Finger millet blast management in East Africa

Creating Opportunities for Improving Production and Utilisation of Finger millet

ICRISAT

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DFID Department for International Development

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Proceedings of the First International Finger Millet Stakeholder Workshop, Projects R8030 & R8445
UK Department for International Development – Crop Protection Programme
held 13-14 September 2005 at Nairobi

Editors

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Foreword

Finger millet, native to East Africa, is entwined in the local culture and traditions. However, in spite of its importance to the livelihoods of millions of small-holder farmers in East Africa, its valuable nutritional and processing properties, the growing demand exceeding supply, and its regional and international trade potential, finger millet has largely been neglected by national and international research organizations and major donors to agricultural research in sub-Saharan Africa. This neglect has contributed to a lack of realization of the potential productivity of finger millet. Increased production, utilization and trade of finger millet in East Africa are currently limited by a number of constraints. The most serious biotic constraint is the blast disease caused by the fungus *Magnaporthe grisea*. Blast affects finger millet at all growth stages, particularly causing major losses through neck and panicle infections.

Recognising the importance of finger millet in East Africa and the serious lack of knowledge of the blast disease and technologies for its management, the UK Department for International Development (DFID) Crop Protection Programme (CPP) funded projects R8030 and R8445, which were implemented in Kenya and Uganda. Significant and rapid advances have been made in understanding finger millet blast in East Africa and in the development and promotion of sound blast disease management strategies through these projects. To initiate the process of fostering innovation and linkages among the key stakeholders in the finger millet production-supply chain in East Africa, a regional workshop was held in Nairobi, Kenya during 13-14 September 2005. The main objectives of the workshop were to present, discuss and disseminate the advances made in the development and promotion of sound blast disease management strategies, to identify opportunities to address other constraints that currently limit production and utilization and to initiate connectivity among the stakeholders involved in the finger millet production-supply chain.

This workshop, the first ever in sub-Saharan Africa devoted to finger millet, provided a unique opportunity for actors from all stakeholder groups to articulate and discuss their activities, constraints and needs and identify priority areas for future investment. Stakeholders included national research and extension services from Kenya, Tanzania and Uganda, farmers, millers and processors, universities, international agricultural research centres, NGOs and development investors. The participation of the Eastern and Central Africa Regional Sorghum and Millet Network (ECARSAM) provided a regional profile and perspective. The potential for innovation in the finger millet sector has been substantially increased through enhanced connectivity and flow of knowledge between the key actors in a finger millet coalition of nearly 20 stakeholder groups across the production-supply chain. Most importantly, it put finger millet on the map for policy makers and a key entry point has been created to address other constraints, such as ineffective weed management, poor grain quality and inefficient seed systems and production-supply chain problems, notably through 'spill-in' and adaptation of relevant technologies developed elsewhere. With further donor investments, the coalition is well-poised to achieve significant increases in finger millet production, utilization and trade in East Africa, to the benefit of producers, consumers, industry and national and regional economic growth.

This volume includes papers presented at the workshop as well as reports and recommendations from the stakeholder interaction sessions held. It is intended to serve as a reference manual not only for scientists involved in finger millet blast management, but all stakeholders involved in the production and utilization of finger millet.

Editors
MA Mgonja
JM Lenné,
E Manyasa
S Sreenivasaprasad

R8445 Facilitating the promotion of improved and blast resistant finger millet varieties to enhance production

Workshop program

Safari Club, Nairobi, Kenya

13 -14 September 2005

ARRIVAL DAY: MONDAY 12 SEPTEMBER 2005

DAY 1: TUESDAY, 13 September 2005

SESSION-TIME	ACTIVITY	RESPONSIBLE
08:00 – 08:30	Registration, Logistics and Review of Documents	P Kaloki, E Manyasa & J Mwangi
SESSION 1	**Introductions, Workshop Context and Opening**	*Chairperson: B Mitaru*
08:30 – 08:45	Introductions	
08:45 – 09:00	Welcoming Remarks	S Silim –ICRISAT
		A Ward-DFID-CPP, UK
09:00-09:10	Workshop Opening	*E Mukisira – KARI*
	Country papers: Finger Millet: importance, advances in R&D, challenges and opportunities for improved production and profitability	
09:10-09:30	Kenya	C Oduori
09:30-09: 50	Uganda	*N Wanyera/J Okwadi*
09:50- 10:10	Tanzania	*D Kisandu*
10:10-10:30	**Health Break and Group photograph**	
SESSION 2	**Finger Millet Research and Development Activities in East Africa**	*Chairperson: B Mitaru*

10:30 – 10:45	Overview and significance of achievements for project R8030	*S Sreenivasaprasad*
10:45 – 11:00	Overview and objectives of Finger Millet project R8445	*M Mgonja*
11:00 – 11:15	Objectives of the workshop	*S Sreenivasaprasad*
11:15- 11:40	Discussion	
SESSION 3	**Progress made on outputs 1 and 2 of R8445 and in related work in UK and ICRISAT**	*Chairperson: S Sreenivasaprasad*
11:40 – 12:00	Kenya	*S Nyaboke*
12:00 - 12:20	Uganda	*J Okwadi /N Wanyera*
12:20-12:40	Pelleting and herbicide trials in the UK	*A Brown*
12:40-13:00	Diversity in Finger millet Germplasm	*H Upadhyaya*
13:00-13:20	Discussion	
13:20 – 14:15	**Lunch break**	
SESSION 4	**Finger millet processing and marketing:**	
	Importance and characteristics of finger millet processing	*Chairperson: A Ward*
14:15 -14:30	Kenya	*B Kanyenji*
14:30-14:45	Uganda	*J Okwadi*
	Finger millet processing: Issues and constraints faced by processors	
14:45-15:00	Unga Group Co., Kenya	*Unga*
15:15-15-30	***Health Break***	
15:30-15:45	Family Diet Uganda	*I Wamala*
15:45-16:00	Maganjo Grain Millers, Uganda	*M Tamale*
16:00-16:30	***Discussion***	
16:30-16:45	Building market links –experiences from grain legumes in Kenya	*B Shiferaw and H Mukhongo*
16:45-17:00	ECARSAM priorities for finger millet	*B Mitaru*
17:00-17:30	***Discussions***	

