	Nigeria
40	TSs61	AT25	Nigeria
41	TSs62	AS16	Nigeria
42	TSs63	AS17	Nigeria

43	TSs65	AS18	Zaire
44	TSs67	AS19	Bangladesh
45	TSs69	AS20	N/A
46	TSs76	AT26	Ghana
47	TSs77	AS21	Ghana
48	TSs78	AS22	N/A
49	TSs79	AS23	Nigeria
50	TSs81	AT27	Nigeria
51	TSs82	AT28	Nigeria
52	TSs83	AS24	Nigeria
53	TSs84	AS25	Nigeria
54	TSs86	AS26	Nigeria
55	TSs87	AS27	Nigeria
56	TSs89	AS28	Nigeria
57	TSs90	AS29	Nigeria
58	TSs91	AS30	Nigeria
59	TSs92	AS31	Nigeria
60	TSs93	AS32	Nigeria
61	TSs94	AS33	Nigeria
62	TSs95	AT29	Nigeria
63	TSs96	AT30	Nigeria
64	TSs98	AT31	N/A
65	TSs100	AS34	N/A
66	TSs101	AT32	N/A
67	TSs104A	AT33	N/A
68	TSs104B	AS35	N/A
69	TSs109	AT34	Nigeria
70	TSs111	AT35	Nigeria
71	TSs112	AS36	Nigeria
72	TSs116	AS37	N/A
73	TSs117	AS38	N/A
74	TSs118	AS39	N/A
75	TSs119	AS40	N/A
76	TSs125	AS41	Nigeria
77	TSs126	AT36	Nigeria
78	TSs127	AT37	Nigeria
79	TSs128	AS42	N/A
80	TSs130	AS43	N/A

*N/A – Not Available.

Data were collected on 62 characters, 39 of which were qualitative and 23were quantitative. The majority of the descriptors were developed from approved IPGRI descriptors of Cowpea, Lima bean, *Phaeolus vulgaris* and Sweet potatoes.

The characters were standardised; a basic matrix of 62 x 80 was prepared and submitted to SAS (Version 9.1). The principal component analysis (PCA) and the hierarchical clustering system produced vector loadings of the variables for the PCA axes and dendrograms respectively.

RESULTS AND DISCUSSION

African yam bean distribution

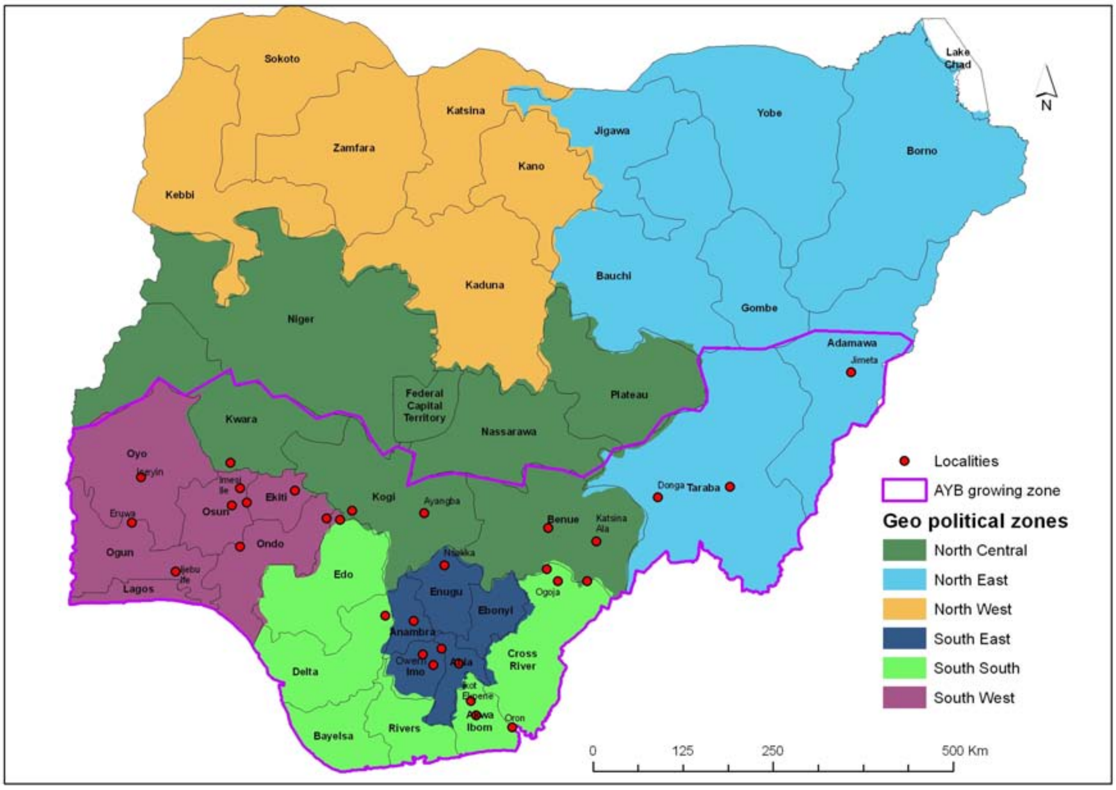
African yam bean grows along a wide length of climate and soil, within the latitudes of 15^0north to 15^0south and the longitudes of 15^0west to 40^0east of Africa. The agro-ecological zones within the centres of diversity of AYB (Table 2) include: the humid forest, derived savanna, southern guinea savanna, northern guinea savanna and the semi arid.

Table 2. The Centres of diversity of African yam bean in Africa.

Countries and Regions	Authors
Congo (Zaire), Natal, Swaziland, Zambia, Rhodesia, Angola, Tanzania, Mozambique, Malawi, Ghana, Central Africa, Dahomey (Togo), Senegal, Ivory Coast (Cote d'Ivore), Nigeria, Ethiopia, Gabon.	Okigbo (1973).
Distributed throughout most of tropical Africa, from Guinea eastward to Ethiopia, southward to Mozambique and Zimbabwe in the east and to Angola in the west. It is however absent from the lowland rainforest of Central Zaire.	Potter (1992).
Its wild forms have been observed in all countries along the gulf of Guinea, from Senegal to the south of Nigeria. They are also found in the eastern and northern regions of Ethiopia, in Eritrea, Mozambique and Tanzania.	Baudoin and Mergeal (2001).
It is widespread in tropical Africa, from Guinea to Ethiopia and south to Angola, Zimbabwe and Mozambique.	Makinder *et al.,* (2001).
West-Central tropical Africa: Burundi, Central African Rep. West tropical Africa: Cote d'Ivore, Ghana, Guinea, Mali, Niger, Nigeria Togo. South tropical Africa: Angola, Malawi Zambia, Zimbabwe	GRIN*

*GRIN – Germplasm Resources Information Network. (http://www.ars-grin.gov)

Figure 1 presents the growing areas of AYB in Nigeria. Five out of the six geo-political zones of Nigeria are conducive for the growth of AYB. There was no information on the growing of the crop in any area of the northwestern geopolitical environment.



GIS Unit, IITA, Ibadan

Developed from the information in: Nwokolo (1987), Ene-Obong and Okoye (1992), Potter (1992), Oshodi *et al.,* (1995), Okpara and Omaliko (1997), Omitogun *et al.,* (1999),Okeola and Machuka (2001), Saka *et al.,* (2004), Ajibade *et al.,* (2005).

Figure 1. The map of Nigeria showing the growing areas of African yam bean.

The suitability of AYB for the diverse climatic regions of Africa and Nigeria suggests that it can potentially serve as an important crop for food security. Its tolerance of varied soil and climate conditions has been noted by Anochili (1984). This advantage alone offers potential for its use in many soils where its adaptability to many environments gives it an ecological advantage over most conventional legumes. Although the crop is nearing extinction (Klu *et al.,* 2001), its sustainability and continuity may depend on its ability to survive in the diverse agro ecological conditions of Africa.

African Yam Bean Characterization

When the data for the selected 62 traits were subjected to PCA, 58 principal axes explained the total variation of the eighty genotypes. Only five of the fifty-eight had eigen vector values above 3.00, eight had values above 2.00 and fifteen had values above 1.00 and together they accounted for 51.96, 62.88 and 79.70% of total variation, respectively (Table 3).

Table 3. Variation distribution into the Principal component axes

PC Axes	Eigen value	Difference	Proportion	Cumulative (%)
1	13.3109420	6.2164991	0.2147	21.47
2	7.0944429	2.4688876	0.1144	32.91
3	4.6255553	0.7320485	0.0746	40.37
4	3.8935068	0.6004333	0.0628	46.65
5	3.2930736	0.8513282	0.0531	51.96
6	2.4417454	0.2279815	0.0394	55.90
7	2.2137639	0.1028988	0.0357	59.47
8	2.1108651	0.1944347	0.0340	62.88
9	1.9164305	0.2025565	0.0309	65.97
10	1.7138740	0.0772831	0.0276	68.73
11	1.6365908	0.1524536	0.0264	71.37
12	1.4841373	0.1102684	0.0239	73.77
13	1.3738688	0.2122000	0.0222	75.98
14	1.1616688	0.0208174	0.0187	77.86
15	1.1408514	0.1438587	0.0184	79.70

The first three PCA axes accounted for 40.37% of the total variation among the 62 characters that described the 80 genotypes. The first PC axis was loaded solely and largely by characters measuring the tubers of AYB (Table 4). The second axis was loaded among other characters by pod length, pod weight, number of seeds/pod, leaf length and width (Table 4). The stem, branch, petiole and peduncle pigmentation with days to anthesis loaded the third axis (Table 4). The pigmentations of plant parts and days to anthesis have been reported to contribute to variations in plant morphology, Ariyo and Odulaja (1991) obtained such result in *Abelmoschus esculentus.*

Table 4. Eigen vectors loadings of the first three Principal components axes

Principal components	**Characters and their eigen vectors**
1	Root shape (0.23), Root defect (0.223), Root skin color (0.235), Root branching (0.211), Root flesh color (0.265), Tuber yield (0.214), Tuber weight (0.234), Tubers/plant (0.257), Tuber length (0.267), Tuber width (0.265), Tuber L: W ratio (0.256), Tuber presence (0.265).
2	Pod length (0.297), Pod weight (0.316), Loculi/pod (0.272), Seed weight/pod (0.282), Seeds/pod (0.299), Seed length (0.211), Plant type (0.21), Leaf length (0.222), Leaf width (0.216).
3	Stem pigmentation (0.382), Branch pigmentation (0.374), Petiole pigmentation (0374), Peduncle pigmentation (0.332), Days to anthesis (0.227).

All the genotypes were classified into five distinct groups (Table 5) using the SAS technique FASTCLUS. This shows any intraspecific dissimilarity between the two groups of genotypes (the tuber forming and the non tuber forming – Figure 2). In figure 2, no similarity was noticed until the inflection point was above 0.50, showing that individual genotype have some peculiar uniqueness. However, wide variability existed among the eighty AYB genotypes, with intraspecific similarities noted at an inflection point of 1.00 and above (Figure 2).

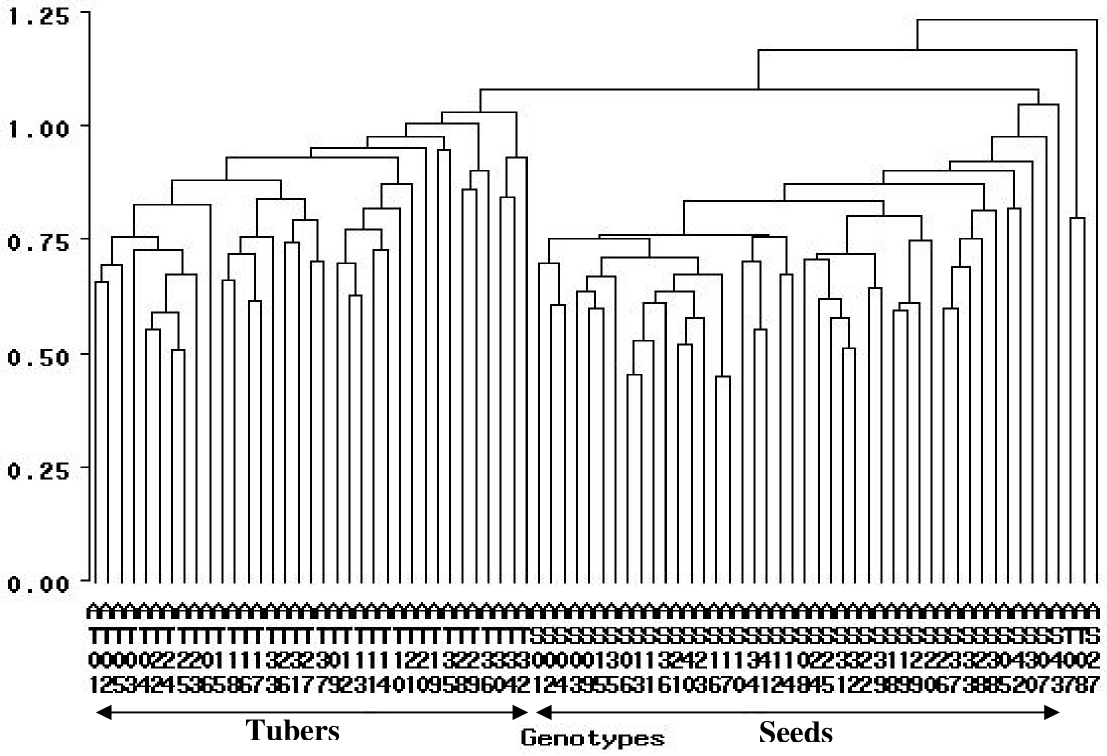


Figure 2. The grouping of the eighty genotypes of African yam bean

Eight quantitative and five qualitative characters with greater discriminatory power were used to identify groups and samples within the groups (Table 5). However, the genotypes from Bangladesh, Ghana and Zaire did not differentiate themselves from the ones from Nigeria. There may be some probability in AYB genotypes as discovered in *Abelmoschus esculentus* and *Abelmoschus caillei* that there is no correlation between the ecological background and genetic diversity (Ariyo, 1987, 1993).

Clusters III and V contained one genotype each, while clusters I, II and IV contained 9, 49 and 20 genotypes respectively. Clusters I, III, IV and V grouped all the seed and tuber producing AYB genotypes in the proportions of 24.3, 2.7, 54.1 and 2.7% respectively. Cluster II grouped all the non-tuber forming genotypes with the remaining 16.2% tuber producing genotypes.

Clusters II and IV were the closest. Cluster I was significantly different from others, with heavier and longer pods. The tubers in cluster V had pink skin color and having the highest individual tuber size and tuber yield per plant. The genotype in cluster V produced the fewest seeds, which were rough. TSs96 could be best selected for tuber production only. TSs81 in cluster III had the shortest pod, yet produced the highest number of seeds per pod. Its efficiency for tuber production was next to TSs96 in cluster V; it can be selected for the improvement of the two main products of AYB. The 14.3% tuber producing genotypes in cluster II had the lowest tuber yield per plant. These six genotypes may be the product of out crossing between the tuber and the non-tuber producing genotypes. The less than 10grammes tubers produced were of low economic value.

Table 5. Major discriminatory characters of the five cluster groups of African yam bean with their means and the coefficient of variation

Groups of genotypes

Descriptors	I	II	III	IV	V
	AT05, AT11, AT15, AT18, AT28, AT29, AT31, AT32, AT36.	AT01, AT02, AT07, AT10, AT13, AT22 and all genotypes with "AS" prefix.	AT27.	AT03, AT04, AT06, AT08, AT09, AT12, AT14, AT16, AT17, AT19, AT20, AT21, AT23, AT24, AT25, AT26, AT33, AT34, AT35, AT37.	AT30.
Pod length (cm.)	25.06 (11.19)	22.21 (11.28)	21.24	21.69 (14.08)	21.70
Pod weight (g.)	6.46 (17.26)	5.58 (20.65)	6.11	5.32 (23.76)	4.73
Loculi/pod	16 (11.35)	15 (16.83)	17	14 (16.62)	14
Pods/plant	7 (28.87)	8 (73.52)	8	6 (41.13)	6
Seed structure	66.7% smooth	69.4% smooth	Smooth	60% smooth	Slightly punched
Seed wt. /pod (g.)	3.75 (18.62)	3.42 (40.81)	3.76	3.04 (28.89)	2.80
Seeds/pod	14 (13.14)	13 (19.09)	15	13 (17.97)	11
Stem pigmentation	55.6% un-pigmented	63% un-pigmented	Pigmented	55% pigmented	Pigmented
Root skin color	66.7% cream	Cream	Cream	Cream	Pink
Tuber yield/plant(g.)	159.39 (19.54)	19.47 (36.7)	278.62	68.32 (36.30)	336.68
Individual Tuber wt. (g.)	44.63 (20.17)	9.26 (69.9)	49.32	23.32 (27.34)	80.04
Presence of tubers	Forms tuber	14.3% tuber forming	Forms tuber	Forms tuber	Forms tuber
Loculi on pods	66.7% Locule structured pod wall	67.4% Locule structured pod wall	Locule structured pod wall	65% Locule structured pod wall	Smooth pod wall

Some of the quantitative traits that exhibited high variability include: pod weight, pods/plant, seed weight, number of seeds/pod, tuber yield/plant and individual tuber weight. The high variation within clusters suggests much out crossing within this taxon and the possibility of genetic advance through selection (Ariyo, 1993).

CONCLUSION

Although there is no clear documentation on the importance of AYB cultivation and its productivity status in Africa, Nigeria was noted for growing the crop most extensively in West Africa (Potter, 1992). The southwest and the southeast are the most prominent producing areas of AYB in Nigeria. AYB is part of the food culture of the Africans; the tubers are a staple food in central and east Africa, the seeds only are essentially a food of West Africans (Okigbo, 1973, Potter, 1992, Klu *et al.,* 2001).

There was significant agreement between PCA and the hierarchical methods of multivariate analysis in this study. It is clear that the tuber, pod, seed and pigmentation characteristics were important components of the genetic variability between AYB genotypes. The presence or absence of tubers in AYB was the most distinguishing morphological trait to classify AYB genotypes.

Since distinguishing characters are well distributed in the different stages of the crop, this pattern of genetic variation would be of great importance to germplasm collectors and plant breeders. The degree of morphological variation recorded among the genotypes indicates wide differences. Molecular characterization will confirm or not these clusters. Further morphological and molecular studies on accessions collected in other countries will tell us how broad the genetic base of AYB is.

The present study reveals a wide variability and hence a vast gene pool for AYB across the major growing areas. Distinctive qualitative and quantitative characters featured at different stages of the life of the plant. AYB does not exhibit narrow genetic diversity. This extensively establishes that there are great genetic potential in AYB yet to be exploited.

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Promotion of underutilised crops for income generation and environmental sustainability

Narayan G. Hegde

INTRODUCTION

Agriculture is the major source of livelihood for over 85% of the 650 million rural population in India. However, over 50% to 60% of these families are not assured of food security due to small land holdings and low soil productivity. Out of the 109.4 million holdings, over 46.16% families are marginal land holders with less than 1 ha land, 14.72% are smallholders owning 1-2 ha while over 18.83% are landless. Thus 79.71% of the total families own only 36% of the land while the remaining 20% families own 64% of farm lands. Lack of irrigation facilities is another serious problem, responsible for lower crop yields. Only about 30% of the 147 million ha agricultural lands have assured irrigation and the remaining 100 million ha are dependent on rainfall for crop production. Out of this area, about 60 million ha are located in semi-arid and arid regions, where the crop yield is significantly lower than the average national yields.

There is a direct correlation between the size of land holdings and access to water resources, because most of the large holders are influential enough to mobilise Government resources and capable of making their own investments for establishing irrigation facilities. With assured irrigation, such farmers take further initiatives to develop their lands to facilitate soil and water conservation and adopt improved agricultural practices by investing in expensive external inputs to increase crop yields. However farmers deprived of irrigation facilities hesitate to apply the requisite inputs and end up with lower crop yields that deplete soil productivity. Most of the farmers who are deprived of irrigation facilities, can hardly take even a single crop profitably, which can provide employment for a period of two to three months during the year. Due to these problems of underemployment and lower productivity, over 40% of the rural families are living in poverty with an annual income less than USD 500 per family and most of them are landless, small and marginal holders.

Unemployment and poverty compel many of these families to migrate seasonally to rich agricultural areas or to cities in search of employment. Distress migration affects their quality of life, particularly, the health and education of their children. Considering the plight of these poor who are dependent on agriculture and deprived of employment opportunities in other sectors like service and industries in rural areas, the Government of India has been focusing on promotion of special agricultural development packages, which can help smallholders to enhance their crop yields and income. These include watershed development to promote soil and water conservation, support for advanced irrigation systems that make efficient use of water for improving agricultural production, promotion of horticultural crops which are hardy and drought tolerant, eco-friendly agriculture and direct linkages with the market and food processing industries.

As the income from fruits, vegetables and cash crops is higher than that from food crops, farmers prefer to grow such high value crops, although there is a risk of price fluctuation. However it is extremely difficult for small farmers to compete with large farmers whose cost of production is significantly lower due to superior quality land and well established infrastructure. Therefore there is good opportunity for small farmers to take up cultivation of new and underutilised crops which can give them an edge by ensuring more earnings due to lack of competition. With small scale production, it is also easy to find a good market for lesser known products. With this background, BAIF Development Research Foundation, a Civil Society Organisation committed to helping small farmers to earn their livelihood, initiated the promotion of underutilised crops in various parts of India. This paper focuses on the approach and impact of this programme.

Experiences of Introducing Underutilised Crops in India

There are many herbs, shrubs and trees, which have significant economic uses but which are severely neglected. Cultivation of some of these species is restricted to a small region in spite of their potential to grow in other regions. Realising the advantages of these species, serious attempts have been made during the last five decades to popularise the cultivation of underutilised plants by several international and national organisations. Among them, a few species have performed exceedingly well by competing even with traditionally grown local crops and have provided sustainable income to farmers. Many other species, in spite of their adaptability, economic potentials and initial acceptance, were ultimately rejected by farmers, while some others had a serious problem of adaptability outside their native areas.

One of the most successful examples of promoting underutilised plants in India has been the cultivation of leucaena (*Leucaena leucocephala)* as a multipurpose tree for providing fodder, fuel and timber to small farmers, while covering wastelands under greenery. Leucaena was introduced to this country in the 1920s, as a crop for reclamation of sodic soils. The genotype introduced was dwarf, which was grown on pasture lands in arid regions of Mexico and Australia. However neither the State Agriculture Departments nor the farmers adopted cultivation seriously because of its slow growth and limited use as fodder. Due to lower returns, this species was almost totally neglected. However, in the early 1970s, BAIF promoted cultivation of leucaena as a perennial forage legume on degraded lands which were unsuitable for agricultural production. As growth was slow, the fast and tall growing Salvador type leucaena was introduced from Hawaii and several studies were carried out to improve its quality and yield of forage and wood. However the response was lukewarm as the farmers were not convinced of obtaining a higher income from this species. Various post-production technologies such as production of protein rich leaf meal were explored to add value to the produce and the use of wood for paper and pulp production was promoted. The advantages of planting leucaena for ecological conservation on degraded lands instead of eucalyptus were also highlighted. A series of workshops and seminars was organised and the supply of superior quality seeds was ensured. As a result of these efforts, leucaena was eventually well accepted by farmers. As a pulpwood crop, leucaena proved to be more profitable than any other crop on drylands (Hegde, 1991). Paper mills also started promoting contract farming of leucaena. Over the last 20 years, leucaena has become an important tree species adopted by farmers in India.

Some other underutilised tree crops which have gained prominence in recent years in India are tamarind (*Tamarindus indica*), *anola* or Indian gooseberry (*Emblica officinalis*), ber (*Zizyphus mauritiana*) and kokum (*Garcinia indica*). Tamarind, which originated in South America, has been present in India for several centuries and is now extensively used in Indian cooking. However tamarind has not been cultivated as a regular crop. By and large, the trees are established through natural seeding on community lands and farmers generally establish a few trees in their backyards or field bunds for household use. The State Forest Departments have been raising seedlings for roadside establishment as avenue trees and for distribution to farmers, but the response from farmers has been poor due to the long gestation and lack of clarity about its yield and economics. Harvested fruits are sun dried for a few days; the pulpy fruits are separated from the outer brittle shell, deseeded and mixed with a small quantity of salt (1-2%) before storing or selling in the local market. During the last two to three decades, the demand for tamarind has increased significantly because of the use of modern technologies for processing pulp into ready-to-use cubes and powder. However, farmers were still reluctant to take up the cultivation due to poor returns. To overcome this problem, various Agricultural Universities and Forest Research Stations identified superior germplasm having high acid content and yield. Vegetative propagation techniques were developed to produce elite planting materials, which have spreading growth habit and short gestation period. The new tamarind plantations established from grafted plants could come into production at the age of four to five years and generate a substantial income as compared to traditional fruit crops like mango, thereby encouraging farmers in arid regions to establish tamarind plantations on a large scale.

Indian gooseberry (*Anola*) is a well known tree species in India and fruits are used extensively for medicinal purposes. It not only grows naturally in village forests but is also cultivated on sodic lands of Uttar Pradesh State, because of its economic viability. Indian gooseberry has been in good demand because of its use in various herbal medicinal preparations. However since the 1960s and 1970s, with the domination of modern medicine, the demand for herbal medicines reduced drastically resulting in a poor price for Indian gooseberry. Thus farmers from other regions were not interested in cultivating Indian gooseberry, while existing growers developed products such as pickle, jam, juice, squash, candy, etc. and marketed them as vitamin C-rich healthy products. In the 1990s, with greater awareness of the use of herbal medicines, Indian gooseberry regained its importance and the demand for its fruits increased substantially. During this period, scientists developed superior varieties, techniques for vegetative propagation and improved cultivation practices, which helped in extending its cultivation to many other states, particularly in arid and semi-arid regions across India (Daniel and Dudhade, 2007).

Ber (*Zizyphus mauritiana*) which bears small sour fruits, was domesticated in the 1950s for cultivation in arid regions. With application of modern technology and selection of superior table varieties, good quality fruits are now available in the market. The fruit can also be utilised for production of candy, jam, squash, etc. Presently, *ber* is being cultivated on degraded lands which were otherwise not suitable for cultivation.

Kokum (*Garcinia indica*) is another fruit grown in the Western Ghats region of Western India, with food and nutritional value. The trees grow naturally in the tropical humid forests and their cultivation in homesteads is limited. As in mangosteen fruits, the seeds are covered with sweet juicy pulp. The thick, waxy fat extracted from *kokum* seeds is used in Ayurvedic medicines and cosmetics. The outer shell is soft, acidic and red in colour. Fresh shells are either dried with salt for using as spice or processed into syrup for preparing a refreshing drink, having neutraceutical value. The demand for *Kokum* products has been increasing in recent years and with easy availability of good planting materials, farmers in the Western Ghats region have started planting *kokum* as a plantation crop (Sawant, 2005).

In a study undertaken by BAIF to popularise underutilised fruit crops, it was observed that farmers were hesitant to take up cultivation due to lack of awareness of economic benefits, availability of good quality planting materials, and to a poor marketing network and lack of technology available for post harvest processing and value addition. Based on these constraints, BAIF initiated the promotion of less known fruit trees by setting up field demonstrations, developing field manuals for best practices, training field extension workers and farmers and distributing posters and handouts. Decentralised nurseries were established to produce and supply better quality grafted plants. Farmers' Organisations were promoted for forward and backward linkages. These efforts made a significant contribution in popularising several underutilised fruit crops (Hegde, 2002).

Higher income and a short generation period are major considerations for cultivation of many other underutilised tree crops as well. *Mahua* (*Madhuca indica)* is an oilseed tree which grows on village common lands in Central India. Its flower consists of a sweet and juicy corolla which drops a few days after flowering. The local people, particularly tribals, collect the fallen corolla and consume it in the fresh or dehydrated form. The seeds contain 30% edible oil. However as many of the interior villages do not have oil extraction facilities, local people sell dried seeds to middlemen or in the local market. As local traders offered a very low price, which was not adequate to even recover the cost of labour, seed collection was not attractive to the locals. As a result, a large quantity of seeds was wasted while the local people lost employment opportunities. Realising the loss of opportunity for the poor and landless, BAIF promoted a cooperative of oil extraction units in a few clusters, each covering three to four tribal villages of the Valsad district in Gujarat State. With efficient oil extraction locally available at a nominal cost, seed collection ultimately turned out to be attractive as seed collectors could meet their edible oil needs, while cake could be fed to livestock. Thus the average seed collection in each cluster increased from five tons to 55 tons during the third year. Techniques have now been developed to produce grafted plants of *mahua* which start bearing in the third year. Looking to the economics and short generation period, farmers are now keen to establish plantation of *mahua* on their degraded lands as a commercial crop.

An assured market is another important consideration for promotion of underutilised crops. This is particularly true for non-edible products such as medicinal herbs. In the early 1990s, BAIF promoted the cultivation of medicinal plants to establish a direct link between growers and processing units. The background of the project was concern for endangered medicinal plant species due to indiscriminate harvest of naturally grown medicinal herbs from forests. Middlemen and manufacturers of herbal medicines encouraged local people to collect these plants and procured them at low prices. There has also been wide variation in quality, resulting in wastage of precious herbs. To overcome this problem, BAIF identified the most important medicinal herbs having good demand from processing units and motivated small farmers to cultivate these herbs in their field using the elite planting materials, with a buy-back assurance. However the processors backed out of their promise of purchasing the quantities produced, as they felt that procurement of materials collected from forests was cheaper, while cultivators expected a higher price which would at least cover the cost of production. In the absence of any buy-back guarantee, heavy fluctuation in prices and a significant fall caused by a glut in the market, was observed. Meanwhile, women's groups involved in the cultivation of medicinal herbs grew four to five herbs required for production of herbal tea, set up their own processing units and started marketing this tea through various local outlets.

Another programme of BAIF in the recent past was promotion of *patchouli* (*Pogostemon cablin*) cultivation, an alien crop for farmers in the tribal regions of Gujarat. Farmers adopted this crop successfully, mainly due to favourable agro-climatic conditions for higher yield, low investment and assured buy-back arrangement from a commercial firm involved in extraction of essential oils who already had a well established market for their aromatic oils and were aware of sources of elite germplasm. They had also developed the technology for micro-propagation and standardised cultivation practices, especially suited for small farmers. Based on their yield data, the processing firm offered a buy-back price which was remunerative for farmers. Thus the cultivation of *patchouli* attracted local farmers, particularly in the vicinity of 50-80 km from the extraction unit. The processing unit provided timely solutions to all the technical problems of growers. This resulted in mutual respect and inter-dependence, as growers could not sell their produce and the processors could not obtain raw materials in the open market. After five years of its introduction, the farmers started finding the programme attractive as compared to traditional food crops. With so many success stories, BAIF proposed to introduce several promising species for food and nutritional use for the benefit of small farmers.

OBJECTIVES

The general objective of this programme was to enhance the income of small tribal farmers through introduction of high value, underutilised food crops in their farming systems. The specific objectives were:

- To study the techno-economic feasibility of cultivating underutilised trees and shrubs having food and medicinal uses;
- To study the factors affecting their adaptation;
- To popularise cultivation of promising underutilised species.

PROGRAMME AREA

Considering the scope for improving the earnings of the tribals, BAIF initiated the promotion of various underutilised food crops under the on-going agri-horti-forestry programme. The programme covered over 10,000 tribal families spread over 300 villages in the hilly terrains of the Western Ghats in the districts of Valsad, Navsari and Dangs in Gujarat State and Thane and Nashik districts of Maharashtra State. This region receives a high rainfall of over 2500 mm spread over a period of five months from June to October.

However due to shallow lateritic soils, undulating topography and lack of ground water, crop production is mainly confined to the rainy season and villages in interior areas face serious shortage of drinking water for two to three months in summer.

The temperature in these districts ranges from 40 ^{o}C in April to 6-8^{o} C in January. The villages selected were located on the periphery of the forests where most of the agricultural lands were unsuitable for intensive agriculture. A majority of the local population was represented by different tribal communities, traditionally dependent on collection of forest products for their livelihood. However during the last five to six decades, natural forests could not support their livelihood due to severe deforestation and increasing population pressure and they were compelled to take up agriculture on degraded lands. Moreover, as employment opportunities were restricted to only two to three months, most families migrated to nearby cities as wage earners for a major part of the year. With an average holding of 0.5 to 1.0 ha, the tribals found it difficult to sustain their livelihood, while neglect of agriculture further depleted soil fertility.

As a result, there was increasing poverty and unemployment on one side and severe depletion of natural resources and biodiversity on the other. Considering this crisis, BAIF promoted a sustainable development programme to motivate farmers to take up an agri-horti-forestry system of farming which provided year-round employment and regular income, while conserving the eco-system. Looking to the average size of the land holding, the model prepared was to establish fruit tree plantations on 0.4 ha of land, after properly developing land to conserve soil and water resources in-situ. Preference was given to fruit trees as the generation was comparatively short and the farmers could produce income every year without cutting down trees. Considering scarcity of water during the summer months, the fruit crop had to be drought tolerant and acceptable to local people.

Mango being a popular fruit crop, participants unanimously selected mango as the main crop. However, growers had to wait for four to five years before the mango started bearing fruit. This waiting period was very crucial and it was necessary to introduce various income generation interventions to sustain the livelihood of participating families and to discourage them from migrating to cities, thereby neglecting their orchards. One such opportunity was to promote various food crops as inter-crops between fruit trees. This ensured food security and generated additional income. Establishment of fruit and forest nurseries and cultivation of seasonal vegetable and mushrooms were also attractive. Living fencing of orchards was promoted by using fodder, fuel, timber and minor fruit species to ensure protection from domestic and wild animals. Thus the agri-horti-forestry system was designed taking into consideration agro-ecological conditions and local needs. This system was well accepted by small farmers in tribal villages.

Introduction of locally grown food crops as intercrops was essential in the initial stage until they were convinced of the benefits of new, unknown crops, apart from meeting their requirement of foodgrains. The major crops grown in these districts were sorghum, pearl millet, finger millet, maize, green gram, horse gram and pigeon pea. With good seed, improved agricultural practices and water conservation measures, crop yields went up by 50% to 100%, although about 20% of land was covered under fruit crops. Encouraged by success in increasing crop yields, participant families were motivated to introduce vegetable and seasonal fruit crops like watermelon in the intervening space and were able to earn about Rs.12,000 to Rs.15,000 (USD1=Rs.41) per year, before trees started bearing. This income motivated them to remain on their farms and migration of women and children almost ceased. Subsequently, with production of fruits, food grains and milk, net income of these families increased significantly to Rs.25,000 to Rs.30,000 per year and lifted them out of poverty. This unique programme has now been recognised by the Government of India for wider replication. This programme has also demonstrated the approach for conservation of eco-system and bio-diversity while providing a sustainable livelihood for poor families. With plenty of biomass generated on the farms, local families did not have to go to forests for collection of firewood, fodder and timber, which resulted in regeneration of natural forests.

While popularising this model, BAIF was also concerned about further enhancement of income of these families in the future. One of the options was to introduce less known high value crops as intercrops instead of restricting it to only low value food crops.

APPROACH

The strategy was to introduce various other fruit species, instead of promoting only mango as the main crop in the system. The fruit species included in the study were cashew *(Anacardium occidentale*), custard apple (*Anona squamosa*), Indian gooseberry (*Emblica officinalis*), tamarind (*Tamarindus indica*), ber (*Zizyphus mauritiana*) and jackfruit (*Artocarpus heterophyllus*). Although, farmers were aware of these crops, none of these were cultivated on a large scale in these districts. The newly introduced intercrops for studying their adaptability and economics were annato (*Bixa orellana*), Safed musli (*Chlorophytum borivilianun) and* Aloe vera (*Aloe barbadensis)*, apart from a few new vegetable crops in place of locally grown cereals and pulses. It was ideal to introduce these crops as sole crops, but due to doubts of farmers about their profitability, it was decided to cultivate them as intercrops. With regard to fruit species, farmers were persuaded to set aside an area of 0.1 to 0.2 ha for new crops, while retaining mango on the remaining area. This was acceptable because of a minimum assured income from mango and cereal crops, which enabled them to take the small risk of testing new crops on a smaller area. Observations on growth, yield and income from fruit trees required five to six years, while the suitability of newly introduced intercrops could be studied within two to three years.

The fruit crops under study were established in fields owned by over 1000 farmers who came forward to participate in this new venture. Cashew was planted by over 800 participants while each of the other fruit crops was planted by 20 farmers. It was difficult to persuade farmers to establish plantations of jackfruit even on 0.2 ha land. Hence the establishment was restricted to field bunds and borders, by using plants raised from seeds. Grafted plants of elite varieties were procured from reputable nurseries. Plantations received spot irrigation during the initial three years. These cultivators nurtured plants according to recommendations made by experts. Various interventions such as water conservation through contour bunding, establishment of wind breaks, application of nutrients and plant protection using integrated pest management were also carried out to improve crop productivity. Intercrops were cultivated during the rainy season (June to October) under rainfed conditions.

For studying suitability of intercrops, plants of annato raised from tissue culture were supplied by a local pharmaceutical company, which was prepared to provide the technology for cultivation, with a buy-back arrangement. More than 300 farmers planted annato on 0.2-0.4 ha. This being a perennial shrub, the spacing provided was 5 x 5 m and economic life was ten years. The firm also sent their experts to the field to instruct staff as well as farmers. Safed musli is a 16-18 months tuber crop, established by 10 farmers on raised furrows at 1 x 0.3 m spacing, using rhizomes. Planting materials of Safed musli known as fingerlets were collected directly from traditional growers in the neighbouring state and planted in June-July after the onset of rains. Rhizomes are pulled up in February or March and replanted in June for thickening. Rhizomes harvested in the second season, heavy and rich in medicinal constituents, are sold for processing. Aloe vera was planted by 12 farmers at a spacing of 0.5 x 0.5 m, using suckers. Plants were ready for harvest two to three years after planting, depending on soil fertility and availability of moisture. Observations made under different field conditions were analysed. Based on the profitability and marketability of the product, BAIF took up the promotion of relevant species on a wider scale.

PROGRAMME IMPACT

All newly introduced fruit and intercrop species could be established on degraded lands with a low mortality rate and good growth. Among these fruit species, cashew was found to be the most acceptable species among farmers. These trees established well with low mortality because of their ability to tolerate long dry spells, relatively free from pests and diseases, except tea mosquitoes which damage young shoots, a good demand for nuts, long shelf life and low price fluctuation. Although cashew was a new crop for this region, farmers in the neighbouring districts of Maharashtra, were aware of its cultivation. Hence after experiencing good harvests and convenience in handling the nuts, farmers came to prefer cashew to mango. While average gross income from mango was Rs. 60,000 per ha, gross income from cashew was Rs. 55,000 per ha. However, mango entailed higher uncertainty due to price fluctuation. As India is importing raw cashew and exporting processed cashew, there is substantial demand for cashew. This has stabilised the price and in fact, increased it. With the establishment of decentralised cashew processing units, managed by Growers' Cooperatives, farmers were able to get a better price for their products. This has further encouraged farmers to take up cashew cultivation on a large scale. On the other hand, marketing of mango was very sensitive as harvested unripe fruits had to reach the customers within a short period of six to eight days. In the absence of well planned distribution, growers were forced to sell fruits in the marketplace, where traders depressed the price. There are further opportunities to improve the yield of cashew because of the availability of new hybrid varieties, improvement in vegetative propagation and cultivation practices.

With regard to custard apple, although plants established well in less fertile soils as compared to cashew and mango, and fruit yields were high and regular, farmers were hesitant to take up large scale cultivation because of the marketing problem. Generally, custard apple fruits were harvested fully mature to ensure proper ripening and better quality pulp. However such fully mature fruits ripened within one to two days and this posed a serious problem of marketing. Custard apple is generally purchased by the urban elite as fresh fruit, while processed products do not fetch a premium price. Price fluctuation for fresh fruit is also a serious problem affecting profitability. Hence it was not advisable to extend cultivation, particularly far from cities, unless a cold chain was established to handle the fruit.

Budded plants of *ber* bear in the second year and yield profusely from the third year. The distinctive feature of the *ber* tree is its adaptability to drought as well as salinity. Farmers in North Gujarat use saline water for irrigation, without any ill effects on the tree. *Ber* is an attractive fruit for children but it is not as delicious as mango, citrus or guava. The demand for fruit is limited and price falls drastically during the peak season. Of late, *ber* fruits are processed into jam, squash, dehydrated fruits, etc. but have yet to become popular with consumers. Hence large scale cultivation of *ber* is extremely risky and not advisable, until the processed products become popular.

Tamarind and Indian gooseberry trees are highly drought tolerant and hence more suitable for semiarid regions where other fruit crops do not establish well. These species establish well and start cropping from the fourth and second year respectively. These crops have good potential for the future, due to increasing demand from the food processing industry. However the present market is not able to absorb large quantities of fresh fruits and so farmers are unable to get higher prices. Nevertheless, these crops have considerable scope in arid regions unsuitable for mango, cashew and other fruit crops. Such programmes should have a direct link with processing industries to ensure a ready market and a remunerative price.

Commercial cultivation of jackfruit is still in a primitive state in India, primarily because of the difficulty in procuring elite planting materials, long generation, lack of knowledge about yield and income, restricted use, sporadic demand and unorganised market. Trees come into bearing after six to eight years and there is a wide variation in the fruit size and the number of fruits borne by different trees. Marketing of fruit, both young as a vegetable and mature for dessert use is a serious problem, because of the smaller volume of produce, difficulty in handling fruit by urban women and lack of awareness of use of the fruit. Being a wildly growing fruit, families owning jackfruit trees generally share fruit with their relatives and neighbours. Hence marketing of jackfruit is extremely difficult in rural areas where it is generally grown. Even today, jackfruit grown by farmers in small numbers are collected by middlemen and sold as ripe fruit in the local market. However, in North India, tender immature fruit are used as a vegetable but growers get a poorer return due to low yield. In the Southern States, where ripe fruits are popular, people hesitate to buy large fruit because of the difficulty in separating fruitlets from the gummy fruit and the high cost of bulky fruit which normally weighs 10-15 kg. Hence a suitable system for processing and marketing is essential for popularising this species. With the present technology available for production and processing, it is difficult for jackfruit to compete with other fruit crops which are currently cultivated by farmers. Hence farmers should be encouraged to grow jackfruit on field bunds or along water channels, until competitive markets are developed for the fruit.

Based on this study, BAIF is now popularising mango and cashew in high rainfall areas and Indian gooseberry and tamarind in low rainfall areas to sustain the interest of farmers and to help them realise a better price. To ensure a better price for produce, small-scale cooperative processing units have been established in Maharashtra, Gujarat and Karnataka States. Although such units do not have the capacity to process the entire quantity of fruits grown by members, the procurement price fixed by cooperatives can prevent traders from exploiting growers. Processing units generate additional employment for local youth, preferably those from landless families.

Among newly introduced inter crops, annato seeds are used for extracting an edible pigment, while Safed musli and Aloe vera are used for preparing health tonic and Ayurvedic medicines. Aloe vera is also used in cosmetics. The firm which promoted the cultivation of annato had projected a yield of 0.5 kg per plant in the first year and 1 kg, 2 kg, 4 kg, and 7-8 kg in the second, third, fourth and fifth year and onwards respectively. However, plants established under this programme started bearing in the second year, with 0.1 kg, 0.2 kg, 0.5 kg 1.0 kg in the second, third, fourth and fifth years respectively. Thus the price of Rs. 25 per kg offered by the firm was not attractive to growers. Some efforts were made to explore alternative markets as the price in the international market was almost eight to ten times higher than what was offered locally. However in the absence of technology for processing and low volume of production, further persuasion about price realisation and cultivation was not credible. Farmers uprooted plants after observing yield for three years.

With regard to Aloe vera, many Ayurvedic firms and local herbal healers had promised to purchase fresh leaves at a very remunerative price. Aloe vera being hardy, farmers owning degraded lands were satisfied with production. However, processors and herbal healers came forward to purchase fresh leaves at only 20% of the price offered earlier. Thus the growers were disappointed and did not want to continue cultivation. *Safed musli* was selected mainly because of the high price prevalent in the market, particularly in Madhya Pradesh State. While initiating the trial, the profitability of this crop was so high that farmers were anticipating almost 500% higher income over the food crops grown by them. However looking to the poor marketing outlet, BAIF introduced this crop with caution on a small scale. As anticipated, by the time the crop was harvested after 16 months, the price had fallen down drastically due to lack of buyers and processing facilities. There is no future for this crop unless a strong tie-up is made with the processing industry.

Thus the farmers who participated in cultivating the above three less known crops could not earn more than they could have earned from vegetables and food crops. However they had other sources of income for their livelihood. Hence they did not mind taking part in this new study. In spite of minor setbacks, they were able to appreciate the initiatives.

CONCLUSION

There are many underutilised food and non-food plant species, having good potential to contribute to the income of farmers. However it is essential to validate their adaptability, demand for the produce and profitability in comparison to alternative crops grown in the region. While promoting underutilised fruit trees and medicinal crops in the Western Ghats region of Gujarat and Maharashtra States, it was observed that the success in promotion of underutilised crops was dependent on crop yields, price for produce and marketability either in fresh or processed form. It is easier to promote food crops, because of the local market but difficult to promote medicinal crops without prior buy-back arrangements.

Promotion of underutilised crops without marketing back-up being risky, it is advisable to introduce such crops on a small scale, without seriously affecting the assured source of income. This will also give time to expand the market in the future. Subsequently, successful species can be replicated on a large scale.

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A case for promotion of tropical underutilised fruits for improvement of livelihoods

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Tropical fruits are important multi-purpose species for small-holders. Many species provide foods that supplement and improve diets, as well as fuel, timber, fodder, medicines and industrial products. Fruit trees also have positive environmental benefits as they provide perennial ground cover, as well as storing and recycling plant nutrients.

Many rural people cultivate fruits in home gardens or orchards, or collect produce from the wild as a source of valuable supplemental nutrition and additional income. The nutritional importance of fruits is appreciated, although consumption is low in many developing countries due to low production and high price.

Since 1991 CUC has been working to improve a number of UFTs (underutilised fruit trees) to increase UFTs fruit productivity and income potential for poor farmers. The research has focused on collection, characterisation and evaluation of germplasm, developing propagation methods, distribution of quality planting materials, processing and product development, capacity partner human resource building and information dissemination (including developing manuals for farmers with poor literacy skills). This paper summarises the results and the progress of a project undertaken by CUC through The Under-utilised Tropical Fruit in Asia Network (UTFANET) programme and provides evidence to support the cultivation of underutilised fruit trees to improve livelihoods.

INTRODUCTION

Many of the poorest people in the world rely on agriculture for their livelihoods. Although there has been some progress in improving food and nutrition security and reducing poverty in some regions due to agricultural technology developments, widespread poverty and malnutrition still exists across the world. The number of hungry people in the world is currently rising at a rate of four million a year (FAO, 2006). The effects of climate change, the continued rise in global populations, increase in food prices, globalisation and rapid urbanisation are likely to have a further negative impact on food availability, income generation and welfare. These are issues to which agricultural production will have to adapt.