17: 30-18:00	Synthesis and summary of main issues for discussion in groups	*J Lenné*
18:00	Logistics and end of day break	*J Mwangi*
19:00	Workshop Dinner	*All*

DAY 2: WEDNESDAY, 14 September 2005

Session-Time	Activity	Responsible
SESSION 5	Working group discussions and reporting	*J Lenné*
08:30 – 08:45	Group formation for the different discussion topics and TOR	*J Lenné*
08:45 – 10:15	Group work and discussions	*All*
10:15 – 10:30	**Health break (at group's convenience)**	
10:30 – 12:00	Plenary presentation and discussions	*All*
12:00 – 13:30	Group formation and second session for group discussion	
13:30-14:30	Lunch	
14:30-15:30	Group work and discussions cont.	*All*
15:30 – 15:45	**Health break at groups convenience**	
15:45-17:15	Groups report back to plenary and discussion	
17:15 -18:00	**Summing up and next steps**	*J Lenné*
18:00	**Workshop closure**	

Opening Session

Welcome Address

EA Mukisira[1]

Ladies and gentlemen,

On behalf of the Kenya Agricultural Research Institute (KARI), welcome to Nairobi.

This workshop is the first of its kind in Kenya, and possibly anywhere in the region – focusing exclusively on finger millet, not clubbing together various millet species that may have different research needs and opportunities.

Various kinds of millet are grown in Kenya. Finger millet occupies around 65,000 ha, with yields of 1.2 to 1.5 t ha^{-1}. The main production zone is Western Kenya, where the flour is widely consumed; the crop is also an essential ingredient in opaque beer. It has considerable potential for industrial use, provided production and marketing constraints can be resolved. And there are opportunities even beyond the traditional production areas – for example, field trials are showing its potential as a forage crop in Europe.

On a personal note, I have a small demonstration plot in my rural home, where I grow sorghum, pearl and finger millet. Some is for home consumption, but much of the harvest goes to neighbors who are interested in growing improved varieties of our traditional crops, but cannot find seed. Unfortunately, technology availability and dissemination has not matched the level of interest from growers and consumers.

Research strategy

KARI's new 10-year research strategy will help raise the profile of the crop, through better targeted, demand-driven research. The strategy focuses on market chains, and considers all stages – production, marketing and consumption. The objective is to increase crop diversification and income among smallholder farmers.

KARI's finger millet agenda centers on breeding for yield and stress resistance. Various issues arise. Can we build on its intrinsic good storability and insect resistance? How can we make progress in hybridization? Can we use biotechnology tools and marker-assisted breeding to locate and transfer

[1] Deputy Director (Research), Kenya Agricultural Research Institute.

genes for specific traits – for example, change grain color without losing other attributes? Some of these targets can be reached with the materials and technology currently available in other cereal crops. There are many things we can do even without transferring crocodile genes into finger millet!

Another research area is post-harvest technologies for processing and utilization. We must build on the nutritional properties and multiple uses of the crop, develop new products and easier processing methods, and remove the common perception (especially in rural communities) that it is inferior to wheat or rice. Farmers are selling finger millet (at low prices) to get money to buy wheat flour. Let us place finger millet where it should be, by creating awareness among rural communities.

KARI provides full support for increased finger millet research. We seek to use a combination of conventional methods and cutting edge science, and engage the African scientific community in research. We look to partners to assist us in expanding PhD opportunities, which can add value to the research program in a structured and cost-effective way.

Every stakeholder group – researchers from within and outside East Africa, extension, farmers, industry, NGOs, donors – is represented here. That is a good sign. Clearly, there is broad interest in the crop, strong support for what we aim to do, and commitment from the national research programs in all three countries. For many years, finger millet in East Africa has suffered from lack of attention and policy support. I am convinced this is the beginning of a new era.

I formally declare the workshop open, and wish you all success in your deliberations.

Thank you.

Opening remarks

Andrew Ward, Deputy Program Manager, Crop Protection Programme, DFID, UK

DFID's goals parallel the UN Millennium Development Goals. We focus primarily on poverty alleviation. Additional support is provided to regional bodies, and to 10 research programs (including the Crop Protection Programme, which funds the finger millet project) that are managed by other organizations on behalf of DFID.

The current project builds on successful earlier work on blast disease by the University of Warwick, funded by DFID (project R8030). This research produced key outputs on the disease pathogen and its management. The current project (R8445) is an extension of R8030. It aims to disseminate and build on those outputs, in order to promote finger millet cultivation in East Africa.

Welcome Remarks

Ladies and Gentlemen, I am extremely delighted to see the various finger millet stakeholders gathered here today. Despite finger millet being a strategic crop in the region, it has largely been neglected in terms of research and development. Finger millet plays a major role in the diets of many inhabitants of eastern and southern Africa and unlike other cereals, it has high levels of calcium and iron and lysine - an amino acid limited in most cereals. The importance of this cereal is exemplified by the name it is referred to in Tanzania 'Ulezi' which literally translates as 'bringing up or nurturing' thus emphasizing the role of finger millet as the food for infants, breastfeeding mothers and as food given to those who are recuperating from diabetics and other illness. I am sure all the esteemed stakeholders gathered here know the major constraints in finger millet and what comes to my mind as a lay person on the crop include agronomy, disease, low productivity, poor post harvest systems and issues related to output markets. We know that in Kenya, for example, there is a large deficit and processors import most of their finger millet grain from neighboring countries.

As a person who is from the region, worked as a scientist and now a manager, I have always advocated for the need to bring the crop back into our agenda. Your gathering here answers my prayers and partially meets that wish. What I hope for is that this gathering will result in action.

I wish you all successful deliberations.

SN Silim
Director
ICRISAT
ESA

Finger Millet (*Eleusine coracana*) (L.) Gaertn) in Uganda

NMW Wanyera[1]

Abstract

Uganda is dominated by agriculture with over 80 percent of the 24.6 million people involved in subsistence farming. The most important cereals are maize, finger millet and sorghum in that order. Finger millet is the second most important cereal in Uganda after maize and exceeding sorghum both in area and production. It is the staple food for over 50% of the country's 24.6 million people and increasingly a major source of income.