Complete reliance on major crops to achieve food and nutrition security, poverty alleviation, and ecosystem conservation has been questioned. Much of the increase in crop production required today will have to come from so-called marginal lands, which are not suitable for the production of many of the major crops. The agricultural sector needs to respond in ways beyond the traditional focus on higher yields (Fresco, 2003). There is awareness that in all types of agro-ecosystems, diversification of crop species is a crucial element for sustainability (Collins and Hawtin, 1998; Padulosi *et al.*, 1999).

Both the FAO and WHO identify dietary diversification as key to combating micronutrient deficiencies (Anon, 2005). Fruit trees contain accessible sources of essential vitamins and minerals and valuable nutrition (Verheij and Coronel, 1991; Anon, 2005) and their use can increase dietary diversity (Williams and Haq, 2003). Underutilsied fruits, cultivated in home gardens or orchards, or collected from the wild combat hidden hunger and thus have a direct impact on well being and health (Anon, 2005; ICUC, 2006). Underutilised tropical fruits provide a broad portfolio of crops to improve dietary diversity (Williams and Haq, 2003). There are many underutilised fruits that are important locally, but are not available to national or global markets. These fruit tree species are also important multi-purpose species in providing non-food products, such as fuel, fodder, medicines and industrial products for income generation.

Many of these species have been traditionally grown in mixed cropping systems. The fruit trees enhance resilience against the effects of adverse weather conditions, poor soils and pests (Verchot *et al*., 2005). In regions where climate variability is commonplace and adverse impacts of climate change are expected,, the role of fruit trees in buffering against production risk and providing a continuous supply of environmental services can be of great importance (Ong and Leakey, 1999). Underutilised fruit trees, therefore have potential to provide sustainable environmental services, such as reducing land degradation associated with rainfall variability and poor agricultural practices. They stabilise the soil, assist the cycling of nutrients and enhance biodiversity. They also provide improved infiltration of water, therefore reducing runoff and transportation of sediments and soil nutrients (Verchot *et al*., 2005).

The sale of fresh and processed fruit products generate income which often acts as an economic buffer and safety net for poor households. Traditional methods of product processing have developed into cottage industries where products are sold in local markets. Women generally hold the knowledge base for such processing and utilisation, therefore providing increased income and empowerment to potentially vulnerable members of society (Williams and Haq, 2003; Haq, 2004). Processing of fruits produce and product diversification has the potential to create new market opportunities with employment at various levels. Opportunities for diversification of livelihoods occur, and the development of rural micro-enterprises such as community participatory production and village level processing and marketing (InWEnt/GFU, 2003; Haq, 2004).

The Centre for Underutilised Crops (CUC) at Southampton University was established in 1988 as a unit for scientific research, education and an innovation centre. The goal of the centre is to promote sustainable use of underutilised crops for under-resourced poor farmers and the agro-industry, through providing food and income security. Research focuses on assessing, developing and utilising untapped biological diversity of underutilised crops and wild plant species. Thus the CUC aims to domesticate and incorporate into farming systems those species that are under-developed and grown by many farmers throughout the world.

The CUC's policy is to work within commodity groups: cereal and pseudo-cereals, fruit and nuts, vegetables and legumes, roots, tubers, and industrial and medicinal crops. The CUC's activities are undertaken in order to produce outputs which will contribute to the above purpose and goal. The principle activities are research and development led projects and programmes, the assembly and dissemination of information and the building of its partners' human resource capacities necessary for fostering their participation in programmes and their uptake of outputs

In 1991, CUC set up a global programme on 'Fruits for the Future', with the objective of improving the economic, social and nutritional status of people through increased production and utilisation of underutilised tropical fruits. As a consequence of the interest shown by the National Agricultural Research Systems (NARS) in this programme, CUC, along with its Asian partners established a research network of nine countries called Underutilised Tropical Fruits in Asia (UTFANET) in April 1995.. This paper presents a case study on the promotion of underutilised tropical fruit trees through the endeavours of this network over a three and half year period (April 2000-October 2003) funded through National Lotteries Charity Board (NLCB) and CUC.

STRATEGIC APPROACH

UTFANET developed a three pronged strategy to achieve its goal, which included:

- Identifying research for development
- Providing knowledge based information dissemination.
- Developing human resources and capacity building.

1. Research for development

The network identified national priority species and assessed the species' genetic diversity with the help of farmers' participatory surveys. The nine countries, Bangladesh, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam identified 3 priority species: jackfruit (*Artocarpus heterophyllus* Lam), pummelo (*Citrus maxima* Merr) and mangosteen (*Garcinia mangostana* L.).

For most underutilised fruits there are no recognisable breeding and selection methods for identification of desirable traits and assessment of diversity has been inadequate. Suitable ideotypes for various uses, such as for food or medicines, growing in small-scale production systems, plantations and other niche farming systems have yet to be identified. UTFANET developed descriptors, identified ideotypes; surveyed, evaluated and selected superior lines of jackfruit, pummelo and mangosteen in the nine partner countries. Superior clones were identified and nurseries established for further characterisation, evaluation and multiplication (Table 1).

Table 1. Jackfruit, mangosteen and pummelo accessions and promising lines of UTFANET-member countries

Country	Jackfruit (n=9)		Mangosteen (n=5)		Pummelo (n=8)	
	Collection/ characteriz-ation and evaluation	Selection	Collection/ characteriz-ation and evaluation	Selection	Collection/ characteriz-ation and evaluation	Selection
Bangladesh	70	10	NA	NA	93	5
India	53	33	1	1	40	8
Indonesia	28	4	NA	NA	NA	NA
Nepal	300+	47	NA	NA	132	4
Pakistan	10	10	NA	NA	6	NIY
Philippines	148	NIY	82	NIY	31	NIY
Sri Lanka	77	3	572	2	66	6
Thailand	62	2	7	NIY	52	2
Vietnam	200	8	4	4	50	9

n - number of countries working on survey and germplasm collection and identification of promising lines for the three crops
NA - not assigned
NIY - not identified by end of programme
NRY - not reported by end of programme

A major constraint to fruit tree production is the availability of quality propagation material. Propagation using seed results in segregation from generation to generation, producing deterioration of the stock. Vegetative propagation preserves genetic uniformity and reduces fruiting time. Appropriate methods of propagation vary between species and techniques have not been standardised. UTFANET established the best practice propagation methods for a number of fruit crops. Superior planting material was then propagated (Table 2) and distributed to farmers and nurseries (Table 3). Training programmes on grafting techniques were provided for nursery managers and farmers. (Table 4). As a consequence of the partners' endeavours, the use of appropriate propagation methods, and multiplication of materials for distribution to farmers to establish their own nursery with quality materials has increased income for farmers using the three tree species chosen in these countries.

Table 2. Recommended grafting techniques identified for propagation of Jackfruit, Pummelo and Mangosteen

	Recommended grafting technique		
	Jackfruit	Pummelo	Mangosteen
Bangladesh	Veneer Cleft Epicotyl	Side Veneer Cleft	
India	Softwood Epicotyl	Budding Airlayering	
Indonesia	Top		
Nepal	Splice Cleft	Veneer	
Pakistan	Cuttings		
Philippines	Modified cleft	Budding	
Sri Lanka	Wedge	Wedge	Cleft Approach
Thailand	Cleft	Cleft	Cleft
Vietnam	Cleft	Cleft	Cleft

Source: Haq, 2007

Table 3. Distribution of grafted jackfruit, pummelo and mangosteen during project implementation.

Country	Jackfruit (JF)	Pummelo	Mangosteen
Bangladesh	28 nurserymen each planted up to 5 grafted and tissue cultured JF as mother plants. 192 grafted JF and 100 tissue cultured JF were distributed to 128 farmers and nurseries for further grafting and distribution.	27 nurserymen each planted up to 5 grafted pummelo as mother plants. 148 grafted pummelo were distributed to 140 farmers and nurseries for further grafting and distribution.	Not in programme
India	60 plants distributed during training. 65 grafts and distributed to local farmers. (50 farmers in all). 190 grafts were ready for distribution	133 pummelo plants distributed to 45 farmers for planting as mother trees.	2 selected mangosteens planted at CHES, Chethalli Field Gene Bank for observation and production of future mother plants.
Indonesia	150 seedlings of three selected accessions planted at Solok Experimental Institute as parent stock. 600 seedlings distributed in January and July 2003	Not in programme	Not in programme
Nepal	480 grafted plants distributed to 6 private nurseries (for mother plants) and 25 fruit growers (for orchard establishment. 17 training participants received 5 plants each. Approximately 200 plantlets were available for distribution in 2004.	500 grafted pummelo distributed to 4 nursery owners and 30 farmers. 17 Training participants also received 5 plants each	Not in programme

Philippines	16,000 grafted seedlings distributed in 2001 under national programme	Not in programme	35 germplasm accessions conserved as seedlings or asexually propagated in *NPGRL, #IPB in association with $IPGRI. Need further selection.
Sri Lanka	230 grafted seedlings distributed to training participants, home gardeners, farmers, nurserymen and Colleges. Many seedlings also distributed to nurseries	460 grafted seedlings distributed to 18 nurseries, 50 farmers, 2 agricultural enterprises, 2 Schools of Agriculture, 1 Army Camp and 1 College. Many seedlings also distributed to nurseries	265 grafted seedlings distributed to 11 nurseries and 18 local farmers, 2 Government farms and 1 botanical garden. 532 grafted plants distributed by trained nurserymen/women. 3556 seedling plants distributed by trained nurserymen/women.
Thailand	1000 grafted plants distributed to 48 male and 69 female (total 117) farmers.	1000 grafted plants distributed to 19 male and 32 female (total 51) farmers.	100 grafted plants distributed to 16 male and 4 female (total 20) farmers.
Vietnam	500 grafted plants distributed to 300 farmers of three provinces.	500 grafted plants distributed to 20 farmers of three provinces	100 grafted plants distributed to 9 farmers of three provinces.

*NPGRL(National Plant Genetic Resources Laboratory), #IPB (Institute of Plant Breeding), $IPGRI International Plant Genetic Resources Institute.

Table 4. Number of farmers and nursery persons trained in grafting techniques in UTFANET countries

Country	No. of farmers and nursery persons trained in grafting techniques
Bangldesh	98
India	63
Indonesia	20
Nepal	17
Pakistan	25
Philippines	28
Sri Lanka	355
Thailand	30
Vietnam	20
Total number trained	656

Product diversification has the potential to enhance underutilised crops' importance in both developing and developed countries' markets (Akinnifesi *et al.*, 2005). It is envisaged that this can be done without much investment as technology is already available for commercially important fruit species, such as banana, mango, pineapple, avocado and citrus. It is important to develop, adapt and transfer these technologies to underutilised fruits. Such technologies allow the growth of a wide diversity of products, adding value and increasing the shelf life of products.

Capacity to store and market fresh produce is a major problem for small scale farmers and producers. A narrow production season and low shelf life can cause a glut in the market leading to low prices, followed by relative scarcity and high prices. Processed products provide a longer shelf life and easier storage. However quality and consistency of products are the major factors which hinder the marketability of underutilised fruit products. Best practice hygienic procedures are often unknown and appropriate equipment unavailable, leading to poor quality and inconsistent products or products which degrade quickly.

Consumer requirements and appropriate processing and marketing strategies can vary between regions and are often unknown to small scale producers, particularly outside their local areas. By combining well established principles and appropriate equipment with good standards of quality and hygiene, it has already been demonstrated that small scale food processing enterprises can produce quality marketable products (Haq, 2007).

The UTFANET programme assessed the status of the processing and marketing of underutilised fruits in Asia. It examined post harvest handling, processing and marketing of underutilised fruits in five (Bangladesh, India, Nepal, Vietnam and Sri Lanka) of the UTFANET countries. The following recommendations were made to overcome constraints.

(a) Improve access to information
(b) Improve quality of products
(c) Increase range of products
(d) Improved storage and availability of raw materials
(e) Improved packaging
(f) Access to appropriate equipment
(g) Assistance with marketing of products.

Research into the development of products has been carried out by the above five countries and flow charts for processing were produced for endusers. This has encouraged small producers to become entrepreneurs within a cooperative, leading to livelihood improvement. At least three SMEs in each country have taken up the marketing of these products. Products, such as jam, pickles, juice, leather, candy, etc., are now produced by local women's groups and marketed by entrepreneurs in some countries.

2. Knowledge based information dissemination

There is little scientific information on the genetic resources, agronomic requirements or post harvest processing of many underutilised fruit species, nor on the management and production systems in which underutilised fruits are grown that affect the quality and quantity of produce. Underutilised fruits are often subject to heavy post harvest loses, both in quantity and quality, during harvesting and transportation. Prior to the commencement of the UTFANET programme, CUC was involved in reviewing the available scientific literature on best practice for the management and production of ten underutilised fruit tree species from propagation to harvesting. The review was part of the 'Fruits for the Future' programme and included jackfruit and mangosteen. CUC made this information available through a number of field manuals that provided information on Why, Where, and How to grow the species and included harvesting, processing and storage processes for each species. The CUC has disseminated information for these ten selected species in user friendly formats for farmers, processors, entrepreneurs, trainers, NGOs, extension workers, researchers and policy makers through training workshops, field manuals, factsheets, posters, websites, databases, monographs, CDs and DVDs.

The CUC has developed a large volume of information on new and underutilised crops. Much of this information is unique and original. CUC has established a data base to house and organise this valuable resource. The database lists information on a species basis. It contains essential botanical and agricultural data. The CUC database also provides information on the uses that have been made of each species. Much of the information is derived from ethno-botanical literature and other sources. The database contains ecological information of the edaphic, climatic and agronomic requirements of each species and the cropping and farming systems to which each species is best suited. It contains facts about institutions, scientists and projects working with each species. Bibliographic information is drawn from other databases, together with contact telephone, fax ad e-mail numbers. The CUC database is continuously updated and can be viewed at the CUC website.

"Fruits for the Future" is a programme of the CUC dedicated only to underutilised tropical fruits. The programme includes monograph publications with accompanying extension materials for extension assistants and farmers. The CUC has also produced fact sheets and posters on processing methods for fruit products, and training manuals for processing methods and small business development.

This database formed the foundation to provide information on the post harvest handling, processing and marketing of the three underutilised fruit species in the UTFANET programme. As part of the programme CUC developed training materials including posters and technical manuals for end users in the nine partner countries.

Technical manuals contained three distinct sections:
Module I: Post harvest handling.
Module II: Processing methods for fruit products.
Module III: Starting a small scale fruit processing enterprise.

These modules provide information on:

- Increasing the range of products
    - Range of possible products
    - processing methodologies
    - Nutritional and medicinal value and niche market potential of products
- Supply of raw material
- Equipment

    - Availability of equipment and cost
- Marketing
    - Market assessment and analysis
    - Improving market channels
    - Branding
- Hygiene
- Quality control
- Legal aspects
- Establishing working groups/cooperatives and securing credit for purchase of
    - Equipment
    - Raw material
    - Facilities
- Record keeping

Technical manuals and posters were successfully used in training programmes for small scale producers, entrepreneurs and extension persons (see Section 3).

3. Human Resource Development

In order to facilitate the dissemination of information from the UTFANET programme, Resource Centres were established to provide equipment, the development of community participatory products using training materials produced through the programme (see Section 2), lectures and workshops for trainers and the community involved in UFTs. Training courses were provided on food technology, hygiene and quality control to improve the quality of product, as well as market assessment, analysis, and product pricing. These training courses provided information on the range of possible products, their processing methodologies, medicinal properties, nutritional value, potential for niche markets and the potential supply of semi-processed fruits to large food companies. The centres also helped to establish a community network to improve marketing entrepreneurship

Other training programmes developed as part of the UTFANET programme outputs were:

- Crop improvement in Malaysia
- Establishment, cultivation and management for orchards in Vietnam
- Jackfruit propagation and nursery management in the Philippines
- Mangosteen propagation and study visits to fruit growing areas in the Philippines
- Practical training on the production, management of tropical fruits in Thailand,
- Vegetative propagation and nursery management in India
- Regional training course on the conservation and use of tropical fruits in India.

The following numbers of people attended training courses and benefited from the UTFANET programme:

- Specific subject areas- 65 benefited
- In-country farmers' trained- 865 benefited
- Ph.Ds: Five individual benefited from member countries

CONCLUSIONS

Underutilised fruit trees are grown by farmers as part of their crop diversification activities in household farms, community gardens and in agroforestry systems. The increased availability of quality planting materials of three species, jackfruit, pommelo and mangosteen has raised interest and use of these species in the network countries as a direct result of the UTFANET programme. The processing and marketing chains developed through the project, enabled community groups to work together by using the same facilities in a cooperative manner to generate income for their families. The appropriate training materials to develop stakeholders' processing and marketing skills have helped the community and government agencies to understand the constraints involved and how to overcome them. The information on improved propagation, production, processing, marketing and disseminated, through the resource centres, has enabled more women groups to become involved in product development and marketing in the network countries.

It is clear from the project that farmers better appreciate the value of domestication and improvement of underutilised fruits and their understanding will further enhance the production and utilisation of underutilised fruit trees in participatory countries. Thus, the diversity in diet and income for small farmers has been, and will continue to be enhanced.

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Domesticating and commercialising indigenous fruit and nut tree crops for food security and income generation in Sub-Saharan Africa

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Research data on indigenous fruit and nuts has accumulated considerably in Sub-Saharan Africa, and their role is being recognised in the domain of poverty reduction. An *ex ante* impact analysis in southern Africa indicate that indigenous fruit can reduce vulnerability of rural households to poverty. Hence, research has been on-going in development of long-term domestication strategies, selection of priority species, germplasm collection and genetic improvement, propagation systems and field management, harvesting and post-harvest technology, economic analysis and market research. There are similarities in the approaches and lessons learnt in different regions, especially in West and Southern Africa. The selection, management and cultivation of IFTs are generally characterised by integration of silvicultural and horticultural approaches. Time to fruiting of wild fruit trees have been reduced from more than 12 years in the wild to less than four years in all three regions. This paper synthesises available studies on the domestication of indigenous fruit trees as tree crops, and commercializing their products, highlights the lessons learnt and provides the way forward to tap into the opportunities presented by IFTs to enhance food security and income generation in sub-Saharan Africa

INTRODUCTION

The harvesting, utilization and marketing of indigenous fruit and nuts have been central to the livelihoods of the majority of rural communities throughout Africa (Akinnifesi *et al.,* 2007; Leakey *et al.,* 2005) and can make a difference during periods of famine and food scarcity (Mithofer and Waibel, 2003, Akinnifesi *et al.,* 2006). Harvesting of fruits from native forests and semi-domesticated trees growing on-farm and homesteads can substantially boost rural income and employment opportunities in Africa (Leakey *et al.,* 2005; Ruiz-Perez *et al.,* 2004). Market and financial analyses in southern Africa show that indigenous fruits contribute to household income, and women and children are the major beneficiaries (Ramadhani, 2002).through value addition and fruit processing (Saka *et al.,* 2004, 2006). Indigenous fruit trees provide higher value-to-weight ratio and are easier to transport than timber or wood products (Teklehaimanot, 2004). Several indigenous fruit tree crops are excellent sources of vitamin C that can reduce malnutrition that is widespread many SSA countries. For example, baobab (*Adansonia digitata*) pulp produces more than 10 times as much vitamin C as the same weight of oranges (Sidibe *et al.,* 1998).

Focusing on wild collection and management of semi-domesticated trees on farm and homestead has been indicated as an effective way of reducing costs, providing households with improved species diversity in terms of desired fruit and tree traits (Kruse, 2006). However, wild harvesting (extractivism) and over-extraction have led to supply shortages in many cases (Simons and Leakey, 2004). As forests recede due to deforestation, wild fruit trees become liable to overexploitation and extinction. Relatively little research and development attention has been given to the promotion of indigenous trees as tree crops for wider cultivation. Domestication of indigenous fruit trees emerged as a farmer-driven, market-led process and has become an important agroforestry initiative in the tropics (Akinnifesi *et al.,* 2006, Tchoundjeu *et al.,* 2006; Leakey *et al.,* 2005). In the last decade, the World Agroforestry Centre (ICRAF) has advanced research on domestication and commercialization of indigenous fruit trees in order to improve rural livelihoods—nutritional status, household income, entrepreneurial opportunities and economic empowerment--and promote biodiversity conservation and the sustainable use of natural resources in the tropics.

There is increasing enthusiasm among researchers and development practitioners to explore the opportunities to meet food needs of humanity through indigenous fruit trees (IFTs). Much of this work has been undertaken in Africa, and it builds on the efforts of smallholder farmers who had initiated the first step towards domestication through retaining, selection and cultivation of semi-domesticated fruit trees (Leakey *et al.,* 2005; Tchoundjeu *et al.,* 2006; Akinnifesi *et al.,* 2006, 2007). As a result, there is an increasing emphasis on promoting IFTs with economic potential as new cash crops, product development, commercialization and marketing of agroforestry tree products (AFTPs). This paper provides a synthesis of the lessons learnt and the way forward for domesticating indigenous fruit trees as tree crops, and commercializing their products in West, East and Southern regions of Africa.

PARTICIPATORY DOMESTICATION APPROACHES

Domestication involves a long-term iterative and integrated strategy for tree selection and improvement, for the promotion, use and marketing of selected products and their integration into agroforestry practices (Akinnifesi *et al.,* 2006). Indigenous fruit tree domestication is based on the concept of 'ideotypes' derived from an understanding of the tree-to-tree variation in commercially important traits (Leakey *et al.,* 2005; Leakey and Akinnifesi, 2007), and participatory selection of superior clones and cultivars with users following objective criteria, vegetatively-propagating and integrating them into farming systems.

Participatory domestication research and development in the humid lowlands of West and Central Africa began in 1998 with an initial focus on *I. gabonensis* in Cameroon and Nigeria but has expanded progressively to Equatorial Guinea, Gabon, the Democratic Republic of Congo and Ghana in the last four years (Leakey *et al.,* 1998; Tchoundjeu *et al.,* 2005), *D. edulis* (Leakey *et al.,* 2002; Anegbeh *et al.,* 2005). In southern Africa, it started in 1996 in Malawi, Zambia, Zimbabwe and Tanzania with a focus on *Uapaca kirkiana* and *Sclerocarya birrea* (Kwesiga *et al.,* 2000; Akinnifesi *et al.,* 2004, 2006, 2007). In both regions, participatory tree domestication approaches involved the following steps:

i. Selection of priority indigenous fruit tree species based on farmers' preferences and market orientation;
ii. Identification of superior or elite trees based on established criteria by users, marketers and market preference (tagging and naming trees for purpose of ownership and property rights recognition);
iii. Development and applying efficient vegetative propagation and nursery management techniques for producing quality propagules for on-farm dissemination;
iv. Integration of improved germplasms into farming systems; and,
v. Post-harvest handling, processing and marketing research of fresh and processed products from domesticated species.

Taking Advantage of Genetic Diversity

The first step in IFTs domestication is to identify the most valuable trees for smallholder farmers and for the market. The key steps include i) verifying the importance and potential of indigenous fruits in the rural economy, ii) initiating tree selection and improvement of germplasm, iii) to develop and promote the wider cultivation of superior cultivars of indigenous fruit, and iv) to commercialise new IFTs products through a functional supply chain (fruit storage and processing, product quality assurance, value-adding, marketing research, rural revenue generation and enterprise development). The early results obtained by ICRAF indicated that indigenous fruit trees could be propagated and cultivated. Some of the trees had fruited within three years and this increased the enthusiasm of researchers. In southern Africa, a region-wide germplasm collection and multi-locational provenance and family trials was initiated with partners during 1996-98 (Akinnifesi *et al.,* 2004).

Choosing the 'Big Five' priority indigenous fruits species

Given that participatory domestication involves selection and management of the most highly valued trees and cultivars, prioritisation is the first logical step in obtaining premium species. Guidelines for systematic priority setting in different regions involving the participation of local communities and partners have been developed (Franzel *et al.,* 1996, 2007) and applied in West Africa (Adeola *et al.,* 1999), and with modifications in southern Africa (Maghembe *et al.,* 1998) and East Africa (Teklehaimanot, 2007; Jama *et al.,* 2007). The guidelines involves (i) Team building among stakeholders to agree on approaches and adapt methods to local conditions, (ii) Identifying clients and assessment of users' needs (farmers, marketers, etc); (iii) Inventory of all species used by clients, including potentially useful ones; (iv) Identify the most important products from IFTs in the target region. Consider only those with the greatest importance; (v) Selection of smallest number of species with highest benefits: (vi) Estimating the production value of key species to set priorities and; (vii) Synthesise previous results, review the process and select the final choice of species (Franzel *et al.,* 1996). Results from the priority setting exercises in four eco-regions of Africa are illustrated in Table 1.

Table 1. List of the five most preferred priority indigenous fruit tree species in selected regions

Region	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Method	Source †
East Africa (Ethiopia, Kenya, Sudan, Uganda, Tanzania)	*Adansonia digitata* (Baobab)	*Tamarindus indica* (Tamarind)	*Ziziphus mauritiana* (Ber)	*Sclerocarya birrea* (Marula)	*Balannites aegyptiaca Del.*	Field surveys (n=167)	1, 2,3
Southern Africa (Malawi, Zambia, Zimbabwe, Tanzania, Mozambique)	*Uapaca kirkiana* (Wild loquat)	*Strychnos cocculoides* (Wild orange)	*Parinari curatell-ifolia* (Maula)	*Ziziphus mauritiana* (Ber)	*Adansonia digitata*	Field surveys (n=451)	4,5
West Africa (Ghana, Nigeria, Cameroon)	*Irvingia gabonensis* (Wild mango)	*Dacryodes edulis* (African plum)	*Chryso-phyllum albidum* (Star apple)	*Garcinia cola* (Bitter cola)	*Cola nitida*	Workshops, field surveys (n=94)	6
Sahelian zone (Seneghal, Mali, Niger, Burkina Faso)	*Adansonia digitata* (Baobab)	*Tamarindus indica* (Tamarind)	*Vitellaria paradoxa* (Shea)	*Ziziphus mauritiana* (Ber)	*Parkia biglabosa*	Field surveys (n=470)	6,7

†Jama *et al.,* (2007); 2. Teklehaimanot (2007); 3. Chikamai *et al.,* (2005); 4. Maghembe *et al.,* (1998); 5. Akinnifesi *et al.,* (2007), 6. Franzel *et al.,* (2007). 7. Bounkoungou *et al.,* (1998).

Miombo eco-region of southern Africa

In the miombo eco-region of southern Africa, multi-site ethnobotanical surveys were conducted in Malawi, Tanzania, Zambia, and Zimbabwe in 1990-1991 to understand species diversity and role of trees on farm, with respect to their establishment and management, location and arrangement, market opportunities, uses and functions in farmer fields (Kwesiga and Chisumpa, 1992; Maghembe and Seyani, 1991). The surveys identified over 75 indigenous fruit tree species that are an important resource for rural communities as important sources of food and income.

Subsequently, a priority setting workshop identified two species for the region, namely *Uapaca kirkiana* and *Sclerocarya birrea,* and range-wide germplasm collection of both species were undertaken during 1996 in Malawi, Zambia, Tanzania and Zimbabwe (Kadzere *et al.,* 1998). Further surveys were conducted in four countries leading to the identification of *Uapaca kirkiana, Parinari curatellifolia, Strychnos cocculoides, Ziziphus mauritiana and Adansonia digitata* as the five most preferred species for domestication by farmers in the region. Recently, the different methods used in the region were triangulated to obtain a more reliable consensus (Akinnifesi *et al.,* 2007; Franzel *et al.,* 2007). This approach recognised the effects of location, sample size, time dynamics, socio-economic and ecological niches. Based on these results, the three top regional spearhead priority species (species which drive the domestication programme) were *Uapaca kirkiana, Strychnos cocculoides* and *Sclerocarya birrea* (Akinnifesi *et al.,* 2006). Adapted species such as *Ziziphus mauritiana* and *Casmiroa edulis* and *Tamarindus indica* were also widely accepted by farmers and users

(Akinnifesi *et al.,* 2007). Further, analysis clearly showed that farmers and users greatly prefer exotic and conventional horticultural tree crops such as mangoes, citrus, avocado, bannana among the top ten fruits in Malawi and Zimbabwe where exotics were included in farmer and market surveys (Akinnifesi *et al.,* 2007; Franzel *et al.,* 2007; Ramadhani, 2002). The approach was also applied to IFTs products in southern Africa (Table 2).

Table 2. Participants' priority products in workshops held in Magomero, Malawi, Tabora, Tanzania, and Harare, Zimbabwe.

Magomero	**Tabora**	**Harare**
Mango juice	Baobab juice	Parinari oil
Mango dried	Groundnut butter	Strychnos jelly
Mango jam	Strychnos juice	Marula oil
Tomato jam	Parinari wine	Marula jelly
Baobab wine	Vitex jam	Ziziphus fruit leather
Baobab juice	Syzygium juice	Uapaca jam
Uapaca wine	Marula wine	
Uapaca juice	Flacourtia jam	
Marula wine	Mango juice	
Marula juice	Guava jam	

Source: Ham and Akinnifesi (2006)

Humid lowlands of West Africa

Several priority setting surveys conducted in the humid lowlands of West Africa including Cameroon, Nigeria, and Ghana showed considerable variability among farmers' priority species within and between the countries surveyed (Franzel *et al.,* 2007). The number of species mentioned in each of the three countries ranged from 60 in Cameroon to 172 in Nigeria (Franzel *et al.,* 2007). No single species ranked among the top ten in all three countries. In general, *Irvingia gabonensis, Dacryodes edulis* and *Chrysophyllum albidum were ranked* among the top four in at least two of the countries (Table 1). All three were important as both food and cash earners (Adeola *et al.,* 1998). Unlike southern and East Africa, the priority setting results in West Africa showed less concordance among neighbouring countries. This is probably due to the heterogeneity of ecological conditions between and within countries. Details of the ranking have been documented elsewhere (Franzel *et al.,* 2007).

Sudano-Sahelian Zone of West Africa

In a survey conducted across Senegal, Mali, Burkina Faso, and Niger at the southern margins of the Sahara desert, a total of 59 species were indicated as important, of which 15 were common in these countries (Franzel *et al.,* 2007). The study showed the following order of preference: 1. baobab (*Adansonia digitata*), 2. tamarind (*Tamarindus indica*), 3. karate or shea butter tree (*Vitellaria paradoxa*), 4. ber *(Ziziphus mauritiana)* and 5. nere (*Parkia biglobosa*) (Table 1). There were also country specific species, such as *Balanites aegyptiaca, Diospiros mespiliformis* and *Vitex doniana* in Niger. As in the humid lowlands of West Africa, trees providing food dominated farmers' choices among species. Baobab also provided leaves as food (Sidibé *et al.,* 1996).

Dry Regions of Eastern Africa

Priority setting workshops in dry region of Eastern Africa were carried out by the Association of Forest Research Institutions in Eastern Africa (AFREA) in collaboration with IPGRI-SSA and national partners in 2004 (Chikamai *et al.,* 2005; Jama *et al.,* 2007). The workshops involved participants from Ethiopia, Kenya, Sudan, Tanzania and Uganda and carried out the following: i) national priority setting through brainstorming meetings and discussions senior extension and researchers ii) field surveys involving local community leaders, farmers, pastoralist, traders and other community dwellers in 26 villages in the five countries. The combined results of the two approaches indicated the five top regional priority species as follows: *Adansonia digitata*, *Balannites aegyptiaca, Cordeaux edulis*, *Sclerocarya birrea* and *Tamarindus indica* in a decreasing order of importance. In addition, *Vitellaria paradoxa, Parinari curatellifolia* and *Ziziphus mauritiana* were among the top eight species. Details of the results are documented in Chikamani *et al.,* (2005) and Teklehaimanot *et al.,* (2005).

Overview of the BIG FIVE in Sub-Saharan Africa

The discussion above shows that there has been no systematic continental level research to identify the top priority indigenous fruit trees in sub-Saharan Africa. It seems logical that due to the diverse ecology, farming systems and vast geographical area such research will have little application to cultivation. Therefore, regional priority setting is more relevant. However, for the purpose of comparison with other tropical regions, it is possible to identify the five top priority species in Africa, based on the long-term investment into priority setting in the last ten years, led by ICRAF and partners across Africa.

For such prioritization to be relevant, it is important to identify these as humid tropics, semi-arid and dry regions. For the humid region (West Africa), *D. edules, I. gabonensis* and *C. albidum* are important (Table 1). Of these three, *I. gabonensis* and *D. edules* are most widely traded. There are also regionally cross-cutting species such as *S. birrea* and *T. indica* in southern and East Africa. *Z. mauritiana* in the Sahel, southern Africa and East Africa. *V. paradoxa* is common to dry region of East Africa and the Sahel of West Africa. Therefore, the major five species based on market extent and preference could be (1) *V. paradoxa,* (2) *S. birrea,* (3) *I. gabonensis*, (4) *Z. mauritiana* and (5) *D. edules.* This ranking is based on subjective criteria, mainly personal knowledge of the market and priority setting results from each region. A systematic study identifying continental species is further warranted.

CLONAL SELECTION AND PROPAGATION

Tree domestication refers to how humans select, manage and propagate trees where the humans involved may be scientists, civil authorities, commercial companies, forest dwellers or farmers (Simons and Leakey, 2004). Tree domestication is a paradigm shift from focus on tree improvement based on breeding and conventional forest tree selection to horticultural approaches focused on quality germplasm production for wider cultivation to serve the needs of smallholder farmers.

Clonal selection in southern Africa

An extensive PRA selection was used to capture superior individuals in southern Africa (Akinnifesi *et al.,* 2006). Tree-to-tree variation was measured in wild populations of *U. kirkiana* and *Strychnos cocculoides* with communities, and selection of superior trees was based on market-oriented ideotype products (Akinnifesi *et al.,* 2006). The local knowledge of rural communities was captured by brainstorming at village workshops about objectives of selection with 20-30 people in each group. Together with villagers, the superior trees were identified on the basis of superior traits, and were systematically named and tagged in situ according to year of collection, location and ownership. Site descriptors were documented and fruits sampled for detailed assessment of qualitative and quantitative characteristics, including chemical and organoleptic analysis. Seeds and scions were also collected for growth and multiplication in the nursery. In some cases, duplicate materials were collected by farmers and raised in individual or group nurseries in their own communities. The superior germplasm is subsequently evaluated in clonal orchards on-station and on-farm and fruits are characterised and analyzed for their chemical characteristics. This evaluation identifies the trees for subsequent vegetative propagation and clonal testing, so that high quality planting materials can be available to farmers as soon as possible. Through the selection and propagation of elite genotypes from the wild, new cultivars with superior or better marketable products: fruit size, sweetness and fruit load with improved uniformity have been obtained. Trees with superior phenotypes of *U. kirkiana, S. cocculoides, S. birrea* and *V. mombassae* were selected in the region from the wild, based on jointly determined criteria with rural community dwellers (farmers, marketers, traditional chiefs, school children) in Malawi, Zambia, Zimbabwe and Tanzania.

Clonal Selection in West and Central Africa

The selection of superior indigenous fruit trees involved quantitative descriptors of variation in indigenous fruit and nut traits (Leakey *et al.,* 2000), and phenotypic selection indicate significant tree-to-tree variation in measured traits (Atangana *et al.,* 2001; *Anegbeh et al., 2005*; Leakey *et al.,* 2005). Phenotypic variation in fruit and nut traits of *I. gabonensis* and *D. edulis* have been widely reported (Atagana *et al.,* 2002; Anegbeh *et al.,* 2005; Leakey *et al.,* 2005). This allowed selection of 'superior trees' for vegetative propagation using the 'ideotype' concept for *I. gabonensis* and *D. edulis* (Leakey *et al.,* 2005, 2006). The ideotype included traits of economic importance like size of different components of the fruit and/or kernel, visual traits like colour of the skin, or flesh, organoleptic traits, nutritional traits (including protein, fatty acid and vitamin content and, food thickening properties (Leakey *et al.,* 2005). Genetic selections were also aimed at the identification of market-oriented 'ideotype', as they were based on seasonality of fruiting, yield or any other relevant trait that may enhance the value or utility of a product.

Role of Propagation in Domestication

Participatory domestication, in which farmers are trained to use vegetative propagation techniques, would enable farmers in different locations to select cultivars for different set of characteristics thus ensuring in the short to medium term that farm-level inter- and intra specific diversity is maintained (Akinnifesi *et al.,* 2006; Tchoundjeu *et al.,* 2006; Schreckenberg *et al.,* 2006; Leakey and Akinnifesi, 2007).

Grafting and air-layering of indigenous fruit tree have addressed precocity problems, and enabled selection of superior fruit traits (Akinnifesi *et al.,* 2006). Vegetative propagation is needed to rapidly multiply, test, select from and use the large genetic diversity in wild tree species on-station and on-farm. Mature tissues have capacity to flower and fruit, and can be multiplied or captured through grafting, budding and air-layering (Leakey *et al.,* 2005; Tchoundjeu *et al.,* 2004, 2006), and micropropagation (Mng'omba *et al.,* 2007 a, b). Because of ease of propagating juvenile tissues by cuttings, it has been a preferred option for participatory domestication of short gestation fruit trees such as *D. edulis* in West Africa in village nurseries (Leakey *et al.,* 2005). Also the tissue culture of juvenile tissues has proved more successful than matured for miombo fruit trees, e.g. *U. kirkiana* (Mng'omba, 2007; Mng'omba *et al.,* 2007a).

Some of the miombo fruit trees are not amenable to propagation by juvenile stem cuttings, e.g. *U. kirkiana, P. curatellifolia* and *S. birrea*. Stem cutting was unsuccessful for most miombo fruit trees (Mhango and Akinnifesi, 2001; Akinnifesi *et al.,* 2004a, 2006). Grafting is the most efficient way to rapidly effect improvements in these fruit trees. Airlayers were promising for *U. kirkiana*, but it not successful for *Parinari* and *Strychnos* species (Mhango and Akinnifesi, 2001). The results showed that the factors determining grafting success are: the skill of the person, the time of the year scion is collected and the interval between scion collection and grafting (Akinnifesi *et al.,* 2004a, 2006, 2007). Table 3 shows data for relative tree growth and indicative fruiting of *U. kirkiana* trees from grafted, marcotted and seedling stocks at four years after establishment (Akinnifesi, unpublished data).

Table 3. Relative tree growth and indicative fruiting of *Uapaca kirkiana* trees at Makoka orchard from grafted, marcotted and seedling stocks, at four years after establishment (Akinnifesi, unpublished data).

Parameter	**Marcots**	**Grafts**	**Seedling stock**
Tree height (m)	2.4±0.11	2.0±0.13	2.7±0.14
Bole height (m)	0.39±0.04	0.35±0.04	0.46±0.64
Root collar diameter (cm)	8.50±0.32	9.14±0.35	10.3±0.36
Crown depth (m)	2.0±0.13	0.35±0.04	2.4±0.76
Crown spread (m)	2.7±0.14	2.3±0.13	2.4±0.160
Number of primary branch	17.2±1.33	15.8±0.95	15.3±2.00
Number of secondary	25.0±2.60	19.9±2.60	15.3±2.00
Number of tertiary	15.0±2.97	10.3±2.91	5.6±1.32
Minimum number of fruits	2	3	0
Maximum number of fruits	414	127	0
Mean	78	52	0

In addition, graft take in tissue cultures of *U. kirkiana* was limited by phenolic accumulation at the graft union line, leading to the possibility of early or late rejection (Mn'gomba, 2007; Mn'gomba *et al.,* 2007a). Trees have three ages that may affect the ease of propagation and also juvenility or precocity (period of waiting before first fruiting). These are chronological age (age since planting), physiological age (cell differentiation stage and structural maturity, including level of lignification) and ontogenetic age (state of reproductive maturity). The implication is that if vegetative propagation is used, the appropriate location of the propagule becomes important for trees aimed at fruit production. A tree of seedless bread fruit (*Artocarpus altilis*) established in southern Nigeria from a root cutting did not fruit for about 20 years (personal observation), whereas trees grafted from scions collected from a mature tree had fruited in less than four years (D.O. Ladipo, 1998, unpublished data). Farmers in southwest Nigeria use the rooting method of propagation for *Artocarpus altilis or A. communis*, but the lengthy juvenile period before fruiting can only ensure generational security, i.e. growing trees for future generation. Awareness creation was the major reason for failure of farmers to adopt efficient methods such as air-layering and grafting.

Across the regions covered, different propagation techniques were employed. This includes asexual methods, vegetative propagation (cuttings, grafting, air layering, budding, etc) techniques (Akinnifesi *et al.,* 2006; Tchoundjeu *et al.,* 2006). Other approaches used include rooting of leafy stem cuttings to air layering and grafting. Air layering (or marcotting) is often used to produce the first set of clonal plants from sexually mature trees with desirable traits, and when established as a stock plants, are a valuable source of cuttings or scions for multiplication by rooting or grafting. Farmers enthusiastically adopt these techniques, and made further refinements to the design of the non-mist poly-propagator (Mbile *et al.,* 2004). Techniques for marcotting were also improved. This led to an increase in the post-severance survival of *I. gabonensis* (from 10% to 50%) and *D. edulis* (up to 70%) (Tchoundjeu *et al.,* 2006, 2007). However, *G. kola* has proved difficult to marcot, but it is being successively multiplied (50-60%) using grafting techniques (Tchoundjeu *et al.,* 2007). The rates of tree survival in the clonal orchards are generally high for grafted *A. digitata* (100%) in Zambia, for *U. kirkiana* (80%) in Malawi, and *S. birrea* (90%) in Tanzania, but low (40%) for *S. cocculoides* in Zambia (Akinnifesi *et al.,* 2006). However, the survival of established marcots was low in Malawi, and declined with time due to poor root development. Rejection in grafts is also attributed to stock/scion incompatibility (Mng'omba *et al.,* 2007). Tree orchards established in Makoka from grafted trees started to fruit after two years, but fruit load only became stable after four years.

Micro-propagation for mass multiplication

As the awareness of the potential of indigenous fruit trees has increased in the last decade, demand will inevitably increase, and tree planting initiatives due to efforts in mitigation of global warming will further trigger massive demands for high-value indigenous fruits trees. In the short run, none of the conventional vegetative propagation methods can meet the demand of farmers in sub-Saharan Africa for high quality propagules. Production of IFTs in sufficient quantities for wider-adoption will of necessity depend on biotechnology (Akinnifesi *et al.,* 2007). Tissue culture has recently been introduced in ICRAF southern Africa programme through partnership with advanced laboratories in South Africa, and the Tissue Culture Laboratory at the Bunda College of Agriculture in Malawi. Progress has been made on some priority indigenous fruit trees including *U. kirkiana*, *U. nitida,* and *Pappea capensis* (plum), with the objective of developing a reproducible clonal protocol for rapid regeneration and multiplication, and to determine early graft compatibility using vitro techniques (Mng'omba, 2007). Based on a series of results, micro-propagation protocols have been developed for rapid multiplication of mature *U. kirkiana* and *P. capensis* (Mng'omba, 2007; Mng'omba, *et al.,* 2007 a, b).

The research recognised that incompatibility between stock and scions in fruit orchard could constitute a major bottleneck to production. Phenolic compounds and ρ-cumaric acids were implicated in early graft incompatibility in *U. kirkiana*. Graft compatibility increased with homografts than hererografts—between *U. kirkiana* clone, species and provenances. *U. kirkiana* and *U. nitida* had weak compatibility, and may exhibit delayed incompatibility. Although Jatropha and *U. kirkiana* belong to the same family, there is outright incompatibility or early rejection. The technique seems promising for detection of early incompatibility between close and distant related propagule sources.

TOWARDS SUSTAINABLE MANAGEMENT

Sustainable on-farm management of indigenous fruit trees requires a proper understanding of their ecological and production requirements. It is not fully known whether the management of indigenous fruit trees is different from exotic horticultural tree crops, and there is urgent need for adaptive research on tree management. Cultivation and good tree management improve fruit traits of planted indigenous fruit trees, even for semi-domesticated trees (Maghembe, 1995; Leakey *et al.,* 2005). It is important to understand the extent of improvement in fruit traits due to management from those due to genetic selection. To date, research on tree management of indigenous fruit trees is limited (Akinnifesi *et al.,* 2007; Tchoundjeu *et al.,* 2006). The effect of thinning through re-spacing of a natural stand of *U. kirkiana* on fruit yield parameters has been reported by Mwamba (1995). The result showed that thinning increased fruit load significantly in the first few years following treatment, and increased pulp content per fruit. However, fruit colour and other hereditary traits were unaffected.

Soil fertility and water management

Knowledge of specific soil fertility and water requirement of fruit tree species is important when introducing IFTs in a new location. In Peru, the application of NPK fertiliser, weeding and timely elimination of excessive shoots were reported to have improved performance of peach palm (*Bactris gasipaes*) (Cornelius *et al.,* 2006). Experience from Malawi showed that management of miombo indigenous fruit trees differ from exotics. For instance, the nutrient and water requirements of mango (*Mangifera indica*) were different from those of *U. kirkiana, S. birrea* and *V. infausta* in the same experiment (Akinnifesi *et al.,* in press). Fertiliser application, manure and irrigation did not increase growth and survival in *U. kirkiana* and *S. birrea* contrary to the widely held assumptions that indigenous fruit trees could be managed as cultivated tree crops. Single factors rather than their combination may be more important at strategic periods, e.g. a light irrigation during a period of prolonged droughts or dry season. Timeliness in the application of irrigation and fertiliser application can help synchronise nutrients supply necessary for phenological development. Liming has also been shown to be important for tree crops in acidic soils. In Botswana, Mateke (2003) also showed that application of fertigation had varied effects on *V. infausta, S. birrea* and *S. cocculoides*.

This suggests that research is needed to understand and develop management package for different IFTs.

Pest management

Pests may affect fruit productivity, either directly through fruit infestation or indirectly by attacking roots, shoots and foliage, thereby interfering with the normal physiological processes of the plant. Pests of fruit trees include weedy plants and parasitic higher plants that compete with fruit trees for water, light and nutrients, and herbivorous mites, insects, birds and mammals that physically feed on the plant, and pathogenic organisms (e.g. fungi, viruses, bacteria, mycoplasma) that cause diseases. Fruit trees are known to be easily infested with pests and diseases in the wild, and the level of infestation can easily escalate even further when introduced to a new environment in the cultivated field. For example susceptibility to pest may become a problem as cultivation of peach palm is intensified (*Clement et al., 2007*). Insect pests such as *Palmelampius heinrichi* have reduced fruit yield significantly along the Pacific coasts of Colombia by up to 100%. (Penn, 2006). A parasitic climbing plant known as 'sueda sueda' (*Moradendron* spp.) was reported on 15% of fields, *Fumago* spp. on 34% of fields, although flood water was thought by farmers as helping to reduce the impact of pests. In the Brazilian Amazon, mistletoe is a menace to the introduction of cupuaçu (*Theobroma grandifolia*). EMBRAPA is currently deploying clonal improvement strategies to develop pest-resistant cultivars.

Few pest management studies have been conducted in domestication studies in Africa. Sileshi *et al.,* (2007) synthesises approaches for pest and diseases management. The pest complexes of most wild miombo fruit tree species are not known and also little, if any, published information on pest biology and population dynamics exists. For example, in Botswana domestication of *V. infausta* is seriously hampered by a mite that causes galls on the leaves. The mite spreads easily and quickly if the trees are grown at high density, and severe infection will probably affect production adversely.

Accordingly, pests of miombo fruit trees were conveniently divided into three major guilds as root-damaging, stem and leaf-damaging, and flower, fruit and seed damaging. A tentative number of insect pests damaging various parts of the major miombo fruit trees are presented in Table 4. These records were generated from the Agroforestry pest database (Sileshi, unpublished).

Table 4. The number of insect pests recorded on the priority miombo fruit tree species of southern Africa

Priority miombo fruit tree species	Root damaging	Leaf and stem-damaging			Fruit and seed-damaging insects		Total
		Defoliating	Sap-sucking	Stem boring	Fruit-feeding	Seed-feeding	
Uapaca kirkiana	1	17	11	4	7	1	41
Parinari curatellifolia	1	14	4	?	3	1	23
Adansonia digitata	1	3	8	1	1	-	16
Strychnos cocculoides	-	-	1	-	-	-	1
Anisophyllea boemii	-	1	-	-	-	-	1
Azanza garckeana	-	16	2	2	1	-	21
Flacourtia indica	-	5	4	-	-	-	9
Syzygium guineense	-	2	1	-	1	-	4
Syzygium cordatum	-	17	1	-	-	-	18
Uapaca nitida	-	2	-	-	-	-	2
Vanguaria infausta	-	6	-	-	3	-	9
Annona senegalensis	-	6	1	-	5	-	12
Sclerocarya birrea	-	25	5	16	5	-	51

Source: Sileshi *et al.,* 2007)
- = records are not available

Pre-harvest and post-harvest handling of IFTs

Pre-harvest and post-harvest handling is an aspect of indigenous fruit tree research and development that has been neglected for too long in sub-Saharan Africa (Akinnifesi *et al.,* 2007). The direct and indirect post-harvest losses are estimated at 25 to 50% in developing countries (Kadzere *et al.,* 2001, 2006). Post-harvest deterioration often results from cracks during harvesting, mechanical damage during transportation and storage, and insect pest damage (Kadzere *at al.*, 2001, 2006). The majority of producers (78-84%) had indicated post-harvest losses as a major constraint in *U. kirkiana*. Similarly, Ramadhani (2002) found that 50-75% of producers associated market constraints with perishability of fruits. At the market, there is no agreed number of fruit a consumer could taste freely before buying.

A study was undertaken in Zimbabwe by Kadzere *et al.,* (2004) involving interviewing 180 collectors, 120 processors and 210 producers. The results indicate that the time of the year, colour changes, skin softness and abscission, were the indicators used by respondents to determine ripening depending on species. For *Adansonia digitata*, 85% of users or harvesters climb the tree to harvest because it did not readily abscise when ripe (Kadzere *et al.,* 2001). Most of the harvesters collect fruits that dropped naturally. Other means of harvesting included shaking the trees or throwing objects at the tree crown, hitting the stem, etc to dislodge the fruits thereby damaging tree stem and branches. In many cases, fruits were harvested at unripe, just ripe and well-ripened stages, and were harvested several times during the season (Kadzere *et al.,* 2004). However, allowing fruits to drop often results in contamination and pest and diseases attacks.

Fruit ripening overlapped for many species, raising the possibility of harvesting fresh fruits throughout the year (Akinnifesi *et al.,* 2004a). Harvesting time has been shown to affect ripening and darkening in *U. kirkiana* (Kadzere *et al.,* 2006). Fruits that were harvested in December lost less weight (14%) in storage than those that were harvested two weeks earlier (34%). The soluble sugar content measured six days after harvest was also lower for fruits harvested in December (18%) compared to those in November (9%). This indicates that there are benefits in delayed harvesting to improve fruit skin colour at harvest and during storage, to reduce weight loss and maintain higher soluble sugar content.

More than half of the fruits harvested were often retained for home consumption of *A. digitata, Azanza gackeana, Strychnos cocculoides*, but less frequently for *U. kirkiana* and *Z. mautritiana*, indicating that these were the most frequently sold fruits. Before marketing several methods were used to add value: cleaning, grading, packaging, protecting from sun, but these vary with species.

In terms of fruit processing, there have been reports of small cottage industries in different countries in the regions. Amarula liquor is commercialised in South Africa and sold in more than 63 countries world-wide (Ham, 2005). Wine production from *Syzigium owariense*, *U. kirkiana*, *Tamarindus,* mangoes, and others fruits, e.g. was commercialised at one time by Mulunguzi Wine in Malawi (Ngwira, 1996). *Z. mauritiana* and *S. birrea* are produced at export quality in Lusaka, Zambia. In Tanzania, about 198 rural women were trained in 1998 in making wine, jam and juice from indigenous fruits, and two years later they had trained a further 2045 processors (Saka *et al.,* 2004; Akinnifesi *et al.,* 2006).

Decisions on when to harvest indigenous fruits

In commercial fruit production, decisions on when to harvest are based on objective maturity indices that have been developed for specific commodities using physical, chronological, physiological and chemical characteristics (Reid, 1992; Kader, 2002). For example fruit color changes; shape, size, surface characteristics, abscission, and texture are all physical indicators while numbers of days from flowering, accumulated heat units during the growing period of the fruits are chronological indicators. In citrus the sugar: acid ratio is used to predict fruit harvest while in apples, the distribution of starch in the flesh is also used to predict harvest. These indices, including the accumulation of carotenoids and increased total soluble solids and decreased titratable acidity in *Ziziphus mauritiana* are all chemical indicators. The physiological indicators such as accumulation of ethylene and increased respiration rates can be used to time harvest in climacteric fruits (Kadzere *et al.,* 2006a, b). For long distance transportation, fruits harvested at the fully ripened stage may suffer greater transit losses compared to those harvested when partially ripe or unripe but mature. The use of objective indices allows fruits to be harvested at an optimum stage that enables them to be transported to varying distances to markets as well as ensuring that the fruits contain the desirable aesthetic values to consumers.

In southern Africa decisions of when to harvest indigenous fruits still depends largely on experiences and observations by communities. Depending on the species, indicators used include time of the year (season), color changes, fruit softening and abscission as presented in Table 5 for Zimbabwe. Kadzere *et al.,* (2006b) investigated fruit variability and relationships between color at harvest and quality during storage of *U. kirkiana* fruit from natural woodlands and found that large variations existed in fruit size, color at harvest, color during storage and the soluble solids concentrations after ripening, within and among trees for fruit harvested on the same day at the same location. Later (early December) harvested *U. kirkiana* fruits had a brighter color, higher soluble solids concentrations and were less susceptible to weight loss during storage compared with those harvested at an earlier stage (early November) (Kadzere *et al.,* 2007).

Table 5. Indicators of fruit "ripening", harvesting periods, stages and methods reported by survey respondents for selected indigenous fruits by communities in Zimbabwe

Name of fruit	Indications of fruit ripening	Period of ripening	Stages mainly harvested	Methods of harvest (% of survey respondents from six sites in the year 2000 in Zimbabwe)		
				Gather abscised fruits	Climb tree and pick	Others (e.g. shake tree by hand or objects)
Adansonia digitata	Color change from green to khaki, auditory indicators (ripe fruits make a rattling sounds when shaken whilst unripe fruits do not), fruit abscission in some trees.	April-October	Ripe	61	16	23
Azanza garckeana	Cracks along the sutures on the fruits, Color change from green to brown	April-October	Ripe	5	85	10
Parinari curatelliflol -ia	Color change from green-khaki to orange , abscission, fruit softening and aroma	August-December	Ripe	99	1	0
Sclerocarya birrea	Color change from green to yellowish, abscission, aroma from fruits.	February-April	Ripe and Unripe	94	3	3
Strychnos cocculoides	Color change from deep green to yellowish, or orange, abscission, aroma fruits.	August-December	Ripe and Unripe	69	15	16
Uapaca kirkiana	Textural changes e.g. fruit softening, Color change from greenish to yellowish and usually to a brownish color (some fruits are formed with a yellow or brown color and ripen to a brown color), abscission, aroma.	October – January	Ripe and Unripe	78	5	17
Ziziphus mauritiana	Color change from greenish to yellowish and then brown, abscission, aroma	May-September	Ripe and Unripe	61	15	24

Adapted from Kadzere *et al.,* 2004: Note: the harvest methods per species are not mutually exclusive.

There is the need to develop appropriate techniques for fruit handling, preservation and processing to maximise returns from fresh and processed fruit products. The development of such post-harvest systems requires understanding of current practices and how they influence post-harvest losses.

CONTRIBUTION OF INDIGENOUS FRUIT TREES

Indigenous fruits form a staple food during the hunger periods in the agricultural cycle. A study in Malawi, Mozambique and Zambia revealed that 26-50% of rural households relied on indigenous fruits as a coping strategy during critical seasonal hunger period which usually lasts for three to four months per year (Akinnifesi *et al.,* 2004a). The fruit trees ripen at different times of the year and can be targeted to meet the food needs of rural households (Akinnifesi *et al.,* 2004, 2006).

Without an expanded or new market, the incentives to domesticate and commoditise indigenous fruit trees are not sufficient (Simons and Leakey, 1998; Akinnifesi *et al.,* 2006; Jama *et al.,* 2007). As rural households becomes more integrated into formal market systems, the proportion of the contribution of non-timber tree products (NTFP) to household income increases (Ruiz-Perez *et al.,* 2004). In addition, households that engage in cultivation had higher returns on labour, used more intensive technology for production, and had higher productivity per hectare, associated with stable tenure and enjoyed a stable resource-base. On the contrary, wild harvesting on the other hand, is associated with a declining resource base.

A few indigenous fruit trees products have a large market potential in sub-Saharan Africa. There is evidence of potential market opportunities for indigenous fruit trees in Africa. There is extra growth potential for boosting rural incomes, which in turn will stimulate demand for currently non-tradable goods and services in rural economies. The marula tree (*Sclerocarya birrea*) in the miombo ecosystem of southern Africa is the source of a popular product known as 'Amarula cream.' It is traded in 63 countries world-wide. The share of market margins for selling *U. kirkiana* fruits was estimated in Zimbabwe at 32-45% for collectors, 53% for retailers, and 2% for wholesalers (Ramadhani, 2002).

Until economic returns on IFTs investment is high enough, adoption by farmers of development programs will remain low. Several studies revealed that the cultivation of IFTs or their collection from the wild can be a profitable enterprise. Wild collection for fruits is an efficient labour allocation strategy and its returns on labour are considerably higher than that of crop production enterprises (Mithofer and Waibel, 2003). For example, the collection of *U. kirkiana* generated US$ 50 in Zimbabwe, and $US 78 for S. *birrea* in South Africa (Schackleton, 2002). The real term risk-adjusted rate of return for planting IFTs is 16% (Mithofer and Waibel 2007). Financial analysis showed that each *Dacryodes edulis* tree is worth US$ 50-150 per year and on average, an unimproved *Dacryodes edulis* tree produces US$20 compared to US$ 150 when improved (Leakey *et al.,* 2005). Studies in Malawi, Tanzania, and Zimbabwe (Joordan *et al.,* (2007) found that the percentage of net profit of IFT products reached 28% with higher profits being obtained in locations that are close to the markets (Table 6). In South Africa communities collectively harvest about 2000 tons of *S birrea*, collectively earn US$ 180,000 annually, representing more than 10% of average household income in these communities (Ham, 2005). A popular southern African Natural Products Trade Association (Phytotrade, 2005) reported gross revenue of US$ 629,500 from sale of natural tree products by members. The key fruit tree products among them fetched US$ 126,420 for *S. birrea*, $44,120 for *Ximenia caffra*, $22,250 for *Adansonia digitata* (baobab) and US$ 20,000 for *Kigelia* spp. (Phytotrade M&E report, 2005, 36 pp.). A recent market projection has put the potential market of baobab to 960 million US$ (PhytoTrade, pers. comm.). Studies in Zimbabwe revealed that improvements in tree yield and earlier fruiting of IFTs create incentives for farmers to cultivate indigenous fruits and, that household vulnerability to hunger and poverty can be reduced by 33% during the critical period that occurs between August through March (Mithofer and Waibel 2003; Mithofer 2005, Mithofer *et al.,* 2006). In addition, households that had access to IFTs were able to live above the poverty line throughout the year. The studies revealed further that households used indigenous fruits to diversify their income and that benefits from selling indigenous fruits come at a critical time when income is generally low, and provides nutrition and food when agricultural labour demands are high (Mithofer, 2005).

Feasibility analysis showed that small enterprises of indigenous fruit trees are profitable in Malawi, Zambia, Tanzania and Zimbabwe ranging from 14 to 29% (Table 6).

Table 6. Feasibility analysis of small indigenous fruit enterprises in Malawi, Tanzania and Zimbabwe (Joordan *et al.,* 2007)

Income statement	Malawi (Juice concentrate)	Tanzania (Juice concentrate)	Zimbabwe (Baobab)	Zimbabwe (Jam)
Gross production value ($)	107,400	137,359	61,090	20,209
Total cost $)	61,700	108,187	33,080	11,336
Net income ($)	45,700	29,172	28,010	8,873
Tax ($)	16,000	10,210	9,803	3,105
Net profit after tax ($)	29,700	18,962	18,206	5,767
% Net profit*	27.7%	13.8%	29.8%	28.5%
Cash flow	Net positive for all months			
Net present value	Positive over selected period			
Breakeven price ($)	8.50 per 20kg can	14.64 per 20kg can	0.34 per 50g bar	1.22 per 410g jar

*Profit as % of gross value of production

CULTIVATION, ADOPTION AND SCALING UP OF IFTS

On-farm cultivation of indigenous fruits

Farmers have consistently cited the lack of quality germplasm as a major constraint to diversifying and expanding their agroforestry practices (Simons, 1996; Weber *et al.,* 2001; Akinnifesi *et al.,* 2006; Carandang *et al.,* 2006). Making quality planting material available to farmers in a timely manner is an important step for effective scaling up. Supporting farmer nurseries was suggested as one pathway in promoting decentralised tree seedling production in an efficient way, while at the same time providing opportunities for building natural resource, human and social capital, all three being considered equally crucial in developing more sustainable land use systems. The process is however time-consuming and expensive to undertake for each species, especially when a large number of farmers widely dispersed over distant locations are involved. One of the most effective ways of achieving scaling up of IFTs cultivation is to involve farmers in the entire process of participatory selection, propagation, nursery and tree establishment and management of superior planting materials. This will dramatically shorten the time required to produce and disseminate planting materials from centralised nurseries to farmers. Farmers can be organised to produce high quality seed, seedlings and vegetative propagule as evidenced in small-scale nursery enterprises managed by farmer groups in West Africa (Tchoundjeu *et al.,* 2006; Akinnifesi *et al.,* 2006). This approach seems to be uniform in southern Africa (Akinnifesi *et al.,* 2006a) and West Africa (Tchoundjeu *et al.,* 2006). In southern Africa, farmers were encouraged to develop their own nurseries to graft and establish trees on-farm. The main scaling up approaches used by ICRAF to disseminate agroforestry technologies including IFTs in rural farming communities in southern Africa include direct training of farmer trainers and local change agents; direct training of partner institutions' staff; farmer-to-farmer exchange visits and, support to existing national agroforestry extension initiatives.

Indigenous fruit tree seedlings have been disseminated to farmers in Malawi, Zambia, Zimbabwe and Tanzania since the late 1990's. Farmer-to-farmer exchange and farmer training have been important methods of training large number of farmers in nursery establishment and tree management. About 13,000 farmers have been trained in tree propagation, nursery establishment and management, and farm management. Special emphasis has been given in each community to train a few people in grafting techniques, as this is central to the domestication programme. These trainees can then offer services to other farmers and farmer groups, as well as manage their own commercial nurseries. In Malawi the majority of nurseries were of the group-type (86%). That makes it easy to train farmers in groups, and farmer training in nursery management has been on-going in the past ten years.

Roshetko and Verbist (2000) recognised three pathways by which improved germplasm can be made available to farmers: 1) distribution of seed originating from national research centres, community-based NGOs and the private sector, 2) dissemination of selected seeds originating from farmers and farmer groups, and 3) direct diffusion through informal farmer-to-farmer exchange. In IFT tree domestication, the extent to which the establishment of nurseries by smallholder farmers can be strengthened through training will determine the success and sustainability of new tree crop development. This includes training smallholder farmers to collect quality germplasm from superior trees in a way that ensures genetic quality, efficient establishment and management of nurseries, tree establishment and management on-farm, harvest and post-harvest handling activities, and marketing of germplasm and tree products.

Implications for landscape management

Many local communities have been actively engaged in domesticating tree species and production systems as well as gradually adapting these to their household needs (Wiersum, 2007; Leakey *et al.,* 2005). In the cocoa-agroforests of humid zones of West Africa, the ecosystem becomes gradually altered. Cash crops are planted in intensive nearly monoculture system, with scattered upper-storey shade trees. Arable crops are managed in the under-storeys. These landscapes modified from primary or secondary forests gradually become mixed agroforests, and homegarden systems with varying tree/crop intensification. Eventually they may gradually shift in diversity and composition from polyculture mixed-species, multi-storeyed plant communities towards more cropland and monoculture systems. However, studies showed that such a trajectory of change is not always uniform, as some smallholder cultivators gradually change their 'intermediate' fruit tree production systems towards more specialised arboricultural practices, others smallholders may maintain these systems although they modify the species composition and/or specific management practices (Wiersum, 2007).

Vegetative propagation and tree density can be used to alter the crown architecture of domesticated trees. In terms of managing trees at landscape level, it is important to realise that the stature of domesticated indigenous fruit trees will change. For example, grafted and marcotted *U. kirkiana* in Makoka, Malawi are dwarf in stature such that their fruits can now be harvested while sitting down on a chair. These were trees that are usually climbing in the wild, and it is a positive improvement. It is expected that trees that are in the emergent or dominant canopy are likely to become co-dominant or a lower canopy tree when vegetatively propagated. These have implications on the type of insects needed for pollinization, shade versus light tolerance or requirement, etc. The above and below ground tree architectures need to match the predominant land use as well. For instance, a fruit tree with an aggressive rooting system may become over-competitive with associated crops, and fruit trees that are dominant or emergent may require more light and tolerate less shade.

LESSONS LEARNED AND ISSUES FOR SCALING UP TREE DOMESTICATION

Although most of the fruits from IFTs are still being harvested from the wild, there is a general move away from sole dependence on wild harvesting towards on-farm management. Domestication research and development has also progressed significantly, especially in Africa and Latin America for indigenous fruit trees. Listed below is a summary of the lessons learnt, challenges remaining and way forward to the scaling up of IFTs:

- Research and development on the domestication of IFTs has advanced only in a few species such as, *Uapaca kirkiana, Sclerocarya birrea, Parinari curatellifolia* in southern Africa, *Dacryodes edules*, *Irvingia gabonensis* in West Africa, *Vitellaria paradoxa* and *Adansonia digitata* in the Sahelian region of Africa. There is need to expand the range of IFTs currently being researched in different regions.
- The investment needs for wider cultivation and scaling up of tree domestication of indigenous fruit trees include, i) quality planting material in sufficient quantity, ii) adequate skills and resources for village-level nurseries in decentralised systems, and iii) facilities for micropropagation and tissue culture centers for rapid multiplication of specialised propagules (Akinnifesi *et al.,* 2006).
- Measures to speed up the multiplication of improved planting materials are necessary. These include the application of biotechnology and tissue culture techniques in germplasm multiplication and delivery which require greater attention.
- Droughts and climate change may affect fruiting potentials of IFTs; cycles and seasonal variability and cause major reduction in fruit production and quality. It is important to investigate how tree planting affects climate change on the one hand and, how trees are (can be) affected by and or adapted to climate change on the other. This will ensure that sufficient resilience is built in to tree domestication efforts.

- Farmers and researchers have complementary knowledge and knowledge-deficiencies, so that integrating this knowledge from both parties through participatory processes has been shown to speed up technology adoption and performance.
- There are comparatively few studies that provide conclusive evidence on the profitability and payback periods of IFTs cultivation, vis-a-vis wild collection. Smallholder farmers may need initial incentives or credit lines for tree establishment, management and value addition.
- Adoption of tree-based practices such as IFTs is more complex than those of conventional crops because of the multi-year cycles required for testing, modification and eventual "adoption" by farmers. There is need to understand the key factors that drive adoption of improved IFTs and their impacts at multi-scales, i.e. household and landscape levels. Such studies will provide insights into the level of technology change that would stimulate adoption and impact of IFTs. Such studies are important to guide investment, adoption and policy decisions regarding IFTs.
- As technology development processes become complex, uptake of these technologies by farmers will remain low. The development and dissemination of IFT systems must continue to emphasise practices that require little capital and simple methods of scaling up, improved processes and techniques to wider communities. Such low-cost techniques include small-scale nursery operations, vegetative propagation, use of organic manures and tree management.
- For market-led IFT initiatives, the market attribute of IFT products must be unique or substantial enough and should be comparable or superior to conventional product sources to make an impression in the market. For instance, *Adansonia digitata* has very high vitamin C content in its dry pulp (more than 5 g of ascorbic acid per 100g)--this is ten times as high as the equivalent weight of orange.
- Second generation issues such as the potential occurrence of new pests following the introduction of new trees must be carefully investigated as IFTs are domesticated and improved germplasm are selected.
- There is need for improved systematic data gathering to update knowledge on the contributions of IFTs to household, community and national income and livelihood strategies in Africa. This will this enhance the opportunities by policy makers and development organizations in using IFTs as a potential intervention strategy for reducing poverty.
- There is need for innovative research and development efforts on IFTs to help bring about improvements in cultivation, scaling up, markets and small-scale enterprises in Africa. The improved market performance of AFTPs would stimulate growth in the rural economy.
- Adoption of agroforestry is not a simple direct relationship of technological characteristics only, but is a matrix of several groups of factors including household, community level factors, institutions, the socioeconomic constraints and incentives that farmers face. As a result, rather than technology change alone, it is recommend that the development of IFTs should put balanced emphasis on the economics, the people and the institutional and policy context under which farmers operate.
- Enacting policies to ensure that intellectual property rights of farmers (farmer breeders), community custodians and breeders right of researchers are well protected.

This will ensure that benefits from IFTs domestication are not exploited by large-scale commercial growers.

- There is need to engage in a pro-active increase in awareness creation and raising the profile of the contributions of IFTs in policy debates and development intervention programmes. This will also require a long-term investment and an appraisal of policies governing land and tree tenure in many countries in the tropics to reduce institutional constraints to tree planting and enact policies that facilitate cross-border trades and harmonization of exploitation, transportation and germplasm exchange.
- There is need to involve reinforcing, not only, parental participation in knowledge-intensive fruit trees domestication and marketing process, and capacity building, but also in preparing the next generation of indigenous trees cultivators through involvement of school children in the process of 'bringing out trees from the wild'.

CONCLUSIONS

The high local demand for exotic fruit trees indicate clearly the urgency and need to provide fruits throughout the year to supplement food requirements. There is the prospect for transforming farming systems and rural livelihoods of smallholder farmers through domestication and commercialization of indigenous fruit trees. This remains challenging in sub-Saharan Africa. The lack of improved germplasm, high post-harvest losses and poor market access emerged as dominant constraints. The policy and commercialization components will ensure realization of social benefits through nutritional and food security, poverty reduction and employment as well as environmental benefits. The various priority setting exercises and domestication activities indicate that, across the regions of Africa, there is considerable experience and knowledge on indigenous fruit tree domestication. However, constant updating of species prioritization to cater for emerging peoples' needs and preferences is needed. Through good science, the regions have developed robust domestication approaches to obtain improved superior tree clones or cultivars, with superior fruit and tree traits. Two clear opportunities for institutional involvement were foreseen. The first is to re-orient national research institutions and agricultural extension systems to support participatory domestication of indigenous fruit trees through awareness creation, sensitization and dissemination of agroforestry technologies, involving fruit trees, in the region. Secondly, the science of IFTs domestication can be brought to scale, if farmers and group of farmers can become engaged, of their own volition, in the testing and adapting fruit tree domestication options. Effective extension and dissemination systems will help stimulate production, utilization and marketing. This will require the development of simple domestication guidelines for extension workers and farmers. Research has shown that improving markets and quality of indigenous fruit and products would be a major driver for increased investment by the private sector in the production and commercialization of indigenous fruit trees.

Acknowledgements
We would like to thank the BMZ and GTZ for providing the funds for implementing the project on 'Domestication and Marketing of Indigenous Fruit Trees for Improved Nutrition and Income in Southern Africa' (Project No. 2001.7860.8-001.00), and the

CIDA Canada for funding the Zambezi Bazin Agroforestry Project (Project no. 050/21576). We would like to thank our partners, National Agricultural and Forestry Research and Extension Systems, private entrepreneurs and Non-governmental organizations (NGO's) collaboration in the project in the four countries.

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Underutilised crops for famine and poverty alleviation: a case study on the potential of the multipurpose *Prosopis* tree

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In its native Latin America, the *Prosopis* tree (also known as Mesquite) has multiple uses as a fuel wood, timber, charcoal, animal fodder and human food. It is also highly drought-resistant, growing under conditions where little else will survive. For this reason, it has been introduced as a pioneer species into the drylands of Africa and Asia over the last two centuries as a means of reclaiming desert lands. However, the knowledge of its uses was not transferred with it, and left in an unmanaged state it has developed into a highly invasive species, where it encroaches on farm land as an impenetrable, thorny thicket. Attempts to eradicate it are proving costly and largely unsuccessful.

In 2006, the problem of *Prosopis* was hitting the headlines on an almost weekly basis in Kenya. Yet amidst calls for its eradication, a pioneering team from the Kenya Forestry Research Institute (KEFRI) and HDRA's International Programme set out to demonstrate its positive uses. Through a pilot training and capacity building programme in two villages in Baringo District, people living with this tree learned for the first time how to manage and use it to their benefit, both for food security and income generation. Results showed that the pods, milled to flour, would provide a crucial, nutritious food supplement in these famine-prone desert margins. The pods were also used or sold as animal fodder, with the first international order coming from South Africa by the end of the year. Collecting the pods also helped to prevent the unregulated spread of the tree. The wood provided a high quality charcoal, and the timber, which is harder than oak, is currently being developed as a certified, sustainably managed product for regional and international markets.

Subsequent spontaneous diffusion of this knowledge and skills base between community groups in Baringo District provides further evidence of its acceptability and usefulness by beneficiary groups. This demonstrates how knowledge can change perceptions, turning a problem into a valuable resource. On a global scale, the habitats that *Prosopis* invades are typically arid and resource poor, and often correspond with poverty and conflict affected areas. As such, it holds the potential to provide vital food, fuel and income generation in extreme marginal conditions. Yet this evidence of its usefulness might still be insufficient to halt the eradication programmes being planned for this underutilised tree.

INTRODUCTION TO THE GENUS *PROSOPIS*

Prosopis is a leguminous and highly drought resistant tree. Many species of *Prosopis* exist, but *P. juliflora* and *P. pallida* are the only two species that are truly tropical, native to Central and South America but have since spread to the Pacific and Australia, India and Pakistan, Africa and the Middle East, through deliberate introductions and then weedy invasions. In more sub-tropical areas, *P. glandulosa* and *P. velutina* from North America are the most commonly introduced and invasive species. It is well acknowledged that left uncontrolled, *Prosopis* becomes a highly invasive weed, and the issue of how to control it has caused much debate.

Prosopis trees were deliberately introduced pan-tropically during the last two centuries, into Australia and the Pacific (Panetta and Carstairs, 1989), India and Pakistan (Reddy, 1978; Luna, 1996), and throughout Africa (Hughes, 1991; Jama and Zeila, 2005). Tolerance to drought and poor quality soils, tolerance of repeated cutting and the generation of multiple products were all reasons for the widespread introduction of these trees firstly by colonial administrations and lastly by development agencies. However in all areas, indigenous knowledge on its management and uses was not transferred, and as a consequence, introduced trees have become an invasive pest.

In its native South America, *Prosopis* is utilised as an important natural resource, particularly the wood which can be used as a fuel, either directly or as charcoal, and as timber for poles, boards and cants. The wood has a very high calorific value for burning (FAO, 1997) and also makes good charcoal. For structural use, the heartwood is strong and durable and has relatively high dimensional stability with low shrinkage (FAO, 1997). In addition to wood products, the legume pods *Prosopis* produces are high in sugars, carbohydrates and protein, and typically produce yields ranging 1–8 t/ha per year but can produce yields up to 10 t/ha (Felker, 1979). Being a deep rooted tree, pod production is far less dependent on rainfall than fruit trees, and *Prosopis* generally produces pods every year, independent of rainfall, making it a crop that people and livestock can depend on in drought stricken areas (Pasiecznik, 2001).

Additional uses include: as a source of nectar and pollen for honey production, exudates gums, tannins, dyes, fibres and medicinal use. The extensive use and management of *Prosopis* in its native environment has prevented it becoming an invasive weed. Regular pruning allows the trees to produce useful timber products rather than reverting to impenetrable thickets and using the pods reduces proliferation by seed.

However, although there continue to be widespread attempts to eradicate *Prosopis*, even though these are proving largely unsuccessful, there is a developing consensus that the only way of controlling its spread is by converting weedy stands to managed agroforestry systems. This paper uses a case study in the Baringo district of Kenya to demonstrate how the transfer of indigenous knowledge may have the potential to control the problem of an invasive weed whilst benefiting resource-poor communities.

INTRODUCTION OF *PROSOPIS* INTO KENYA

The origins and pattern of introduction of *Prosopis* species into east Africa are not well known as it clearly existed before the large-scale introductions that occurred in the 1980s. *P. juliflora* may have been introduced by livestock from Sudan or southern Africa or by traders from India or southern Africa. Although it is considered that there were isolated *Prosopis* trees in Kenya in the 1930s, the first documented introduction of the tree in Kenya was in 1973, when seeds were imported from Brazil and Hawaii for the rehabilitation of quarries in the saline soils at Baobab Farm near Mombasa (Jama and Zeila, 2005). However, the first major planting programmes of the 1980s occurred as part of a dryland forestation scheme supported by the FAO and funded by various aid agencies including Finland, along the Tana River, and Norway in Turkana District.

As far as is known, no efforts were made to manage the first plantations and by 1990 naturalisation and invasion were both observed. No interventions were made at that time as people were unaware of the risks posed by this non-native invasive species. So, throughout the 1990s, *Prosopis* quickly spread, aided by livestock, and local perceptions of *Prosopis* became increasingly negative. In a report (Aboud *et al.,* 2005) based on 73 interviews carried out in the Baringo district, local people highlighted the following problems with *Prosopis*:

- It was regarded as highly aggressive forming impenetrable thickets that choked out other plants and reduced biodiversity.
- It blocked irrigation schemes when it occurred near watercourses.
- It was also thought to actually encourage soil erosion because the understorey of herbaceous plants was eliminated by competition.
- By extensively drawing on groundwater, dense stands of *Prosopis* were thought to lower the water table.
- It was also perceived to cause problems with livestock; although palatable, it was thought to cause tooth problems for goats, and digestive problems for sheep and goats if fed over a prolonged period.

In a similar study in the Baringo district (Mwangi and Swallow, 2005) of 65 individuals in the Ng'ambo area and 48 in the Loboi area, 85–90% favoured complete eradication.

By 2004, the Ilchamus community in the Baringo district of Kenya had begun legal action against the FAO and the Government of Kenya, aided by a local NGO, 'Community Museums of Kenya'. They claimed that *P. julifora* was introduced without adequate assessment of the future risks. With increasingly negative coverage in the media, the government considered whether to declare *Prosopis* a 'National Disaster' and opt for wholesale clearing of stands by bulldozer and introducing biological control agents.

Control and eradication of *Prosopis*

As *Prosopis* became recognised as a problem woody weed in many countries, a wide range of control measures have been developed. Most control programmes have been attempted against *P. glandulosa*, *P. velutina* and *P. ruscifolia*, and fewer major control programmes have been implemented on *P. juliflora* and *P. pallida*. The most extensive eradication attempts have occurred in the USA for almost a century, but these have generally had limited success (Jacoby and Ansley, 1991). Similar but less intensive eradication programmes have also been implemented in Argentina, Paraguay, South Africa, Sudan, Pakistan and Australia. These programmes all showed that it was virtually impossible to completely exclude *Prosopis* species from a site once they had become established, so the term 'eradication' became gradually replaced with that of 'control'.

The three main recognised methods of controlling *Prosopis* species in its native range are mechanical, chemical and fire (see Jacoby and Ansley, 1991). Biological control has also attracted much interest especially in Australia and South Africa.

Hand clearance is the simplest form of mechanical control and was the first method used for controlling *Prosopis* in the Americas. Trees are felled, then all stumps and seedlings uprooted. Whilst being very effective, it is generally considered too labour intensive and expensive except for clearing smallholdings of high value land. Root ploughing and chaining are often the most effective mechanical means. For root ploughing, large trees are first felled. Chaining involves pulling two large chains between two large tractors, pulling over larger trees and uprooting them. Both of these methods are effective but incur high costs.

Chemical treatments use herbicides to kill the trees. Effectiveness is often limited by the poor uptake of the chemical as *Prosopis* has thick bark and small leaves with a protective waxy layer. Formulating an appropriate mixture of chemicals for trees of mixed ages and sizes within a stand can also prove difficult. Many chemicals, also failed to completely kill the trees and infested sites frequently needed respraying every 5–7 years.

Fire is probably one of the original tools used to manage *Prosopis*. Young seedlings can be destroyed by fire, but older trees build up a layer of protective thick bark and will resprout after fire. Fire can, however, be used to prevent the reestablishment of young *Prosopis* seedlings or to remove dead trees that have been killed by chemical treatment.

The limited success of chemical and mechanical treatments, has generated increased interest in biological control methods using bruchid beetles that are host specific and can destroy substantial amounts of seed thereby having the potential to limit invasion. (Kingsolver *et al.,* 1977). The majority of the work on biological control has been carried out in South Africa with the *Algarobius prosopis*. Using the bruchid beetle in conjunction with another seed feeding insect, *Neltumius arizonensis*, has proved the most successful method.

Changes in grazing practice may also have an impact on the spread of *Prosopis* seed. Ingestion and passing by cattle has been shown to improve the germination of the seed (Peinetti *et al.,* 1993; Danthu *et al.,* 1996). Conversely, seed that has passed through sheep (Mooney *et al.,* 1977), goats (Harding, 1991) or pigs (Peinetti *et al.,* 1993) shows much reduced viability compared to cattle.

In the Baringo district, a survey of the Ng'ambo and Lobio areas (Mwangi and Swallow, 2005) showed that minimal attempts had been made to control *Prosopis* at a community level. Most efforts were being done by individuals or families on homesteads and smallholdings using mechanical methods, uprooting seedlings or whole trees, cutting, and pruning, and burning cut stumps. The majority of individuals in the Ng'ambo district reported that they uprooted or cut *P. juliflora* trees during land preparation. The frequency of this activity varied from once to four times a year with some reporting that they uprooted seedlings continuously throughout the season. A net monetary balance was calculated taking account of the benefits such as selling the products as posts or fuel wood and the losses such as the amount of labour required to clear the trees. This identified that the highest losses were associated with individuals who identified themselves as herders, despite the benefits of *Prosopis* as fodder during periods of scarcity.

FACTORS AFFECTING UTILISATION OF *PROSOPIS*

In its native South America, *Prosopis* is utilised extensively and not considered an invasive weed. Where it has been introduced, the extent to which it is utilised varies widely around different areas of the world. Much of this is dependent on both people's knowledge and perception of the tree which are influenced by a wide range of factors. The most important of these is how it affects their livelihoods (Binggeli, 2001; Pasiecznik *et al.,* 2001) but many other factors are involved including damage to properties or ecosystems, the aesthetics of the species and also its portrayal in the media (Veitch and Clout, 2001). Studies in India (Pasiecznik *et al.,* 2001) have shown that levels of income and occupation are an important influence. Those on a lower income regard it as an important source of firewood, whereas those on a higher income who can afford bottled gas have a negative perception of *Prosopis* as they do not need to use it as a source of fuel. Pastoralists and herders are also more likely to have a negative perception due to the possible negative effects on livestock, such as digestive and tooth problems, whereas housewives who have to gather firewood are more likely to regard it as a positive asset.

In Kenya, the uses of *Propsopis* can vary within a localised region of the country. For example, a study of two regions within the Baringo district (Mwangi and Swallow, 2005) showed that *Prosopis* was extensively used but the uses differed markedly between the districts. In the Ng'ambo region, 94% of respondents used *Prosopis* wood for construction poles whereas in the Loboi region, the most popular use was for fuel wood (58% of respondents). A number of barriers to its use were reported. The strong thorns made harvesting the products difficult and also caused punctures in vehicles used to transport products. The weight of the wood made transportation of poles difficult and its hardness made it difficult to cut. Marketing of *P. juliflora* was also reported to be difficult as its products were already abundant throughout the area.

It is now acknowledged that a degree of control may be achieved through intensive utilization of tree products and by improved management. Trading of its products, converting a weed into a valuable resource, presents an opportunity for socio-economic benefits to the communities living in marginal areas of the country where extensive areas of *Prosopis* are found. Furthermore, invasive *Prosopis* is now common in many parts of Sahelian and eastern Africa, including Kenya and Niger where large populations face malnutrition due to drought, a situation exacerbated by mass movements of refugees in response to food shortages and military conflicts. In these situations *Prosopis* has potential at least as a famine food, if not as a regular source of nutrition.

The following section focuses on a training programme in the Baringo district to control and exploit the *Prosopis* tree where a number of initiatives were put in place to improve the knowledge and management practices. Around Marigat and Salabani locations in Baringo District, KEFRI managed a two year pilot project funded by the FAO on improved *Prosopis* management and utilisation, from 2004. Practically, there was one year of effective work on the ground which ended with a final field day and workshop in Marigat in August attended by senior government officials and representatives from UN agencies such as UNEP, FAO and others. Details of this training course are in Pasiecznik *et al.,* (2006). The course dealt firstly with how a *Prosopis* stand should be managed to turn it into a useful production system, then focused on its principal uses as timber, fuel wood and as a potential human food. These are outlined in the following sections.

PLANTATION MANAGEMENT

The initial step towards converting weedy thickets into productive stands was to improve knowledge on plantation management. A full account of how plantations can be managed is provided in Pasiecznik *et al.,* (2001) and this emphasised the importance of maintaining an optimum density for the system in question. For example, a single rotation coppice system may contain trees at a density of 5000 trees/ha whereas an open silvopastoral system may only have 100 trees/ha. These recommendations can vary considerably according to conditions such as soil fertility and rainfall.

Around Marigat and Salabani, invasive stands were initially completely cleared leaving only rows of trees that were high-pruned. Tree stumps were removed, or killed by burning. These cleared strips were then either sown with forage grasses such as *Cenchrus ciliaris*, or cultivated with rainfed crops. These permanent systems were experimented with by Farmer Field Schools comprising local people and a coordinator, and these provided a focal point where opinions could be exchanged and the system adapted. This system of extension appeared to be a successful mechanism for encouraging local communities to experiment with *Prosopis*.

It is also important that the remaining trees are managed properly. Unlike traditional timber species, *Prosopis* are cut frequently throughout their lifetime. The most common operations are the removal of selected stems and side branches to form a single stem, crown pruning, coppicing, lopping and pollarding. In February 2006, HDRA/KEFRI training in the region provided a demonstration of *Prosopis* management on a single tree basis. This included: selecting trees to keep and those to remove, singling or high-pruning multi-stemmed shrubs and trees, removing seedlings, killing cut stumps, tools for pruning and clearing, and environmental benefits from thinning and pruning. These techniques are now being applied by trainees to trees around their own homes and fields. A follow-up visit to Salabani in November 2006 showed that these concepts had been taken up by the local community. Around many farmsteads, thinning and pruning was carried out by individuals on their own land, leaving single-stemmed trees at wide spacing as had been recommended. This had also been applied to public buildings such as the grounds of the local school, showing that the knowledge had been successfully adapted and adopted. The same techniques were also disseminated in two outreach demonstration courses in Garissa and Bura, also attracted much interest. It was recommended that such demonstrations now be taken nationwide, and to more remote villages in each district.

USING *PROPOSIS* AS TIMBER

Turning *Prosopis* wood into timber products is a key way of adding value to the products. *Prosopis* timber is generally very hard and durable and it has been used for products such as railway sleepers, parquet flooring and in joinery (FAO, 1997).
Training and awareness-raising courses on timber processing took place in Garissa, Baringo and Tana River districts in 2006. This used the simplest machinery, the chainsaw but with added guide attachments. The use of simple guides or attachments fixed to the chainsaw bar differentiates chainsaw milling from the more widespread but more dangerous method of 'freehand' milling. Three types of guides, frame mills, rail mills and carriage mills are commonly used, and the properties of these are described in Pasiecznik *et al.,* (2006). Detailed reports of both courses and all project outputs are also available on the project website (http://chainsaw.gwork.org).

Figure 1. Chainsaw milling a short Prosopis log into boards with an 'Alaskan' frame mill, Bura (Photo: N.M. Pasiecznik)

A full economic study was also undertaken comparing the economics of chainsaw milling over the nearest alternative systems using (circular) bench saws (Samuel *et al.,* 2007). This study showed that the biggest difference between the setups was the time to pay back the capital, with the chainsaw frame milling only taking 101 days whilst the bench saw would take over six years.

Training courses were generally well received with frequent requests on where to purchase the milling attachments. Prior to this, there had been only one attempt to mill *Prosopis*, with a local landowner purchasing logs at Ksh 300 each and taking them 100 km to Nakuru to the nearest sawmill. However, these sawmills were not accustomed to the hardness of the timber, and cost of transport was prohibitively high. In contrast, this new approach, with low capital investment, low operational costs, and 'turning trees to timber' on the spot where they fall, allowed a completely novel concept of timber processing.

An example of one demonstration, showed the potential for producing timber on site. A local carpenter was buying timber from Garissa, 100 km away, which made up a major part of his running costs, and he estimated that the nine 3 ft lengths of 2x2 in (90 cm by 5x5 cm) that had been produced from a short *Prosopis* log in 15 minutes had a market value of Ksh1000 (US$15), and he stated that he would now find a chainsaw operator to start converting *Prosopis* trees and use this local timber for making furniture.

A further training course for converting sawn boards into finished products was later held at the request of people from the Baringo district. Four hand-held power tools; a planer, belt sander, jigsaw and drill, a hand saw and a selection of spare blades, drill bits, sandpaper, etc. were demonstrated in Garissa and Bura. Here, people were exposed to 'turning trees to timber' and 'turning timber to traded products', the transformation of a *Prosopis* log into finished parquet tiles and craft items in the same afternoon. This was taken one stage further at a carpenter's workshop in Marigat, with a continuous production line set up, where logs were milled and the boards processed into finished items, producing a wide range of products, from chapatti boards and stools, to parquet flooring tiles and shaped craft items for the tourist market, such as wooden Africa and Kenya shaped wall hangings, animal shaped chopping boards, etc.

A telephone survey of Nairobi-based timber companies indicated that there was a ready market for products. Prices for finished hardwood tongue-and-grooved parquet flooring at Ksh600-1200 (US$9-18) per square metre, made potential supplies from *Prosopis* very attractive. More work is required to produce quality finished samples and begin a serious campaign to attract the interest of these and similar companies in Kenya. A UK marketing survey (Bakewell-Stone, 2006) also identified a number of potential importers of *Prosopis* timber products which can be taken forward when a consistent supply is forthcoming. KEFRI are to further test local markets by preparing samples, calculating returns, and arranging the first *Prosopis* timber stakeholder meeting.

Conservative estimates of the amount of *Prosopis* wood available suggest that there is an ample supply to meet demand. The original *Prosopis* plantations established in Kenya are now 16-20 years old, and these are now ready for exploitation as a timber. Trees from a 1500 ha *Prosopis* plantation established in the 1980s now have diameters over 40 cm, thus giving mean annual diameter increments in excess of 2 cm/yr. At 2 x 4 m spacing, and with a utilisable bole of 40 cm over bark diameter and 1.5 m in length, there would be an estimated standing timber volume of 250 m^3/ha. Taking a very low conversion rate of only 20% recovery, guaranteeing that all sapwood would be removed, this gives a potential 50 m^3/ha of sawn timber, or 75,000 m^3 in just this one single plantation.

Although accurate data for the area of plantations established in the 1980s are not available for the country as a whole, a conservative estimate of 15 times that for the Bura plantation would give a total area of mature stands of 22,500 ha, which could yield over one million cubic metres of sawn timber. This would make a significant impact on Kenya's timber balance, and this does not take into account timber from naturalised stands which are also known to contain very large standing volumes with diameters in excess of 40 cm.

Growth rates are also high. This indicates to potential buyers of *Prosopis* timber for parquet flooring or other uses that adequate supplies exist and can be sustained at least in the near future. Although such exploitation would begin with low levels, as experience, technologies and markets would need to develop, it is clear that the supply of *Prosopis* timber is not in doubt, and improved management leading to the production of longer and straighter stems, thus improving recovery, can only benefit the situation. The appropriate technology of chainsaw milling for converting *Prosopis* logs to sawn timber in remote areas has been tested in 2006, and the economics have been assessed and compared with tractor bench saws, and comparisons with other mobile sawmills is in progress. In areas such as drylands that have no history of timber exploitation, there is a distinct lack of appropriate processing skills, and any training and development must appreciate this if it is to succeed. Risks in drylands are often so high and returns so low as to severely limit investment, and high value timber has been identified as the one product that has the potential to realise significant profits and livelihood improvements.

USING *PROSOPIS* AS POLES

Although highest returns can be made from turning *Prosopis* wood into cants and boards, the production of posts and poles continues to meet an import need for local rural construction. It has good durability in these structures although the sapwood is easily and quickly attacked by insects (Pasiecznik, 2001). A recent development has been the contracting of the Forestry Department to provide long, thin, flexible sticks of *Prosopis* for making the framework of simple structures for Somali refugees in Garissa District. For use as fence posts, some anecdotal reports note that they are resistant to decay for at least for two years, whilst others note infestation with wood borers. A study was completed this year (Chepkwony JC, 2006, BSc thesis, Moi University, Nairobi, Kenya) which found that *Prosopis* heartwood was unsuitable for pressure treatment with a timber treatment agent, with only minimal uptake in the wood. Further studies are being considered by KEFRI, using water soaking or heat-treatments to reduce immediate attack. Amerindians used to reduce insect attack by only harvesting on a waning moon, which may reduce sugar content in the sapwood, and this technique could also be tested in any future trials.

USING *PROSOPIS* AS FUEL WOOD

Prosopis wood is used extensively for domestic fuel in arid and semi arid zones around the world. The wood burns evenly and hot due to its high carbon content (Goel and Behl, 1992) and has a high calorific value (NAS, 1980; Khan *et al.,* 1986) making it very suitable for this purpose.