It grows in all ecological areas of the country. Its preference as food is related to tribal and social groupings and readily available supply of other foods like banana, sweet potato, maize or cassava. The areas where finger millet can grow are also determined by rainfall and soils.

Finger millet technologies released to the farming community over the years include improved varieties resistant to blast and crop management packages.

Wider utilization of finger millet grains in livestock feeds, beer, and biscuits and in making other finished products will help in widening its consumption and production. This is an opportunity to be exploited.

[1] Serere Agricultural and Animal Production Research Institute (SAARI), P.O. Box Soroti, Uganda

Introduction

Finger millet is grown in almost all ecological areas of the country. Its distribution is closely related to the different tribal groups, their social history, background where they live, soil type, rainfall pattern, altitude and the yield potential of the varieties.

Agriculture constitutes the most important sector of Uganda's economy. Uganda's climate is modified by mountains and water surfaces. There are two distinct rain seasons in a year in the southern half of the country allowing favorable distribution of perennial crops. But rainfall pattern tends to become monomodal as North Teso, Karamoja, Acholi and West Nile are approached. Karamoja and part of Ankole have a semi-arid type of climate.

Finger millet is the second most important cereal crop in Uganda after maize. Some of its local names are: Akuma (Ateso), Kal (Luo), Bulo (Luganda), Wimbi (Swahili), Oburo (Rukiga/Runyankole), Bird's foot, Coracana and African millet (English). It is grown in an estimated annual area of 412,000 hectares producing 700,000 mt (FAO, 2005). The average finger millet yield is 1.6 mt/ha. This yield can be raised to 3.0 mt that improved varieties are capable of. Production is estimated at an average of 626,000 mt for the period 1994-97 and projected to be at 751,000 mt by the year 2002. Consumption in the same period is estimated to be at 650,000 mt and projected to grow to 773,000 mt by the year 2002. This projection is based on an annual population growth rate of 2.7%. Its consumption outstrips production at current levels and this is projected to continue, unless new improved varieties are adopted. Finger millet production is concentrated in the east, north and southwest of the country. In these regions it is a basic staple food playing a very important role in meeting dietary needs (Oryokot 2001).

History and distribution

Finger millet probably originated in Uganda or Ethiopia (Doggett 1989) and has been cultivated in Uganda for a long time. For many years, India was considered the ancestral home of *E. coracana,* which had developed by selection.

Uganda has extensive genetic variability in finger millet landrace, especially for panicle compactness and shape (Gopal Reddy et al. 1993). It is grown throughout the country with the main areas of concentration being the eastern, northern and western areas of the country. Finger millet requires moderate (up to 1000 mm) rainfall, which is well distributed. It does best on free-draining sandy loams receiving well-distributed rainfall during the growing season and not subject to prolonged droughts. Its thick adventitious root system makes it ideally suited to these conditions (McMaster 1962). The absence, however, of deep roots to draw on sub-soil moisture makes the crop extremely sensitive to dry spells when the top soil dries out rapidly. Finger millet grows best when average maximum temperature exceeds 27 degrees centigrade and the average minimum does not fall below 18 degrees centigrade and in relatively fertile soils.

Where annual rainfall is relatively high and distributed throughout the year, finger millet is of only minor importance, and maize is grown as the major cereal. In such areas, which include montane areas and the Lake Victoria fertile crescent, high humidity through the year makes drying of millet difficult. Where conditions are more severe, either in rainfall reliability or in soil fertility, finger millet gives way to the hardier sorghum. The changeover to sorghum is a common sight in the north, north-east and south-west.

Finger millet plays an important role in both the dietary needs and incomes of many rural households. It is a basic staple food in all the areas grown. Although finger millet is less rich in total protein than some other cereals, the main protein fraction (eleusinin) has high biological value with high amounts of tryptophan, cystine, methionine and total aromatic amino acids (phenylalanine and tyrosine). All these are crucial to human health and growth and are deficient in most cereals. The two sulphur-containing amino acids, methionine (approx.5%) and cystine, especially, are lacking in the diets of millions of the poor who live on starch foods such as cassava (Oryokot 2001). Finger millet is therefore an important preventive against malnutrition, especially Kwashiorkor. As a result, children from finger millet eating parts of the country suffer less from nutritional diseases compared to those from banana eating areas. Finger millet is also a rich source of calcium. Some samples contain 0.33% calcium, 5-30 times more than in most cereals. The phosphorus and iron contents are also high.

In addition to its importance as a staple food, finger millet contributes greatly to the incomes of many households, especially the women. Finger millet is brewed to give a local beer that is sold for money or used to pay for labor. A thriving traditional beer brewing industry exists in all Ugandan urban and rural areas. In the rural areas, local beer is used as payment for labor for carrying out the more laborious farm chores, such as weeding and harvesting crops. Finger millet may also be sold directly as grain in local markets where there is always a ready demand.

Besides its versatility as a grain, finger millet has several other advantages; it is reputed to taste better than most cereals. Finger millet has no major storage pest problems and can be stored cheaply for long periods, provided it is dried well to low moisture content. These attributes combine to make finger millet a suitable crop for ensuring food security in drought prone areas of the country.

Production

Finger millet production in Uganda is under small-scale producers growing mainly traditional varieties. As a result, crop yields are low, averaging 1,550 kg/ha (1999 – 2005 average). This yield level still is one of the highest among finger millet producing countries. The current demand for the crop, which out-strips current supply, could easily be met if new improved varieties capable of producing up to 3,000 kg/ha under good management were grown. Up to 65% of the country's finger millet acreage is in the districts of Apac, Lira, Gulu and Kitgum, Iganga, Kamuli, Kumi, Soroti and Tororo. Finger millet production for the period 1999-2004 is shown in Table 1.

Table 1. Area (000 ha) and production (000 metric tons) of major cereals in Uganda (1999-2004).