In Kenya, views commonly held by many people in Marigat or Bura are that before the 1980s, the land was bare, dust storms were commonplace, and women had to walk long distances in search of firewood. With the spread of *Prosopis*, firewood is now easily accessible and in plentiful supply, and the dust storms have ceased completely. The government is starting to realise the exploitation of invasive stands as a means to control weedy invasions while also providing much needed firewood for Somali refugees, while also reducing conflict with local people over collection of firewood. There are an estimated 140,000 refugees in camps around Garissa town, and the UNHCR has very recently contracted the Forestry Department to supply them with 500 tonnes of firewood. Similar schemes could provide valuable sources of firewood to Sudanese and Somali refugees in camps in northern and north-eastern Kenya, while also providing much needed local employment, revenue for the state and help to control the spread of *Prosopis* on government land.

Prosopis charcoal is consumed widely in urban areas and is widely acknowledged to be of high quality. There are many regions of the world where charcoal makes a large contribution to the local economy including Haiti (Lea, 1996), India (Kanzaria and Varshney, 1998) and Peru (Diaz Celis, 1995). It is more popular than that from other trees according to a recent KEFRI survey. However, Kenyan government policy is that the production and transport of charcoal is illegal unless a license has been applied for and approved. This law was introduced in an attempt to stop the cutting of natural forests for charcoal, seen in earlier decades as one of the main causes of deforestation. However, changing this law alone has been identified as the one single most important means of promoting *Prosopis* exploitation, as charcoal is widely and commonly used in rural and even in urban areas (Choge and Pasiecznik, 2005). This issue was clearly stated in a policy brief produced in 2005 (Choge and Pasiecznik, 2005) and may have already led to some change in the perception of the issue, supported by continuous lobbying from KEFRI and other groups. The Ministry of Environment and Natural Resources has now submitted a Cabinet Memorandum for discussion by parliament, with a request for an immediate but restricted lifting of the ban, to allow the production and sale of charcoal from *Prosopis* areas, i.e. where *Prosopis* is causing problems through its invasiveness.

In two cases, this ban was lifted on a special trial basis. Around Garissa, 240 ha of government land infested with *Prosopis* was leased via the Forestry Department with permission to exploit and sell charcoal. The use of improved 'Casamance kilns' was promising, with up to 49% recovery in three days. Land was cleared but stumps were left, and were only removed when incentives were provided, such as the provision of seedlings of improved mango varieties. The biggest success of the project was in starting-up trade, but the project failed to establish and develop a solid market for charcoal in the district. The price for charcoal is Ksh120-140 (approximately US$2) per 25 kg bag.

In Baringo, a similar scheme was established as part of the FAO pilot project. However, there was little uptake of charcoal making in the area which was generally believed to be because the local people are pastoralists and would not change the activities of their ancestry. Thus, although some entrepreneurs have begun to produce and sell charcoal and have witnessed an improvement in their livelihood, this is making an insignificant impact on *Prosopis* invasions. There may be scope for leasing government land in the region to people from outside the area in an attempt to reduce tree density. As in India, however, removal of the roots must be a stipulation of any leasing agreement with charcoal makers, or otherwise resprouting will lead to tree densities equal or worse than before, within only a year after cutting.

USING *PROSOPIS* FOR HUMAN CONSUMPTION

Although food products made from *Prosopis* flour are consumed in the native range in South and Central America, this indigenous knowledge has not followed *Prosopis* trees across the Atlantic and the fruit are unused or provide only fodder for livestock. Pasiecznik (2002) argues that in Central and South America, many rural economies rely heavily on native *Prosopis* to supply a trade in processed products.

Before January 2006, *Prosopis* pods were occasionally sucked and chewed by children, but producing and consuming food using milled *Prosopis* pod flour was unheard of in Kenya. This changed in 2006 in areas where the project has worked, though further training, demonstration and extension is still needed, also developing and adapting methods for reducing risks of negative health effects.

During the training course run in Marigat, Baringo in February 2006, a strong demand was shown by local beneficiaries for experience in food uses. Maize and wheat flour were most commonly used, occasionally millet flour. Wheat flour was used for chapatis, pancakes, mandazi and cakes, and maize flour for the traditional ugali and uji. For mandazi, participants noted, a proportion of the wheat flour could be substituted with maize flour, being cheaper, to reduce the cost with no real effect on taste. This was used as an example of how *Prosopis* flour could and should be used, as a low cost and nutritious substitute for up to one fifth of the flour in any of the previously described foods. A large sack of flour had already been prepared using a tractor powered hammer mill given as part of the FAO project. The participants, however, felt this flour was too coarse, and it was then sent to a ‘posho mill’, a type of mill found in every village, privately-owned for hire, to mill locally purchased grains. Milling the pods, not just to release the protein in the seed, but also to prevent further spread of the seeds as a weed, was very much a new concept to the participants, and this knowledge may have large impacts as the tree and pods are adaptively managed in the future.

Figure 2. Preparing foods with Prosopis pod flour (with Prosopis trees in the background), Garissa (Photo: N.M. Pasiecznik)

The quality of the flour for chapatti making was found to be greatly improved by sieving to remove coarseness. The group went into production with minimal trainer input, making chapatis at different mix ratios, pancakes, mandazi, ugali, uji and cake, and they were entirely proactive in the new recipes. Participants also experimented with other uses including roasting the flour to make a form of coffee substitute and making a *Prosopis* cake.

The general consensus was that the best ratio was 20% *Prosopis* flour mixed with other flours. The most acceptable proportions in a mix depend on what it is being used for, as due to its very low starch content it is less suitable for bread making. Other previous work on cooking with *Prosopis* flour (Cruz, 1986) showed that bread containing up to 5% *Prosopis* flour was acceptable whereas biscuits could contain up to 25%. Hand ground flour with the seeds and capsules removed was not popular as it was considered to be too bitter. Including the seeds increases protein content and reduces bitterness.

There were also discussions on how to take this knowledge forward, by making *Prosopis* foods for other events such as weddings, church gatherings and women's group meetings. A 'recipe book' produced after the Baringo training (Choge *et al.,* 2006) was also in great demand. Further outreach and training is needed to take this to the more drought-hit districts of Turkana, Mandera and Wajir

The fruit produced by *Prosopis* is high in sugars, carbohydrates and protein. Pods from species of section Algarobia, which includes the common weedy species in Africa, contain 7-22% protein, 30-75% carbohydrates, 11-35% crude fibre, 1-6% fat and 3-6% ash (e.g. Oduol *et al.,* 1986; Galera *et al.,* 1992; Anttila *et al.,* 1993). Care should be taken in interpreting food value data for *Prosopis* from the literature as these may be given for whole pods, for only the pulp (mesocarp) or seed fractions. The proximate analyses of whole pods from *P. juliflora* and *P. pallida* from many parts of the world are given in Pasiecznik *et al.,* 2001).

The main soluble component of the pulp of *P. pallida* is sucrose (46%), representing over 90% of total soluble sugars, while the reducing sugars, glucose, fructose and xylose, are present in very small amounts (Cruz *et al.,* 1987; Sáenz *et al.,* 1987).

Dietary fibre represents 30% of the pulp and is largely insoluble. More than half of the fibre fraction consists of neutral polysaccharides (Bravo *et al.,* 1994). High iron levels have been reported in *P. juliflora* from Ecuador and Brazil (Figueiredo, 1975; Marangoni and Alli, 1988) but no figures for its bio-availability are given. The vitamins C, B6 and calcium pantothenate are present in significant amounts in pulp from P. pallida pods (Grados and Cruz, 1996).

The fat content of pulp is low, but is reported to be 7% in *P. pallida* seed cotyledons (Jiménez and Vergara 1977) with the major fatty acids found in extracted oil being linoleic acid (39%), oleic acid (29%), palmitic acid (13%) and stearic acid (10%). Similar values have been reported for *P. juliflora* (Marangoni and Alli, 1988).

Table 1 shows the composition of flour from whole *P. juliflora* pods produced in the course of the present study. This confirms the product as a high protein, high sugar material of considerable human food value.

Table 1. Composition of flour from whole pods of *P. juliflora* from Baringo District, Kenya

Component	(value/100 g dry matter)
Protein (g)	16.2
Total sugars (g)	13.0
Fructose (g)	3.2
Glucose (g)	0.8
Galactose (g)	0.8
Sucrose (g)	7.5
Maltose (g)	<0.4
Lactose (g)	0.7
Carbohydrate (g)	69.2
Energy value (kJ)	1530
Dietary fibre (g)	47.8
Fat (g)	2.12
Monosaturated fatty acids (g)	0.4
Polyunsaturated fatty acids (g)	1.06
Saturated fatty acids (g)	0.56
Sodium (mg)	20
Ash (g)	6.0
Total solids (g)	93.5

Table 2 shows an analysis of amino acid content of a flour sample taken from the Baringo district. In common with previous data (Cruz *et al.,* 1987), this confirms that in the flour nearly all the essential amino acids are present in amounts which fulfil the requirements of the FAO/WHO 'standard protein', thus indicating an acceptable nutritional quality of the protein. Methionine and cysteine are the limiting amino acids. It is much higher in lysine than wheat flour making it particularly suitable for vegetarians who often lack this amino acid. Medical studies also show it to release sugars into the blood much more slowly than wheat flour, typically taking 4-6 hours rather than 1-2 hours which make it particularly suitable for diabetics (Bakewell-Stone, 2006).

Table 2. Amino Acid content. Analysis after hydrolysis 24 h at 110°C

Amino Acid	Content (g/100g dry matter)
Cysteic acid	0.00
Aspartic acid	1.99
Threonine	0.42
Serine	0.62
Glutamic acid	1.43
Proline	1.22
Glycine	0.41
Alanine	0.47
Cystine	0.07
Valine	0.54
Methionine	0.08
Isoleucine	0.34
Leucine	0.82
Tyrosine	0.18
Phenylalanine	0.38
Histidine	0.32
Tryptophan	0.00
Lysine	0.47
Arginine	0.76

Clearly, if *Prosopis* is to be adopted as a human food in Kenya, as is already the case in South America, then it is also necessary to test the product for microbial contamination, mycotoxins and antinutritional factors. A sample of flour from Kenya was tested by Leatherhead Food International, Leatherhead, UK, and results were 38 ppb Ochratoxin A, 4.7 ppb for Aflatoxin B1 and 5.8 ppb total aflatoxin. The levels of total aflatoxin and Aflatoxin B1 exceed the stringent EU maximum levels for cereals of 5 and 3 ppb, respectively, but not the maximum levels adopted in the USA (10 ppb), Brazil (20 ppb) or India (30 ppb) (FAO, 2004). The Ochratoxin A level in *Prosopis* flour exceeded the maximum level of 5 ppb that has been proposed as an international standard by CODEX for Ochratoxin A in wheat, barley, rye and their derived products (USFDA, 2003).

However, only one Kenyan *Prosopis* flour sample has been analysed so far and this had been produced from pods harvested in the wild and stored for several months. Far higher levels of Ochratoxin A are occasionally found in samples, included in European grain samples, when harvest, drying and storage conditions favour fungal growth and toxin production (Jørgensen *et al.,* 1996; Elmholt and Rasmussen, 2005). Similarly, significant levels of aflatoxin in common food products have been routinely reported in West Africa (Bankole and Adebanjo, 2003) and East Africa (Kaaya and Warren, 2005). In Uganda, 29.6% of common food samples analysed tested positive for aflatoxin and approximately 12% exceeded 100 ppm total aflatoxin (Kaaya and Warren, 2005). Nevertheless, these results are of sufficient concern to warrant further study to determine toxin levels in freshly harvested pods, and in pods and flour after various periods of storage, and to develop appropriate harvesting and storage methods to minimise risk to human health. Among steps that may be necessary are early harvest, thorough drying and control of moisture levels during storage, discarding infested seeds, control of insect infestation and avoidance of carry over of inoculum in storage facilities.

Appropriate methods can be found in the traditional and improved storage methods used in South America where *Prosopis* originated. Traditional pod stores in North America tend to consist of large baskets made from natural fibres, with a rain-proof roof, raised off the ground to prevent predation and to keep the pods dry (Felger, 1977). In Brazil, standard agricultural barns or special rooms with wooden floors and walls are used for storing other dried animal feeds (e.g. da Silva, 1996). In Peru, rustic closed rooms were used, made from mud bricks, but these have largely been replaced with built block buildings (Grados and Cruz, 1996). Special storage units for *P. pallida* pods are built, 5 x 5 x 4 m high, which are capable of storing 40 t of pods (Díaz Celis, 1995). In India, layers of dry pods are laid down alternately with layers of sand. This is said to increase storage time to three years. Periodic checking of the pods in the store is recommended to assess any damage due to fungal infections, high moisture content or pests. Removal of infected pods should be carried out immediately. In Peru, however, once a pod store is filled, it is sealed with clay and opened only when the whole batch is to be sold.

USE OF *PROSOPIS* AS ANIMAL FEED

Although the project concentrated on the use of *Prosopis* as a human food and for timber use, there is considerable scope for the use of pods as an animal feed. Ripe pods are highly palatable with a moderate level of digestible protein and high energy content (Yadav *et al.,* 2004; Mahgoub *et al.,* 2005). Initial feasibility studies (Pasiecznik *et al.,* 2006) suggest that there is a ready market in the region of at least 300 t/month. This could potentially bring in £86,400 a year into some of the most marginal communities and remove 70 billion seeds from the district, thus also having a significant impact on the spread of the weed.

Despite this potential, there are still barriers to overcome before this can be taken up on a scale that has a significant impact. Firstly, it appears that local collection and milling for zero grazing does not comply well with traditional extensive grazing of livestock by pastoral groups who are unwilling to collect and mill what they see as forage and not fodder. There are also some concerns about the impact of feeding *Prosopis* pods to livestock with one study claiming a small proportion of cattle becoming ill when fed pods (Alder, 1949) and another claiming neurological damage (Tabosa, 2006). However many of the concerns have been stirred up in newspaper reports culminating in the presentation of a toothless goat in a court in Nairobi to demonstrate its ill effects (East African Standard, 30 September 2006). Lastly, there have been reports in the Kenyan press of farmers

(East African Standard, 3 April 2007) being dissatisfied with the price they were receiving for the pods in relation to the amount of time it took them to gather them.

CONCLUSIONS

It is widely acknowledged that *Prosopis* has caused many problems due to poorly managed introductions. Most eradication attempts have proved unsuccessful and it is generally becoming accepted that control through utilisation is a more feasible course of action. With invasive species, the most appropriate methods of control may be found in the place where it originally comes from, and looking at ways in which it is used in its native Americas, where it is generally less of a problem, has generated a number of ways the plant can be exploited. These were demonstrated in Baringo district and follow up visits have confirmed that these techniques have been taken up into the community by spontaneous diffusion. So far, use of timber and human food has received the most attention, however, there is also great potential for use as a cattle feed, although some barriers need to be overcome to establish this.

At present the market for products is still in its infancy, but has shown some movement in the last year with six timber companies in Nairobi interested in seeing wood samples and a feed company putting in an order for 8 tonnes of pods. Further initiatives need to be put in place to establish marketing channels and supply chains for the products to maximise its exploitation potential.

Meanwhile *Prosopis* is still a topic of debate in the Kenyan press and articles highlighting both the positive and negative virtues of the plant continue to be published. It is not clear whether these case studies will provide sufficient evidence of the benefit that can be brought to communities to turn around a large body of people still calling for its complete eradication.

Acknowledgements
This paper would not have been possible without the financial support from Kennington Overseas Aid (a local NGO from Oxford, UK) for funding work in Kenya in 2006, along with DFID (UK) for supporting parallel work on timber utilisation (as part of FRP project R8510), and which both overlapped with an FAO-funded project in the area (TCP/KEN/3002). The authors also wish to thank all those that have been involved in promoting *Prosopis* as a resource for the resource-poor, especially Peter Felker on the global stage, international consultants Clemens Fehr and Petra-Bakewell-Stone, and many others in Kenya, including numerous KEFRI and ILRI technical staff, George Muthike, Joseph Matere and other national scientists from diverse organisations. The support of the directors of KEFRI and ILRI, Dr Paul Konuche and Dr Carlos Seré, respectively, is gratefully acknowledged.

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Sustainable supply of plants entering the trade

Monique J. Simmonds

ABSTRACT

An overview of some of the projects being undertaken at Kew is provided. These projects involve: the identification of species of plants with potential social and economic uses, their sustainable supply and the quality of plants entering the trade. Due to changes in land use and the challenges associated with climate change there is an increasing need to justify how we can conserve not only plant species but also the knowledge about their traditional uses. Examples, of research on medicinal plants in Africa will illustrate how the use of molecular-based phylogenies, ethnobotanical knowledge, chemosystematics and global information systems can support the selection of species for further study. Research on plants used in traditional Chinese Medicine will highlight the need for improved knowledge about the need to be able to identify species of plants entering the trade.

NB: Abstract only - manuscript not submitted.

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New crops for functional molecules: Açai and Blackberry

Suzie Zozio and Dominique Pallet

A steady increase in the development of natural food colorants and functional food sources has been observed in recent years, not only due to consumer preferences for natural pigments but also for their health-related benefits and nutraceutical properties. Anthocyanins are a viable replacement for synthetic colorants due to their bright, attractive colours and water solubility, allowing their incorporation into a variety of food systems. We have studied two news crops for their functional molecules content: Açai and Blackberries.

AÇAI

Euterpe oleraceae Martius is a large indigenous palm tree from the Brazilian Western Amazon Forest in the region of the Amazon River and its tributaries and estuaries in South America. It belongs to the family of Palmae (Arecaeae) and to the class of Liliopsida Principes. Its fruit, known as açai, is of great economic value to native and lower class people of Brazil, Colombia, and Suriname because it serves as a major food source. The açai palm tree (Figure 1) can reach up to 25 m in height. The trunk grows from 15 to 25 cm in diameter and forms into tall multi trunk trees. Its wood is used in rustic constructions around the areas where it can be found.

Figure 1. Açai palm tree

The fruit (Figure 2) is a kind of cherry of 1 to 1.5 cm in diameter, violet, becoming nearly black when ripe, and generally used for the production of liqueurs, sweets, and juices.

Figure 2. Açai fruit

Açai as a functional food

A recent study using modern procedures and a standardised freeze-dried acai fruit pulp and skin powder found nutrient analysis results from 100 g of powder to equal 533.9 calories, 52.2g carbohydrates, 8.1g protein and 32.5g total fat. The carbohydrate portion includes 44.2g of fibre (Schauss et al. 2006). Having nearly one-third of its mass as dietary fibre, acai is an exceptional source of this valuable macronutrient: a 100 g serving of the powder would provide all the recommended daily fibre for adults. (30g per day). Acai is particularly rich in fatty acids, feeling oily to the touch. It contains high levels of the monounsaturated fatty acid oleic acid (56.2% of total fats). It is also rich in palmitic acid (24.1% of total fats, a saturated fat) and the polyunsaturated omega-6 fatty acid linoleic acid (12.5% of total fats). (Schauss et al., 2006). Two phytosterols are present, which compete with dietary cholesterol for absorption and so may reduce blood cholesterol levels; it is also unusually rich (78-91% of total sterols) (Lubrano, 1994; Schauss 2006).

This fruit has recently captured international interest, not only due to its perceived novelty and exotic flavour but also due to potential health benefits associated with its phytochemical composition. Considerable interest has been generated by its high anthocyanin content, a group of polyphenols and its antioxidant capacity. (Coïsson *et al.,* 2005).

Two anthocyanins, cyanidin-3-glucoside and cyanidin-3-rutinoside were found to be the predominant anthocyanins. Additionally, other major polyphenolic compounds present in açaí juice were identified. Beneficial health effects of plant polyphenolics have been recognised to originate from their ability to inhibit oxidative reactions.

A recent study using a standardised oxygen radical absorbance capacity or ORAC analysis on a freeze-dried Acai powder reported that this powder showed a high antioxidant effect against peroxyl radical (1027 µmol trolox equivalent/g). This is approximately 10% more than lowbush blueberry or cranberry on a dry weight basis (Wu, 2004).

Acai as a natural food colorant

In regard to its high anthocyanins concentration, 1400 mg/L expressed in equivalent cyanidin-3-glucoside of juice of açai, and its stability, açai can be used as a new source of pigments. Coïsson *et al*. (2005) concludes that açai juice could be use as a natural functional pigment for flavouring and colouring yogurt.

BLACKBERRIES

Rubus glaucus Benth, the Andean blackberry or "mora de Castilla" is native to a broad area from the northern Andes to the southern highlands of Mexico. Although common in the wild, it is also abundant in the gardens of hundreds of towns and villages, especially in Ecuador and Colombia. In two Ecuadorian towns, Ambato and Otavalo, nearly every garden has the plants, this fruit appears in the markets most of the year. In Colombia, the mora de Castilla has become an increasingly important cash crop. Its fruits (Figure 3) are large (up to 3 cm long). When fully ripe, they range from dark red to nearly black in colour. Their seeds are small and hard, with little flesh adhering to them.

Figure 3. Blackberry fruit

Blackberry as a functional food

Blackberries are also of particular interest in this regard, due to the high anthocyanin and phenolic contents that contribute to its noted antioxidant capacity. In addition, recent studies have demonstated the strong antioxidant activities of anthocyanins such as cyanidin-3-glucoside detected in blackberries. The antioxidant capacity of the a freeze-dried blackberry powder measures by ORAC was 674.2 ± 52.4 µmol trolox equivalent /g. (Elisia *et al*., 2007)

Blackberry as a natural food colorant

Considering the high anthocyanin concentration (1250 mg/L expressed in cyanidin-3-glucoside) *Rubus glaucus* can be also used as a new source of anthocyanin pigments.

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Description and analysis of the sustainability of underutilised tropical fruits with high commercial potential: Blackberries (*Rubus spp*), Red-Pitahaya (*Hylocereus purpusii*) and Peach Palm fruits (*Bactris gasipaes*) in Costa Rica and Nicaragua

O. Quiros, I. Alfaro, M. Garcia and D. Gomez

ABSTRACT

Research is being carried out to describe and analyze new strategies for the sustainability of underutilised products with potential for development, using 3 species in Central America. The research project forms part of a project to improve quality, safety and innovation management along the production to consumption chain. The research involves stakeholders; 1) Inventory of key; 2) details of the chain; 3) systematization of technological options; 4) identifying innovation and building public-private alliances.
The paper will show that:

1) In Costa Rica there are three farmers organizations dealing with blackberries and only one with peach palm fruits. In Nicaragua there two growers organizations dealing with red pitahaya and only one processor organization.
2) In both countries focus is on small grower associations. The production has a worth for blackberries at a steady price of 1500 Colones/ kg for export and 300 - 900 Colones/kg for the domestic market. In the case of peach palm fruits the price was 100 Colones/kg at farm gate and for red pitahaya 80 Colones per dozen fresh fruits,
3) In 2005 67,83 tons of blackberries were exported and 155,311 tons went to the domestic market. Data for the other 2 species will be given.
4) retailers and supermarket chains are the most important channels for the commercialization of the three fruits.

Constraints to efficient production and marketing will be itemised.

NB: Abstract only - manuscript not submitted.

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Potential uses of underutilised crops for nutritional and medicinal properties

S.K. Mitra, P.K. Pathak and I. Chakrabortyl

India has a rich heritage of indigenous fruits with wide variability between different species, in their morphological, physical and chemical composition. Consumers today are becoming increasingly conscious of health and nutritional aspects of their food. The indigenous fruits which are at present underutilised have an important role to play in satisfying the demand for nutritious, delicately flavoured and attractive natural foods of high therapeutic value. The indigenous tropical fruits of India like aonla (*Emblica officinalis*), bael (*Aegle marmelos*), jackfruit (*Artocarpus heterophyllus*), jamun (*Syzygium cuminii*), karonda (*Carissa congesta*), kokum (*Garcinia indica*), phalsa (*Grewia subinaequalis*) etc. are rich in nutritional and medicinal properties. Fruits of aonla, phalsa and jamun contain high levels of ascorbic acid. Aonla, bael and phalsa are good sources of calcium while karonda contains an appreciable amount of iron. The fruits of aonla, bael and jamun are generally well known for their medicinal properties.

The countries in Southeast Asia and their neighbors, endowed with a climate conducive to many tropical plants, are the centers of origin of many fruits trees. India is the home of some of the world's most useful plants thriving in her diverse agro-ecological zones and altitudes – in the monsoon tropics of the south to temperate and alpine north – western Himalayas, from the extremely arid and semi-arid north-western plains to the humid tropics of the east. Several less-known fruit species which have the potential for commercial exploitation are yet to realise this (Pareek and Sharma, 1993). Most of these species have wide adaptability and environmental tolerance and hence can thrive even in most adverse situations. These fruits are the only source of food for people living in villages meeting their requirements of vitamins and minerals. Because of their curative properties, these fruits have been used in Indian's systems of medicine such as Ayurvedic and Unani from time immemorial. Apart from their nutritive and medicinal values quite a few of these underutilised fruits have excellent flavour and attractive colour and are suitable for several processed products. In spite of these quality attributes most have not undergone any conscious phase of domestication and human selection. Their cultivation is very restricted and they grow mainly wild.

AONLA (*Emblica officinalis*)

Aonla is indigenous to tropical south-eastern Asia, particularly in central and south India (Ghosh, 1998). In India, forests have been the traditional source of aonla fruit for medicinal uses with annual harvests estimated to be about 50,000 tonnes (Singh, 2003). Increasing demand from industry, especially for ayurvedic formulations, and appreciation of nutraceutical and medicinal properties for home consumption has resulted in the growing of this tree as a cultivated crop. In India, it is estimated that aonla is cultivated on about 70,000 ha, having a productivity of 3.3tonnes ha^{-1} (Mitra, 2006).

The fruit is nutritious and is a rich source of vitamin C. Ascorbic acid and other constituents are well retained in dried aonla fruits (Roy, 1996). Potassium and iron content are relatively high in the fruit.

The fruit has a very high content of ascorbic acid and is analgesic, anti-inflammatory, and antipyretic. Vitamin C is also antihepatoxic, antinephrotoxic, antioxidant, and promotes chromosomal stability Basak (2003). The fresh fruit contains as much as 4.45% tannin (Pathak, 2003) compounds of which ellagic acid, gallic acid, corilagin, etc. are important. Ellagic acid is antimutagenic and anticarcinogenic (Basak, 2003). Gallic acid scavenges free radicals generated by various metabolic processes. The fruit contains (-) epicatechin which is hypoglycemic, anti-inflammatory and its antiviral action is effective against Moloney murine leukaemia virus. The fruit contains an appreciable amount of linoleic acid, which promotes immunomodulation in the human body. Ingestion of linoleic acid by the patients having multiple sclerosis reduces the frequency and intensity of heart attacks (Pathak, 2003). The fruit contains kaempferol, quercetin, and rutin. All these compounds are partially cardiotonic. It also contains phyllemblin which regulates blood pressure and respiration (Pathak, 2003).

The root bark is astringent and is useful in treating gastric ulcers. The stem bark is also astringent and is useful in treating jaundice, diarrhea, and myalgia. The flowers are cooling and aperient. The leaves are useful in alleviating conjunctivitis, inflammation, dyspepsia, diarrhea, and dysentery. Seeds are reported to be useful in treating asthma, bronchitis, and biliousness (Basak, 2003). The seeds contain a fixed oil, phosphaids, and a small quantity of an essential oil with a characteristic odour. The fixed oil (16%), is brownish yellow in colour and contains fatty acids in the following proportions: linolenic (8.78%), linoleic (44.0%), oleic (28.4%), stearic (2.15%), palmitic (2.99%), and myristic acids (0.95%) (Kapur, 1990).

Aonla fruit is not palatable for direct human consumption because of its high acidity and astringent taste. Fruit is consumed mainly in the processed form. The excellent nutritive and therapeutic values of the fruit offer great potential for processing into several quality products. In general, aonla fruits are utilised for three purposes:

(a) Food items: RTS, nectar, squash, jam, preserve, candy, pickle, sauce, chutney, dehydrated shreds, etc.
(b) Ayurvedic preparations: Chavanprash, trifla, amlakai girth, trifla churan, and trifla prash tablets.
(c) Cosmetic preparations: in face packs, hair oil, shampoos and tooth powder.

BAEL (*Aegle marmelos*)

Bael belonging to the genus *Aegle family Rutaceae* and consists of 2-3 species of which only one is cultivated. It grows wild in sub-Himalayan tracts of central India, Sri Lanka, Pakistan, Bangladesh, Thailand and most South-East Asian Countries.

Bael is known for its high medicinal and nutritional properties. Almost every part of the bael tree is used. The fruit is very rich in sugar, riboflavin (Vitamin B_2) and minerals (Table 1). The ripe fruit is a tonic, restorative, laxative and good for the heart and brain. The mature fruit is astringent, digestive and stomachic, and is usually prescribed for diarrhea and dysentry. The fruit pulp contains limonene which is not only a direct (A) antimutagen but also antiinfluenza A and B viruses. Tannic acid present in fruit is antimutagenic, acting directly, and antiherpes simplex virus 1. Cuminaldehyde in the fruit adds an odour to the fruit pulp. This is found as characteristic of antifungal and insecticidal material (Basak, 2003). Adecoction of the unripe fruit, with fennel and ginger, is prescribed in cases of hemorrhoids. Marmelosin derived from the pulp is given as a laxative and diuretic (Morton, 1987). Aegeline 2 isolated from leaves has antihyperglycemic activity as evidenced by lowering blood glucose levels (Shweta *et al.,* 2007). Ripe fruits can be used for the preparation of beverages (ready to serve nectar, squash) and toffees. The unripe fruits are commonly used for the preparation of a preserve, candy and dry products (powder). Bael fruit peel constitutes about 20-25% of the total fruit weight depending upon the varieties/ genotype. The peel being very hard is not liked by animals as such. However, it can be fed to animals in ground. When ground and mixed with concentrate it is relished by cattle.

JAMUN (*Syzygium cuminii*)

Jamun is an important underutilised fruit of Indian origin. It belongs to the family Myrtaceae. Jamun is a tall and evergreen tree found throughout India. Jamun fruit has considerable nutritive value (Table 1); it is a very good source of iron. Vitamins present in jamun are thiamine, riboflavin, nicotinic acid, vitamin C and folic acid.

Medicinaly, the fruit is astringent, stomachic, carminative, antiscorbutic and diuretic. Jamun fruit contains polyphenols like delphinidin, malvidin (with bioside sugars). These are essentially hydrolysable tannins. Fruit also contains tannic acid derivatives such as gallic acid, corilagin and ellagic acid (Basak, 2003). Gallic acid in this fruit besides exerting the effects of tannin derivatives is useful in treatment of antiinfluenza A and B and polio 1 virus. Citric acid present in the fruit is a known antibacterial compound. This compound kills and cleanses *Escherichia coli* from the urinary tract.

Jamun bark is a digestive aid, astringent in the bowels and an anthelmintic. It is a good palliative for sore throat, bronchitis, ashma, thirst, dysentery, blood impurities and ulcers. The seeds contain an alkaloid jambosine, and a glycoside, jambolin or antimellin, which halts the diastatic conversion of starch into sugar, and thus used to lower the blood sugar level. The seed is also rich in fatty acids (palmitic, stearic, oleic and linoleic) and tannin (12-13%). Bark decoctions are taken in cases of asthma and bronchitis and are used as a mouthwash for its astringent effect on mouth ulcerations, spongy gums and stomatitis (Mitra, 2006).

KOKUM (*Garcinia indica*)

Kokum belongs to the family Guttiferae. This is an evergreen tree found in the tropical forests of India. Kokum is an important minor fruit of Maharastra. The tree is very hardy and grows under rain fed conditions, on ripening the fruit turns red/ dark red and is valued for its nutritive and medicinal properties. The fruit is known to reduce obesity and regulate blood cholesterol level, keeping the heart healthy (Roy, 1996). Fruit are steeped in sugar syrup to make 'amrutkokam'a healthy soft drink to relieve sunstroke which is popular during summer (Peter, 2001). It is a traditional home remedy in case of flatulence, heat stroke and infections (Kirtikar and Basu, 1984). Many therapeutic effects of the fruit have been described in traditional medicine based on Ayurveda. These include its usefulness as an infusion, in skin ailments such as rashes caused by allergies, treatment of burns, scalds and chaffed skin, and as a remedy for dysentery and mucous diarrhea, an appetiser and a good liver tonic, to improve appetite and to allay thirst, as a cardio tonic and for mitigating bleeding, piles, dysentery, tumours and heart diseases (Mishra *et al.,* 2006)

One of the ingredients of kokum, hydroxycitric acid (HCA) has been patented for use as a hypocholesterolaemic agent. HCA is a potential anti-obesity agent (Jena *et al.,* 2002). It suppresses fatty acid synthesis, lipogenesis, food intake and induces weight loss. Garcinol- a polyisoprenylated benzophenone purified form from fruit rind, displays antioxidant, anti-cancer and anti-ulcer properties (Yamaguchi *et al.,* 2000). Apart from HCA and gracinol, kokum contains other compounds with potential antioxidant properties. These include citric acid, malic acid, polyphenols (Cadenas and Packer, 1996), anthocyanin pigments and ascorbic acid (Peter, 2001). Its antioxidant activity is higher than that reported for many fruits (blueberry, strawberry, orange, banana, plum) and vegetables (garlic, spinach, cauliflower, carrot, cabbage, beet, onion). Besides, it is cheap, readily available to all strata of society, with medicinal properties attributed to it (Mishra *et.al.,* 2006). Kokum seed is a good source of fat, called kokum butter. Like a few plant species which are known to accumulate triacylglycerols (TAGs) that are rich in stearic acid, kokum has been reported to accumulate more than 30% stearate in its seed oil (Daniel *et al.,* 2003).

JACKFRUIT (*Artocorpus heterophyllus*)

The jackfruit belongs to the diverse Mulberry family, Moraceae and is found mainly in the tropics. The jackfruit is the largest of all tree-borne fruits grown in tropical Asia (Anon, 2004).

Ripe fruit has a high nutritive value. In India it is called the “poor man’s fruit”. The fruits are normally fibrous and contain mono-, di-, and polysaccharides. The ripe fruit also significantly contributes to the nutrition of low income families as a source of vitamins, minerals and calories. It has a fairly good content of β-carotene. Jackfruit is an important source of pectin and contains about 1.9 – 2.2 per cent protein (Table 1). Fructose, glucose and sucrose are the major sugars in all parts of the fruit, except in the outer spiny rind, which is devoid of glucose. Capric, myristic, lauric, palmitic, oleic, stearic, linoleic and arachidic acids are the major fatty acids (Chowdhury *et al.,* 1997).

The Chinese consider jackfruit pulp and seeds tonic, cooling and nutritious, and to be useful in overcoming the influence of alcohol on the system. The seed starch is given to relieve biliousness and the roasted seeds are regarded as an aphrodisiac. The dried latex yields artostenone, convertible to artosterone, a compound with marked androgenic action. Mixed with vinegar, the latex promotes healing of abscesses, snakebite and glandular swellings (Anon, 2004).

The bulbs of the ripened jackfruit can be eaten fresh or cooked (with coconut milk), or made into ice cream, chutney, jam, jelly, paste and leather. The ripe bulbs are mechanically pulped to make jackfruit nectar or reduced to concentrate powder. Frozen canned jackfruit pulp retains a good colour, flavour and texture. Fully grown unripe fruits are used as vegetables. Tender young fruits may be pickled with or without spices.

KARONDA *(Carissa congesta*)

Karonda belongs to the family Apocynaceae. The tree is usually 3-5m tall; the stem is rich in white latex and its branches have sharp spines. The fruit is globose to broad ovoid in shape and about 1.0-2.5cm long. Young fruits are pinkish white and become red to dark purple when mature. The fruit is a rich source of iron and vitamins (Table 1). The fruit has potential for processing, it is in use for making juice, squash, pickle, preserve, candy and fermented beverages (Roy, 1996).

Ethnomedically the fruits are used as an astringent, antiscorbutic and as a remedy for biliousness. A leaf decoction is used against fever, diarrhea, and earache. The roots serve as a stomachic, vermifuge, and remedy for itches (Subhadrabandhu, 2001). The roots contain salycylic acid and cardiac glycosides causing a decrease in blood pressure (Morton, 1987).

PHALSA (*Grewia subinaequalis*)

Phalsa belongs to the family Tiliaceae. The fruits are small in size and ripen gradually on the plant. The popularity of phalsa fruit is due to its pleasing taste. The juice when extracted gives a deep crimson red to dark purple colour and is very popular. The juice is extremely refreshing and is considered to have a cooling effect especially in hot summers (Roy, 1996). Unripe phalsa fruit alleviates inflammation and is administered in respiratory, cardiac, and blood disorders, as well as in fever reduction. Infusions of the bark are given as a demulcent, febrifuge, and treatment for diarrhea. The root bark is employed in treating rheumatism. The leaves are applied on skin eruptions and they are known to have antibiotic action (Morton, 1987).

Table 1. Composition of the edible part (100g edible portion; fresh weight basis).

	Aegle marmelos	***Artocarpus heterophyllus***	***Carissa congesta***	***Emblica officinalis***	***Garcinia indica***	***Grewia subinaequalis***	***Syzygium cuminii***
Water (g)	55- 62	72- 94	83- 91	77- 81	87.5	72- 81	84- 86
Protein (g)	1.8- 2.6	1.2- 1.9	0.39- 1.1	0.07- 0.5		1.3 -1.6	0.7
Fat (g)	0.2- 0.4	0.1- 0.4	2.6- 4.6	0.1- 0.2		0.9- 1.8	0.15- 0.3
Carbohydrate (g)	28- 32	16.0- 25.4	0.5- 2.9	15- 22		14- 16	14- 16
Fiber (g)	3- 6	1.0- 1.5	0.6- 1.8	1.9- 3.4		1.2- 1.8	0.3- 0.9
Total sugar (g)	12- 20	20.6		4- 10	8.15	9- 11	6- 7
Total minerals (g)	1.7	0.9	0.6	0.6		1.1	0.4
Calcium (mg)	85	20.0- 37.0	21.0	13- 20		129.0	8- 15
Magnesium (mg)		27.0					
Phosphorus (mg)	50	38.0- 41.0	48.0	26.0		39.0	15- 169
Potassium (mg)	600	191- 407		225		350.0	55.0
Sodium (mg)		2.0- 41.0		1.2		4.0	26
Iron (g)	0.6	0.5- 1.1	28.0	0.48- 0.5		3.1	1.2- 1.6
Vitamin A (IU)	91.6	175- 540	1619	17.0		800	80
Thiamine (mg)	0.13	0.03- 0.09	0.04	0.03			0.03
Riboflavin (mg)	1.19- 1.2	0.05- 0.4	0.07	0.05			0.01
Vitamin C (mg)	8.6	7.0- 10.0	9.0- 11.0	500- 625	9.40	22.0	6-18
Energy (kj)	137	88- 410	42- 59	65		72.4	62.0

Source: Bose *et al.,* (2002), Gopalan *et al.,* (1987), Gunasena *et al.,* (1996), IBPGR (1986), Morton (1987), Page (1984), Verheij and Coronel (1992).

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28

Orkney Bere - developing new markets for an old crop

Peter Martin, John Wishart, Arthur Cromarty and Xianmin Chang

INTRODUCTION

Bere (Figure 1) is a very old barley (*Hordeum vulgare*) landrace which was once widely grown in the northern parts of Britain and which is still grown on a small scale in a few parts of the Highlands and Islands of Scotland, particularly in Orkney. Most modern barley is grown for malting or animal feed but Bere is unique amongst barley in the UK in being grown for milling and, in Orkney, Bere meal (flour) is still used in a range of bakery products like bread, biscuits and bannocks. Although the market for Bere is now small, numerous historical accounts show that it once played an important role in the economy of Orkney and probably most of the Highlands and Islands of Scotland.

Figure 1. Bere barley growing at Orkney College.

The origins of Bere are obscure and it is not clear when or where the crop was first grown. Historical accounts often refer to Bere as "Bygge" or "Big" which probably originated from "Bygg", the Old Norse for barley. It has, therefore, been suggested that Bere, or an earlier form of it, may have been introduced to the UK by the Vikings (Jarman, 1996). One of the earliest written references to Bere comes from Fitzherbert writing in 1523 who described it as having "small cornes and little flour". Bere was also referred to as Scots Bere or simply "corn" and in the 19th century and early part of the 20th century several types – Common Bere, Black Four-row, Buchan, Victoria and Winter White Bere - were still available or referred to (Pringle, 1874; Wright *et al.,* 2002). How these different types are related to today's Bere is not known. Although Victoria Bere was considered a markedly improved variety (Lawson and Son, 1852), Buchan Bere was more suited to Orkney's climate (Pringle, 1874).

Bere has been intimately associated with the Orkney Islands and its agriculture for hundreds, possibly thousands, of years. It was a versatile crop which provided meal for baking, malt for brewing and distilling and straw for animal bedding and thatching (Newman, 2006) and was a currency used for paying land rents. It was also a valuable commodity for an important export trade (Thompson, 2001). Bere was also of considerable economic importance in Scotland's Western Isles during the 18th and 19th centuries when large quantities were used to supply the Campbeltown distilleries (Barbour, 1997; Glen, 1970; Pacy, 1873). This may have been because there was a lower rate of tax on Bere than barley malt as a result of its lower alcohol yield during distillation.

Bere was also grown more widely in the UK and has been equated with *Haidd Garw* or "coarse barley" which was grown on upland soils in Wales (Hunter, 1952). There are also references to it being grown in Ireland in the 1800s (Lewis, 1837) and the improved variety, Victoria Bere, originated from a selection made in Belfast Botanic Gardens in 1836 (Lawson and Son, 1852). Bere was taken to North America where European settlers on the East coast found that Bere from Scotland grew better than two-rowed varieties (Briggs, 1978) and a question about Bere production and the land area under Bere is even included on the 1848 Canadian census form (AllCensusRecords, 2007), probably reflecting transport of the crop to Canada by Scottish settlers. It is likely that Bere was also taken to other countries settled by the Scottish.

There is little readily available information tracing the decline in the cultivation of Bere in the Highlands and Islands but it is likely that this resulted from a number of factors including the appearance of higher yielding varieties with short straw which were better suited to mechanised agriculture. In Orkney the decline coincided with a change in farming from grain production to grass as the beef industry developed from about the middle of the 1800s (Thompson, 2001). By the end of the 20th century, only about 10 ha of Bere were being grown in Orkney, Shetland and Caithness (Jarman, 1996). Bere is also still being grown on a very small scale by a few crofters on the Western Isles (including North-Uist, Benbecula, South-Uist and Barra), sometimes on sandy "machair" soils which are alkaline and manganese-deficient (Scholten *et al.,* 2007). It is surprising that Bere has survived in cultivation down to the present day but in recent years this is largely thanks to the dedication of just a few enthusiastic growers. In Orkney, this has been facilitated by the commercial outlet for Bere meal provided by Barony Mills.

Apart from a few bakery products, the only new products developed until recently with Bere have been a whisky distilled at Edradour Distillery in 1986 for Michel Couvreur (Royal Mile Whiskies, 2007) and a limited-edition beer produced by Orkney Brewery in 1990.

Although Bere is probably the longest cultivated type of barley grown in Britain, very little research has been done on it. It is a 6-row barley (Jarman, 1996), but it has also been described as irregularly 4-rowed (Percival, 1910). It is susceptible to frost damage and so is planted late in the Spring after which it makes rapid growth and although traditionally one of the last crops sown, it was usually the first to be harvested (Wright *et al.,* 2002). As a result of its rapid growth (Percival, 1910), it has been described as a 90-day variety (Jarman, 1996). It is reputed to be tolerant to acidic soils (Wright *et al.,* 2002) but also grows on more alkaline sandy coastal soils (machair) derived from beach sands (O'Dell, 1935; Scholten *et al.,* 2007). Bere is susceptible to both powdery mildew disease (*Blumeria graminis* f.sp. *hordei*) (Wright *et al.,* 2002) and leaf stripe (*Pyrenophera graminea*) (Cockerel, 2002) and has weak straw (Peachey, 1951) making it very susceptible to lodging.

The Agronomy Institute opened at Orkney College UHI in 2002 and one of its chief objectives is to identify and help commercialise new crops in the Highlands and Islands of Scotland. From the start, it has put considerable effort into promoting Bere for niche markets and this has included agronomic trials aimed at developing best practices for modern Highlands and Islands agricultural conditions and commercialisation activities focussed on finding new markets. This paper reviews some of the progress made in both areas.

MATERIALS AND METHODS

Identification of recent cultivation practices with Bere

To identify recent agronomic practices with Bere, seven farmers who had grown Bere in Orkney since the 1980's were interviewed informally in 2003.

Standard experimental practices used in trials

In the two trials described in the following sections, there were a number of practices common to both and these are outlined below. Prior to ploughing in the spring, an application of cattle slurry was made to fields at about 10,000 l ha^{-1}. Fields were planted with a Massey Ferguson combination drill (MF30) using a seed rate of 160 kg ha^{-1} with N, P and K fertiliser being applied in the drill. Herbicide (15 g ha^{-1} Ally (20% w/w metsulfuron-methyl) and 1 l ha^{-1} Optica (600 g l^{-1} mecoprop-P), both in 200 l ha^{-1} of water) were applied by a tractor-mounted hydraulic nozzle sprayer (Andereau) with a 12 m boom at GS 30. Experimental plots were 16 m long by 6 m wide and at harvest a sample area was combined (Sampo 2025 combine with a 2.3 m cutter bar and on-board weighing system) from the middle of each plot with two passes of the combine (each 2.3 m wide and 16 m long), giving a harvested sample area of 73.6 m^2. The grain from each sample area was weighed on the combine and a 100 g subsample taken for moisture content measurement. The mass of grain harvested from each sample plot and the sample area were then used to calculate plot grain yield in t ha^{-1} which was converted to 15% moisture content.

Planting date and seed rate trial

This trial used a split plot design with five replicates. There were two main plot treatments for time of planting - early planting (15 April 2003) and a traditional mid-May planting (16 May 2003). There were three subplot treatments for different seed rates (130, 160 and 190 kg ha^{-1}). At planting, the same amount of compound fertiliser was applied to all treatments (N, P (P_2O_5) and K (K_2O) at 28, 56 and 56 kg ha^{-1} respectively).

Inputs trial

This used a split plot design with four replicates and was planted on 24 April 2003. There were four main plot treatments for different fertiliser application rates (F0: no N, P and K; F1: N, P and K at 15, 30 and 30 kg ha^{-1}, respectively; F2: N, P and K at 30, 60 and 60 kg ha^{-1}, respectively; F3: N, P and K at 45, 60 and 60 kg ha^{-1}, respectively). Compound fertiliser (11-22-22) was applied at planting with an additional 15 kg ha^{-1} of N applied as a top dressing to the F3 treatment on 15 May. There were three subplot treatments for different fungicide and growth regulator treatments (I0, no growth regulator or fungicide; IF, fungicide; IG, growth regulator). The fungicide, BAS 493 F (kresoxim-methyl, epoxiconazole and fenpropimorh), and growth regulator, Cerone (2-chloroethylphosphonic acid), were applied to the crop, at rates of 0.25 and 0.5 l ha^{-1} of product, respectively in 200 l ha^{-1} of water by knapsack sprayer (Cooper Peglar CP30) with 1.5 m boom at GS 37-39. The fungicide treatment was included in the trial because high levels of powdery mildew occurred in Bere grown by the Institute in 2002.