Crops	1999		2000		2001		2002		2003		2004	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
Millet	376	606	384	534	389	584	369	590	400	640	412	700
Maize	608	1053	629	1096	652	1174	676	1217	710	1207	750	1350
Sorghum	275	413	280	361	282	423	285	427	295	443	285	420

Source: FAOSTAT data, 2005

Varieties

Several well-known local varieties are grown in different regions of the country. Most of these varieties are identifiable at maturity by characters such as plant height, maturity period, panicle shape and size, and grain color. These varieties are generally low yielding. Considering the projected increasing deficit in finger millet production, new and improved high yielding varieties must be sown.

In the past three decades, research has been conducted, mainly at Serere Agricultural and Animal Production Research Institute (SAARI) to develop improved finger millet varieties. In 1965, finger millet improvement research work was initiated at Serere under the East African Agriculture and Forestry Research Organization (EAAFRO), then a department of the East African Community. The broad objective was to develop high yielding varieties resistant to pests and diseases and acceptable to farmers over a wide range of environments. An additional objective of developing high quality varieties to diversify utilization of crop is being pursued.

In meeting the overall object of increasing yield and improving on the grain quality, several strategies are being followed. The genetic potential is being improved to allow the new varieties to exploit the environment better for maximum yields. This includes developing varieties that have resistance or tolerance to the finger millet blast disease caused by a fungus (*Pyricularia grisea* (Cooke) Sacc.), which is one of the diseases causing the greatest yield loss in susceptible varieties. In addition, short duration varieties for areas with unpredictable end to the rains, and which best utilize the current uncertain rainfall patterns, are being developed. Further, white seeded, high protein varieties are being developed, that are targeted at the agri-food industry, especially for manufacture of high value baby foods.

Over the years, the cereals program has released improved finger millet varieties, namely: ENGENY, GULU E, SERERE 1, PESE 1, SEREMI 1, SEREMI 2, and SEREMI 3. Three more varieties are on restricted release, namely, SX 8, SEC 915, and SEC 934. Several agronomic recommendations have also been made to improve the farmers' yields: use of proper rotational system, seed bed preparation, timely planting, row planting, and use of farm-yard manure (Komalimu 1985).

Advances in research and development

The ultimate objective of the finger millet research in Uganda is to improve the yield and quality of finger millet varieties for Uganda and the East African environment. Specifically, the objectives are:

- To develop improved varieties of finger millet through germplasm evaluation and breeding
- To develop early maturing finger millet varieties resistant to lodging, diseases (blast), and for specific end-use

- To evaluate local and introduced finger millet varieties for grain quality, malting potential and yield for local and industrial use
- To improve finger millet yields through the use of integrated agronomic management technologies
- To promote post harvest handling and storage technologies in finger millet
- To establish strong partnership with clients and other end-users

Highlights of research progress

- Finger millet germplasm increased from 940 to 1,340 accessions in the year 2004 (collaboration with ICRISAT)
- Characterization of germplasm both at morphological and molecular levels has been done in collaboration with University of Georgia, Athens, USA
- 43 entries showing consistently high resistance to both neck and finger millet blast were identified from the germplasm collection and will be utilized in the breeding program
- Epidemiological studies revealed that blast was severe in Pallisa district and early sowing of finger millet help in minimizing crop loss through disease escape. Over 300 blast isolates were collected from both cultivated and wild relatives of Eleucine spp. in Ugamda.
- Studies on processing and value addition (malting, Weaning foods, milk-based beverages and infant foods) were initiated in collaboration with Makerere University, Department of food science, Kampala.
- Baseline survey on rate of adoption was completed and reported.
- Improved blast resistant finger millet varieties (Gulu E, Seremi 1, Seremi 2, Pese 1, SX 8, and SEC 915) have undergone promotion on-farm testing. (DFID R8445)
- Malting qualities of all released improved and pre-release varieties are being done in collaboration with Makerere University, Kampala, and the brewing industry.

Marketing and Utilization

Cultural, religious and traditional factors strongly influence the demand for finger millet in Uganda, especially in the eastern, northern and western region, where it plays important roles in gift giving, a symbol of fertility and manhood, etc. Those cultural influences create strong demands for finger millet where it is produced. In urban areas, however, it does not compete well with subsidized rice and wheat products. And high labor requirements to prepare it dampen demand.

Localized markets and seasonality characterize the market for finger millet in Uganda. Marketing factors include poor marketing infrastructure, limited processing facilities, etc.

Domestic trade is brisk but international trading is yet to develop – prices of finger millet in Uganda vary between $0.2 and $0.3/kg depending on season and distance from producing area.

Manufactured products from finger millet are not widespread but there are finger millet flour, Soya-millet by Maganjo Grain Millers, East African Foods Ltd., Kasawo Grain Millers Ltd., Family Diet, and other processors to be discovered.

As a food source and local brew, finger millet is the second most important cereal in Uganda but needs value addition for transformation into a powerful commercial commodity.

Production constraints/Challenges

The major constraints to finger millet production are excessive labor and many of the soils of the marginal areas where finger millet is grown are of low fertility. Drought, high temperature and nutrient stresses are constraints to production. Crop damage by insects is minimal but pests such as birds and *striga* weed are a constant serious threat to the crop. Finger millet blast disease is by far the most devastating, causing over 50% yield loss (Esele 1989).

Other constraints to finger millet production include poor incentives and marketing arrangements – low pricing, poor and inaccessible market channels, inaccessibility to credit facilities and inadequate improved processing and product development facilities at commercial levels.

HIV/AIDS epidemic and its contribution to labor supply in the agriculture sector; and less interest in taking millet as a business venture among trained youth is another challenge.

Erratic changes in government policies against the commodity are also a constraint to its promotion.

Opportunities for improved production and profitability

- Implement realigned activities under the new NARS system with more collaboration with different partners
- Address emerging issues
- Intensify research on control and management of pests and diseases, drought stress and develop technical packages for finger millet
- Increase labor productivity using simple planters, harvesters and threshers to be developed and introduced through DAP project
- Intensify dissemination and promotion of the crop – training at various levels, information materials and demonstrations
- Popularization on the consumption of finger millet in diverse uses – porridge, bread, cakes, biscuits in schools, training institutions, school feeding programs, and traditional dishes in the hotel industry

National level emerging and/or perceived opportunities

- Potential uses of millet in food, feed and industrial application
- Improved national and regional trade of the commodity
- Establishment of national stakeholder consultative groups to lobby for the sub-sector and coordinate production, processing and marketing of finger millet products

Conclusion

Finger millet has tremendous contribution to make towards Uganda's food security and economy in the future. Improvement of the pricing and marketing by taking into consideration various factors, for example, quality, region use, and availability of market outlets will go a long way to boost finger millet production as a cash crop.

Wide dissemination of finger millet technologies will create awareness about the importance of the crop.

Popularization on the consumption of finger millet in diverse uses – porridge, bread, cakes, biscuits in schools, training institutions, school feeding programs, hospital feeding, especially to HIV/AIDS and TB patients and traditional dishes in hotel industry will be another strategic plan for wide utilization of the crop.

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Finger Millet in Kenya: Importance, Advances in R&D, Challenges and Opportunities for Improved Production and Profitability

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Abstract

Developing countries in Asia still produce the majority of the world's millets. However, millet production in Africa has risen 25% since the early 1970s, and its importance in domestic diets is growing steadily. Finger millet accounts for 8% of the area and 11% of production of all millets, worldwide (Bennetzen et al. 2003). It is grown on over 4 million ha globally and is a primary food for millions of people in the drylands of East and Central Africa, and southern India. The wide adaptability of the crop could be attributed to its C_4 nature.

Finger millet is an important food crop in Kenya. It is also used in beverages, for cultural purposes, and sold for cash – fetching over double the price of sorghum and maize. Its good storability makes it suitable for food security, while the high nutritional value is stimulating industrial interest. The crop is grown by smallholder farmers, mainly west of the Rift Valley, on 65,000 ha yr^{-1}. Hectarage has declined since 1978 but production has fallen only marginally. Grain yields are 500-750 kg ha^{-1} on-farm, compared to 3.8-4.0 t ha^{-1} on research stations. But there is potential for large yield improvements, considering that little research on the crop has been done in Kenya. A few varieties are in the pre-release stage. Ongoing work focuses on emasculation techniques, variety development, agronomy, weed control, and utilization (grain quality and purity, development of food products).

Finger millet farmers face numerous challenges, including labor, credit, marketing, weeds, pests and diseases (blast). The problems also include competition from other crops, low government priority and limited research attention, and lack of processing equipment (especially dehullers). Despite these challenges, finger millet is still widely used and valued; and new food products such as bread, malt fodder, feed, foods for babies and convalescents, have industrial potential. With more research and an enabling policy environment, the crop has great potential for expansion.

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Introduction

Finger millet is the most important small millet grown in eastern and southern Africa. It is a subsistence and food security crop that is especially important for its nutritive and cultural value, and also commands higher market prices than other cereals. In eastern Africa, it is produced in the lake region countries of Uganda, Kenya, Tanzania, Rwanda, Burundi, and eastern Democratic Republic of Congo and also in Ethiopia, Sudan and Somalia (Obilana et al. 2002). It is an important cereal in Tanzania, Zambia, Malawi and Zimbabwe (Gomez 1993). Finger millet is suitable as a subsistence food crop because being small-seeded, it can be stored safely for many years without insect damage. This is particularly valuable in drought-prone areas where harvests frequently fail.

Finger millet is grown in Kenya on about 65,000 ha yr^{-1}, mostly by smallholder farmers (CGIAR 2001). The main production areas are west of the Rift Valley (Oduori 1993). Yields on farmers' fields are generally low, just 15% of their theoretical maximum in Kenya (Takan et al. 2002). According to Mburu (1989), finger millet hectarage in Kenya has been declining since 1978 with a greater variation in hectarage than production. However, production figures from Western Province, the largest producer, show variation, with an average of about 7,700 tons between 1995 and 1998 (Fig 1). Mitaru et al. (1993) reported finger millet grain yields of 500-750 kg ha^{-1} in Kenya. Yields in Western Province, 1995-98 period, ranged between 800 and 900 kg ha^{-1}. Yields of 3.8-4.0 t ha^{-1} have been achieved in research trials.

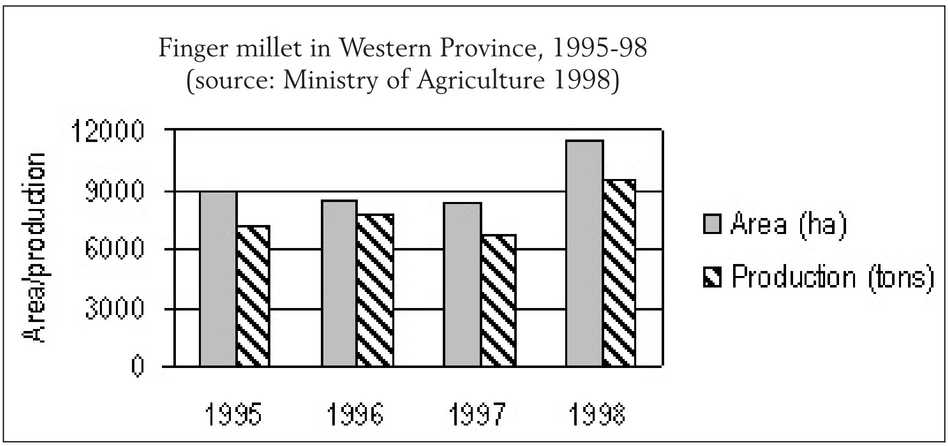

Figure 1: Production trends in Kenya.