Analysis of data from field trials

Yield data from the two above trials were analysed by ANOVA using Genstat Release 9.1 (Lawes Agricultural Trust). The statistical significance of main effects was determined from *F* ratios in the ANOVA table while that between treatments was tested by least significant differences (LSD) using a 5% significance level.

Analysis of minerals and vitamins in Bere flour

For analysis of minerals and vitamins, Bere was grown in Orkney in 2002 and grains were ground into Bere flour using a traditional three-phase grinding process by Barony Mills, a water powered mill operated in Orkney by the Birsay Heritage Trust. The resulting wholemeal flour and a white flour, obtained by sieving with an 8N mesh which gave 62% extraction, were analysed for vitamins and minerals by Direct Laboratories, RHM Technology and other UKAS-accredited laboratories (Theobald *et al.,* 2006). Because of cost, it was only possible to analyse single samples of each flour.

Baking properties of Bere flour

The above flours were used for baking trials performed by RHM Technology. For these, wholemeal or white Bere flours were mixed, respectively, with wholemeal or white wheat flours at inclusion levels of 0, 10, 20, 30, 40 and 50%, using a standard recipe and procedure. The final bread products were analysed for loaf height and volume.

Development of whisky and beer from bere

For the production of whisky, Bere which had been grown in Orkney in 2003 and 2004 was malted by Bairds Malt in Inverness and distilled by Isle of Arran Distillers at their Lochranza site. For the production of beer, Bere was grown in Orkney in 2005, malted by Crisp Malt at Great Ryburgh in Norfolk and used for the development of a beer in 2005 and 2006 by Valhalla Brewery, Unst, Shetland. The diastatic power of Bere malt is reported as ^{o}L and was determined by the standard Institute of Brewing (IOB) methodology.

RESULTS

Identification of recent cultivation practices with Bere

Most farmers had used a seed rate equivalent to about 160 kg ha^{-1}. The most reliable yield data for Bere came from fields grown for Barony Mills between 1998 and 2003 and these showed that yields from a 1.6 ha field in Birsay had varied from 2.8 to 3.8 t ha^{-1} (average 3.1 t ha^{-1}). These yields were achieved with a low level of inputs - in only one year was herbicide used, no fungicide was applied and only low levels of fertiliser were used (N, P and K at 34, 68 and 68 kg ha^{-1}, respectively). Other growers had also used few inputs. None of the growers thought that pests or diseases constrained yields. Most farmers referred to the middle of May as the traditional time for planting Bere and they had usually followed this practice. The most common problems mentioned by farmers in growing the crop were lodging and low yields.

Planting date and seed rate trial

There was a significant ($P<0.001$) main effect of planting date on yield and the average yield for the earlier date across seed rate treatments was 4.33 t ha^{-1} compared with 3.66 t ha-[1] for the later date. Seed rate had no significant effect on yield and the yields of the different treatments are shown in Table 1.

Table 1. Yields of Bere grain (t ha^{-1}at 15% moisture content) with different planting date and seed density treatments and probability levels of the *F* ratio for treatment main effects and interactions from the ANOVA table.

I. Planting date x seed density treatment means

Planting Date	Seed Densities (kg ha^{-1})			Planting Date Averages
	130	160	190	
15 April 2003	4.24	4.35	4.40	4.33
16 May 2003	3.70	3.67	3.60	3.66
Seed Density Averages	3.97	4.01	4.00	

II. Least significant differences (LSD) of treatment means and the probability levels of the F ratio for main treatment effects and interactions

	Planting Date x Seed Density	Planting Date	Seed Density
LSD	0.21*	0.17	0.10
d.f	8	4	16
Probability of the F ratio	0.465	0.018	0.930

* Except for comparing means with the same level of planting date when the LSD is 0.30 (16 d.f.)

Inputs trial 2003

Both fertiliser and inputs had significant ($P< 0.05$ and $P<0.001$, respectively) main effects on yield, but there was no significant interaction. Table 2 shows treatment means for the fertiliser and input treatments. Amongst the fertiliser treatments, all levels caused a small but significant ($P<0.05$) increase in yield compared with the unfertilised control but there were no significant differences between these treatments. Compared with the no-input treatment (I0), there were small but significant increases in yield from both fungicide (P<0.001) and growth regulator (P<0.01). Considering the individual treatment means, the application of fungicide at all levels of fertiliser and growth regulator at fertiliser levels F1, F2 and F3 all gave higher yields than the treatment at the same fertiliser level where neither was applied and differences were significant (P<0.05) at fertiliser levels F1 and F3.

Table 2. Yields of Bere grain (t ha^{-1}at 15% moisture content) with different fertiliser and chemical input treatments and probability levels of the *F* ratio for treatment main effects and interactions from the ANOVA table.

I. Fertiliser x chemical input treatment means

Fertiliser treatment	Chemical inputs			Fertiliser Means
	None	Fungicide	Growth regulator	
F0	4.66	4.94	4.62	4.74
F1	4.65	5.20	5.02	4.95
F2	4.80	5.00	5.10	4.97
F3	4.80	5.11	5.16	5.02
Chemical Input Means	4.73	5.06	4.97	

II. Least significant differences (LSD) of treatment means and probability levels of the F ratio for main treatment effects and interactions

	Fertiliser x Chemical Input	Fertiliser	Input
LSD	0.30*	0.15	0.16
d.f	31	9	23
Probability of the F ratio	0.279	0.012	< 0.001

* Except for comparing means with the same level of fertiliser when the LSD is 0.33 (23 d.f.)

Visually, the most striking aspect of the trial was the lack of lodging in the plots which received a growth regulator and measurements of straw length showed that this treatment significantly (P<0.001) reduced straw length by about 17%.

By about ear emergence, powdery mildew was very conspicuous below the flag leaf in plots which did not receive the fungicide treatment. Measurements of percentage senescence showed that this was least for both the flag leaf and leaf below it in the fungicide treatment.

Analysis of minerals and vitamins in Bere flour

A range of minerals was present in both wholemeal and white Bere flours (Table 3a). Several (calcium, iron, magnesium, phosphorus, potassium and zinc) were present in greater concentrations in wholemeal than in white Bere flour, suggesting that they are located predominantly in the outer layers of the grain. In contrast, concentrations of chloride, copper, manganese, iodine and sulphur were similar in wholemeal and white Bere flours, suggesting that these nutrients are predominantly found in the endosperm. This is unusual amongst cereal grains, as in wheat the majority of minerals are present in the outer layers of the grain, such as the pericarp. Selenium and sodium were not detected in Bere flours.

Table 3a. Mineral content of wholemeal and white flours derived from Bere barley.

	Wholemeal Bere flour	White Bere flour
Magnesium (mg/100g)	110	80
Phosphorus (mg/100g)	410	333
Potassium (mg/100g)	410	320
Chloride (mg/100g)	117	111
Iron (mg/100g)	6.1	5.6
Zinc (mg/100g)	2.4	2.0
Calcium (mg/100g)	40	30
Copper (mg/100g)	0.59	0.55
Sulphur (mg/100g)	120	110
Manganese (mg/100g)	1.3	1.3
Selenium (μg/100g)	Not detected	Not detected
Sodium (mg/100g)	Not detected	Not detected
Iodine (μg/100g)	60	60

Bere flour also contained a range of vitamins (Table 3b). The thiamin, riboflavin, niacin and tryptophan/60, vitamin B6, vitamin B12, pantothenic acid and folate content of wholemeal and white Bere flours were similar. Concentrations of vitamin E and biotin were slightly higher in wholemeal flours. As is the case for other cereal flours, vitamin A (as retinol or β-carotene), vitamin B12, vitamin C and vitamin D were not detected in Bere flours.

Table 3b. Vitamin content of wholemeal and white flours derived from Bere barley.

	Wholemeal Bere flour	White Bere flour
Vitamin A (retinol) (μg/100g)	Not detected	Not detected
Vitamin A (carotene) (μg/100g)	Not detected	Not detected
Thiamin (mg/100g)	0.50	0.52
Riboflavin (mg/100g)	0.06	0.05
Niacin (mg/100g)	0.50	0.52
Tryptophan/60 (mg/100g)	2.5	2.3
Vitamin B_6 (mg/100g)	0.22	0.21
Vitamin B_{12} (μg/100g)	Not detected	Not detected
Total folates (μg/100g)	107	105
Pantothenic acid (mg/100g)	1.0	1.0
Biotin (μg/100g)	1.7	1.4
Vitamin C (mg/100g)	Not detected	Not detected
Vitamin D (μg/100g)	Not detected	Not detected
Vitamin E (mg/100g)	0.51	0.45

Baking properties of Bere flour

Loaf height and volume decreased with increasing level of Bere for wholemeal bread (Figure 2) but for white bread this did not occur until 20% inclusion. With both types of bread, crumb colour became darker as more Bere was added.

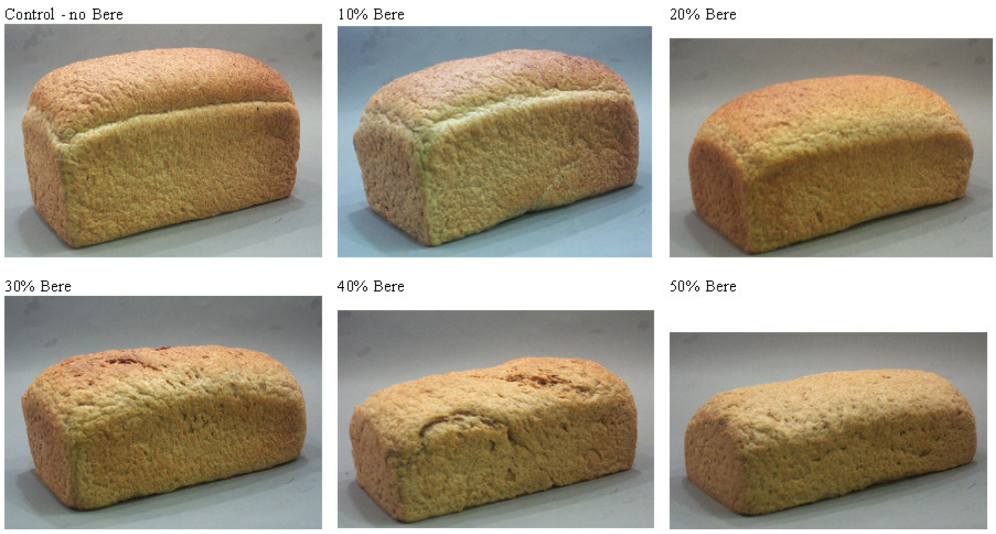

Figure 2. Loaves of bread made with wholemeal wheat flour and different proportions of wholemeal Bere flour.

Development of beer and whisky from bere

Prior to malting Bere grain for whisky production, two grain samples were micromalted by Bairds. These both showed high total nitrogen (1.90-1.95% dm) and low predicted spirit yield (351-354 l t^{-1}). Bairds malted 19 t of Bere grain to produce 16.4 t of malt which was distilled by Isle of Arran Distillers in October 2004. The Lochranza Distillery manager considered the new make spirit to be very different on the nose compared, for example, to the main stream commercial barley variety Optic and "was not so sweet orangy / citrus" (G. Mitchell, personal communication, 2004). The spirit was stored in fresh Bourbon casks (Figure 3) and by May 2007 had taken on "a nice fruity aroma, pears, apples and some citrus flavours. It also has a nice floral appeal along with the vanilla odours from the wood" (G. Mitchell, personal communication, 2007).

Figure 3. New products being developed with Bere in collaboration with the Agronomy Institute. Island Bere (left) is a beer produced by Valhalla Brewery in Shetland while the cask on the right contains Bere spirit produced by Isle of Arran Distillers which is maturing into a single malt whisky which will be sold around 2014 (at about 10 years from distillation).

Before producing Bere malt for beer production, Crisp Malt micromalted a sample of Bere in July 2005 and this also had a high total nitrogen (2.18% dm) which is “higher than normally used for brewing malts” (C. Scott, personal communication, 2005). Crisp Malt’s Technical Director considered the manufactured malt to have “a unique balance of flavours, characterised by malty, sour, sweet, astringent and dry notes” (B. Johnson, personal communication, 2007). A recipe for a Bere beer was developed by Valhalla Brewery by making several test batches of ale which were taken to tasting sessions in both Shetland and Orkney during 2005 and 2006 and modifying the recipe to take into account consumer feedback. The final recipe retained the characteristic bitterness of Bere but did not allow this to dominate the beer. The commercial product, “Island Bere” (Figure 3), was launched in Orkney in May 2006. It has an ABV of 4.2% and is described by the brewery as being “a smoky flavoured ale with a slightly bitter after-taste” (S. Priest, personal communication, 2006).

Apart from the high nitrogen content of Bere malt, another characteristic of it was its high diastatic power (97-107^{o}L in samples micromalted by Bairds and 123^{o}L for malt produced by Crisp Malt).

DISCUSSION

Farmer interviews in 2003 identified lodging and low yields as their two main concerns in growing Bere. They showed that in recent years Bere had been grown in Orkney with low levels of fertiliser and very few inputs and that grain yields were between 2.8 and 3.8 t ha^{-1}. More recent data from on-farm trials with no inputs other than herbicide and N, P and K fertiliser (at a rate of 20, 40 and 40 kg ha^{-1}, respectively) also produced similar yields (2.5 to 3.5 t ha^{-1}). These yields compare with about 6.0 t ha^{-1} for a good modern barley variety grown in Orkney with an application of herbicide and fungicide and with fertiliser at a rate of about 50 kg ha^{-1} for each of N, P and K. As a result of this study, one of the priorities of the Institute's Bere research programme since 2003 has been to identify agronomic practices which increase yield and reduce lodging. The practices which have been investigated include planting date, seed rate and the use of common inputs (fertiliser, fungicide and growth regulator).

Most of the Orkney farmers interviewed indicated that the traditional date for planting Bere was mid-May. In 2003, use of an earlier planting date (late April) resulted in an 18% increase in yield and this was repeated in further trials during 2004 and 2005. Adoption of an earlier planting date, therefore seems to be an important input-free way of increasing the yield of Bere and current recommendations in Orkney are to plant Bere in the last two weeks of April. It is not clear what the benefits of a mid-May planting date would have been in the past, but it might be related to Bere's susceptibility to heavy, late frosts. Previously, these may have been more common than at present and the possible loss of an early planted staple crop may have been an unacceptably high risk for farmers in earlier times.

Different seed rates (between 130 and 190 kg ha^{-1}) were shown not to have a significant effect on yield in 2003 and this was again found to be the case in a second trial in 2004. A standard rate of 160 kg ha^{-1} has therefore been used for planting Bere.

The 2003 inputs trial suggested that Bere does not show a large yield response to mineral fertiliser. This was again seen in a trial in 2005 where the yield of the control treatment (0:0:0) was not significantly different from that of treatments where N, P and K, respectively, were applied at rates of 30, 11 and 16 kg ha^{-1} and 60, 22 and 32 kg ha^{-1}. A fourth treatment, where N, P and K were applied at 90, 33 and 48 kg ha^{-1}, yielded significantly less than the control (3.37 kg ha^{-1} compared with 3.82 kg ha^{-1}). This may have resulted from increased lodging with higher fertiliser levels, an effect which has been seen in more recent trials. The indication at present is that there is no benefit from applying more than about 50 kg ha^{-1} each of N, P and K and where fields are in the first year after ley even lower levels of N are sufficient.

In the 2003 inputs trial, the fungicide and growth regulator treatments resulted, respectively, in a 7% and 5% increase in yield. In more recent trials, comparable treatments have given higher increases in yield - 9% and 11% for growth regulator in 2004 and 2005, respectively and 5% and 11% for fungicide in 2004 and 2005, respectively. From 2004, trials also included an application together of both fungicide and growth regulator and this treatment increased yield by 15% in 2004 and 22% in 2005. In the 2005 trial, planting date was investigated together with fungicide and growth regulator treatments and in this trial yield was raised from 3.4 t ha^{-1} for the traditional mid-May planting without fungicide and growth regulator to 5.1 t ha^{-1} for an April planting with the application of both chemicals together (a 47% increase). These results demonstrate that substantial increases in Bere yields are possible by using a combination of an earlier planting date and the application of fungicide and growth regulator. The benefit of growth regulator is not simply one of increased yield but also easier and quicker harvesting because of less lodging.

Economic analyses of the fertiliser, growth regulator and fungicide treatment data from 2003 to 2006 indicate that with a Bere grain price of £150 t^{-1}, the most profitable treatments have been those where no more than 50 kg ha^{-1} of nitrogen fertiliser has been used and where either a growth regulator or growth regulator and fungicide have been applied.

A number of minerals (particularly iodine, iron, magnesium and phosphorus) were shown to be present in significant quantities in wholemeal and white Bere flours although most are at lower concentrations in white Bere flour. Zinc is present in significant quantities in wholemeal but not white Bere flours. A range of vitamins are present in Bere flours, notably the B vitamins, thiamin, pantothenic acid and folate.

Knowledge of the nutrient profile of Bere flours may be used to incorporate them into food products aimed at having a beneficial impact on the diet of specific target groups in the UK. For example, Bere flour has quite high levels of folate and it is recommended that women of child-bearing age who could become pregnant take a 400µg supplement of folic acid per day, prior to conception and up to the 12^{th} week of pregnancy (Department of Health, 1992). Consumption of Bere products during this period could be one way of supplementing folate intake. There could also be the potential for developing functional foods based on Bere and a Bere-based breakfast cereals is one potential route for new product development.

Although Bere flours are a source of minerals and vitamins, cooking is likely to influence their nutrient profile and the analysis of nutrients within Bere flour products would be necessary before making any health claims.

Baking trials with Bere flours indicated that inclusion of wholemeal Bere flour with wholemeal wheat flour was unlikely to produce a commercially acceptable loaf because of a decrease in loaf volume. Nevertheless, with white flour, up to 20% inclusion seems possible. More recent, but informal, baking trials have shown that very acceptable loaves can be made by mixing up to 25% wholemeal Bere flour with white wheat flour.

Micromalting showed that Bere malt has a high nitrogen content and this results in it producing a lower spirit yield on distillation than modern malting barleys. For example, the predicted spirit yields of 351-354 l t^{-1} for Bere compares with about 410 l t^{-1} for modern varieties. Valhalla Brewery also estimated that, to compensate for Bere's lower alcohol yield, about 15-20% more Bere malt was needed to make Island Bere than would have been required if malt from a modern, low nitrogen variety had been used. For brewing and distilling this is clearly a major disadvantage since it makes Bere products more expensive. This is further aggravated by the higher cost of Bere grain per tonne which is necessary to compensate farmers for the lower yields obtained from the crop. As a result, it is likely that Bere beer and whisky will remain niche market products for which consumers will have to be prepared to pay a premium if they are to remain viable. In return, most consumers will also expect a unique and pleasant taste. Although it is too early to determine whether Bere whisky and beer will be commercial successes, the initial feedback from both Isle of Arran Distillers and Valhalla Brewery indicate that use of Bere malt is producing a unique product which is likely to be very acceptable. It is also significant that other Scottish distilleries have started to use Bere for whisky production. For example, Bruichladdich Distillery in Islay started to use Bere in 2006 and has plans to expand its usage during 2007 and 2008, when about 40 ha will be planted.

The diastatic power (DP) of a malt is the sum of the starch degrading enzyme activity in the malt. The high DP of Bere has been described previously (Hayter and Riggs, 1978) and the values reported in the present study compare with 35-40^{o}L for standard ale malts, 100-125 ^{o}L for lager malts and over 160^{o}L for some high nitrogen 6-row North American malts (O'Rourke, 2002).

Even with the development of new markets for Bere, the small scale niche nature of these markets, makes it unlikely that large areas of the crop will be grown. Nevertheless, there will still be several advantages associated with a small-scale revival of interest in Bere. In particular, new markets will allow this old, heritage crop to continue to be grown on farms in areas where it has been traditionally grown for centuries. For farmers prepared to grow the crop, it will also provide an alternative source of income at a time when many are looking for new diversification options as a result of recent changes to EU farming subsidies. Straw from the crop is also a valuable source of bedding for livestock and with straw yields of about 5 t ha^{-1} (fresh weight) this can add an additional £85 to £200 ha^{-1} to the crop's value, depending on local availability. There are also likely to be environmental benefits associated with an expansion of Bere because Highlands and Islands agriculture is dominated by livestock and an increase in the area of arable crops is considered desirable for biodiversity, particularly if Bere stubble is left to overwinter. New Bere markets not only benefit growers and the companies producing the new products, but the communities where these enterprises are located. This is because of the employment opportunities which are created and because small companies in peripheral areas like the Highlands and Islands tend to use more of their profits within the community, which are often very small. For example, the islands of Unst, Arran and Islay where Valhalla Brewery, Isle of Arran Distillery and Bruichladdich distillery are located had populations of 720, 5,058 and 3,457 respectively in 2001 (Fleming, 2003).

CONCLUSION

Bere is a very old barley landrace which in 2002 was grown on a very small area by just a few farmers in isolated parts of Scotland's Highlands and Islands. The prospects for continued commercial cultivation of the crop were bleak because of its low yield, tendency to lodge and a lack of markets. Agronomy trials at Orkney College have shown that yields can be substantially increased and lodging reduced by using an earlier planting date with a growth regulator and fungicide. Provided end users are prepared to pay about 50% extra for Bere grain compared with modern varieties of barley, these improved yields should make growing the crop commercially viable in Orkney. New markets for the crop have recently been developed with the production of niche whisky and beer products and this has resulted, in 2007, in an expansion of the area planted with the crop in Orkney (15 ha) and Islay (12 ha) and at least 20 ha of Bere are scheduled to be planted in each island in 2008 for whisky production. Further market outlets will be sought for Bere to ensure that it can continue to be grown on farms in parts of the Highlands and Islands.

Acknowledgements

The authors are grateful to Highlands and Islands Enterprise (Research Challenge Fund) and the Leader + and Hi-Links programmes for funding aspects of the research and development described in this paper. We would also like to acknowledge the contribution of the British Nutrition Foundation, ADAS and RHM Technology to the results presented here and would particularly like to thank Barony Mills, Valhalla Brewery, Isle of Arran

Distillers, Bairds Malt, Dunlossit Estates and Bruichladdich Distillery for their collaboration in these projects.

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SUCCESS, FAILURES AND LESSONS LEARNED - NON-FOOD CROPS: CASE STUDIES

29

Biodiversity, conservation and sustainable use of medicinal plants

Alan Hamilton

The use of plants as medicines represents by far the biggest use of biodiversity on a species-by-species basis. There are widespread reports of threats to medicinal plants and much more efforts should be devoted to their conservation, especially at the critical community level. Plantlife is currently working with partners in the Himalayas and East Africa to mount case-studies on community based conservation of medicinal plants, for the identification and then dissemination of best practices. Plantlife welcomes offers of collaboration in this field, so vital both for biological conservation and for human livelihoods (healthcare, income and culture).

MEDICINAL PLANTS – RESOURCES OF THE FUTURE

Plants have provided the principal sources of medicine for the human species since time immemorial, just as they have been the main sources of food. Even today, it is estimated that the majority of people worldwide rely primarily on traditional (largely herbal based) medicine for the greater part of their primary healthcare. They do so for various reasons – belief in their efficacy, availability and cost.

The use of plants as medicines represents by far the biggest use of biodiversity on a species-by-species basis (around 50,000 species; Hamilton, 2004). Many species are used only locally, a reflection of the traditionally close ties that have existed everywhere in the world between people and their local natural worlds.

There are concerns about conservation of medicinal plants, from the perspectives of both biological conservation and livelihoods. Medicinal plants represent a very substantial sub-set of total plant diversity (about 1 in 5 of all plant species). The loss of these plants and knowledge about them would constitute a major disaster, especially given that humanity will need all the resources that it can muster to face the challenges of the turbulent and uncertain years ahead. Apart from concerns about loss of herbal medicine, the extinction of these species will eliminate the opportunity of developing new pharmaceutical drugs based on their properties. Although only a few plants have so far yielded pharmaceutical drugs (around 100 species), the drugs thus available play a tremendous role in the western pharmacopoeia (according to one study in the US, 57% of all prescriptions contain at least one major active compound derived from or patterned after compounds found in biodiversity, mostly plants; Grifo and Rosenthal, 1997). Provided that plant species remain and especially if knowledge of their traditional uses is retained, then it is certain that wonderful new drugs will continue to be derived from them, just as has been the case in the past.

LOCAL MANAGEMENT – THE KEY TO CONSERVATION

The principal challenge in improving the survival chances of medicinal plants is to develop better ways of managing their wild populations, a matter which, of course, has always to be achieved locally. *Ex situ* conservation and cultivation of medicinal plants have their uses for the conservation of medicinal plants, for instance preserving samples of species' germplasm or (in the latter case) providing alternative supplies that can take some of the pressure of over-harvesting off wild populations. However, the focus must primarily be placed on *in situ* conservation. This is not just because this will generally be cheaper than *ex situ* conservation and will better preserve the total genetic diversity of the species. It is also because plants are major components of both global ecosystem and human economies, and conservation cannot be considered to have been adequately achieved if it is thought to be only about storing away samples of the plants in out-of-reach repositories.

Although there is some cultivation of medicinal plants, the great majority of species are harvested for use from the wild. Given the high values that can be placed on these resources – for healthcare, income or cultural purposes – these links between people and wild plants represent potentially powerful platforms for building modern conservation initiatives. The motivating forces are the long-term benefits that will remain available, provided that the plants are not destroyed.

Many factors influence the fate of wild medicinal plants. Commercial over-harvesting and habitat destruction are two principal threats, with climate change a mounting problem. Local conditions of land tenure and resource ownership are fundamental for determining how well these resources are managed. Medicinal plants can be found under a variety of tenurial regimes, for instance growing on private land, communally owned land or land under government charge. In the case of government land (such as national parks and forest reserves), it is widely thought that good management can only be achieved if local communities interested in these resources are involved in their management. This is especially so given the low levels of resources (staff, money) generally available to park and forestry departments in the sorts of places where medicinal plants are harvested, and additionally because it is very difficult to prevent illicit harvesting of these resources if policing is only by officials of the state.

Several 'more distant' factors influence the fate of medicinal plants. These include government policies in a range of domains – including regarding land and resource ownership, community and cultural development, healthcare (including attitudes taken to traditional or herbal medicine), collection, trade and use of medicinal plants, and laws and regulations relating to industries that depend on these plants.

EFFORTS OF PLANTLIFE TO IMPROVE MANAGEMENT OF MEDICINAL PLANTS

Traditionally, medicinal plants gathered for local medical use has often benefited from beliefs and practices that favour their conservation. However, over recent years, such beliefs and practices have tended to decline as traditional societies and cultures have been transformed and economies become more monetarised. The result is that many populations of medicinal plants around the world are not or barely managed. This is an expanding problem, given that medicinal plants are in increasing demand (for the cosmetics and other industries, as well as more specifically medicinal purposes) and that, in some parts of the world (e.g. parts of Africa), herbal medicine is a growing business, as western-style health facilities decline. In 2006, 130 new doctors were trained in Uganda, but 160 doctors emigrated.

Plantlife International is a UK-based non-governmental organisation devoted to plant conservation. In 2005, it launched a new Plant Conservation and Livelihoods Programme, which has since concentrated on medicinal plants. Recognising the key role of local communities in this field, Plantlife has sought local partners in the Himalayas and East Africa (the two target areas of the programme) to trial approaches and methods with rural communities for the conservation of these plants. Projects supported during 2006-2007 are listed in Table 1. Detailed information on the various projects is available on the Plantlife website at: www.plantlife.org.uk/international/plantlife-med-plants.htm

Table 1. Projects supported by Plantlife International on conservation of medicinal plants with various partners in the Himalayas and East Africa during 2006-2007. See Acknowledgements for a list of Plantlife's partners.

Category	Location	Matters addressed
International	India	2-week course on conservation of medicinal plants
		Field testing of standard for sustainable wild harvesting
Himalayas: regional	China	China/India/UK Dialogue: medicinal plant conservation
	Nepal	Identification & conservation of Important Plant Areas for Himalayan medicinal plants (5 countries)
Himalayas: community projects	China	Community organisation for medicinal plant conservation
	India	Ladakh: medicinal plant availability for local healthcare
		Sikkim: assessment of populations of key species
		Uttaranchal: community organisation for conservation
	Nepal	Improved management of commercial wild species
	Pakistan	Sustainable wild harvesting and cultivation promotion
East Africa: community projects	Kenya	Availability of medicinal plants in high demand
	Uganda	Mpigi: community organisation for conservation
		Sango Bay: sustainable use of key malaria trees
		Tooro: home herb kits for primary health care

The field projects are based on proposals submitted to Plantlife, which are screened and subject to peer review. Plantlife is indebted to several international experts on conservation of medicinal plants who have served on a voluntary review panel. The useful suggestions that frequently result from this process are passed on to those who have proposed the projects.

The field projects cover many aspects of medicinal plant conservation, often several in any one case. This diversity reflects the wide range of local conditions under which the projects are mounted and priorities identified by the implementing organisations and local people. Aspects include awareness-raising, resource assessment, the development of community institutions for medicinal plant management and processing, mechanisms for conserving local knowledge and for encouraging its transmission between generations, training, preparation of management plans for wild medicinal plants, promotion of cultivation, and development of improved producer/trader relationships. The project context varies. Conservation concerns can arise in several ways, for example worries about declines in the availability of medicinal plants for local health treatments or for income generation through sale, erosion of local cultures and awareness of the need to conserve genetic diversity. Evidently, conservation of medicinal plants can be a complex business.

Apart from projects directly with local communities, four regional or international projects have been supported, as follows:

- *International training and capacity building on medicinal plants conservation and sustainable utilization*. This was a 2-week course held at Bangalore (India), organised by the Foundation for Revitalisation of Local Health Traditions (FRLHT). It was a significant event in the history of conservation of medicinal plants, in that it was probably the first ever such substantial international course held on this subject. Twenty-four participants attended, including 9 from Africa, 7 from other Asian countries and the remainder from India. Many useful exchanges of experiences and best practices occurred during the course (Fig. 2).

Figure 1. Participants on the FRLHT training course discuss management of wild medicinal plants with members of a community forest management committee.

- *Identification and Conservation of Important Plant Areas for Medicinal Plants in the Himalayas*. Representatives from 5 Himalayan countries (Bhutan, China, India, Nepal, Pakistan) prepared national reports containing lists and descriptions of sites provisionally identified as Important Plant Areas for medicinal plants in the Himalayas. The reports also contain accounts of national policies relating to medicinal plants and experiences in field conservation. A subsequent workshop co-organised with the Ethnobotanical Society of Nepal (ESON) included an evaluation of best conservation practices (see website to download a copy of the report).

- *China/India/UK Dialogue on Conservation of Himalayan Medicinal Plants*. This meeting was a spin-off from the course mentioned above and was co-organised with the Kunming Department of Botany, Chinese Academy of Sciences. Two experts from FRLHT attended, together with 2 staff from Plantlife International and 15 from various organisations in China (especially Yunnan) concerned with medicinal plants (local government, academia, forestry, industry, etc.) (Fig. 3). The Dialogue allowed comparisons to be made between policies and conservation experiences relating to medicinal plants in China and India. The Dialogue itself has had a spin-off, resulting from the introduction of the concept of Medicinal Plant Conservation Areas (MPCAs) into China (originally developed by FRLHT in India). It seems likely that the first MPCAs in China will soon be piloted.

Figure 3. Dialogue meeting in China. Dr Kinhal and Dr Goraya from FRLHT with Dr Li Dezhu, Director of the Kunming Institute of Botany.

- *Field consultation on the International Standard for Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP*. This was a case study in southern India, organised by FRLHT, to test a new an *International Standard for Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP)*, being developed by German Bundesamt für Naturschutz (BfN), WWF Germany and TRAFFIC, IUCN Canada and the IUCN Medicinal Plant Specialist Group.

LESSONS ON BEST PRACTICE

Approaches and methods used for conservation of medicinal plants will always be site-specific to an extent. At the same time, critical analyses, especially drawing on several case studies, can be valuable for identifying approaches and methods that have more general applicability. The following documents, prepared under the programme and posted on Plantlife's website, contain such critical analyses:

- *Identification and Conservation of Important Plant Areas for Medicinal Plants in the Himalaya*, co-written by Alan Hamilton and Elizabeth Radford of Plantlife.
- *Conservation and Sustainable Use of Medicinal Plants: Approach and Experience of the Foundation for Revitalisation of Local Health Traditions (FRLHT).* This document was prepared following the international course on conservation of medicinal plants organised with FRLHT. The report contains concise accounts of FRLHT's approaches and methods, developed over 13 years engagement in conservation of medicinal plants in southern India. This experience is unparalleled worldwide. The document has been checked with FRLHT for accuracy.
- *China/India/UK Dialogue on Conservation of Himalayan Medicinal Plants*. This report is a product of the Dialogue meeting described earlier. Because highly knowledgeable people from China and India were present at the meeting, the Dialogue represented an outstanding opportunity to compare policies and conservation experiences regarding medicinal plants in these two vast countries. The report includes an account of the Allachy-supported project on conservation of medicinal plants at Ludian, China, explicitly noting the potential value of this site for Medicinal Plants Conservation Areas, as have been developed in India. The report has proved a point of reference for taking this idea forward in China.

CONCLUSION

Conservation of medicinal plants represents a massive challenge, with much more effort needed in many places. Efforts made to conserve medicinal plants may not only benefit these plants themselves, but also biodiversity more generally. This is because of the high value that can be placed on medicinal plants by communities. Improved management of habitats for medicinal plants can benefit many more species.

There is a need for much more effort in conservation of medicinal plants. Accordingly, Plantlife urges organisations to increase their efforts in this field, especially at the critical community level. For its part, Plantlife is developing new regional programmes on community-based conservation of medicinal plants in the Himalayas and East Africa. We welcome enquiries about our work and offers of collaboration.

Acknowledgements
Plantlife acknowledges with profound gratitude grants made available for the support of this work from the Allachy Fund for Livelihoods from Wild Plants and from the Rufford-Maurice-Laing Foundation. Plantlife also acknowledges the work of its various partners in the Himalayas and East Africa, who share our concern for the future of these resources. Organisations in the Himalayas and East Africa which have worked with Plantlife on medicinal plant conservation during 2006-2007 include (among others),

Applied Environmental Research Foundation (AERF), Ashoka Trust for Research into Ecology and the Environment (ATREE), Ethnobotanical Society of Nepal (ESON), Foundation for Revitalisation of Local Health Traditions (FRLHT), Government Postgraduate Jahanzeb College (Pakistan), Joint Ethnobotanical Research and Advocacy (JERA), Kunming Institute of Botany (Chinese Academy of Sciences), Ladakh Society for Traditional Medicines (LSTM), Ministry of Agriculture (Bhutan), National Museums of Kenya (NMK), NOMAD RSI, Pragya (India), Tooro Botanical Gardens, Uganda Group of the African Network of Ethnobiology (UGANEB), WWF-Pakistan, and Yangzhou University (China).

The following members of the Advisory Group for the Medicinal Plants Conservation Initiative have provided expert opinion that has helped steer the work: Ashiq Ahmad (WWF-Pakistan), Dr Wolfgang Kathe, Dr Sonia Lagos Witte (Grupo Etnobotánico Latinoamericana), Dr Danna Leaman (Chair, Medicinal Plants Specialist Group, IUCN), Patrick Maundu (Kenya Resource Centre for Indigenous Knowledge, National Museums of Kenya), Professor Pei Shengji (Kunming Institute of Botany, Chinese Academy of Sciences, Dr Susanne Schmitt (WWF-UK) and Darshan Shankar (Foundation for Revitalisation of Local Health Traditions, FRLHT, India).

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Establishing of *Agave Americana* industry in South Africa

A. Boguslavsky, F. Barkhuysen, E. Timme, and R.N. Matsane

South Africa has high levels of unemployment and low standards of living in rural areas. The Eastern Cape Province is particularly impoverished, with unemployment of about 60 % in the Great Karoo region alone. *Agave americana* (AA), the only plant of value in the arid Karoo is currently used for the production of an alcoholic beverage, with the bulk of the plant being not utilised. Research was carried out with a view to the greater utilization of the plant. The research demonstrated the commercial potential of the AA plant for the production of fructans, fibre, textiles and paper products. A long term programme on AA plant utilization was therefore launched by a consortium including national and provincial governmental departments, local authorities, funding agencies, industrial partners and research organisations. A comprehensive concept for establishing AA agro-processing complexes in the Great Karoo was developed and is reported here.

INTRODUCTION

South Africa has high levels of unemployment and low standards of living in rural areas. The Eastern Cape Province is particularly impoverished, with unemployment of 60 % in the Great Karoo alone. Land claims by emerging farmers are currently in progress, but the 5000-hectare farms to be allocated will not be sufficient for economic independence without some crop cultivation. The climate and soil of the Great Karoo are not favourable, however, for the cultivation of commercial crops. The only plant of value which grows in the arid Karoo and that can also grow on eroded soil is *Agave* a*mericana* (AA). This plant is currently used for the production of an alcoholic beverage by fermentation of the heart (pina) of the plant, chiefly for export purposes. The current production of the alcoholic beverage does not meet the demand, resulting in the expansion of AA cultivation in the Great Karoo. Nevetheless, the viability of this industry alone is not high enough since the bulk of the plant is not utilised. The pina waste left after juice extraction is used as compost, and 95% of the leaf waste is left to decompose on the fields.

The genus Agave, comprising around 140 species, occurs, and is cultivated, in arid and semi-arid regions world-wide. This family includes leaf fibre plants, such as *Agave americana, Agave sisalana and Agave tequilana* (AT). Agave plants are native to Mexico and other parts of the Caribbean region. This plant was taken from there to Europe, Africa and the Far East by the Spaniards and Portuguese, where it naturalised rapidly, especially in the highly arid regions around the shores of the Mediterranean (Lewin *et al.,* 1985). The best known, and most common application of AT is the production of tequila, an alcoholic beverage, from the sap of the pinas. However, recently research programmes were launched in Mexico and other countries to evaluate the potential of Agave for other applications. According to the Mexican company 'Nekulti', 25% of *Agave's* fresh weight is inulin, a valuable component widely used in the food industry as an additive, sugar substitute and prebiotic agent (NUTRA, 2005, website).

Inulin is a generic term for a polydisperse chain of fructose units having degrees of polymerisation (DP) varying from 2-60, normally with an average of ~12. Fructans are oligo- or polysaccharides which comprise at least two adjacent fructose monomers. They have value in the health and food arenas, and occur in nature in a polydisperse form. The DP has a bearing on the functional behaviour of these fructans and determines their end use. Molecules with a DP of 2-7 are known as oligofructose, whilst the larger molecules are known as inulin.

Fructans function as prebiotics due to the inability of the human gut to digest their specific linkage type, thus making them available in the colon where health benefits arise due to the stimulation of bacteria, such as bifidobacteria, with concomitant production of short chain fatty acids which enhance gastrointestinal functions (Roberfroid *et al.,* 1998; Manning and Gibson, 2004). Fructans have also been shown to modulate endocrine and immune functions (Silva *et al.,* 2004), promote absorption of calcium and magnesium, reduce cholesterol and stimulate vitamin synthesis (Roberfroid 2005). Long chain or 'gamma' inulin has been successfully tested as a vaccine adjuvant (Cooper, 1995; Petrovsky, 2005) due to the ability to stimulate the 'alternative complement pathway', and has been used in the preparation of 'microspheres' for the controlled release of drugs (Wu and Lee, 2000; Poulain *et al.,* 2003), In the food industry, fructans find use as fat substitutes due to their functional properties, as additives to control viscosity and moisture (Silva, 1996) and as low calorie sweeteners (López-Molina *et al.,* 2005; Roberfroid, 2005).

In October 2005, Nekulti announced the development of a gentle enzymatic process for the recovery of inulin from the Mexican *Agave* plant. It was found that inulin from *Agave* is more soluble in cold water than inulin derived from chicory, indicating that it can find a much broader range of applications as a food additive. Inulin from *Agave* has the added benefit of being cheaper than that from chicory. The large scale commercial production of inulin from AT was launched in February 2006, with an initial capacity to produce 150 tons of pure, dried inulin a month. Within two years, the capacity may increase to yield as much as 5000 tons per year. Such large scale production will target the worldwide demand for inulin, the main focus being on Europe and Japan.

Utilisation of leaves for fibre production is another focus area of the AA programme. The AA leaves contain numerous fibres running along their length and these support the cellular tissue and constitute the vascular system of the leaf. Fibres can be extracted mechanically, chemically or by retting in seawater. Recently, a research program, aimed at the evaluation of the potential of AA as a new source of textile fibres, was launched in Tunisia where AA fibres were, for a long time, extracted and used for ropes and twines (Msahli *et al.,* 2005).

The above information attracted interest from local researchers, farmers, industrial companies and potential investors. The rapidly growing world market for fructans and plant fibres is considered by all the local main stakeholders as warranting the expansion of AA cultivation in the Great Karoo. An AA Steering Committee was formed for establishing an AA industry in the Great Karoo including government departments, local authorities, industrial partners, R&D organisations and other stakeholders.

For this ambitious programme to succeed, strong science and technology support is required in a number of disciplines, including biochemistry, textile technology and paper making. However, little knowledge is available of the agronomy of the AA plant, the influence of environmental parameters on fructan and fibre properties, and optimal conditions for the extraction and processing of these products. The present study focused on fructans and fibres extracted from the AA plants growing in the Great Karoo region in South Africa. The outcomes of this research formed a basis for developing a concept for establishing an AA industry in the Great Karoo.

MATERIALS AND METHODS

Fibre and textiles

Fibre extraction

Agave Americana leaves were randomly harvested in the Graaff-Reinet area and supplied to CSIR for evaluation. The leaves were decorticated on a one door decorticator manufactured according to the design principle of a Brazilian separating machine. This machine, with a manual feeding system, is a very versatile piece of equipment which can be mounted on a stationary or transportable carriage system which permits easy transportation to different growing areas. This unit was designed for fibre extraction from sisal leaves which are much shorter, narrower and thinner than AA leaves. A disadvantage of this machine is that it becomes blocked by fibres when processing AA leaves.

The design of the sisal decorticator was therefore modified to make it more suitable for the processing of AA leaves. Steel side plates were attached to the rotor to prevent the blockage of the machine. The feeding tray and beater bars were modified to accommodate the side plates of the enlarged rotor. For added operator safety, a “tunnel” guard was also added the feeding tray through which the leaves are fed. The size of this was such that the Agave leaf could fit into it but without any space for the hands of the operator. Provisions were also made to vary the rotor speed between 900 revs/min and 1270 revs/min. The modified one-door decorticator is shown in Figure 1.

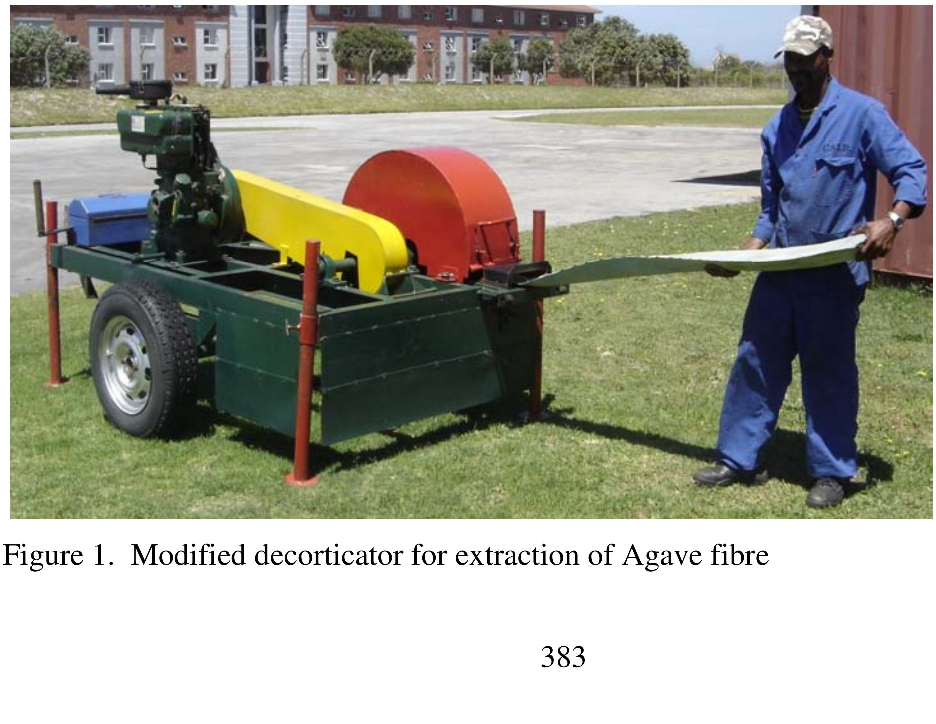

Figure 1. Modified decorticator for extraction of Agave fibre

Fibre yield determination

Freshly harvested leaves were weighed and processed on the decorticator. Extracted fibres were collected, dried and conditioned at a relative humidity of 65 ± 2% and a temperature of 20 ± 2ºC for a minimum of 48 hours. The fibre yield was defined as a weight of conditioned fibre expressed as a percentage of the leaf weight before processing.

Fibre testing

Extracted fibre was air dried and processed in a fibre opening machine. The opened fibres were conditioned at a relative humidity of 65 ± 2% and a temperature 20 ± 2ºC for a minimum of 72 hours. The extracted fibres were tested for mechanical properties (linear density, breaking tenacity and elongation at breaking load). The sample preparation for measuring the breaking tenacity, elongation at breaking load and fibre fineness was done according to the ISO 3060 test method. To determine fibre strength, a bundle tensile test was carried out on an Instron Tensile Tester (Model 4411) at 0 mm gauge length, using Pressley clamps with leather facing. Ten bundles were tested per sample, with bundles being carefully assembled to ensure continuous and parallel fibres in the test area. The gravimetric method (i.e. linear density method) was used for fibre fineness evaluation. This method involves the selection of small representative samples and the preparation of bundles of 10 or more fibres, with a length of 100 mm. The bundles were weighed and the average fibre linear density was calculated.

The fibre cross-sectional characteristics were determined by means of an Olympus CX31 image analyzer, using transmitted light. A thin cross-section of a bundle of fibres, embedded in methyl methacrylate resin, was cut with a microtome and a photomicrograph was obtained by means of a light microscope using 100 and 400x magnification. The images were then digitised using a digital image processing system.

Producing Agave fibre based nonwoven fabrics

The opened AA fibres were processed on a Temafa cottonising line, which included a Lomy machine and a Fine Opener (Linstar). The following variables were incorporated in these trials:

i) One passage through the Lomy
ii) Two passages through the Lomy
iii) One passage through the Lomy followed by one passage through the Fine Opener.