Source: Ministry of Agriculture 1998

However, finger millet production in Kenya as a whole for the 6-year period 1997 to 2002 shows a progressive increase in area cropped, total production, and productivity per unit area (Table 1). At national level, 75% of Kenya's finger millet is produced by small-scale farmers, and 20% and 5% by semi-commercial and commercial farmers, respectively. However, at individual district level, 85% is produced by small-scale farmers, and 10% and 5% by semi-commercial and commercial farmers, respectively. Among small-scale farmers, the average area planted per household is approximately 0.5 to 1 ha. In recent years, smallholder households have increased their area planted and their production of finger millet. The reasons cited for this increase in order of importance are its value as a cash crop, high market demand and high returns; others include the availability of better varieties and improved extension services for the crop.

Table 1. Finger millet production and productivity in Kenya, 1997-2002.

	Area planted (ha)	Yield (t ha^{-1})	Production (tons)
1997	91,773	0.42	38,623
1998	79,988	0.43	34,020
1999	90,082	0.66	59,172
2000	93,150	0.48	44,623
2001	104,292	0.43	44,690
2002	118,570	0.61	72,194
Mean	96,309	0.51	48,887

Source: Ministry of Agriculture 2003 (B Kanyenji, 2007 personal communication).

Production constraints

Farmers face a range of constraints to finger millet production. These differ in different regions of the country but generally the main ones include: declining land fertility, high labor requirements for weeding, lack of high-yielding, well-adapted varieties, diseases, and unavailability of seed of improved varieties. Blast disease is gaining economic importance in almost all regions where finger millet is produced (Takan et al. 2002). About 75% of finger millet farmers use own-saved seed of mostly traditional varieties. About 10% get their seed from/through research institutions (especially KARI), church organizations and NGOs; while 10% buy seed from unregistered seed growers (farmers). Only 5% purchase commercial seed.

As research and development efforts are aimed at developing improved technologies, it is worth noting that women are responsible for the greater share of finger millet production tasks. We therefore need to consider gender aspects in our research, for example, women's ability to handle the recommended production packages and the need to enlighten the community about gender roles and responsibilities in crop production.

Postharvest handling, marketing, processing, and utilization

Harvesting and threshing. Of the total national production, about 60% is consumed by the producing household, 30% sold locally, and 10% used as seed. Over half the harvest is hand-harvested using kitchen knives. Threshing is done in open fields; occasionally the ground is smeared with cow dung to compact the loose soil. Compacting is sometimes incomplete, leading to high levels of contamination with foreign matter, especially in areas with stony soil. Impurities are composed of stones, soil and plant matter. These impurities cause problems for the processor: pebbles can damage equipment and increase maintenance costs and impurities, in general, can affect sales in quality-conscious urban markets. As a result, processors occasionally reject poor quality grain delivered by farmers and grain traders.

Storage. Finger millet farmers use various containers to store grain, depending on the amount harvested and the conditions and length of storage. Gunny bags are commonly used for temporary storage where quick disposal is anticipated. They are also preferred for short-term storage and storing for household consumption. Plastic and metallic containers are used for longer periods of storage, and the use of chemicals is common. The use of granaries has fallen drastically due to the risk of theft and the tendency to quickly dispose of the harvested crop.

Grain marketing

Individual farmers may opt to sell at farm gate or deliver to the local market or grain store. By selling at the farm gate, farmers would save on transportation costs, minimal packaging and farmers have a better bargaining power, however, on the other hand, they will be disadvantaged by the low prices and often get lower prices and run the risk of selling more than intended. There are various modalities of finger millet grain marking: traders can buy at the farm gate or at the local market for resale. Several traders may pool their collection for transport to bigger urban centers. Alternatively, traders based in urban centers may organize transport themselves. Sometimes urban-based millers contract grain store owners at local markets or urban-based traders, to deliver grain to their factories. Some millers develop their own network of contract collectors, who assemble grain for transportation to the mills. About 70% of smallholder farmers sell their finger millet immediately after harvest, in order to meet cash requirements and/or avoid losses due to storage pests. Others may store for limited periods until a buyer is found. A small minority, 5%, may store the crop for 3-6 months, until prices are high. Prices have been recorded to increase by 70-100%, six months after harvest.

Market chain. Finger millet is produced in rural areas while commercial processors are usually based in larger urban centers. The cost of long distance transportation of grain generally reduces the price of grain sold at farm gate or at local markets. The rougher the terrain, the higher the transport costs, and the lower the price at local delivery points. Middlemen often cite transport problems to justify large price differences at each stage: producer, processor and consumer. Middlemen tend to reduce the farmer's price by inflating transport costs, faking a low-demand situation, and/or giving unrealistic specifications, for example, moisture content. However, they also assist small-scale farmers to stimulate commercialization of the crop by creating demand. By offering a ready market, they reduce the farmer's storage costs. Occasionally, the number of middlemen in the marketing chain becomes too large, thereby creating confusion in the industry and reducing profits for farmers.

There are a number of market players at various stages:

- Grain marketing stage: farmer, farm gate buyer, buyer at local grain market (often women), grain storekeeper in local market, traders who transport grain over long distances, grain storekeeper in urban market, and eventually the large-scale trader who supplies the miller (usually under contract)
- Grain processing stage: miller, downstream product manufacturer (eg, baker)
- Product marketing stage: Product salesman (promoter), distributor/ wholesaler, product retailer and eventually the consumer

Market constraints. Farmers face numerous grain marketing challenges and these include lack of market information, transport and price fluctuations. Farmers do not have organized production and collection systems and marketing structures and these have contributed greatly to the slow development of Kenya's finger millet industry. The tendency for processors to be located in urban centers has reduced farmers' profit margins.

Utilization and consumer preferences.

The uses of finger millet in Kenya include porridge, ugali, and brewing of opaque beer (its amylase enzymes readily convert starch to sugar and its 'saccharifying' power is second only to barley). It is also sold for cash, and widely used in cultural events and ceremonies like weddings and paying of bride price (NRC 1996). In most places, food products of finger millet are eaten to satisfy traditional requirements; or as nutritional supplements, for example, for pregnant or nursing women, babies and the infirm.