A Dilo needle loom (maximum working width 600mm, maximum stroke frequency 1200 str/min, needle density 6000 needles/m) was used for producing the AA fibre based needle-punched nonwoven fabrics. The following conditions were used for the trials:

Feeding speed	0.7 m/min
Infeed apron speed	1.20 m/min
Infeed roller speed	1.25 m/min
Stroke frequency	180 and 220 str/min
Punching density	160 punches/cm^2
Depth of needling	-2, 2 and 5 mm
Needle density	6000/m

A supporting lightweight spunbonded polypropylene material was used for the manufacture of nonwovens.

Fructans

Preparation and extraction of fructan material

Leaf Sap: Pressed saps were used as such after removal of insoluble matter by filtration or centrifugation at 8000 g and 20°C for 20 min. On average, 300 ml sap were obtained per kg leaf material.

Leaf pulp: A 1:2 ratio of pulp:deionised water (w/w) was heated to 80°C, held at that temperature, while stirring, for 25 min, and allowed to cool at ambient temperature (~20°C) until the temperature dropped to 30°C. The soluble portion was then separated, with an initial removal of long fibres by filtration through fine muslin.

Leaf base and pina: The epidermis was removed from leaf base tissue. The leaf parenchyma or pina tissue was diced into blocks of 2-3 mm^3. This material (50 g) was homogenised with 100 ml of deionised water, using 20 second cycles, and continuing until a homogeneous mixture was obtained. Homogenates were preheated in an oven at 60±2°C for 30-90 minutes before extraction of each individual sample at 75±5°C for 20 min with constant agitation. After cooling, soluble matter was separated by centrifugation and filtration. A composite sample, comprising aliquots of 16 leaf base extractions, was purified by anion exchange chromatography and used for the profile confirmation.

Analyses

Analysis of sugar content: The standard phenol sulphuric assay (Harris *et al.,* 1995) was used for the analysis of the sugars for yield estimation and for monitoring during the extraction processes. Standard curves, using both fructose and inulin, were prepared for reference. Although the response factor of the inulin polymer (chicory) was different from that of the fructose monomer, all quantitation was based on the monomer standard curve as the relative DP's of the standards and samples were not known. To show the polymer /monomer profile, HPLC analysis was carried out, as described elsewhere (Zuleta and Sambucetti, 2001).

Measurement of protein content and ultraviolet (UV) absorbing contaminants: The presence of protein was monitored by UV absorbance at 280 nm using bovine serum albumin as standard and assuming an equivalent absorption co-efficient. A scan of the samples from 190 to 400 nm was used as an indicator for removal of UV absorbing substances.

Measurement of colour components: A visible light scan (340 to 500 nm) was conducted to determine the wavelength at which the highest absorption occurred. This wavelength was then used to monitor colour intensity.

Fructan purification

Adsorption on activated charcoal: Activated charcoal was used for removal of contaminants, by modifying the method by Nair according to Kim *et al.,* (2002). Activated charcoal was added to the material to a level of 3% (w/w) and hand stirred for 2 min. The mixture was then filtered using Whatman No. 542 paper. The filtrate was analysed for sugar, protein and colour concentrations, and results compared with those obtained prior the treatment.

DEAE Sephadex A-25 or DEAE cellulose anion exchanger: The exchange resin was poured into a column, after being prepared according to the manufacturer's instructions. The sample was then passed through the column and collected for analyses. In each case, the amount of fructan or protein added to the resin matrix was compared to the total fructan or protein recovered from the process, and a recovery yield calculated. The colour yield was based on absorption units.

Separation of high and low molecular mass portions: Ultrafiltration (UF) was used for separating polymeric inulin molecules from free fructose molecules, as the functional properties and end use of fructans depend on their DP. Generally, the lowest desired DP for inulin is around 10, which correspond to a molecule of molecular weight (MW) ~ 2000, whilst free fructose has a MW of 180, and oligofructans, with a DP of 2 to 7 lie in between. The membrane used should therefore be able to retain anything of molecular weight $\geq$ 2000, while those of lesser MW should pass through. A Millipore Stirred Ultra-filtration Cell (Model XFUF 076 01) was used with different membranes for preliminary UF screening, in order to determine which worked best. After UF, the sample was passed through a SEC column to determine the effectiveness of the UF process.

Fructan profile

The composition of the polymeric material of the AA saccharides was determined by HPAEC-PAD after mild hydrolysis in 0.5 M TFA at 60 ˚C for 1 hr. Identification of the constituent monosaccharides was based on a comparison of retention times with the use of the standards. Molecular Mass Distribution by Size Exclusion Chromatography (Churms, 1996) was used to determine molecule size. Sephacryl S100HR, with a fractionation range of 100 000 to 1000 Daltons, was used to estimate average molecular size of the extracts and BioGel P2 , with a fractionation range of 1800 to 100 daltons, was used to separate free sugars and oligofructans from the polymers of 10 or more units.

Agave fibre based paper

Different types of Agave fibre, namely those produced by extraction by the decorticator and those processed by means of a fine opener, were used for a comparative paper making investigation. A beater of 150 litre capacity was filled with clean tap water and 2 kg of Agave fibres were placed in the beater for the pulping process which lasted between 3 to 12 hours. 50 litres of pulp were diluted with 100 litres of water in a vat. A retention aid and gelatine were added to the vat and the mixture was cooked while stirring occasionally. The retention aid bonds the fibres, while the gelatine helps to make the paper smoother, easy to press and to write on.

The tensile strength of the Agave fibre based paper samples was measured on an Instron Tensile Tester (Model 4411) according to the Paper Tensile Test – SI Units specification contained in the Instron's Test methods list. The maximum load to tear a sample was measured and calculated per unit width and for the particular thickness of each sample.

RESULTS AND DISCUSSION

Fibre extraction

The modified decorticator was used for extensive trials in processing leaves of different sizes, age and from various localities. The machine performed satisfactorily, without any blockage problems. It was found that AA fibre was easily extractable from the leaves. For optimizing the extraction process, leaves were processed at rotor speeds of 900 revs/min, 1150 revs/min and 1270 revs/min. It was found that the rotor speed did not affect the breaking tenacity. Increasing the rotor speed to 1270 revs/min, however, yielded coarser fibres. The results obtained indicated that a rotor speed of 900 revs/min was the most suitable for processing the leaves.

Fibre yield varied from 1.7% to 2.7% for different samples, with an average yield of 2.0% for the rotor speed of 900 revs/min.

Fibre properties and structure

The properties of the AA fibres are given in Table 1. It can be seen that the locality of the farm and site on the farm have considerable impact on fibre yield and strength. The fibre fineness, on average, was not affected in the same way by the location of the plants. No correlation was found between fibre properties and the age of the plants at the different localities. Fibres from the Samara Nature Reserve had the best overall properties.

Image analysis provides valuable information about the shape and fine structure of fibres which could assist in identifying those factors having an impact on fibre extractability. Figure 2 shows the cross-sectional images of the fibres differing in fineness. It appears that AA fibres have a non- circular cross-section similar to other coarse plant fibres, such as flax and hemp. The fine structure of the fibres is not as distinct as that of flax fibres, although it can be seen that these fibres occur in bundles comprising several ultimate (individual) fibres. The average perimeter and cross-sectional area of the fibres are 621 μ and 20518 μ^2, respectively.

Table 1. Properties of Agave fibre

No.	*Farm location*	*Place*	*Plant age (years)*	*Yield (%)*	*Bundle tenacity (cN/tex)*	*CV (%)*	**Linear density (tex)**
1	**BLOEMHOF FARM**	Ostrich Camp	10	1.8	19.7	12.0	27.6
2		Ostrich Camp	10	1.7	20.9	10	25.1
3		Ostrich Camp	12	2.5	21.7	12.3	21.2
4		Bloemhof North West Red Gate	12	1.9	15.0	20.8	28.0
5		Bloemhof North West Red Gate	15	2.3	24.0	16.7	31.7
		Average	-	2.0	20.3	14.4	26.7
6	**OODEBLOEM FARM**	Houseland plantation	5	2.1	23.4	16.6	27.8
7		Siding camp	11	1.7	21.5	11.5	27.7
8		Vlaklands plantations	11	1.7	21.1	12.0	32.5
		Average	-	1.8	22.0	13.4	29.3
9	**SAMARA NATURE RESERVE**	Old lands	10	1.6	24.7	17.9	25.0
10		Klipfontein House plantation	10	1.9	25.6	16.6	30.6
11		Klipfontein House plantation	10	2.7	24.7	5.8	28.0
12		Paardekraal plantation	11	2.3	28.0	9.4	20.3
13		Paardekraal plantation	11	2.2	26.8	19.4	22.1
14		Lande plantation	10	1.8	22.4	16.2	33.3
		Average	-	2.2	25.5	13.5	26.9

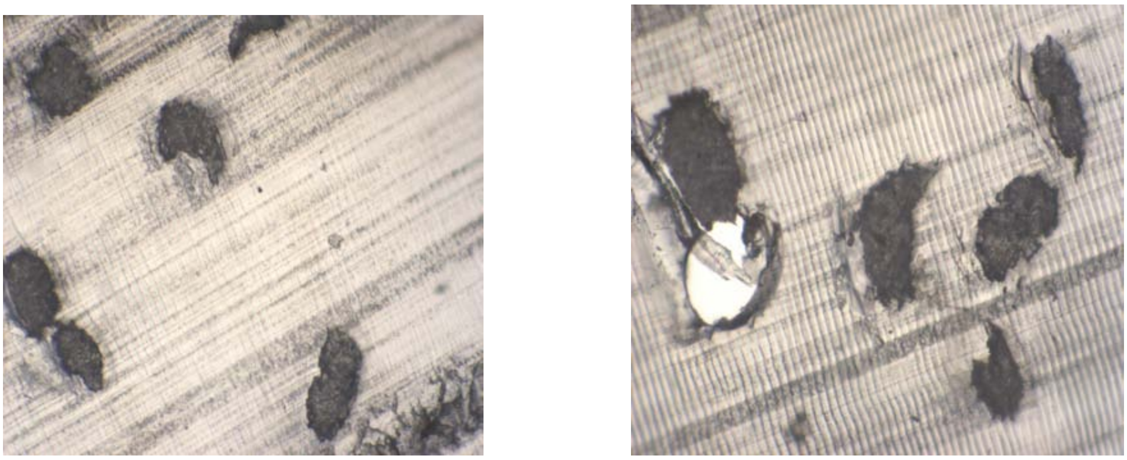

Figure 2. Cross-sectional images of Agave Americana fibres

Nonwoven and paper products

Two potential applications for Agave fibre based nonwoven materials were considered, namely geo-textiles and composite materials for the automotive industry. Kaymac and Brits Textiles, the leading manufacturers of such materials in South Africa, specified the required composition and optimum parameters of the materials. To improve the formation of a web for geo-textile nonwovens, the fibres were blended with polypropylene (PP) fibres in a ratio of 80: 20 (AA : PP) (percentage by mass). A blend ratio of 50 : 50 (AA : PP) (percentage by mass) was used for producing nonwovens for composite materials. The blend composition and processing parameters are given in Table 2.

Table 2. Fibre composition and processing parameters for nonwoven samples

Sample number	*Fibre composition*	*Potential application*	**Processing parameters**		
			Number of web layers	Depth of needling (mm)	Stroke frequency (str/min)
N1	80 Agave/20 PP	Geotextiles	12	-2	180
N2	80 Agave/20 PP	Geotextiles	12	2	180
N3	80 Agave/20 PP	Geotextiles	12	5	180
N4	80 Agave/20 PP	Geotextiles	16	-2	180
N5	80 Agave/20 PP	Geotextiles	16	2	180
N6	80 Agave/50 PP	Geotextiles	16	5	220
N7	50 Agave/50 PP	Composites	20	5	220
N8	50 Agave/50 PP	Composites	28	5	220
N9	50 Agave/50 PP	Composites	2 x 20 sandwich	5	180
N10	50 Agave/50 PP	Composites	56	-2	180

Satisfactory results were obtained when processing AA fibre into nonwovens using blends with PP. The samples of the AA fibre based nonwoven materials were tested at industrial laboratories and positive feedback was obtained on the potential utilising the proposed blends for composite materials and geo-textiles.

The potential of utilizing the AA fibre for paper making was investigated under conditions simulating small scale paper making. Fibre based paper samples were produced from the following three different types of material, in some cases in blends with either flax or bagasse or both:

i) Decorticated fibres
ii) Waste produced on the fine opener (short fibres)
iii) Pina waste generated during tequila production

The properties of the paper samples produced are given in Table 3. It can be seen that the paper strength depends on the beating time and composition of the pulp. Utilizing fibres after extraction on the decorticator requires a longer pulping time in order to achieve the desirable paper quality. The addition of binding materials, such as retention aid and gelatine, and increasing the beating time to 12 hours, ensure maximum strength of paper and uniformity of paper sheets (sample No 2). The AA fibre can also be used in combination with other fibres, such as flax, for producing paper materials. The AA waste fibres are much finer than the decorticated fibres which enables stronger paper to be produced at a reduced beating time. Preliminary experiments on pina waste gave promising results, indicating that it can be used as a raw material for paper making (sample 7). More detailed research is required to evaluate its commercial potential and to make specific technological recommendations.

Table 3. Properties of Agave based paper samples.

No.	*Fibre composition*	*Beating time (hrs)*	*Pigments*	*Thickness (mm)*	*Area weight (g/sq.m)*	**Breaking Load per unit width (N/mm)**
1	Agave 100%	12	Green	2.5	125	0.80
2	Agave 100%	12	no	2.3	139	3.20
3	Agave 100%	8	no	3.8	169	0.97
4	Agave 50% Flax 50%	12	no	3.3	155	1.07
5	Agave 50% Bogasse 50%	12	Green	3.5	161	1.24
6	Agave 40% Flax 30% Bogasse 30%	12	no	3.8	178	0.90
7	Waste 100%	3	no	1.9	137	4.39

Fructans

Extracts showed a wide range of fructan content and varying proportions of polymer to low DP, depending on source and treatment. Composition analysis showed that only fructose and glucose were present. The yield of fructans from the pulp and sap was lower than the yield from pina and leaf base (Table 4), probably due to an inability to separate and dissolve all the soluble material during the decortication or pressing processes. Re-extraction of treated material released a further 2-3 g fructan/100g material, whilst preheating the raw leaf parenchyma to 60°C for 60 min resulted in increased yields. These results suggest the need to ensure maximum solubilisation of fructan in the raw material, and efficient separation from the fibrous constituent of the raw material if viable commercial production is to be achieved.

Table 4. Average Content and Yield of Fructans from AA

Material type	Sugar Content (as fructose) g/100 ml sap or g/100 g solids	Yield fructans g/100 g whole material*
Sap (n=14)	7.4 (Range 2.3 - 24.7)	2.2
Pulp (n=3)	4.7 (Range 2.5 – 8.9)	Not recorded
Leaf base (n=16)	14.4 (Range 5.1 – 24.3)	13.0
Pina (n=4)	22.4 (Range 19.2 – 24.3)	22.4

* 300 ml sap per kg leaf material, 100 g epidermis/kg whole leaf material

The pulping and sap production procedures resulted in more extraneous soluble material being extracted, specifically coloured products and ultra violet absorbing compounds. These contaminants could be removed by use of activated charcoal or ion-exchange, the latter being more effective in removing protein and/or ultraviolet absorbing material. Reduction to around 20% of the starting levels was obtained by a single batch ion-exchange treatment, but evidence of post harvest changes with rapid darkening of the sap, probably due to phenol oxidase activity and the Maillard reaction was noted. Sugar, recovered after the clean up process, of the leaf base extract, was 60%. Positive changes, with respect to removal of contaminants and minimum reduction of fructans, occurred after treatment through the first column, with UV material and colour being reduced to 11 and 20%, respectively, of the original material.

The fructan extracts show molecules of lower DP than chicory (Figures 3 and 4), with the pina material having larger molecules than the leaf extract. The average DP, determined by comparison with standard dextrans, is estimated to be around 16. Literature comparisons show that commercial Agave inulin (Nekutlin™) produced by 'The Colibree Company' has a product profile with 30.4% having a DP lower than 10, 41% with a DP between 10 and 20, and 28.6% with a DP greater than 20.

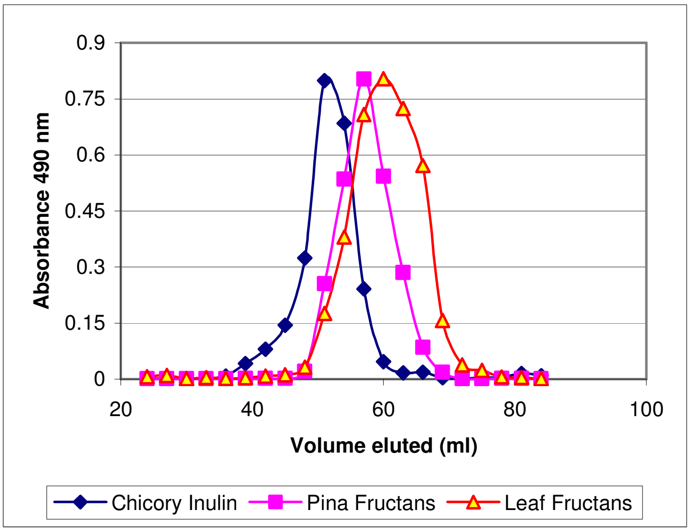

Figure 3. Comparison of molecule sizes using Sephacryl S100HR

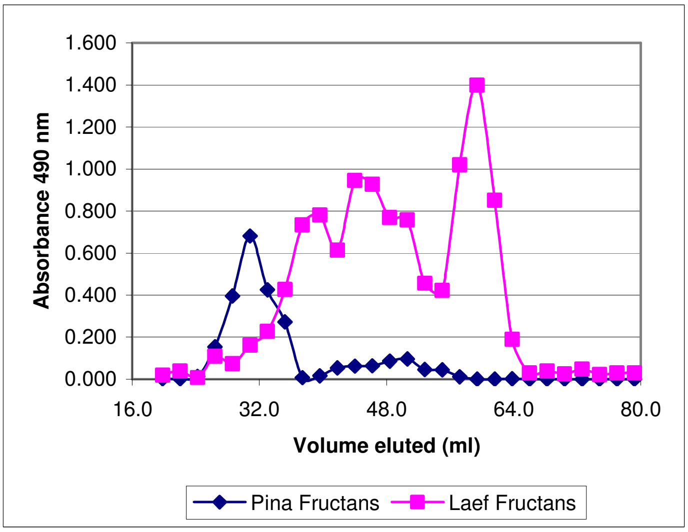

Figure 4. Comparison of molecular sizes of pina and leaf fructans using Biogel P2

The membranes used for UF were not effective in fractionating the compounds as shown in Figure 5. Both the low and high MW fructans were still present in the UF retentate as compared to the AIR (alchohol insoluble residue) precipitate (used to separate polymers from monomers). Further fractionation trials, to separate monomers or very short chains from the inulin, are required, that will result in two products, namely, fructose syrups and inulin

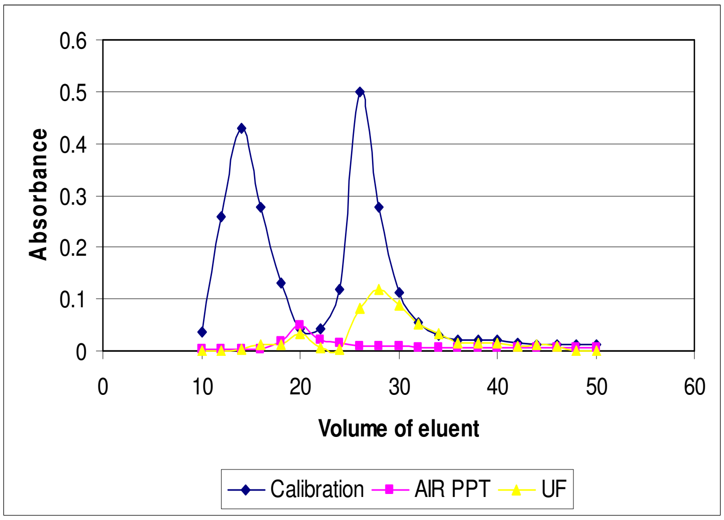

Figure 5. Comparison of molecular sizes of UF and AIR sap passed through Sephadex G-25 SEC column

Commercial fructans for incorporation into other products are required to be colourless and free from associated compounds. Costs to achieve cleaned 'pressed or pulped' leaves would need to be balanced against product value.

As the pina or leaf base appears to be the preferred material, a process design to produce maximum yield is being based on this source. Of note is that the insoluble portion left after extraction would constitute a dietary fibre with good water binding capacity and residual fructan; and could, after relevant assay to meet specification requirements, be presented as an extra product or could be channelled into the paper fibre extraction process, thus negating the need for disposal.

Agave plant utilisation

This research has demonstrated that all parts of the AA plant, namely, pina, leaf base and leaves, can be utilised in various applications. The potential market for AA plant products is presented in Figure 6.

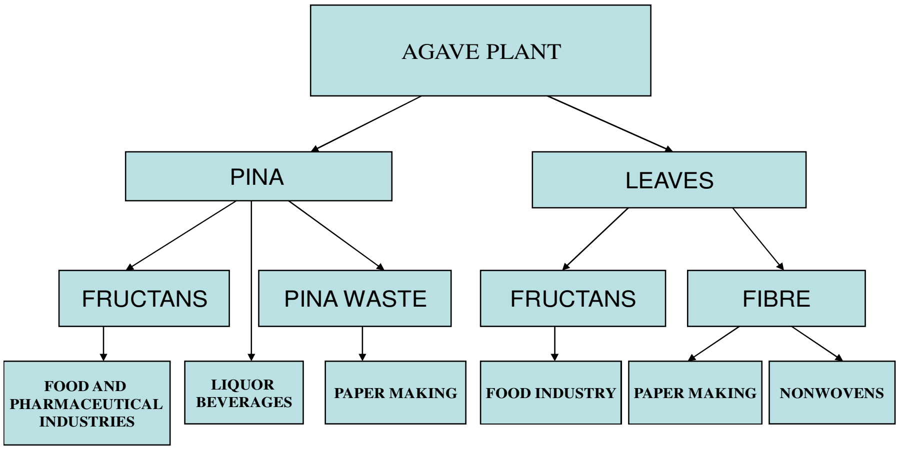

Figure 6. Potential market for AA plant products.

The "zero-waste" utilization of the plant would enable its production and processing to be translated into a viable and sustainable industry. The results of this research formed a basis for developing a general concept for commercialising the Agave plant in the rural areas of the Great Karoo. The concept envisages the following phases for establishing an AA industry in this region:

a) Phase 1. Establishing a pilot AA agro-processing complex in Graaff-Reinet . This first complex will comprise a large scale fibre extraction business, agricultural and paper making SMEs in Graaff-Reinet. The main objective of an agricultural SME will be planting and cultivating AA to ensure a sustainable supply of raw materials for processing SMEs to produce liquor beverage, inulin, fructans and fibre. The complex will supply AA fibre for small scale paper making businesses to produce paper goods, in particular souvenirs, for outlets in Graaff-Reinet and towns in the Great Karoo. The incubation of technologies and optimization of business operations will take place during this phase. A training centre will be established at the complex to train community members involved in Agave projects in other areas of the Great Karoo. Scheduled completion – end of the first year.

b) Phase 2. Establishing AA agro-processing complexes in the Great Karoo. If successful, the pilot project in Graaff-Reinet will be used as a basis for replicating similar AA complexes in other regions of the Great Karoo. Three areas have been identified for establishing such projects, namely, Aberdeen, Pearston and Jansenville. The infrastructure, facilities and expertise gained from the project in Graaff-Reinet will be used for training of staff members and consultancy services for the established SMEs.

During this phase, the CSIR will transfer technologies developed for the recovery of fructans from pina and leaves to the agro-processing complex in Graaff-Reinet. The AA leaves will be used both for the fibre and sap production, the latter to be utilised for the extraction of fructans. The complex will provide its facilities for the piloting and further commercialising of these technologies to ensure maximum value addition and no-waste utilization of the Agave plant. If successful, a fructan production SME will be established as a part of the agro-processing complex in Graaff-Reinet. Scheduled completion – end of the second year.

c) Phase 3. Expansion of the scale of AA complexes in the Great Karoo. During the third phase, the agro-processing complexes established in the abovementioned locations in the Great Karoo will expand their business operation into production of fructans from AA pinas and leaves. The CSIR will provide support for the technology transfer to SMEs producing fructans. Scheduled completion – end of the third year.

The above commercialisation model assumes that land owned by the state (Camdeboo Municipality) will be allocated to the AA project. The proposed commercialisation model includes establishing a Workers Trust which is governed by a Trust Deed. Benefits are channelled to the community and liability is limited to the extent of the assets. This option is attractive to private sector investment partnership because it is easy to form and there is potential for tax exemption.

The Trust will control the business activity of an AA agro-processing complex. The complex will comprise four sections, namely, AA plant cultivation, AA fibre extraction, a paper making and entrepreneurs sub-contracted for manufacturing AA based paper products. The Trust will appoint a manager for the complex who will be responsible for co-ordination of SME activities, marketing and sales. The AA plant cultivation will be carried out on the land specially allocated for this purpose by the Camdeboo Municipality. During the growth and maturing of the cultivated plants (7-10 years), the AA leaves will have to be supplied from commercial farms. The proposed commercialisation model is presented in Figure 7.

Since AA is one of few plants which can grow in Great Karoo and which has considerable potential for large scale cultivation and commercialization, this initiative is of national importance. It would result in the transformation of the rural economy and provide jobs for hundreds of subsistence farmers and entrepreneurs in this impoverished region.

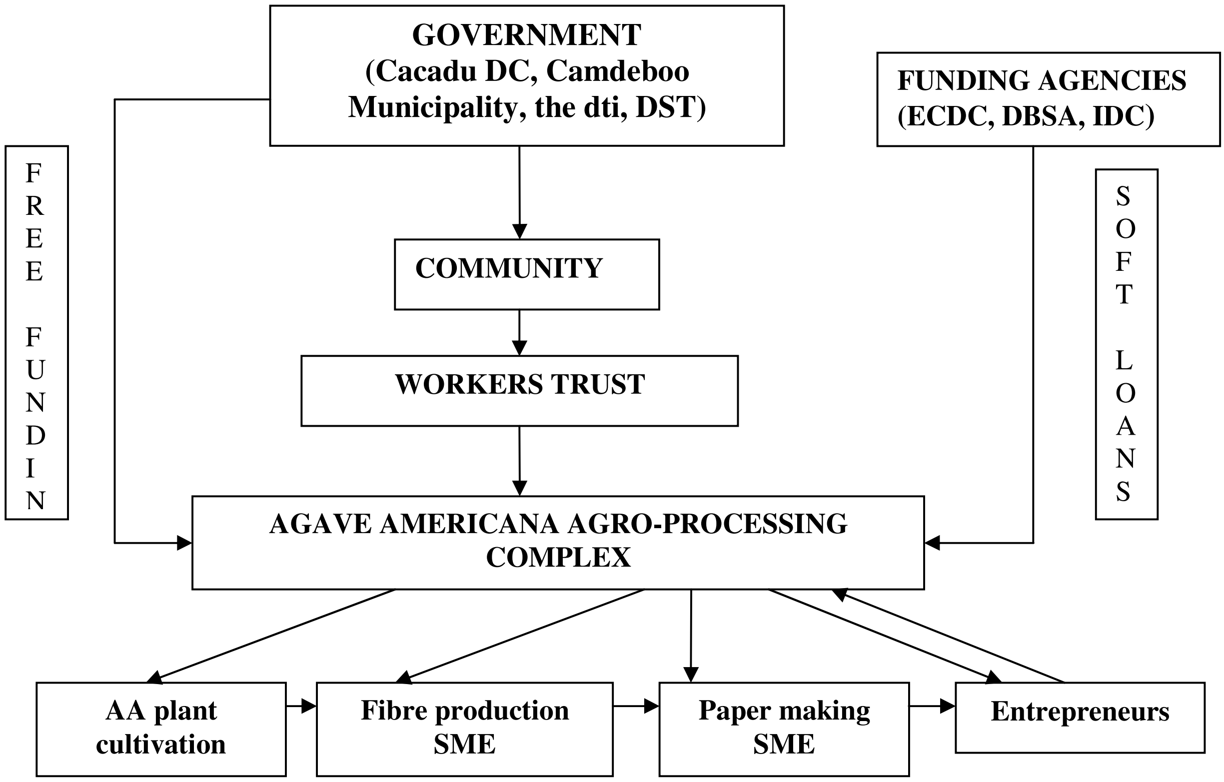

Figure 7. Commercialisation model for an AA agro-processing complex.

CONCLUSIONS

1. It was found that a modified sisal decorticating units is efficient for the extraction of Agave Americana leaf fibre.
2. Agave Americana fibre can be utilised for the production of nonwovens. Two main applications were identified for the Agave Americana based nonwovens, namely, geo-textiles and composite materials for the automotive industry.
3. Pinas of the Agave Americana plant contain up to 25% of inulin, matching the Mexican plant. The leaf base of the local Agave Americana plant contains up to 16% of fructans. Both the pina and leaf base can be utilised for the commercial production of long chain inulin and fructans which have application as vaccine adjuvants in the pharmaceutical industry and fat substitutes and low calorie sweeteners in the food industry, respectively.
4. Pina waste and short fibre textiles are suitable for small scale and commercial paper making.
5. A general concept for commercialising Agave in the rural areas of the Great Karoo has been developed. The “zero-waste” utilization of the plant would enable its production and processing to be translated into a viable and sustainable industry.

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DISCUSSION OF CONFERENCE PROCEEDINGS

31

New crops and their uses: discussion based on the proceedings of the conference

John Meadley

WHY DEVELOP MINOR CROPS?

Climate change
To cope with/respond to climate change/warming – predictable changes in temperature but uncertain changes in soil moisture content.

Peak oil
To respond to peak oil/declining fossil fuels supplies – which increases the need for local food production and food security.

Population growth
To respond to population growth and the need to make use of less fertile land – re-establishment of farm gardens.

Overdependence on a few species
Continuing and increasing over-dependence upon a few species and varieties within species (e.g. rice replacing other food crops such as sago).

Increased dependence upon high yielding varieties
Increased dependence upon high yielding varieties that are dependent upon fertiliser and pesticide use and increase indebtedness of farmers.

Future epidemics
WHO talks of new (AIDS-type) epidemics resulting from intensive livestock production for which medical response will lie in plant species.

Positive characteristics of minor crops
Many minor crops have positive natural characteristics such as:

- Well adapted to local conditions
- Higher nutritional value
- Better water-use efficiency (e.g. millet has a higher protein content and more efficient water utilisation than rice)
- Medicinal properties
- Can thrive on soils with low nutrient status – requiring lower levels of external inputs and less need for credit
- Will intercrop well
- Are part of established farming systems

- Have multi-uses – timber, fruit, leaves, fuel – both raw and processed.

Fast income earners
Many of the leafy vegetable minor crops are fast income earners.

Increase productivity and diversity of income for poor
In India 80% of the people own 36% of the land – hence need to maximise productivity, increase diversity and spread risk.

Empowering women
Many minor crops were traditionally grown by women.

Indicators
Some minor crops are good indicators of soil characteristics.

ISSUES ARISING

Climate change
Difficult to plan for climate change since temperature rises are predictable but soil moisture content is not. The timescale for plants to modify (80-90 years) is very short.

Desirable characteristics
The desirable characteristics of species to be domesticated need to be defined:
- Consumer concerns (visual, taste, shelf life)
- Determinate habit (for ease of harvesting), etc.
- As well as the process of domestication and development (see Akinnifesi paper).

Negative properties
Many minor crops have negative properties (such as bitterness, lodging, hard testa etc.) but also have wide genetic variability that offers potential for improvement.

Market development
Market development is essential. This is affected by:
- Consumer taste (e.g. bitterness)
- Shelf life
- Convenience
- Potential for processing
- Length of growing season/seasonality/constancy of supply
- Standardisation of products
- Presentation
- Demand creation
- Price stability, linked back to farmers' organisations.

Market development outside local markets frequently requires registration with international authorities which can be expensive and time-consuming and needs critical mass. Registration is frequently a complex process.

Supermarket development

- Supermarkets want products to demonstrate good agricultural, manufacturing and employment practice – which can be independently audited
- Supermarkets like labels, fair trade, organic, low environmental impact, low food miles
- Consumers judge on visual, convenience and badges
- Organic/low input/intercropped farming becoming more important and relevant.

Research funding and development

Funding is available from a range of sources but Agriculture, Fisheries and Biotechnology make up only 5% of the total EU research budget. There is a shortage of biological scientists and a continuing need for their training and support (role of IFS).

Managing biodiversity

Biodiversity is valuable for plant breeding but it needs to be managed. Note ICRISAT work with millets on producing core varieties (10%) and mini-core (further 10%) to make biodiversity manageable. Molecular Biology can also help in providing markers for breeding purposes.

Field development

Trials need to move from lab to research field to farmers' fields on a phased basis with regular feedback.

Some established crops are also minor crops

Some major species (e.g. cowpea, sweet potato of cassava) have been well researched for grain or tuber production but not for their leaf (vegetable) production.

HYVs and intercropping

There is generally a conflict between using high input HYVs (max yield of single crop) and intercropping (possibly higher total yield of more than one crop – providing greater security of income).

Farmer organisation

Development of new crops involves not only biology and agronomy and marketing but also the development of business skills, group organisation/dynamics and communications.

Sourcing information and genetic material

- Farmers are key partners in the development of minor crops:
- Many minor crops (e.g. pseudocereals) are grown in remote areas by older farmers
- They have both knowledge and germplasm
- They (and their children) can help in identifying the best germplasm
- They can undertake trials (in a wide range of locations) at low cost
- They can rank varieties.

Farmers also have many weaknesses – like to operate alone, risk averse, lack of technical knowledge etc.

Medicinal plants
This inevitably involves moving into the world of registration – with costs and complex regulations. Apart from understanding the complexities of the process it is essential to be able to produce standardised extracts for evaluation, registration and industrialisation.

Particular value of underutilised fruit species
These have a particular role to play in poor rural communities.

- Food in the hungry season
- Empowerment and income for women
- Extended harvesting period
- Leaf fall for organic matter of animal feed
- High nutritional value
- Intercrop with other species and spread risk
- Can stabilise marginal environments.

Minor crops for survival or added value
Wide range of potential applications – from those that are used at subsistence level to improve the natural environment and the nutrition of the local people to those that are destined to produce high value medicinal products or food additives that require complex development, processing, registration and marketing. Products include:

- Products for local community use
- Locally marketed raw
- Export marketed raw
- Processed foods
- Sophisticated products (health, oxidants etc) that need to be registered.

Role of sophisticated science
Providing that our objectives are clear (i.e. not using science for science's sake) we can use a wide range of sophisticated techniques to develop minor crops (e.g. GIS, molecular biology, phytochemistry, computer modelling etc) whether for use at the village level or within a globalised market.

SECTION 2

PRESENTATION SYNOPSES

1

A Supermarket View on Underutilised Crop Marketing

A. Dhanani

SLIDE 1: UNIVERSAL RULES

All Multiple Retailers expect compliance to the following Good Practices:

- Good Agriculture Practice – GAP
- Good Manufacturing Practice – GMP
- Good Employment Practice - GEP

SLIDE 2: UNIQUE SELLING POINTS

What Sells Currently:

- Certified Organic Farming
- Certified Fair Trade
- Food Value – does the product qualify to be called a "super food"?
- Environmental Impact?

SLIDE 3: THE MULTIPLE RETAILER

General Psychology and expectations:

- Compliance to Best Practice standards, duly certified by third party auditors.
- Current Concern – Food Miles!!
- Expect 100% service levels, delivery of gross margin, growth, convenience (retail and consumer friendliness), competitive pricing.

SLIDE 4: THE CONSUMER

The UK consumer (aided and abetted by the powerful multiple retailers) has a unique psyche that determines his/her consumption habits:

- Primary criterion for purchase is VISUAL. Looks for consistency of shape/size/colour.
- Convenience – ease of use/preparation, minimisation or minimal waste.
- Badges – Organic, Fair Trade, unique origin/producer, etc.

SLIDE 5: CHALLENGES

- The UK offers a unique environment to market virtually any consumer product so long as it is compliant to the above mentioned standards.
- The challenge therefore is to take what is essentially a volunteer product thriving in Mother Nature's bio-diversity in to an industrial scale production environment.

2

Plant Research in the European 7th Framework Programme

A. Schneegans

ABSTRACT

Through its multi-annual Framework Programmes the Research Directorate-General of the European Commission has been financing trans-European scientific cooperation on pre-defined topics with the aim of maintaining and enhancing international competitiveness of European research in the public and private sectors.

Plant sciences and agricultural/forestry research have recently received increased political and public attention in the context of tackling global challenges, most importantly climate change, the emerging energy crisis, the related potential competition between food and biomass production as well as food security issues in view of a growing world population and changing consumption styles. Most of these issues are very complex and require interdisciplinary approaches and international collaboration. Expectations are high that increased efforts in plant research and biotechnology will contribute to quantitative and qualitative improvements in crop production to meet these changing demands. Underutilised crops in particular, may offer a so far untapped potential as regards the diversification of current agricultural systems for providing high quality nutrition, allowing effective production under extreme conditions and developing non-food crops.

The new Seventh Framework Programme (FP7) provides increased opportunities for plant-related research under the Cooperation Programme, the Ideas and People Programmes as well as in the Infrastructure component. The Cooperation Theme 2 "Food, Agriculture and Fisheries, and Biotechnology" (http://cordis.europa.eu/fp7/kbbe/home_en.html) supports cooperative research based on the integrative approach of the "knowledge-based bio-economy" which is built on three pillars: (1) Sustainable production and management of biological resources from land, forest and aquatic environments; (2) Food, health and well being; (3) Life sciences and biotechnologies for sustainable non-food products and processes.

With a budget of over 1.9 billion EUR for the seven-year duration of FP7 Theme 2 supports 'enabling' as well as more applied plant research covering the full scope of the use of plants in agriculture and forestry, such as food, feed and non-food uses, the latter being a new element as compared to FP6.

Funding for research on underutilised crops has come in previous Framework Programmes mainly from the International Cooperation Programme (INCO). In FP7, cooperation with Third Countries has been integrated into the various research themes, sometimes targeted according to topic and geographic area.

The topics published in the first two FP7 calls of Theme 2 do not specifically address underutilised crops. However, by supporting the development of generic tools

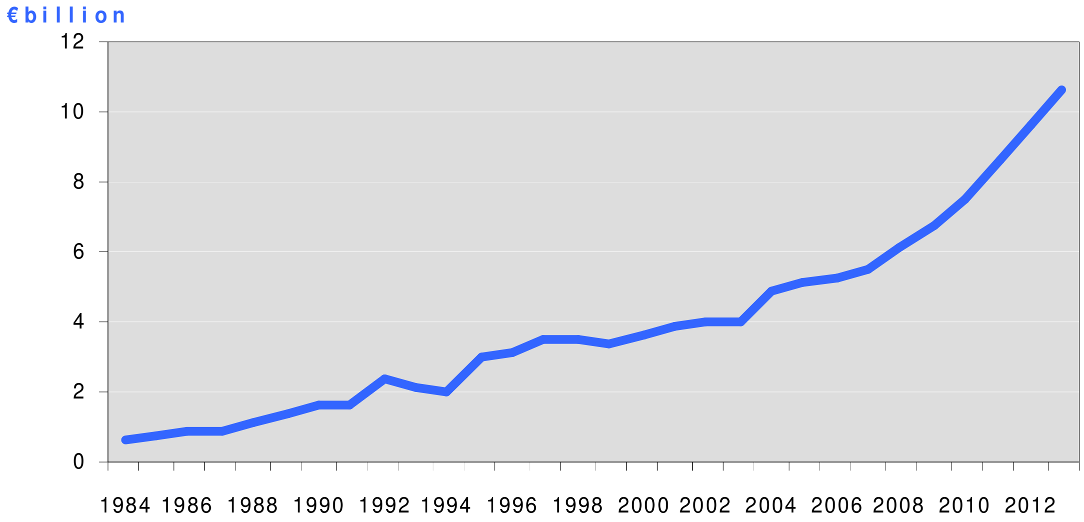
such as for molecular breeding wider benefits are expected for the genetic improvement of plants which will certainly advance breeding efforts, also in underutilised species. In addition, "horizontal" topics such as that on "adaptation of annual crop plants to abiotic stress" (see call KBBE-2007-1, a specific topic for the Mediterranean region) allow for a wide range of research activities on major and "minor" crops. The same applies to the topics dedicated to the development of energy and oil crops.

In the formulation of future call topics and the identification of geographic areas for International Collaboration, the Commission relies heavily on the dialogue with the various actors in research and research policy to make sure that the funding priorities identified match the demands of current and future agriculture.

However, Commission funding represents only a small part of the overall European effort and it is vital that there is a more coherent approach across Europe so as to maximise output. In recent years there has been progress towards realising a more complete European Research Area in the plant and crop sciences, but further advances are still needed. Several Technology Platforms, ERANETS and Expert Groups such as the Standing Committee for Agricultural Research have already played an important role in this respect.

PRESENTATION

SLIDE 1: EU RESEARCH FRAMEWORK PROGRAMMES - ANNUAL BUDGETS BETWEEN 1984 AND 2013.



NB: budgets in current prices. Source: Annual Report 2003, plus FP7 revised proposal

SLIDE 2: FP7 (2007-2013) - THE STRUCTURE

Cooperation – Collaborative research

Ideas – Frontier Research

People – Marie Curie Actions

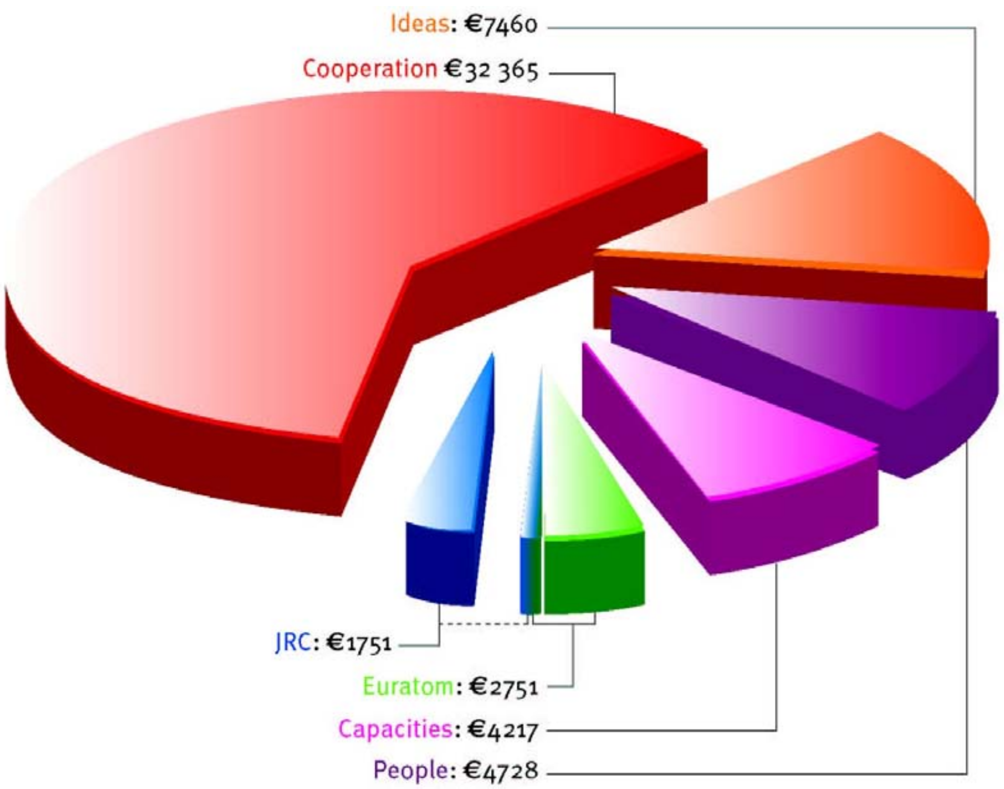
Capacities – Research Capacity

JRC non-nuclear research

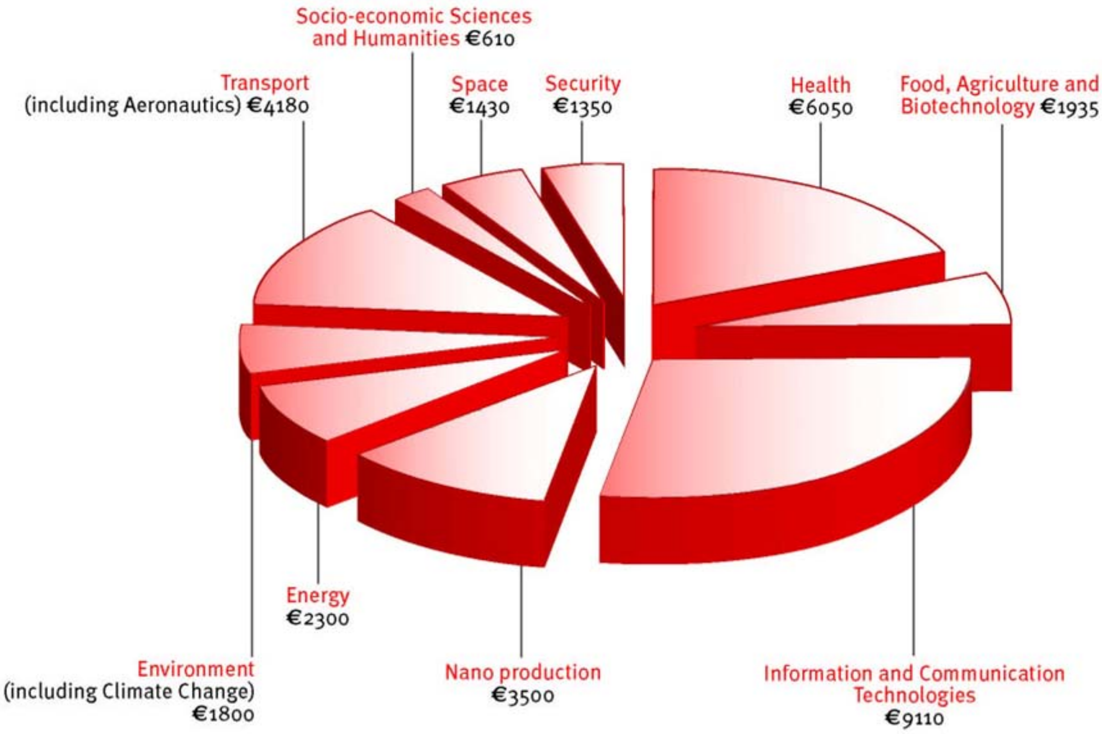
Euratom direct actions – JRC nuclear research

Euratom indirect actions – nuclear fusion and fission research

SLIDE 3: FP7 - INDICATIVE BREAKDOWN (€MILLION)



SLIDE 4: COOPERATION PROGRAMME - THEMATIC AREAS (€MILLION)



SLIDE 5: FOOD, AGRICULTURE, FISHERIES AND BIOTECHNOLOGY - RATIONALE

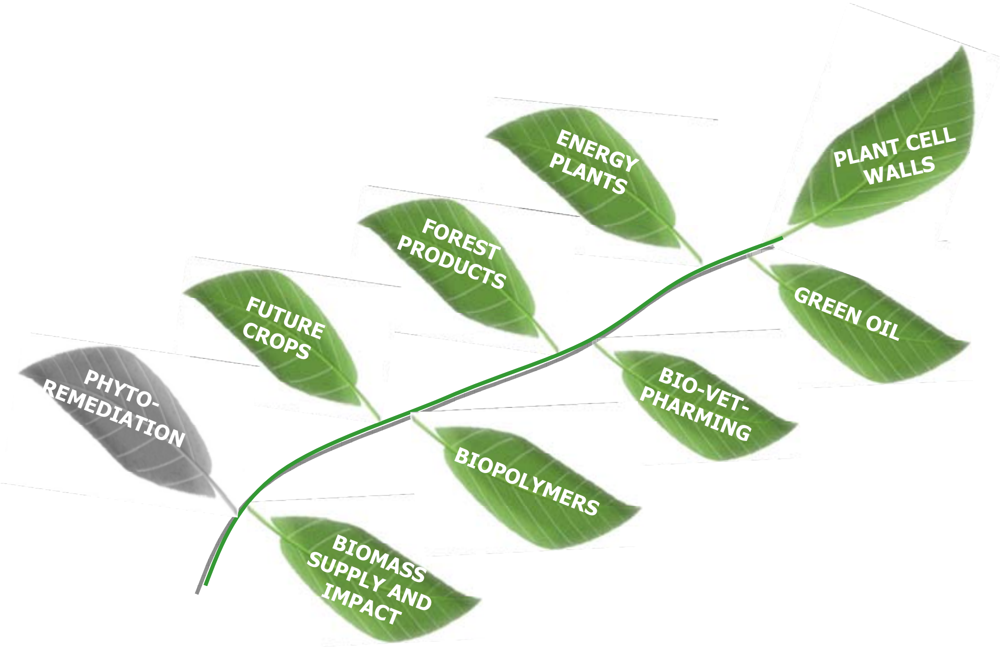
- Build a European Knowledge-Based Bio-Economy (KBBE)
  - 'Bio-economy': All industries and economical sectors that produce, utilise or manage biological resources
- Respond to environmental, social and economic challenges:
  - High quality food for an increasing world population
  - Sustainable agriculture adapted to changing environments (biotic and abiotic stress)
  - Biomaterials and energy from renewable bio-resources
- Involve all stakeholders (incl. industry) in research
- Respond quickly to emerging research needs
- 4 Fs: **Food, Fiber, Fuel** and **Feed**

SLIDE 6: SUSTAINABLE PRODUCTION AND MANAGEMENT OF BIOLOGICAL RESOURCES FROM LAND, FOREST AND AQUATIC ENVIRONMENTS

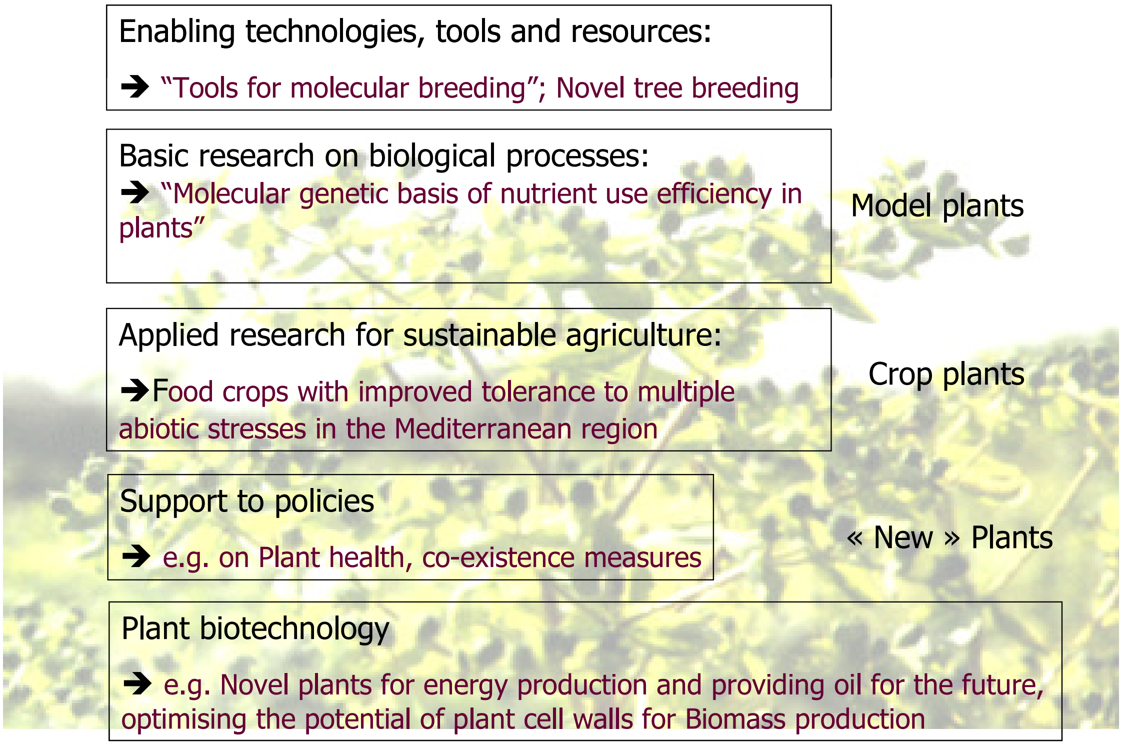
- Enabling research ('omics', converging technologies, bio-informatics) for micro-organism, plants and animals

- Competitive, sustainable and multifunctional agriculture, forestry, fishery and aquaculture
- Animal health production and welfare; animal diseases incl. zoonoses
- Marine resources, fishery, aquaculture
- Development of policy strategies for knowledge based bio-economy, agriculture, fishery as well as rural and coastal areas

SLIDE 7: LIFE SCIENCES AND BIOTECHNOLOGY FOR SUSTAINABLE NON-FOOD PRODUCTS AND PROCESSES

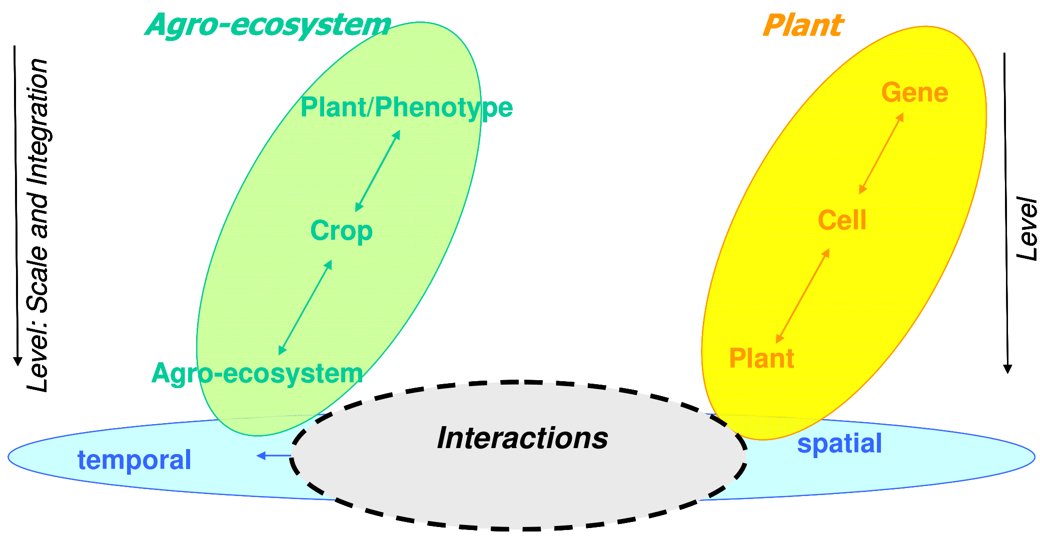


SLIDE 8: PLANT RESEARCH IN FP7 - EXAMPLES



SLIDE 9: COMPLEXITY IN PLANT RESEARCH

- Integration of information from different levels of organisation
- Transfer of knowledge from model to crop plants
- Interdisciplinary collaboration and use of new technologies



SLIDES 10-12: CURRENT EU-INCO PROJECTS ON UNDERUTILISED CROPS

ACRONYM	TITLE	COORDINATOR
CHERLA	Sustainable cherimoya production systems in Latin America	Jose I. HORMAZA, CSIC
INDIGENO	Sustainable production and marketing of indigenous vegetables through urban/peri-urban agric. in sub-Saharan Africa.	Einir YOUNG, University of Wales Bangor
GUAVAMAP	Improvement of guava: Linkage mapping and QTL analysis for marker-assisted selection	Wolfgang ROHDE, Fraunhofer Institute
PAVUC	Producing added value from under-utilised tropical fruit crops with high commercial potential	Fabrice VAILLANT, CIRAD
FONIO	Upgrading quality and competitiveness of fonio for improved livelihoods in West Africa	Jean-François CRUZ, Centre de Coop. Int. Rech. Agron.pour le Dévelop.
BAMLINK	Molecular, Environmental and Nutritional Evaluation of Bambara Groundnut for Food Production in Semi-Arid Africa and India	Sayed AZAM-ALI, University of Nottingham

ACRONYM	TITLE	COORDINATOR
SAFRUIT	Sahelian Fruit Trees	Anders RAEBILD, Royal Veterinary and Agric. Univ.
LOTASSA	Bridging Genomics and Agrosystem Management: Adaptation and Sustainable Production of forage Lotus species in Environ.-Constrained South-American Soils.	Juan SANJUAN, CSIC
INNOVKAR	Innovative Tools and Techniques for Sustainable Use of the Shea Tree in Sudano-Sahelian zone	Jean-Marc BOUVET, CIRAD
FOSRIN	Food security through ricebean research in India and Nepal	Philip HOLLINGTON, Univ. of Wales, Bangor
MARAMAII	Development of innovative and healthful marama bean products targeting niche markets	Ase HANSENThe Royal Veterinary and Agricultural University
Agro-folio	Benefiting from an improved agricultural portfolio in AsiaMarkus SCHMIDTUniversity of Vienna	Markus SCHMIDT, University of Vienna

ACRONYM	TITLE	COORDINATOR
DADOBAT	Domestication and development of baobab and tamarind	Patrick VAN DAMME, University Ghent
ACACIAGUM	Innovative management of Acacia senegal trees to improve resource productivity and gum-arabic production in sub-Saharan Africa	Didier LESUEUR, CGIAR
AMARANTH: **FUTURE-FOOD**	Providing the Key Tools for the Exploitation of Amaranth – the Protein-Rich Grain of the Aztecs	Fomsgaard INGE, Dansih Institute of Agricultural Sciences

SLIDE 13: INTERNATIONAL COOPERATION - AGRICULTURE, FOOD AND BIOTECHNOLOGIES

1. Opening
   1.1 Opening of all activities to participation by Third Countries
   1.2 Certain topics particularly encourage international co-operation

2. Specific International Co-operation Actions (SICA)
   on selected topics, with priority partner countries / regions :
   2.1 BIREGIONAL DIALOGUES, BILATERAL AGREEMENTS, NEIGHBOURS AND EMERGING ECONOMIES: topics jointly identified, based on mutual interest and benefits
   2.2 DEV COUNTRIES: taking into account their needs (focus on MDG)

3

Commercialisation of NTFPs in Malawi

D. Mauambeta

ABSTRACT

Until very recently, baobab and tamarind trees were seen as useless in Malawi. While the baobab tree had over forty uses, none of these was commercial. The result was that most baobab and tamarind trees were being cut down. While the baobab tree was just cut for the sake of cutting, the tamarind was being used for charcoal and firewood production.

Rapid depletion of indigenous woodlands in Malawi has severe ecological consequences. The conversion of woodlands into farmland, the lack of national energy policies and programmes and the rapid increase of urbanisation has led to increased demand for firewood and charcoal. These are contributing factors to deforestation.

In 1996, the Southern African Development Community (SADC) and German Agency for Technical Cooperation (GTZ) designed a project on "*Sustainable Management of Indigenous Forests*" and implemented in Botswana, Malawi, Mozambique and Namibia with the overall objective of developing strategies for community-based indigenous woodland management. The project worked with government and non-governmental organizations. The Wildlife and Environmental Society of Malawi implemented the Malawi component between 1996 and 2006 in Lisungwi Valley, Neno District, Malawi.

Participatory rural appraisals were used to identify the needs of the local population, followed by socio-economic baseline studies and forest inventories. Local communities were encouraged to form themselves into village natural resource committees and other interest groups. Land utilisation plans were established and land utilisation activities were planned together with the communities. Apart from silvicultural activities emphasis was also placed on income-generating activities, particularly through the identification and utilization of non-timber forest products. This was achieved through the project components of producing juice from baobab (*Adansonia digitata*) and tamarind (*Tamarindus indica*) fruits; rearing and selling guinea fowl; bee-keeping and honey production; cane-furniture making.

First results indicate that communities are aware of the ecological problems in their areas. It also is apparent that only through the introduction of income-generating activities can communities be motivated to reduce deforestation caused by land clearing, firewood collection and charcoal production.

Communities are now engaged in a number of income-generating activities, ensuring the supply of forest products and sources of jobs and income. Amongst the activities which have been successfully commercialised are the production of baobab (Malambe) and tamarind (Bwemba) fruit juices and honey. The project made improvements to traditional uses through action research, simple processing methods, quality testing and standardization to make the juice and produce quality honey. Now these products are found in supermarkets, service station shops and similar

establishments. Commercialization of NTFPs has increased household per capita income from about Malawi Kwacha 3000.00 (US$43.00) in 1996 to US$130.00 M

The approach adopted is encouraging innovative ideas / activities which are less destructive, sustainable and have better returns. The technologies being encouraged are simple and cheap. Therefore, simplicity and low cost are critical factors for sustainability and extension to other communities where similar resources occur. Further, the benefit accrued from sustainable management of natural resources is going to the needy, assisting them to get out of the vicious circle of human poverty. Above all, the project is improving the environment and household food security.

PRESENTATION

SLIDE 1: BAOBAB FOREST IN LISUNGWI VALLEY, NENO DISTRICT, MALAWI

SLIDE 2: MAGNIFICENT BAOBAB TREES, IN LIZUNGWI VALLEY, NENO, MALAWI

SLIDE 3: TAMARIND TREE IN LISUNGWI VALLEY, NENO, MALAWI

SLIDE 4: IN SOME EXTREME CASES, BAOBAB TREES HAVE BEEN CUT DOWN TO WORST

SLIDE 5: IN THE PAST, BAOBAB FRUITS HAVE BEEN LEFT TO ROT

SLIDE 6: PREVIOUSLY, COMMUNITIES WOULD CUT DOWN THE TAMARIND TREES TO MAKE CHARCOAL

SLIDE 7: CHARCOAL KILN, LIZUNGWI VALLEY, MALAWI

SLIDE 8: CHARCOAL ON THE MARKET

SLIDE 9:

- **But Commercialization of the Baobab and Tamarind Fruits has changed everything;**
- **Using Traditional Knowledge Systems and Value addition.**

SLIDE 10: NOW, COMMUNITIES COLLECT THE BAOBAB FRUITS AND BRING THEM HOME

SLIDE 11: BAOBAB FRUITS STORED IN A LOCAL GRANARY READY FOR MARKETING

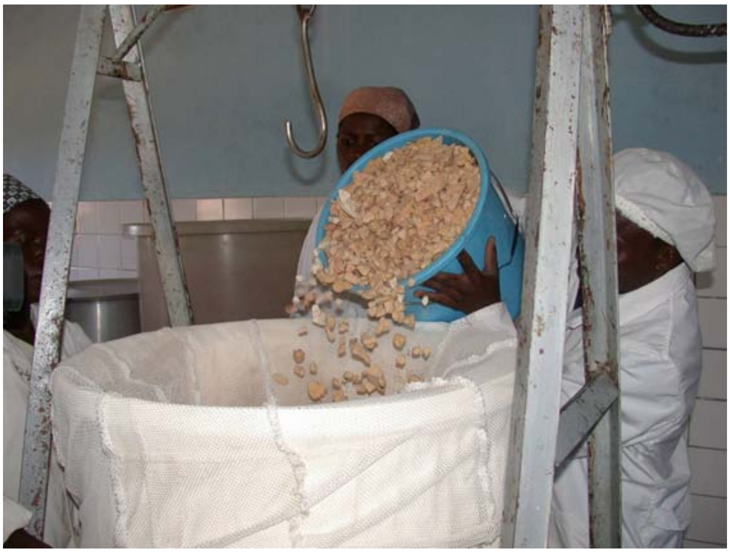
SLIDE 12: VILLAGE HANDS LIMITED, SINCE 1997 HAS COMMERCIALISED BAOBAB FRUITS

SLIDE 13: BAOBAB FRUITS COLLECTED AND BOUGHT BY VILLAGE HANDS LIMITED

SLIDE 14: LARGE SCALE STORAGE OF BAOBAB FRUITS BY VILLAGE HANDS LIMITED

SLIDE 15: CRACKING BAOBAB SHELLS AND REMOVING BAOBAB PULP

SLIDES 16 & 17: SOAKING BAOBAB PULP



SLIDE 18: AFTER SOAKING, REMOVING SEEDS FROM A JUICE EXTRACTOR BAG

SLIDE 19: HEATING JUICE TO KILL MICROBES

SLIDE 20: PRESERVATIVES AND SUGAR ARE MEASURED TO SCALE BEFORE ADDING TO JUICE

SLIDE 21 & 22: AFTER HEATING AND COOLING, PRESERVATIVE AND SOME SUGAR ARE ADDED AND LEFT TO COOL DOWN FURTHER

SLIDE 23: BOTTLING BAOBAB JUICE

SLIDE 24: BOTTLED BAOBAB FRUIT JUICE READY FOR SALE

SLIDE 25: BOTTLED TAMARIND JUICE READY FOR SALE

SLIDE 26: PACKAGED JUICES STORED READY FOR SALE

SLIDE 27: QUALITY CONTROL INSPECTION TEAM FROM MALAWI BUREAU OF STANDARDS

SLIDE 28: VILLAGE HANDS LTD ALSO MARKETS HONEY

SLIDE 29 & 30: VHL HAS EXHIBITED AT INTERNATIONAL AND LOCAL TRADE FAIRS

SLIDE 31: OTHER BAOBAB PRODUCT: BAOBAB JAM- BAOBAB PULP ADDED TO WATER

SLIDE 32 & 33: SIEVING BAOBAB SEEDS, ADDING SUGAR, HEATING AND COOLING

SLIDE 34: BAOBAB JAM READY FOR SALE

SLIDE 35: BAOBAB JAM ON DOUGHNUT READY FOR CONSUMPTION

SLIDE 36: OTHER PRODUCTS: BAOBAB SWEETS AND FRUIT JUICE CONCENTRATES

SLIDE 37: VHL PRODUCTION STAFF ARE VERY HAPPY WITH THIS VENTURE

SLIDE 38: VHL BOARD OF DIRECTORS AND PRODUCTION STAFF

SLIDE 39: MAGOMERO WOMEN’S GROUP, MAKES JAM AND FRUIT JUICES

SLIDE 40: COMMERCIALIZATION HAS LED TO CONSERVATION AND THE BAOBAB TREES, ONCE SEEN AS USELESS

SLIDE 41: COMMERCIALIZATION HAS LED TO CONSERVATION OF THE TAMARIND TREE, ONCE CUT DOWN FOR CHARCOAL

SLIDE 42: OTHER TREES CONSERVED INCLUDE *ZIZIPHUS MAURITIANA*

SLIDE 43: ZIZIPHUS FRUITS FOR SALE

4

Status and Market Potential of Traditional Leafy Vegetables (Marogo) in South Africa

E. van den Heever and C.P. du Pooly

ABSTRACT

Traditional leafy vegetables "Marogo" are crops used in a subsistence-farming basis, in South African rural areas. Leaves of Amaranth (*Amaranthus* spp.) are most commonly referred to as Marogo but leaves of several other species, including *Corchorus* and *Cucurbita* spp as well as *Cleome gynandra*, are also sold as Marogo. During 2005 the ARC-VOPI initiated a study to determine the current status and position of Marogo within the market place. The study included consumer preferences and highlighted existing activities in the market place.

All interviewed consumers in the Free State and Limpopo provinces were utilizing Marogo, while only 44 % in KwaZulu Natal were familiar with the crop. The Limpopo province had the highest consumption and most consumers preferred to eat Marogo on a weekly or daily basis. Most consumers ate Marogo for taste and cultural reasons, followed by health, medicinal and affordability reasons.

The national fresh produce markets sell insignificant volumes of Marogo, mainly as due to inconsistent supply, poor shelf life and lack of knowledge. Few retail groups have Marogo on their standard stock inventory. Local retailers have the perception that commercial spinach (Swiss chard) is dominating sales in this category and they are, hesitant to invest in the future of Marogo. Independent retailers buy Marogo from the markets or source directly from growers or wholesalers. The presence of Marogo on the shelves of greengrocers depends on the area where they are located and they are regarded as the most important retail outlet for Marogo. Although distribution and marketing are major limitations, Marogo is popular and most consumers would like to eat it more often. Consumers prefer to buy it at retail stores, emphasizing the need for strategic partners in the distribution and marketing of Marogo to empower small-scale and emerging growers to enter the commercial supply chain.

SLIDE 1: INTRODUCTION

- Indigenous edible plants and traditional crops have sustained rural populations in developing countries for centuries.
- In South Africa *Amaranthus* spp. is referred to as Marogo, but several other spp., *Corchorus*, *Cucurbita* spp. and *Cleome gynandra*, are under the same trade name.

SLIDE 2:

SLIDES 3-5: INTRODUCTION CONT.

- Traditional leafy vegetables mainly harvested from the wild or on a subsistence farming basis.
- The commercialization could be a practical solution in maintaining the biodiversity and food security in South African rural areas
- Leaves of Amaranthis are most commonly referred to as *Marogo*. However, leaves of *Muxe* or night shade, *Delelele*, *Murudi* (cleome) and *Kale* are also sold in the trade as *Marogo.*
- Market survey been done to investigate the status of *Marogo* in SA

SLIDE 4:

SLIDE 5: MAP OF SOUTH AFRICA

SLIDE 6: MATERIALS AND METHODS

- Market survey done to investigate the status of *Marogo* in SA.
- Interviewed buyers, category managers, and management of the centralised retail chains active in the Fresh Produce sector.
- Interview different market agents, representative of the major National Fresh Produce Markets in South Africa.

SLIDE 7: RESULTS - LOCAL AND NATIONAL FRESH PRODUCE MARKETS

- Johannesburg / Tswane market.
- Sell Marogo in bunches in cartons.
- No sales statistics.
- Highly perishable.
- Phased out because of popularity of Swiss chard.

SLIDE 8: RESULTS - RETAIL INDUSTRY

- Few retail groups have Marogo on their standard stock inventory.
- Some retailers may brand the product Marogo, but it is actually a different leafy vegetable, i.e. Kale.
- Retailers have different views on the feasibility for Marogo.
- Interviews with buyers and/or procurement managers of major retailers.

SLIDE 9: RESULTS - SHOPRITE CHECKERS GROUP

- Big supermarket group.
- Checkers do not sell Marogo.
- Not noticed a specific demand for the product.

SLIDE 10: RESULTS - PICK 'N' PAY

- Gauteng, Limpopo, Mpumalanga and Free State regions do not stock Marog.
- Regards it as a niche product with small volume potential.

SLIDE 11: RESULTS - WOOLWORTHS

- Stock a variety of spinach and speciality leafy vegetable lines but not specific Marogo.
- Consider the introduction of such lines in development of the market for organic and natural products.
- Also consider resource poor farmer to produce the crops.

SLIDE 12: RESULTS - SPAR GROUP

- Spar Group does not stock Marogo under the Fresh Line brand.
- Some stores might stock it, as Spar owners have freedom to buy anywhere.
- Strategy to open many stores in urban areas.

SLIDE 13: RESULTS - FRUIT & VEG CITY

- Opened as a single store as an independent green grocer in 1993, and has since grown to one of the largest fresh fruit and vegetables retailers in South Africa.
- Sells "Marogo", but it is actually Kale.

SLIDE 14: RESULTS - INDEPENDENT RETAILERS/GREEN GROCERS

- This sector buys directly from markets or other sources.
- Depend on where they are situated.

SLIDE 15:

SLIDE 16: RESULTS - INFORMAL SECTOR (HAWKINS)

- This is the biggest sector to supply the crops to the public but how big it is, is unknown.
- Normally there are pickers and sellers in the chain.
- Marogo will come from rural areas to urban areas.

SLIDE 17: RESULTS

- Consumer demands.
- Mostly local and Indian people who know the crop.
- Cooked with other ingredients such as onion and tomato, and is eaten with "pap".

SLIDE 18: % OF CONSUMERS WHO HAVE KNOWLEDGE ON MAROGO, AND FREQUENCY OF CONSUMPTION

	KZN (336)	**Free State (82)**	**Gauteng (33)**	**Limpopo (60)**
Familiar with? Yes	44 %	100 %	76 %	100 %
How often they eat Marogo %	Daily 2 Weekly 43 Monthly 55	Daily 1 Weekly 7 Monthly 43 Not often 49	Daily 4 Weekly 20 Monthly 64 Not often 12	Daily 18 Weekly 35 Monthly 12 Not often 35
How often they prefer to eat Marogo	Daily 3 Weekly 70 Monthly 27	Daily 20 Weekly 31 Monthly 1 Not sure 49	Daily 20 Weekly 44 Monthly 20 Not sure 16	Daily 50 Weekly 43 Monthly 7

SLIDES 19-24: CONCLUSIONS

- Cooked and served with “pap”.
- Regarded as a healthy meal.
- Most consumers know Marogo.
- The national fresh produce markets are selling insignificant low volumes of Marogo, mainly as a result of inconsistent supply, poor post-harvest handling practices and lack of knowledge on the product.
- No statistics are available volumes too low.
- Local retailers have the perception that spinach is dominating sales in the Marogo/wild leaves category, and are therefore hesitant to invest in the future of Marogo.
- It became evident that Marogo is a popular vegetable, and consumers would like to eat it more often
- Most consumers
  -buy Marogo informally, either from hawkers or elsewhere;
  -like to have improved access to Marogo;
  -eat Marogo for its taste, health, culture, and medicinal reasons.
- To meet the demand for Marogo, it should be produced and marketed on a commercial scale.
- Communication strategy:
  -Compiling and implementation of a comprehensive production plan, Identify joint ventures,
  -Develop Marogo supply chain,
  -Skills development and training.

5

The Potential for Utilising Bioenergy within Anaerobic Digestion for CHP

L. Lewis

ABSTRACT

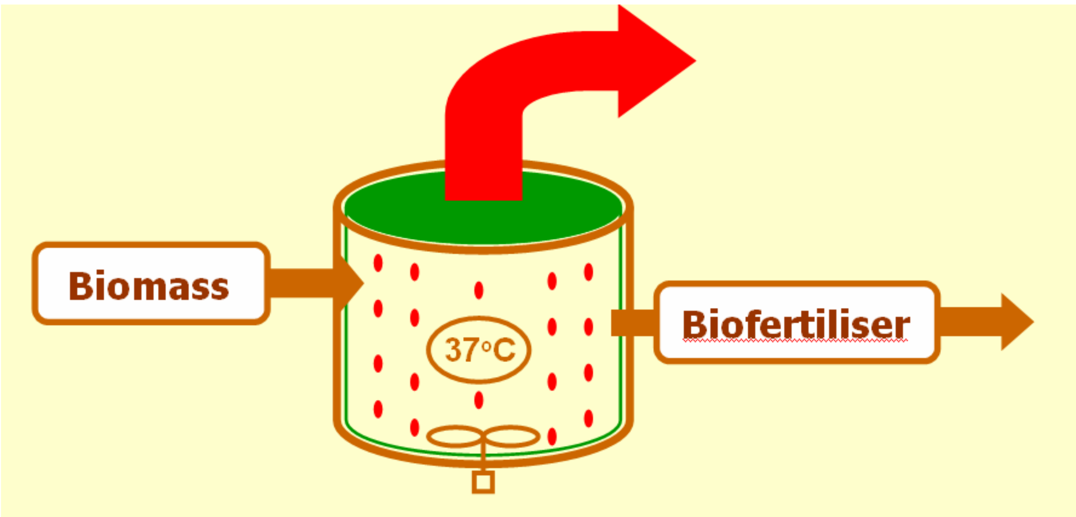
Greenfinch Ltd, a process engineering company specialising in anaerobic digestion, has recently been involved with two consecutive research projects into the use of energy crops for biogas production. The first, a Dti funded project, focused on the growing and digestion of ryegrass as an energy crop. The second was a pan-European consortium investigating the production of biogas from farm crops and agricultural wastes. These projects, combined with Greenfinch's technical experience of designing, building and operating anaerobic digesters has allowed the company to develop a good understanding of the potential for utilising energy crops within anaerobic digestion. The crops referred to are common place within European agriculture, specifically maize, ryegrass, and wheat. The presentation will assess the energy value of crops for biogas production, specific to UK, and discuss situations in Europe where it is now common place to farm for biogas. Utilisation of the energy produced from the CHP will also be considered focusing on the importance of uses for the heat.

PRESENTATION

SLIDE 1: GREENFINCH LTD.

- Based in Ludlow, south Shropshire.
- Specialise in anaerobic digestion.
- 8 years of R&D into the AD of food waste.
- Constructed 7 on-farm AD plants in Scotland.
- Constructed the UK's first biowaste digester in south Shropshire.

SLIDE 2: ANAEROBIC DIGESTION IS A NATURAL BIOLOGICAL PROCESS



SLIDE 3: ANAEROBIC DIGESTION IS A 3-PRODUCT PROCESS

- Most renewable energy & bioenergy technologies do only one thing – produce energy.
- Anaerobic digestion is a 3-product process:
  - AD is a waste management process;
  - AD is a nutrient recycling process; and
  - AD is a renewable energy process.
- As such it has tended to get lost in UK policy making.

SLIDE 4: LOW CARBON PROCESS

Anaerobic digestion reduces greenhouse gas emissions in 4 ways:

- by preventing the uncontrolled emissions of CH_4 (22 times more powerful than CO_2);
- by beneficial use of the biofertiliser in agriculture, displacing mineral fertilisers;
- by reducing the transport of waste; and
- by the production of renewable electricity & heat.

SLIDE 5:

1996 to 1998 – Restaurant Waste

1999 to 2001 – Household Kitchen Waste

2001 to 2003 – Pathogen Research

2003 to 2006 – Ryegrass as an Energy

SLIDE 6: CROPGEN

- www.cropgen.soton.ac.uk
- 8 University & 3 SMEs
- Main objective to assess the production of biogas through anaerobic digestion technology, using agricultural wastes & energy crops, integrated into current farming practises.

SLIDE 7: BIOGAS FARMING

ANAEROBIC DIGESTION OF ENERGY CROPS WITHIN UK AGRICULTURE

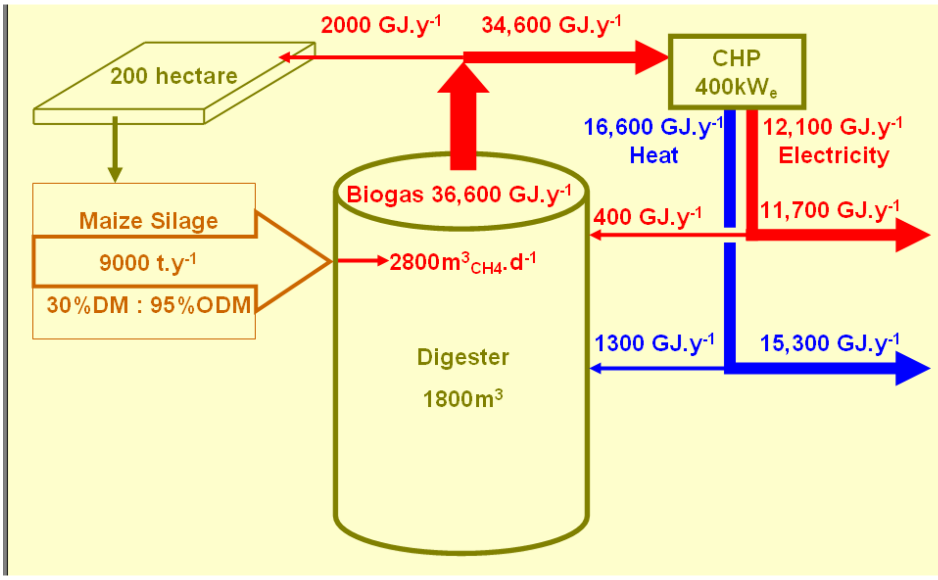
SLIDE 8: CROP DIGESTION TRIALS

- Behaviour of crops within AD
- Design requirements

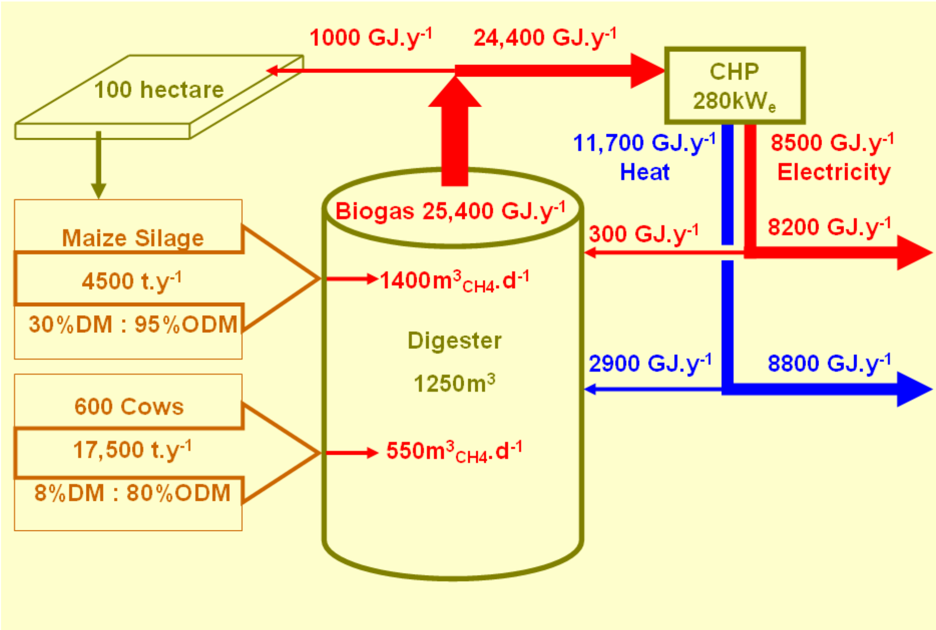
SLIDE 9: ENERGY CROP PARAMETERS

Crop Variety		Maize	Ryegrass	WC Winter Wheat
Crop Yield	$t_{WET}.ha^{-1}.y^{-1}$	45	56	36.5
Dry Matter	%DM	30	20	40
Organic Dry Matter	%ODM	95	88	90
ODM Yield	$t_{ODM}.ha^{-1}.y^{-1}$	12.8	9.8	13.1
Methane Yield	$m^3_{CH4}.t^{-1}_{ODM}$	400	340	350
Gross Energy Yield	$GJ.ha^{-1}.y^{-1}$	182	120	163
Gross Energy Yield	$kW_f.ha^{-1}$	5.8	3.8	5.2
Energy for Crop Production	$GJ.ha^{-1}.y^{-1}$	10	24	10
Energy for Crop Production	$kW_f.ha^{-1}$	0.3	0.8	0.3
Net Energy Output	$GJ.ha^{-1}.y^{-1}$	172	96	153
Net Energy Output	$kW_f.ha^{-1}$	5.5	3.0	4.9
Crop Production Cost	$£.ha^{-1}.y^{-1}$	£720	£450	£625

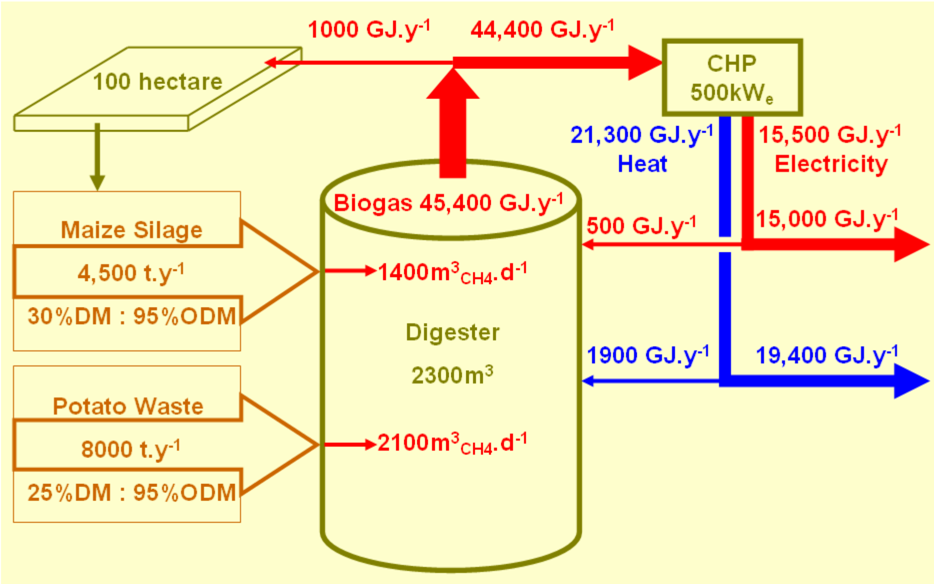
SLIDE 10: ENERGY BALANCE - MAIZE SILAGE



SLIDE 11: ENERGY BALANCE - MAIZE + COW MANURE



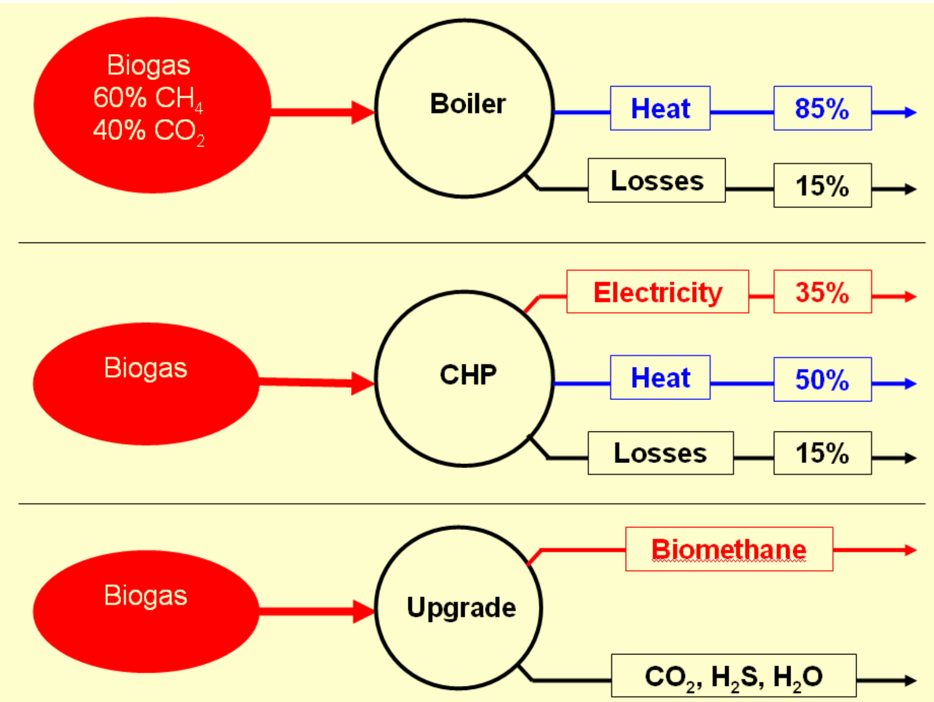
SLIDE 12: ENERGY BALANCE - MAIZE + POTATO WASTE



SLIDE 13: COMMERCIAL ANALYSIS

		Maize	Maize + Pigs	Maize +Potato
Sale of Electricity	£.y-1	295,000	205,000	376,000
Sale of Heat	£.y-1	17,000	17,000	17,000
TOTAL INCOME	£.y-1	312,000	222,000	393,000
Cost of Energy Crop	£.y-1	144,000	72,000	72,000
Cost of Labour	£.y-1	14,000	14,000	14,000
Cost of Maintenance	£.y-1	57,000	40,000	74,000
TOTAL COSTS	£.y-1	215,000	126,000	160,000
INCOME LESS COSTS	£.y-1	97,000	96,000	233,000
CAPITAL COST	£	800,000	700,000	900,000
PAY-BACK	yrs	8.2	7.3	3.9

SLIDE 14:



SLIDE 15: BIOGAS IN SWEDEN - VÄSTERÅS

SLIDE 16: CONCLUSIONS

- The use of crops for energy production is going to strongly depend on the current market opportunity costs.
- The use of digestate as an equivalent to mineral fertiliser will significantly help the energy balance of energy crops.
- The economics & energy balance are improved if there is a use for the heat.
- AD within agriculture needs government support if it is to progress.

6

Overview of Non-Food Crops: The Way Forward

M. Askew

SLIDE 1: THE USES OF NON-FOOD CROPS ARE NOT NEW!

Whilst there is much comment about the historic uses of non-food crops and products, in reality there has been little development in the recent 20 years, with the exceptions of biofuels and starches.

SLIDE 2: EARLY RECENT SUGGESTIONS

Rexen and Munck reported to European Commission that steps should be taken to address potential cereal surpluses in Europe.

SLIDE 3: KEY ELEMENTS FROM REXEN & MUNCK, 1984

1. Develop demo agricultural refineries.
2. Simplify regulation of cereals production and create the basis for a competitive biotech industry in EU.
3. Stimulate use of straw as a competitive product.
4. Instigate R&D programmes for industrial manufacture of cereal based products.

SLIDE 4: THE CURRENT POSITION

- Currently in UK we are talking about bioethanol production from surplus wheat.
- However the world reserves of cereal stocks are at a low level and at the same time USA is projected to use 150% of its cereal exports in bioethanol production!
- What will happen?

SLIDE 5: THE FUTURE?

1. The developing food versus fuel conflict.
2. Apparent lack of interest in non-energy/biofuel non-food produce despite some of their obvious advantages.
3. UK has only 88,000 ha of non-food orientated crops and if OSR is excluded that falls to about 12,00 ha including herbs et cetera

SLIDE 6: PRELIMINARY CONCLUSION

- In UK we are not really developing any significant new land use for non-food crops.

- We are tending to remain with old proven technologies.
- Nothing has changed greatly in the past 20 years despite significant R&D funding especially from multinational funders like EC.

SLIDE 7: MARKET POTENTIAL FOR BIORENEWABLES: REAL OR IMAGINARY?

- We know from the IENICA project that market potential is high and that most non-food bioresources markets are undersupplied in EU.
- IENICA was the first characterisation of markets and constraints on their development.

SLIDE 8: INTERACTIVE EUROPEAN NETWORK FOR INDUSTRIAL CROPS AND THEIR APPLICATIONS (IENICA)

SLIDE 9: THE MARKETPLACE AND IENICA

The IENICA project identified a number of actions that were required for the development of non-food products from plants and animals.

SLIDE 10: KEY IENICA FINDINGS FOR THE MARKETPLACE

1. Need for enhanced supply chain development to enhance economics, consistency of supply, vertical integration.

2. Need for improved understanding of plant metabolism.
3. Need for new processes and co-products. Utilisation of 'wastes' essential.
4. Goals and research targets must match non-food product market needs.

SLIDE 11: IS ANYTHING HAPPENING? CONSTRAINTS UPON DEVELOPMENT

- Lack of awareness of opportunities in industry and public at large.
- Lack of need or financial incentive to change. Investment risk.
- Investment already in existing plant is not changeable.
- There is no guaranteed supply of material nor any market organisation.

SLIDE 12: NOTHING HAS CHANGED IN THE LAST 10 YEARS

- Whilst the constraints are well recognised little has happened to change the picture and it has to be concluded that there has been too much science and technology 'push' and too little market 'pull'.
- First generation biofuels are now dominating the scene.

SLIDE 13: SO, WHERE NOW?

- We need to create sustainable demand in the marketplace.
- However there could be issues that would create instability for agric produce– high cereal prices making them too expensive for bio-producting; low end prices for final product; upcoming cheaper products eg bio-wastes.

SLIDE 14: WILL SECOND GENERATION BIOFUELS ASSIST IN NF PRODUCT DEVELOPMENT?

- Most certainly!!
- The way forward includes developing the market as well as exploiting bio-feedstocks to the fullest extent.
- We need to rethink some of our processes and procedures with a view to full exploitation of feedstocks.
- The answer is in developing what we know and not necessarily seeking new species for farming.

SLIDE 15: DEVELOPING MARKET PULL

- Probably need an integration of policies at governmental level + a mandatory and /or fiscal/financial content.
- Investors need to have some sort of longer term assurances that policies will not change quickly.
- WE NEED AN INTERATED POLICY FRAMEWORK MAPPING AND EMBRACING ALL ASPECTS OF THE NF PRODUCT AREA.

AN EXAMPLE – ROAD VEHICLES AND REDUCTION IN FUEL USE.

SLIDE 16: SAAB BIOPOWER

SLIDE 17: CURRENT USES

SLIDE 18: OPTIMISING USE OF BIORESOURCES

SLIDE 19: REDUCED SPEED = REDUCED FUEL CONSUMPTION

SECTION 3

POSTER ABSTRACTS

ROLE OF BAMBARA GROUNDNUTS (*Vigna subterranea*) IN CROPPING SYSTEMS IN WESTERN KENYA

D.O. Andika, M.O.A. Onyango and Onyago J.C.

The Bambara groundnut (*Vigna subterranea*)is an indigenous African crop that has been cultivated in Africa for centuries. It is a highly nutritious plant which plays a crucial role in people's diets and is currently grown throughout Africa. It is an indigenous food crop in western Kenya and has potential for reducing food and nutritional insecurity. Despite its usefulness in terms of nutrition and improvement of soil fertility, it remains neglected by the scientific community and is commonly referred to as a poor man's crop.

The main objective of the study was to evaluate the role of Bambara groundnut (*Vigna subterranea*) in cropping systems. Structured questionnaires and survey checklists were used in the study to determine the extent of the use of Bambara groundnut in the region. The Bambara crop is mainly grown during the short rain season between September and December. Its production area per house hold has been diminishing over the years since the late 1980s. Over 75% of the farmers grow Bambara groundnut as an intercrop with cereals mainly maize and to a little extent, sorghum and millet. The knowledge of the crop remains low and marketing opportunities need to be developed.