The grain color of a variety is associated with its utility value, and hence has some influence on the market value of the crop. The value of the end product made from a specific variety has an influence on the market price and by implication, on demand for the variety. Traditionally, Kenyan varieties range between brown, red and dark red – the dark red is most popular. In the past, breeding programs have focused on yield and other production factors without attention to grain color. As a result, there was poor adoption of some identified varieties, especially white-grained types. Variety preference is influenced by many factors, including region/ethnicity. Farmers use several criteria for judging the value of a variety, different criteria being used for local and improved varieties. The local varieties are mainly used for brewing opaque beer and other household use and less for industrial processing. Local brewers prefer local landraces of finger millet to pearl millet and maize. On the other hand, farmers choose the new varieties mainly for the industrial processing as they might not be very suitable for brewing beer and other household uses. Industrial processors and household users are more flexible and their consumption depend on the options that are available. Rural and urban consumers use finger millet in more or less the same way but in different proportions, for example, most urban consumers use the fortified and fermented products more than the farming communities.

Processing. Traditionally finger millet was used to prepare various products – fermented porridge, non-fermented porridge (which could be thin or thick porridge, known as *ugali*), and seasoned thick porridge, made from a mixture of finger millet and legume flour. Household processing was limited to threshing, grinding the grain to flour, and preparation of porridge. A significant amount of the grain was also consumed in the local brewing industry, making opaque beer.

Processing of finger millet, such as by fermentation to make it more nutritious, is a recent innovation in some parts of Kenya though very common in Western

Kenya and is more common among urban consumers. Fermentation makes nutrients present in the grain more readily available to the body by reducing the tannin biding ability (Oniang'o 1996). Fortification is the process of supplementing minerals and protein content. Rural consumers generally consume finger millet in traditional ways, with less processing. This implies that rural areas might provide a potential market for industrially processed finger millet, which could be tapped.

Research and Development

Plant breeding. In terms of plant breeding research, finger millet is roughly where wheat was in the 1890s (NRC 1996). Since the 1890s, average wheat yields have risen from about 500 kg ha^{-1} to over 4 t ha^{-1}. Finger millet yields could rise similarly – or much faster, because it is a C_4 crop (wheat is a C_3 photosynthesizer) and because it can benefit from research results and techniques developed on other crops. Finger millet has very wide diversity and variability that would facilitate breeding and selection. Attere (1993) reported that over 2,500 accessions of finger millet have been collected in East and Southern Africa. Kenya has about 1,136 accessions (Oduori 1993).

There has been no hybridization breeding of finger millet in Kenya. Breeding work to date has been restricted to germplasm acquisition (from local collections and international sources) and evaluation to select adaptable varieties. Three varieties, P-224, Gulu-E and U-15, have been released or pre-released. Yields between 1 and 4 t ha^{-1} have been observed in research trials.

Finger millet is almost entirely self-pollinating, so different genotypes can only be crossed with difficulty. There is a long-felt need for an efficient crossing scheme for finger millet. An international small millets workshop in 1986 made useful recommendations (First International Small Millet Workshop 1986) but these have not been implemented especially in Africa. Among these recommendations were:

- Because of the small floret size in small millets, cross breeding is limited; considering the further limitations of contact and hot water emasculation methods, use of gametocides needs to be studied and standardized together with study of genetic male sterile systems, and other mechanisms like protogyny

- Being self pollinated crops, all small millets have been improved through breeding to a very limited extent, hence the need to assess the relative efficiency of various breeding procedures

The author is currently investigating the efficacy of gametocides, specifically Ethrel, in finger millet. Elite finger millet varieties are being hybridized and successful crosses have been made. The purple pigmentation and other morphological traits are being used in detection of successful crosses. The development of an efficient hybridization protocol and exploration of finger millet molecular biology, especially the application of molecular marker-assisted selection, could propel finger millet yields to the level of wheat or rice today.

With enhanced finger millet breeding in Kenya, some of the traits that could be tapped include: blast resistance, robust growth, early vigor, large panicle size, high finger number and branching, high-density grain, resistance to the fungus Helminthosporium and witchweed *Striga*, lodging, adaptation to poor soil and moisture conditions, and grain quality traits (NRC 1996). Working with finger millet genotypes from diverse regions of India, Bendale et al. (2002) found that grain yield per plant was significantly influenced by days to emergence of finger, days to 50% flowering, finger length, finger width, and weight of grains of main earhead.

Agronomy. Some agronomy work has been done in Kenya, mainly in western Kenya. Preliminary work was done on planting time, plant population and spacing, fertilizer types and rates, and planting methods (Oduori 1993). Planting early at the onset of long rains, row planting at a spacing of 30x15 cm, and application of N and P_2O_5 fertilizer at planting (20 kg ha^{-1} each) were recommended. Current research objectives include identifying optimal seed rates, planting methods, plant populations and spacing, fertilizer rates, planting time, mechanization (eg, oxen cultivation), and weed control (King and Mukuru 1994, Mukuru 1993)

Utilization. This area has received the least attention in research. Quality assessment work as reported by Gomez (1993), needs to be followed up. He reports that color, water absorption index and diastatic power (a measure of malting and brewing quality) are screening parameters for evaluating finger millet varieties for food and malting. He suggests placing priority on processing constraints such as grain purity and cleanliness (removal of fine sand and grit prior to milling); and techniques to lighten the color of products for food use. The high nutritional qualities – minerals, calcium and iron content – need to be exploited to develop weaning and supplementary foods. Nungo (pers.

comm. 2005) is developing finger millet recipes at KARI-Kakamega. They include finger millet chapati, mandazi, ginger bites, bread and cake.

Challenges

Finger millet promotion in Kenya faces a number of challenges. Some problems are partly due to its small seed size (NRC 1996). Being small-seeded, the crop must be planted in well-made, fine seedbeds at higher densities (especially if it is broadcast). Subsequently, weeding is very labor intensive, and is further complicated by wild relatives of the crop, for example, *Eleusine indica*, that look almost identical to crop plants at pre-flowering stage. The problem of seed size carries over into processing – it takes more skill and effort to mill small-seeded crops, especially by hand. Hammer mills have to be fitted with very fine screens and run at high speed, and the National Research Council (1996) reported the development of a special mill for millet.