RESEARCH ON BIOLOGY OF *AMARANTHUS CRUENTUS* L. (G6 VARIETY) UNDER CLIMATIC CHAMBER CONDITIONS FROM ROMANIA

Gheorghe Valentin Roman and Maria Toader

The biology of the Amaranth (*Amaranthus cruentus*, L. var. G6), a new crop for Romania, has been studied in the phytotron between 23rd of April – 17th of September 2006, The duration of the vegetative cycle was found to be 131 days or 775.1 ^{o}C GDD (Growing Degrees Days) ($\Sigma t>15^{o}C$).

In phytotron conditions plants developed 8 nodes on their main stem, whole length (measured to the inflorescence apex) was 116.5 cm. 28 leaves developed on the main stem.

Flowering commenced 100 days post-emergence at the base of the inflorescence, seed development was apparent 15 days later, the crop was matured on September 17th. Seed moisture content was 11.93% at harvest; the mean 1000 seed weight was 1.49g. Nutritional value of seed was measured in terms of the carbohydrate (starch), lipid, protein, and other significant components.

This research demonstrated that in the conditions of 2006 in Romania seed content was higher in protein, starch and lipids than in samples from Slovenia. Differences were 0.49% for protein, 1.8% for starch and 0.75% for lipids.

GENETIC DIVERSITY AND CONSERVATION OF BAOBAB (*Adansonia digitata* L.) POPULATIONS IN BENIN

A.E. Assogbadjo, T. Kyndt, B. Sinsin, G. Gheysen, P. Van Damme

Baobab (*Adansonia digitata* L.) is a multi-purpose trees used daily by rural African communities. The present study aimed at investigating the level of morphometric and genetic variation and spatial genetic structure within and between threatened baobab populations from the three climatic zones of Benin.

A total of 137 individuals from six populations were analysed using morphometric data as well as molecular marker data generated with the AFLP technique.

Five primer pairs resulted in a total of 217 scored bands with 78.34% of them being polymorphic. A two-level ANOVA of 137 individuals from six baobab populations revealed 82.37% of the total variation within populations and 17.63% among populations ($P < 0.001$). Analysis of population structure with allele-frequency based *F*-statistics revealed a global F_{ST} of 0.127 ± 0.072 ($P < 0.001$). The mean gene diversity within populations (Hw) and the average gene diversity among populations (Hb) were estimated at 0.309 ± 0.000 and 0.045 ± 0.072, respectively. Baobabs in the Sudanian and Sudan-Guinean zones of Benin were short and produced the highest yields of pulp, seeds and kernels in contrast to those in the Guinean zone, which were tall and produced only a small number of fruits with a low pulp, seed and kernel productivity. Statistically significant correlation with the observed patterns of genetic diversity was observed for three morphological characteristics: height of the trees, number of branches and

The results indicate some degree of physical isolation of the populations collected in the different climatic zones and suppose a substantial amount of genetic structuring between the analysed populations of baobab. Sampling options of the natural populations are suggested for *in* or *ex situ* conservation.

AERIAL YAM – A POTENTAIL UNDERUTILISED CROP FOR THE RESOURCE OF POOR PEOPLE OF BANGLDESH

Abul Kalam Azad, Mian Sayeed Hassan and Md. Abdur Razzaque

The Aerial Yam (*Dioscoria bulbifera* L.) is an underutilised tuber crop in Bangladesh. It is currently grown in parts of the country but has potential as a vegetable crop over the whole country. It is rich in carbohydrates, sodium and potassium and can supplement staple crops in times of food shortage. Returns from the crop are good and involve little investment and can serve as a vital role in alleviating poverty. Selection for high yield and seed multiplication would be needed in extending its area of cultivation. The popularisation of the crop could enhance family income generation.

DOMESTICATION OF BAOBAB AND TAMARIND IN WEST AFRICA

A.E. Assogbadjo, B. Fandohan, S. Edon, B. Sinsin and P. Van Damme

African baobab (*Adansonia digitata* L.) and tamarind (*Tamarindus indica*) are two key economic trees used daily in the diet of rural communities of West Africa. These species are threatened in the wild, not yet well domesticated whereas their conservation status is still unknown in the West African region. As such, the DADOBAT project financed by the European Union, aims at developing sustainable production systems of baobab (*Adansonia digitata* L.) and tamarind (*Tamarindus indica* L.) in Benin, Ghana, Mali and Senegal, based on characterisation, conservation, and use of local genetic resources. Six work packages will be developed during four years to attain the above mentioned objective.

The main objective of work package 3 DADOBAT project is to develop optimal strategies for the baobab and tamarind trees domestication in the parkland agroforestry systems of West Africa. This work package specifically aims to: (i) Identify best propagation methods (by seeds and vegetatively); (ii) Identify the best potting mixture; (iii) Identify dormancy and causes of accessions. The best methods for breaking dormancy and (iv) Identify superior in terms of growth and stress resistance.

As a first step, local perception of tree variation in the two species will be elucidated through ethnobotanical surveys on human/cultural significance of morphological variation, use forms, preferences and management of variants, in order to identify and document processes of artificial selection and their targets. Different morphotypes will then be described based on quantitative descriptors of the trees parts and products. Considering the different identified morphotypes, germplasm will be subsequently collected for longevity and propagation tests.

It is expected that this project will provide, on the basis of scientific research, technical knowledge and guidelines to the main actors allowing them to solve bottlenecks that limit wider domestication opportunities of baobab and tamarind trees for the benefits of local farmers.

HOUSEHOLD ANALYSIS ON LOCAL KNOWLEDGE, DOMESTICATION AND USE OF *Moringa oleifera* IN THE VOLTA REGION OF GHANA

Suzanne Enoh-Arthur and Patrick Van Damme

A survey of different localities in Ghana in assessing the extent of local knowledge, of the domestication and household use of *Moringa oleifera* was carried out. This study evaluates the involvement of women in the Volta region of Ghana in the *Moringa* production chain. They agreed with their Senegalese counterparts that *Moringa oleifera* is indeed ‘mother’s best friend’, as it is well-appreciated in household nutrition. The responses from 26 females from north, mid and south Volta localities indicated some local knowledge of domestication and household use of *Moringa oleifera.* According to literature 'Yevu-ti', meaning white man's tree, is the local Ewe name for the species used in the Volta region. This study has revealed 3 other local Ewe names for the tree. In the north and mid Volta, it was found that many women who knew the Moringa tree used it in their household for food and other purposes but only about 30-50% of them planted the tree on their farms or in their surroundings. In south Volta, however, all respondents who knew the tree were involved in its domestication and application in household nutrition and traditional medicine amongst other uses. The majority of the respondents interested in *Moringa oleifera* production and utilisation were middle-aged, married women, and parents with children under the age of 18 years benefiting directly from the minerals and vitamins contained in the tree's leaves, which are prepared as a vegetable. The study has justified the need to continue further investigation on characterisation, domestication and use of this underutilised tree species.

COLLECTION, CONSERVATION AND USE OF UNDERUTILISED CROPS NIGER (*Guizotia abyssinica*) AND SESAME (*Sesamum indicum*) FOR POVERTY REDUCTION OF MARGINAL FARMERS IN NEPAL

Ram Narayan Chaudhary

Nepal is predominantly an agricultural country and in Nepal the population engaged in agriculture is around 66% Agriculture contributes 39% in GDP. Eighty percent of Nepalese live in rural areas and 67% of the area is under rainfed agriculture. Oilseeds occupy 5% of the total cropped area and cover 50% of the cash crop area. Of the oilseeds crops rapeseed-mustard is the most important. Niger (*Guizotia abyssinica*) and sesame are traditional oilseed crops of Nepal and are grown by marginal poor farmers. The area under oilseed crops is 187823 ha, production is 141989 ton while productivity is 756 kg/ha (MOAC 2004/05).

The area under niger and sesame is around 6000 ha and 5000 ha respectively. The productivity is very poor, around 200-300 kg/ha. The low productivity can be attributed to several biotic, abiotic and socio-economic factors. In Nepal production in mid-hills, inner terai and terai regions. Niger and sesame are grown as rainfed crops on marginal to poor soils including sands and loams or well-drained clays. Mostly poor farmers grow these crops without giving much importance. Niger is exportable and during 2004/2005 about 12 M/T niger seeds were exported. Sesame has varied use such as oil extraction, pickle and sweet making and for religious purposes. However the potential of these crops is underutilised. . These crops are important, as oils obtained from them are a major source of edible oil.

Addressing their needs requires that we broaden the focus of research and development to include a much wider range of crop species which are neglected but which are of direct relevance to the rural economy of these poor areas. Studies on such crops in term of research and development are important. Thus research and development of niger and sesame crops can boost total oil production and consumption in the country.

It will help in reducing oil imports. It can raise the income of poor rural farmers if the productivity of crop is enhanced through cultivation of high yielding varieties and proper use of manures and fertilisers and necessary crop husbandry practices.

The goal of the project is poverty reduction by use of neglected and underutilised crops. During 2007 landraces of sesame and niger were collected in Siraha, Dhanusha, Udaypur, Chitwan and Arghakhanchi districts. A total of 10 accessions of sesame and 20 acccessions of niger will be evaluated in field trials during the coming rainy season.

PLANTS, PEOPLE AND THE ENVIRONMENT

***N. Haq, C. Bowe, M. Rahman, S. Naranjo, M. Hudson and I. Williams*.**

The benefits of underutilised plant species in addressing important issues in a changing world have become more apparent. The species have traditionally provided food and nutrition, income, energy, medicine and industrial uses (Williams and Haq, 2003) and still represent potential resources: The Centre for Underutilised Crops (CUC) at Southampton University carries out a broad range of research activities for the improvement and use of underutilised crops and other plants for sustainable development in a changing environment under the theme of “plants, people and the environment”. This research theme encompasses all aspects on the commodity chain from germplasm resources to processing and marketing and the projects are implemented in partnership with other partners both in developed and developing countries around the world.

Since 1990 CUC has focused on improvement and promotion of underutilised tropical fruits. This work continues with CUC acting as a partner within several consortia PAVUC (Producing Added Value from Underutilised Tropical Fruit Crops) in Latin America, DADOBAT (Domestication and Development of Baobab and Tamarind) in Africa and projects on germplasm characterisation, evaluation, improvement and adaptation of fruits trees in Asia.

Studies are now being conducted into plant diversity in relation to morphology, nutraceutical characteristics and the ecological niche. Modelling techniques are also applied to study the relationship between diversity and environment in order to select appropriate germplasm for adapting crops to climate change. This research involves tamarind, baobab, jackfruit, pummelo, mangosteen and a number of legume species. Other studies are being conducted on agro-ecological systems to analyse the temporal and spatial distribution of indigenous crop diversity used in cropping systems by smallholders in Malawi.

An investigation is being conducted into the political concept of ‘Food Sovereignty’ defined as ‘the right of people, communities and countries to define and implement their own agricultural and food policies and strategies for sustainable production, distribution, and consumption of food’(World Forum and Food Sovereignty 2001).

An ongoing investigation on genetic effect of *Brassica* spp. for phytoremediation of heavy metal pollution is progressing and current results are presented in a separate poster.

CUC is also part of "CROPGEN" which has been involved in the classification, selection and testing of crop species and their residues with respect to their potential use as energy crops. Additionally CUC is developing projects in the UK and abroad to identify appropriate species that can be used for sustainable biofuel and bio-composite production.

STUDIES ON DIVERISTY OF UNDERUTILISED TROPICAL FRUITS AND THEIR ADPADTATION TO ECOSYSTEMS IN A CHANGING CLIMATE

Colm Bowe and Nazmul Haq

Climate change is likely to have a significant impact on food, nutrition and availability of industrial raw materials. The increase in variability in rainfall and rising temperatures is leading to unpredictable variability in weather and increased likelihood of extreme events such as drought. The crop species which at present support these services may not have the capacity to meet the demands and needs of populations under these changing conditions. The impact on people's livelihoods will be greatest in the developing world, mainly because the populations of these countries are more dependent on agriculture for food goods, services, national income and employment. Poverty, limited resources and poor infrastructure constrain these countries' abilities to invest in and develop technologies to enable adaptation to climate change. Smallholders within these countries have little flexibility in terms of changing planting materials, practices or technologies to variability. It is therefore of high priority to identify means by which farmers in marginal areas can minimise their exposure these kinds of risk.

An investigation is being carried out on the potential germplasm diversity of underutilised tropical fruit species for reducing the amplitude of impact that year to year variability and changes in climate trends, have on the production of these species. The study aims to elucidate how germplasm diversity of these species adapted to a range of ecosystems can be selected for sustainable production in the face of continuing climate change. Initial work has been carried out on jackfruit (*Artocarpus heterophyllus*) in Asia. Work is also being conducted on tamarind (*Tamarindus indica*) and baobab (*Adansonia digitata*) in Africa. This involves:

1. Mapping (geo-referencing) germplasm records
2. Assessment of spatial variation in germplasm characters
3. Combining germplasm records with digital environmental datasets in a GIS system
4. Using Multivariate statistical methods such as Principle Component Analysis (PCA), Canonical Correspondence Analysis (CCA) and Multiple regression to derive relationship between diversity and climate, soils and production systems.
5. Using derived information on relationships to predict adaptation of suitable high quality germplasm under different climate change scenarios
6. Socio-economic analysis of benefits of the use of newly identified germplasm and their fitness within the existing production systems

Initial results from PCA analysis of morphological characteristics showed jackfruit to cluster in component space based on country. Major difference appeared to be due to fruit size and percentage pulp. The influence of environmental factors and production system on this variation will be analysed.

COLLECTION AND CHARACTERISATION OF GERMPLASM OF SOME UNDERUTILISED PLANT SPECIES IN PAKISTAN

Zahoor Ahmad, S. Hussain, M.S. Iqbal, M. Irfan, N. Rehman, A. Jamal, A. Qayyum and A. Ghafoor

Two projects funded by the Pakistan Agricultural Research Council under Agricultural Linkage Program and Southampton University, UK, were carried out on underutilised crops with potential for greater use in Pakistan. Those considered most important for crop diversification were collected, namely *Nigella sativa* (109), *Plantago ovata* (107), *Sesamum indicum* (216), *Ricinus communis* (78), *Cyamposis tetragonoloba* (116), *Linum usitatissimum* (102), *Crotolaria juncea* (112), *Vigna unguiculata* (215), *Phyllanthus amblica* (20) and *Tamarindus indica* (24).

Germplasm collected was largely for characters contributing to yield. High genetic variability for quantitative traits in *Nigella sativa, Plantago ovata, Ricinus communis, Sesamum indicum* and *Cyamposis tetragonoloba* was recorded. There was low variability in *Tamarindus indica* and *Linum usitatissimum* among the species characterised. Based upon evaluation data, elite germplasm lines particularly for yield were identified. Seed of 4 accessions of *Nigella sativa* showing high yield potential were multiplied and distributed to farmers. In *Phyllanthus emblica*, three clones namely Desi, Shisha and Banarasi are mainly found in Pakistan. Desi are wild, while Shisha and Banarasi are vegetatively propagated in cultivation.. The fruits from Shisha clones are used in pickles and Banarsi with large fruit size are preserved and processed for a variety of uses.

RICEBEAN: FOOD SECURITY THROUGH POPULARISATION OF AN UNDERUTILISED GRAIN LEGUME IN INDIA AND NEPAL

P.A. Hollington, K.D. Joshi, R.A.E. Mueller, P. Andersen, J.P. Yadavendra, N. Kumar, S.B. Neog, J. Bajracharya and P.K. Shrestha

Ricebean (*Vigna umbellata*) is a neglected legume cultivated on small areas by subsistence farmers in hill areas of Northern India and Nepal. Most is grown as animal fodder, while a smaller proportion is used for human nutrition. Ricebean is intercropped with maize, and grown on rice bunds or on terrace risers, as a sole crop on the uplands or as a mixed crop with maize in the *khet* land (bunded parcels of lands where transplanted rice is grown) as a fodder and or green manure crop during spring. It receives almost no inputs, and is grown on residual fertility and moisture and in marginal and exhausted soils. The area and production of ricebean is declining due to introduction of high yielding maize varieties and increasing use of chemical fertilisers, and consumption is decreasing due to increased availability of more preferred pulses in the local markets. No modern plant breeding has been done, and only landraces are grown. Despite this, as a legume ricebean should have an important contribution to make to mixed subsistence farming systems. It is important culturally, and is thought to possess important nutritional characteristics which could give it a major role in improved diets and food security in the areas where it is currently grown and elsewhere. This poster describes a major initiative funded under the INCO programme of the EC's FP6 to popularise ricebean on a wider scale.

We involve three European partners (all universities), and five in S Asia: two Agricultural Universities and a major NGO in India and in Nepal a large NGO and the National Agriculture Research Council.

Our objectives are to analyze the supply chain for those stages where product value is potentially lost, or where information on ricebean quality may be compromised or lost; to asses genetic diversity and indigenous knowledge on ricebean in India and Nepal using a range of techniques, and to characterise germplasm for phenological traits and suitability for a range of cropping systems and environments; to assess the potential impact of improved pulse availability on local human nutrition; to develop an index to allow breeders to assess the value of new legumes in terms of monetary value to consumers; and to develop better marketing methods for high-quality, protein-rich products to increase market accessibility and product value, and to promote export value; and to develop policies in support of these to build food security.

The work is structured in five workpackages: Supply-chain, consumer demand and marketing; assessment of genetic diversity and indigenous knowledge; molecular markers; germplasm characterisation and adaptation; and nutrition and health.

The poster will detail these areas, and present project results not presented elsewhere in the conference. We hope it will serve to advertise the project, and lead to the development of linkages and aid networking.

CHARACTERISTION OF BAOBAB AND TAMARIND ACCESSIONS IN WEST-AFRICA

Sitske De Groote, Patrick Van Damme, Colm Bowe and Nazmul Haq

Baobab and tamarind are species with high potential for arid and semi-arid areas in the developing world. They can provide food, medicine, wood and a number of secondary processed products for income generation that can help to meet basic needs of an increasing number of people in a context of decreasing land availability. Despite their potential, both species remain underutilised. Nevertheless, baobab and tamarind are among the top five species for enhanced domestication in West-Africa.

For this, we focus on matching the intraspecific diversity of locally important trees to the needs of subsistence farmers, product markets and agricultural environments, starts from the characterisation of the diversity of baobab and tamarind populations.

The DADOBAT project (Domestication and Development of Baobab and Tamarind) aims at developing sustainable production systems of baobab and tamarind in Benin, Mali and Senegal based on characterisation, conservation and use of local genetic resources. This is expected to have a positive impact on food security and income generation in the countries involved.

The specific objective is to identify superior accessions, leading to cultivar development which can then be introduced in improved agroforestry systems.

Baobab and tamarind populations in different agro-ecological zones of Benin, Mali and Senegal will be characterised for tree-to-tree variation in a range of commercially desirable traits. Consumer preferences will be identified through ethnobotanical and market surveys, and producer preferences will be established through dialogue with farmers, industry and small and medium enterprises. Agronomic parameters, such as yield and stress resistance, will also be used in the development of ideotypes.

Characterization and analyses of genetic diversity of populations will permit the selection of superior germplasm and suggest conservation strategies for the species, as cultivar development implies a risk of genetic erosion.

Different ideotypes will be identified targeting different market opportunities. Characterisation of existing variation will identify which germplasm matches the developed ideotypes. Selected germplasm will then be propagated and used in participatory domestication programmes.

DEVELOPMENT OF IMPROVED CROPPING TECHNIQUES OF BAOBAB AND TAMARIND

Amadou Malé Kouyate and Patrick Van Damme

Gathered plant products play a fundamental role in the socioeconomic life of populations in West Africa. Among these, baobab (*Adansonia digitata* L.) and tamarind (*Tamarindus indica* L.) are favoured by populations, but can be considered as underutilised crops. The project Domestication and Development of Baobab and Tamarind (DADOBAT) addresses issues of new crop/niche development through a holistic research approach and envisages multidisciplinary activities to broaden availability of improved plant material for introduction into agroforestry systems, in Benin, Mali and Senegal. The present poster describes the development of improved cropping techniques of baobab and tamarind which is one of DADOBAT work packages.

To identify management practices for optimal leaf production and quality, and plant growth and development; to identify optimal irrigation method, watering frequency for optimal yield and water use efficiency; to identify fertiliser needs and establish influence of fertiliser on plant growth and development; and elaborate didactic tools for improved cropping techniques.

This work package covers: (1) the influence of pruning and other simple management techniques will be assessed on trees selected from the wild; on station research will (2) look into the possibilities of irrigation, as leaf (and bark) production is strongly related to water availability. Fertilisers are basically never applied to either

species; in this WP, however, (3) different fertiliser regimes will be applied to both species, and (4) influence on leaf quality will be assessed. Tests will typically be multi-locational and multi-annual. Later, and beyond the present project's life span, fruit quality as influenced by irrigation x fertiliser regimes will be assessed.
Expected results include;
- Optimal combination of management practices for leaf production and quality, and plant growth and development should become apparent.
- Optimal watering regime (in terms of WUE, and taking into account water scarcity in most experimental zones) will become known and documented.
- Fertiliser recommendations should become available for different agro-ecological zones.
- A Cropping manual presenting management techniques (incl. irrigation and fertilisation) will be made available.

ECO-PHYSIOLOGICAL CHARACTERISATION OF *Tamarindus indica* AND *Adansonia digitata* FOR UNDERSTANDING DROUGHT STRESS TOLERANCE/RESISTANCE IN SITU AND EX SITU

Sali Bourou, Aïssata Ba, Marème Niang Belkp, Macoumba Diouf and Dogo Seck

Ecosystem degradation in the world is often related to climatic changes. The most important factor for agricultural production in sub-Saharan Africa is probably precipitation. Precipitation has however been increasingly scarce and irregular in the last decades, leading to a lower agricultural production. This has caused food insecurity in the region. Therefore it is necessary to diversify food production by introducing wild or semi-domesticated fruit trees in agricultural production systems, as a means to contribute to ecosystem preservation and farmer's income.

Tree species such as *Tamarindus indica* and *Adansonia digitata* play an important role in nutrition, socio-economics and ecology of traditional communities and are thus key species in crop diversification programmes. The nutritional, socio-economic and ecological importance of these species is widely recognised. Leaves, fruits and bark are consumed by humans and livestock. Additionally, they are also extensively used in traditional medicine.

Introduction of tree species in traditional farming systems requires good knowledge of the plant material and the selection of plus trees in relation to drought response. The aim of this study is to characterise the response of tamarind and baobab to drought and to study their mycorrhizal associations in Senegal.

The characterisation of the response of both species to drought stress is done at two levels: *in situ* (adult trees) and in the greenhouse/phytotron (young stage).

A sample of three mature trees will be chosen for each diameter class (the stand will be divided in three diameter classes) in two different agro-ecological zones. Water potential, water balance, net photosynthesis, chlorophyll fluorescence, stomatal resistance will be measured; water balance and sap flow will be monitored and results will be linked to precipitation (rainfall) and other climatic parameters as relative humidity and temperature. A phenologic diagram will be established for adult trees.

Young plants will be kept in the greenhouse and phytotron, where drought stress is induced by water supply suspension. The following parameters will be measured: physiological parameters such as net photosynthesis, chlorophyll fluorescence, stomatal resistance and morphological parameters such as root biomass, shoot biomass, shoot height. In the second part of this study, the mycorrhizae naturally associated with both tree species will be identified.

Soil samples and fine roots will be collected under ten mature tamarind trees in 3 stands in each agro-ecological zone. Tamarind and maize will be cultivated in the greenhouse on these soils for trapping mycorrhizae, and spores from soil and root of these young plants will be isolated. Isolated spores will be identified using morphological and molecular characterisation. Subsequently, the effect of these mycorrhizal associations on growth and development of young plants will be evaluated.

Eco-physiological behaviour of *Tamarindus indica* and *Adansonia digitata* is characterised; the strain of mycorrhizae associated with tamarind roots are known and their effects on growth and development are understood.

SUBSISTENCE FARMERS' PERSPECTIVE ON NEW AND UNDERUTILIsED CROPS: INCORPORATING DESMODIUM INTO FARMING SYSTEMS IN AFRICA

V.A. Solomon, L.Wadhams and Z. R. Khan

The study explored the need for incorporation of Desmodium in farming systems from the perspective of subsistence farmers. Desmodium sp. is widely used in conjunction with Napier grass in the Rothamsted-ICIPE 'push-pull' strategy for stem-borers and striga control. Data were collected from subsistence farmers in the Suba Region of Kenya and Western Nigeria. Preliminary analysis indicates that subsistence farmers are willing to incorporate new and underutilised crops into their farming systems if the crop has obvious benefits to them, especially if the crop has food and economic value. It is concluded that for new and underutilised crops to reach their optimum capacity in yield and utilisation, there is a need to strengthen the capacity of subsistence farmers through agricultural extension communication and education. In this paper, the economic importance of Desmodium to subsistence farmers is discussed.

BASIL: AN ORNAMENTAL AND CULINARY HERB

M.D. López and M.J. Pascual-Villalobos

Ocimum basilicum L. (Lamiaceae) is a popular culinary herb, the leaves either fresh or dried and, add a mint like flavour to food. The plants have ornamental value, particularly the purple varieties. Basil essential oil produced in the Mediterranean region, the USA and Africa has applications in cosmetics.

A basil germplasm collection was grown at "Torreblanca" Experimental Station in Murcia (Spain). The objective was to study the morphological and chemical variation among accessions. Differences were found in earliness, plant height, growth habit, leaf size and leaf colour of the genotypes. Yields of essential oil ranged from 0.5 to 1.8 % of fresh weight. The main components of the oils were linalol and estragole although a number of other monoterpenoids and phenylpropanoids were also identified. The products isolated from basil essential oils are being studied, as botanical insecticides against pests of stored grain.

DOMESTICATION OF NELLI (*PHYLLANTHUS EMBLICA* L.) IN SRI LANKA FOR FOOD AND NUTRIENT SECURITY

D.K.N.G. Pushpakumara

Nelli or Amla (*Phyllanthus emblica* L.) of the family Euphorbiaceae is a medicinal fruit tree which grows naturally in the dry deciduous and savannah forests of India and Sri Lanka. The economic part of Nelli is the fruit with high nutritive and therapeutic values. It is one of the highest sources of vitamin C. The medicinal properties of elli has been mentioned in old ayurvedic texts and is the basis for many ayurvedic preparations. Although Nelli has a wide range of domestic and industrial uses, it is currently neglected in Sri Lanka and its uses are not properly exploited. Multi disciplinary, multistakeholder research has been undertaken with the objective of domestication of elli in Sri Lanka in collaboration with University of Peradeniya, Sri Lanka Council for Agricultural Research Policy, Private Sector, ICRAF Sri Lanka and ICRAF South Asia, New Delhi.

Germplasm was collected from 68 accessions with geographic locations (using a GPS) in different growing ares of Sri Lanka and the morphological characters were recorded using a descriptor list. Statistically significant variability was observed for fruit weight and flesh thickness and seed:flesh ratio. The fruit weight ranges from 3-25 g, the flesh thickness range from 3-15 mm and it forms 30-50% of the fruit. Selection criteria were identified for mother plants and links were established with Indian scientists to exchange already improved germplasm. Studies on reproductive biology of the species revealed that it is seasonal in the dry deciduous area with one major flowering and fruiting season but in the wet areas it has two fruiting seasons. Its sexual system is monoecious with a highly variable sex ratio (90:1-250:1). Seed and vegetative propagation techniques were tested successfully for Nelli. Marketing channels were identified and value added products were documented. A popularsation campaign was established through newspaper articles and radio programmes. Selected seedlings were distributed among rural organizations with support from a private company and NGOs and plant growth, development and production are being monitored.

PROGRESS OF ACUC-CARP-UP RESEARCH ACTIVITIES ON SELECTED UNDER-UTILISED FRUIT TREES IN SRI LANKA

D.K.N.G. Pushpakumara and H.P.M. Gunasena

The effective domestication of underutilised fruit trees (UFT) requires the collection and characterisation of germplasm and selection of elite mother plants. However, in Sri Lanka, organised collecting and characterisation of UFT germplasm is limited to few species such as *Artocarpus heterophyllus* (Jackfruit), *Durio zibethinus* (Durian), and *Garcinia mangostana* (Mangosteen). A new research programme has been was initiated to collect, characterise and conserve germplasm of gal siyambala (*Dialium ovoideum*), lavulu (*Poturia campuchiyana*), jambu (*Syzygium* spp.), goraka (*Garcinia quaesita*), madan (*Syzygium cumini*), orange (*Citrus* spp.), uguressa (*Flacourtia indica*), veralu (*Eleocarpus serretus*) and gaduguda (*Baccurea mottleyana*).

Meetings were held with stakeholders of UFTs to identify current levels of understanding of the species and these led to the preparation of status reports on each species - including distribution of each species in Sri Lanka, availability of planting material, level of collection, utilization, marketing, processing and postharvest problems. Based on availability of fruits, so far germplasm collecting was started with four species, namely gal siyambala, lavulu, jambu and goraka to represent different climatic regions and characterised using morphological descriptors based on the perceived importance of the species for future utilisation. The exploration and collection of five species revealed the availability of a wide genetic diversity reflected by morphological characters. Selected elite mother plants possessed outstanding characteristics for fruit quality. Seeds collected from germplasm of each species were used to identify germination requirements of each crop and germination can be easily practiced for all species at low cost and no seed treatments. Germinated seeds were potted with the identification tag of the mother plant and progeny number and used to establish progeny trials for further selection. Vegetative propagation techniques for each species were reviewed and the most suitable techniques were further tested for large scale planting material production. Establishment of a germplasm unit and a progeny trial at University of Peradeniya and Department of Agriculture Farms was initiated. The evaluation of growth performance of seedlings and grafted plants established under progeny trial is progressing.

PRESENT STATUS AND FUTURE PROSPECTS FOR UNDERUTILISED FRUIT TREES IN SRI LANKA

H.P.M. Gunasena and D.K.N.G. Pushpakumara

Underutilised crops have made a significant contribution to Sri Lanka's agriculture from time immemorial. These crops formed part of the traditional subsistence farming systems, which contributed to the daily needs of food and nutrition, in addition to meeting the medicinal requirements of the rural households. In the past two decades the underutilised species have been receiving more attention as promising targets of research and development to alleviate hunger and poverty in Sri Lankan rural communities. The presence of a wide range of specie diversity covering over 237 species from 56 families has been noted. These species represent an enormous wealth of agrobiodiversity, having a high potential for supporting enhanced incomes, food and nutritional security and minimising hidden hunger caused by micronutrient deficiencies - mainly mainly vitamins and minerals. The challenge of the Millennium Development Goals for Sri Lanka is not only to halve hunger by 2015, but also to reduce pervasive poverty, which currently exceeds 30%. Two emerging issues relating to underutilised crops have to be stressed. One is the herbal medicinal value of underutilised crops and the other is global climate change and the fate of future agriculture, which is more and more evident.

More than 75% of the Sri Lanka's rural people use traditional medicine. These are becoming popular among the more affluent also due to their exceptional healing abilities for diseases such as hypertension, diabetes and cancer. Large numbers of underutilised species are presently used commercially for the preparation of herbal medicines, some of which are exported. The industrialists find it hard to collect adequate volumes of these, hence the demand is high, and severe erosion of genetic diversity is taking place due to wild collecting and lack cultivation. Consequently, collection and conservation is urgently needed. The other is the climate change which calls for diversification as dependence on a few crops will be too risky. Therefore, underutilised crops will provide ample opportunities for cultivators to develop sustainable farming systems.

The role of underutilised crops in farming systems is strongly linked to the cultural heritage of the country, which makes it easier to promote them. Many of traditional crops have specific agro-ecological niches, mostly grown in marginal lands often unsuitable for improved crop varieties. Therefore, Sri Lanka has taken several initiatives to promote them by establishing multi-stakeholder networks.

Research and development programmes on underutilised multipurpose species were initiated as early as 1987 under the Multipurpose Tree Research Network sponsored by Winrock International. This network laid the foundation for collection and characterisation of underutilised tree species such as *Gliricidia* and *Calliandra*, mainly for soil amelioration. Subsequently, the International Centre for Underutilised Crops (ICUC) based at the University of Southampton commenced networks on underutilised fruits (UTFANET), and its activities culminated in the establishment of the Asian Center for Underutilised Crops (ACUC) at the Secretariat of the Sri Lanka Council for Agricultural Research Policy (CARP) in 2003. ICUC has conducted a series of training programmes for small-medium entrepreneurs on fruit processing, which had positive outcomes in that more that half of the trainees established viable fruit processing industries. ACUC has provided research grants to Pakistan, Nepal Bangladesh and Sri Lankan scientists to work on specific underutilised crops. In addition, CARP provided funds to collect, classify and analyse chemically of many underutilised species of fruits, which have been documented. Sri Lanka-USAID Cooperate Germplasm Development program operated by the Department of Agriculture has also collect and established *in situ* germplasm banks at Gannoruawa and this program is yet continuing. The most recent is the involvement of the World Agroforestry Center (ICRAF) in underutilised tree research and development which involves development of medicinal and fruit tree networks, and collections, molecular characterisations and documentation of selected species.

Several surveys conducted over the years have revealed that there are many problems in the promotion of underutilised crops. Some of these are lack of formal seed and planting material supply systems, inadequate information on production techniques, harvesting, processing and value addition, storage and marketing. The priority research areas have been identified for many of the underutilised species and a coherent R&D programme is being implemented.

MOROGO (TRADITIONAL LEAFY VEGETABLE) IS NOT A WEED OR POOR MAN'S CROP ANYMORE

W.S. Jansen van Rensburg, H.J. Vorster and S.P. Ntombela

The leaves of various wild and weedy species are harvested form the veldt and fallow land in South Africa. These are collectively known as *morogo* in the Sotho languages and *imifino* in the Nguni languages. The preference for a specific species depends on ethnicity, climate, age and gender but the most popular morogo species are amaranth, cleome, cucurbits, corchorus and cowpea.

Morogo was labelled as a poor man's crop or famine food during the latter half of the previous century due to the exclusive promotion of "modern" crops by extension services. The youth tends to prefer the more fatty "fast foods". However, this perception is changing in Africa. Many of the species usually harvested from the wild are now cultivated in home gardens and are rapidly becoming cash crops.

However, there is still a lot to be done to improve the perceptions of morogo. Although studies suggested that the market for morogo is limited, it has the potential to be exploited as a crop to enhance food security and as a cash crop and delicatessen item. Informal tasting by restaurateurs and chefs indicated that some morogo dishes would be very acceptable for the modern and western palette and that several morogo species could be included in modern diets if recipes are developed to incorporated it into daily diets. Currently the marketing of morogo is mostly done informally from wild harvested material. If morogo is to be marketed more widely attention should be given to develop optimum cultivation practices and "modern" recipes.

THE UNDERUTILISED BERRYCACTUS (*Myrtillocactus geometrizans*) CONTROLS DIABETES SYMPTOMS IN EXPERIMENTAL INDUCED WISTAR RATS

A. Guzmán-Tovar.,R. Topete-Viniegra, D. Hernández-López, F. Vaillant, R. Camacho-Reynoso and S.H. Guzmán-Maldonado

The hypoglycaemic activity of berrycactus (Myrtillocactus geometrizans) extract was evaluated on streptozotocin-induced (STZ-induced) diabetic rats. Berrycactus extracts showed an effect of satiety in non diabetic and diabetic rats. Also, body weight gain was higher in groups of rats receiving berrycactus compared to those of the control group receiving water. Hypoglycaemic experiments showed that blood glucose concentration in nondiabetic rats receiving berrycactus was similar to that of control group along a 4-h hypoglycaemic experiment and a 4-week chronic experiment. Berrycactus lowered blood glucose concentration in diabetic rats along a 4-week chronic experiment compared to that of control group. Berrycactus extract lowered up to 50% the concentration of blood triglycerides, 33% total cholesterol and 40% low density lipids (LDL) in diabetic rats. Levels of high density lipids (HDL) were similar to that of control group. A decrease of reduced glutathione (GSH) (up to 38%) and glutathione-S-transferase (GST) (up to 30%) in kidney and liver of nondiabetic rats was detected and up to 43% (GSH) and 31% (GST) in kidney and liver of diabetic rats after berrycactus supplementation. These encouraging results suggests the need for clinical studies in human.

NUTRITIONAL AND FUNCTIONAL DIVERSITY OF BERRYCACTUS (*Myrtillocactus geometrizans*) COLLECTED FROM THE ARID AND SEMI ARID HIGHLANDS OF MEXICO

A. Guzmán-Tovar.,R. Topete-Viniegra, D. Hernández-López, F. Vaillant, R. Camacho-Reynoso and S.H. Guzmán-Maldonado

The nutritional and functional characterisation of berrycactus (*Myrtillocactus geometrizans*) collected from the four major sites of production in Mexico was evaluated. The chemical composition, vitamin C and minerals were determined. Also, the total contents of phenolics, anthocyanins and tannins as well as phenolic acid were analyzed. Berrycactus show 4.8-5.3 % protein and 21.8-23.2 % fibre, higher to that of prickly pear and other fruits. Also, the contents of ash and lipids were around 4%. The carbohydrates content in berrycactus was approximately 50-60 %. On the other hand, berrycactus is a good source of iron, copper and magnesium; a 100 g portion contribute with 15% of the daily requirements of these minerals. The vitamin C content was 100-200 % higher to that of other fruits including prickly pear. The concentration of functional components in berrycactus was as follows: tannins 2916 ± 11 mg EC/100g, total phenols 450-790 mg EAG/100 and phenolic acids 0.51 ± 0.06 to 38.65 ± 1.25 mg/g including gallic, protocatechoic, vanillic, caffeic, benzoic acids, among others.

PHYTOACCUMULATION OF HEAVY METALS BY BRASSICA SPECIES

Moupia Rahman, Nazmul Haq and Ian Williams

Plants play a significant role in maintaining the environment, particularly through the management of soil. They have the ability to remediate contaminated land by uptaking heavy metals from soil and can reduce the impacts of anthropogenic air pollution by absorbing CO_2 via photosynthesis.

Several Brassica species (*B. juncea, B. campestris* and *B. Napus*) are known to be good in uptaking heavy metals from soil and transporting them into shoots and leaves (Ghosh and Singh, 2005). However, the characteristics of these species vary greatly between cultivars and between species (Wahab *et al.,* 2001), including plant height, number of nodes per plant, number of leaves and size, number of fruits, size and shape, etc. These species also shown variability in their ability to accumulate heavy metals, in particular Cd, Pb, and As, and this variability may be due to some "effective characteristics" (Dushenkov, 1995). Variability for phytoaccumulation of several heavy metals is found within and between plant species (Macnair 2002; Boyd and Martin, 1998). However, the genetic mechanism for such variability in accumulation of heavy metals by plants is not clearly understood. This study aims to understand the nature of variability of certain traits and the genetic mechanism(s) controlling such variability within and between the species.

Brassica juncea is known to be good accumulator of heavy metals. Two varieties, *vars. Rai* and *Bari* of *Brassica juncea,* have been chosen for this study. Heavy metals, Cd, Pb and As have been used for the experiments. Initially, a study of these two varieties and their hybrids was undertaken to identify the behaviour in relation to uptake of heavy metals of targeted morphological traits. This experiment was followed by growing these two varieties of Brassica and their hybrids in hydroponics' conditions. These experiments were carried out under the greenhouse conditions at the University of Southampton {temperature (14-28) ± 7^0C, light intensity (750-1980) lux and day length (13-16) hd^{-1}}

This paper reports preliminary results on the selected morphological traits of the parents (vars. *Rai* and *Bari*) and their hybrids (including their reciprocal hybrids). It appears that in var. *Rai* there are correlations ($p<0.05$) between stem diameter and leaf length, stem diameter and leaf width. Similar results were observed when var. *Rai* was used for accumulation of Cd and var. *Rai* showed higher biomass when compared with *Bari*. *Rai* has also shown correlation ($p<0.05$) between biomass, leaf length and stem diameter with 0.5 and 1 ppm for As and Pb.

The effect of different concentarions (0.5 and 1 ppm) on uptake of Cd by vars. *Rai* and *BARI*, their hybrids and reciprocal hybrids was investigated. It was found that var. *Rai* showed a higher uptake than var. *Bari* for both strengths. However at the higher concentration (1ppm) the uptake of Cd by var. *Rai* was higher. It was observed that there is a strong correlation between the root systems and the uptake of Cd by both varieties.

As differences in uptake of Cd for both concentrations was found, future experiments will be carried out with a range of concentrations of Cd and As using vars. *Rai, Bari* and their hybrids. This will allow to estimate the tolerance with different concentrations and to understand the mechanism of targeted traits for tolerance.

CROPS FOR BIOGAS PRODUCTION; YIELDS, SUITABILITY AND ENERGY BALANCES

Andrew Salter, Charles Banks, Nazmul Haq and Sonia Heaven

When farmers realise they can produce energy from crops, the question often asked is "Which crop should I grow?" Bio-ethanol and bio-diesel can only be produced from a relatively limited range of crops, although the production of ethanol from lignocellulosic materials will lead to an increased range of materials used. In contrast to these liquid bio-fuels, one of the advantages of anaerobic digestion is that almost any organic material can be used. Crops with high lignin content can be more difficult to digest but most crops, at some growth stage, can be used.

The amount of biogas that can be produced from any crop is a result of the methane potential (how much methane can be produced from each kilo of volatile solids) and the overall yield of the crop (how much volatile material can be produced per hectare). Both of these are affected by climate, crop growth conditions and growth stage at harvest. Crop selection is affected by geographic location and crops that are ideal at one location may not be suitable at another. Thus in Austria and Germany, maize provides a good source of feedstock for digesters but in Finland conditions are poor for maize growth and it does not provide a suitable source of material.

The ability to choose from a wide range of crops allows the farmer to use other advantages of the material grown. Most of the crops used to date for bio-fuel production have high requirements for nitrogen, usually supplied in a form produced using fossil fuels. Legumes have a symbiotic relationship with certain bacteria (rhizobia) that gives them the ability to fix nitrogen from the atmosphere and soil, resulting in a reduced requirement for the application of mineral based nitrogen. This has multiple benefits including: reduced use of fossil fuels and therefore reduced CO_2 emissions, improvement of the soil quality, and reduction of farmers' costs. Legumes may also be intercropped with other species, for example vetches and oats, to increase yield. Farmers may therefore look beyond the crop solely as producer of energy and select species that have added benefits for the soil and following crops.

In producing renewable energy it is also vital to consider the energy balance - how much energy is required to produce and process the crop into a form of usable energy, compared to the energy value of the fuel produced. Values have been reported in the literature for the energy requirement of various farming operations. Given knowledge of the operations for land preparation, sowing, maintaining and harvesting a crop it is possible to derive an energy requirement for crop production. When combined with the energy requirements for operating a digester, and disposal of the digestate, it is possible to derive an energy balance for the production of biogas. A guide to energy balances for a number of crops and the required growing conditions have been included in a crop database developed as part of the Cropgen project. The energy balances can be used to compare crops and the relative efficiencies of the different bio-fuels. Thus depending on the crop grown; AD production of biogas has an energy efficiency ranging between 4 and 7, output to input, bio-ethanol has an efficiency of 2 to 2.5 and bio-diesel production using solvent extraction 1.5 to 2.

There is no single answer to the farmer's question "which crop should I grow?". The 'simplest' answer is to grow the crops which give the highest yields at the required harvested growth stages, but the farmer should also be considering crops that will reduce fertiliser requirement, enhance soil structure and reduce costs.

ANTIFUNGAL PROPERTIES OF *Tulbaghia violacea* Harv. (WILD GARLIC) PLANT EXTRACTS AGAINST *Altenaria solani* AND *Sclerotium rolfsii*

N. Mudziwa, M.L. Motsei., E. Van den Heever, P. Soundy and E.S. Du Toit

Tulbaghia violacea is indigenous to South Africa belonging to the family *Alliaceae*. This plant has medicinal properties. Its antifungal, antibacterial and antiviral properties have been widely used by South African traditional healers for the treatment of flu, fever, cold, tuberculosis, cancer of the oesophagus, asthma and many other diseases.

A study was conducted to determine the best season for harvesting and to determine which part of the plant has the highest bioactivity. Crude extracts, prepared, separately, from each of the above ground and below ground parts of *T. violacea*, restricted the growth of two plant pathogenic fungi, *Alternaria solani* and *Sclerotium rolfsii*, in an agar/Petri dish inhibition assay. The highest levels of inhibition (>90%) was observed when using the crude extracts prepared from both the above ground and below ground parts of *T. violacea* plants that were harvested at the end of the growing season, and that had been treated in the field with ammonium sulphate fertiliser (50kg.ha^{-1}). The lowest levels of growth inhibition were observed from plant material that had been harvested during November and December. The application of calcium nitrate did not affect plant bioactivity, as was observed for both of the pathogens.

Further screening will be conducted to verify these results and the minimum inhibition concentration will be determined using plant material that has been treated with ammonium sulphate fertiliser (50kg.ha^{-1}).

PRODUCTION AND MARKETING CHAIN ANALYSIS OF BAOBAB AND TAMARIND

Emmy De Caluwé, Hamady Djouara and Patrick Van Damme

In West Africa, the multipurpose baobab and tamarind tree species are important to producers as they form part and parcel of their (traditional) farming systems, and to both producers and consumers as their products can be sold to generate income whereas their consumption improves the quality of diets. In most producing countries, such as Benin, Mali and Senegal, there is an existing domestic market for both species. The presence of local markets could be used as an indicator of commercial potential of any underutilised species. However, to strengthen the local markets it will be necessary to establish the size of the market, target consumers and the type of products in demand. Therefore, efforts to find potential markets for tamarind and baobab products will be useful to exploit its potential. Both baobab and tamarind already have limited penetration into international markets of fruit and nutraceuticals, but until now these efforts have largely been uncoordinated and thus remain limited in their impact. Reliable scientific studies on the real nutritional and functional potential of baobab and tamarind will lead not only to more commercial interest, but also to the development of appropriate technologies that will allow better supplies.

The general objective is to elucidate market potential of baobab and tamarind products, taking into account current limitations and constraints. The specific objectives are to (1) describe the local market of baobab and tamarind through quantity, price, etc.; (2) document the value chain of baobab and tamarind with all its actors; (3) identify strengths, weaknesses, opportunities and threats of the baobab and tamarind marketing channels; and (4) describe the socio-economic impact of baobab and tamarind.

The different market channels will be described through semi-structured and informal socio-economic interviews with local producers, rural assemblers, producer organisations, co-operatives, wholesalers, distributors, retailers and consumers. Existing local markets of baobab and tamarind and price fluctuations will be documented based on interviews and participatory research. The strengths, weaknesses, opportunities and threats of the baobab and tamarind market will be identified and recommendations will be formulated.

The expected results are (1) the local market of baobab and tamarind are described; (2) the seasonal highs and lows are known; (3) price fluctuations are explained; (4) the different marketing channels are documented; (5) strengths, weaknesses, opportunities and threats of the baobab and tamarind marketing channels are analysed; and (6) the socio-economic importance is known.