The production constraints include: labor intensity in both cultivation and processing, difficulty in processing (special dehullers are needed), non-adoption of available technologies like row planting, lack of improved varieties and credit, weeds (wild *Eleusine*), pests (*Striga* and shootfly), diseases (blast), low priority in research, poor cultural practices, limited uses, unpredictable markets, moisture stress in dry areas, competition from other crops with better economic returns, and lack of commercial food products (Mitaru et al. 1993, Oduori 1993). Blast caused by the fungus *Pyricularia grisea* (a close relative of rice blast) is the most serious disease (NRC 1996, CGIAR 2001). The crop is not vulnerable to many pests, except shoot fly and stem borers, which can be controlled by insecticides. Birds are also a problem, especially the notorious *Quelea quelea* and other small grain-feeding birds.

Opportunities

In Kenya, finger millet grain is used only as food and in brewing beer. But it can be used in a variety of other ways. Flour can be used for baking bread and various other products with good flavor and aroma; several brands of finger millet flour produced by different companies are available in Kenyan supermarkets. Malted finger millet (sprouted seeds) is a nutritious food, easily digested, particularly recommended for infants and the elderly. The straw makes good fodder that contains up to 61% total digestible nutrients, more nutritious than pearl millet, wheat or sorghum. The grain can also be used for poultry feed.

The key issue is nutritional quality. Finger millet grain is high in methionine, an amino acid lacking in the diets of the poor who live on starchy foods like cassava, plantain, polished rice, and maize meal. It is higher in protein, fat and minerals than rice, maize or sorghum (Reed 1976). It has a better nutritional profile than maize, for example, calcium >5000%, iron and manganese >350%, higher levels of copper and essential amino acids (NRC 1996). The protein content (7.4%) is comparable to that of rice (7.5%). The main protein fraction (eleusinin) has high biological value, with good amounts of tryptophan, cystine, methionine and total aromatic amino acids, which are crucial to human health and growth and are deficient in most cereals. For this reason alone, finger millet is important in preventing malnutrition. It can also assist in management of measles, anemia and diabetes. Finger millet thus has industrial potential in the manufacture of baby foods, foods for sick persons, and breakfast cereals.

Malting is the process of germinating finger millet to activate enzymes that break down the complex starches into sugars and other simple carbohydrates that are easy to digest. The malting qualities of finger millet are second only to barley – but barley is a temperate crop, while finger millet thrives in tropical areas where malnutrition is endemic. With its good malting qualities, finger millet could provide cheap and nutritious foods for preventing malnutrition in babies, which causes large numbers of deaths throughout the tropics (NRC 1996). The germinated (malted) grain can be used to liquefy any starchy food: wheat, rice, maize, sorghum, millet, potatoes, cassava (manioc), yams, etc (NRC 1996). Thus, it can be used to make cheap, easily digestible liquid foods for children.

There is growing market demand for finger millet in Kenya: it fetches over double the price of sorghum and maize (Oduori 2000). A survey in western Kenya showed that finger millet production was most commercialized in Kisii district and least in Teso (Obilana et al. 2002). The crop enhances household income through trade and sale. The crop is partly commercialized in some countries, especially in Zimbabwe and Malawi, where finger millet malt is used in brewing commercial traditional beer, Chibuku (Mushonga et al. 1993, Mnyenyembe 1993). Grain marketing boards also provide an avenue for commercialization. In Kenya, the National Cereals and Produce Board trades in finger millet, and has recently begun milling as well.

Due to the high traditional values attached to finger millet, the crop will continue to be grown (Obilana et al. 2002). Because it is often grown in favorable production environments (unlike other millets), yields can be competitive with those of rice and other 'green revolution' cereals (CGIAR 2001), especially if research efforts are increased (NRC 1996). Yields can be improved in Kenya even with existing technologies, for example, improved varieties and crop management methods (Oduori 2000).

Conclusion

Finger millet is still an important cereal in Kenya, despite the fact that area under the crop is highly variable by location and also from year to year. However, there is general upward trend in crop area for all the millets in Africa. The crop serves special food and traditional/cultural needs and earns cash for households. Yields are low across Kenya due to a range of reasons, but mainly because of very low technological information from research. With increased research to provide information in production, processing and utilization – and an enabling policy environment – the crop has great potential for productivity growth and higher utilization and trade in Kenya.

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Germplasm Collection and Evaluation of Finger Millet in Tanzania: Challenges and Opportunities for Improved Production

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Abstract

Finger millet is a traditional crop that is grown in many parts of Tanzania under a range of climatic conditions. It stores well for a long period and is therefore dependable in terms of household food security. However, production in Tanzania is declining, largely due to lack of support from research and extension services. Finger millet research has lacked financial and policy support since the 1970s. This has increased possibilities of genetic erosion. Finger millet landraces from the main growing areas were collected during the period 1993-96, for conservation and utilization in crop improvement. A total of 282 landraces were collected and conserved at the National Plant Genetic Resources Center in Arusha. Seventy-nine accessions were selected and evaluated in the Southern Highlands in 1997, and showed considerable morphological diversity. The results further suggested that local cultivars had high yield potentials of up to 4 t ha^{-1} under recommended practices. Most landraces expressed high resistance to diseases and low susceptibility to lodging. Yield results differed from one location to another, indicating a need to establish the importance of Genotype X Environmental (GXE) interaction, and highlight the need to develop varieties that are either widely adapted or with specific adaptation. To increase production, it is critical to influence policy to place greater emphasis on finger millet research and extension and also to work closely with industry and private sector to help turn the productivity into profitability.

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Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.) is a member of the family Gramineae and the tribe is Chlorideae. East Africa is believed to be one of the centres of origin and it has a long history of finger millet cultivation, and there is extensive variability among landraces, especially for panicle type (compactness and shape) (Rachie and Peters 1978, de Wet et al. 1984).

Finger millet is produced in most Eastern and Southern Africa countries. It is extensively grown in Uganda, Tanzania, Ethiopia, Kenya, Rwanda, Burundi, Zimbabwe, Zambia and Malawi (Mnyenyembe and Gupta 1998). It is cultivated mainly by small-scale farmers using traditional production practices. Shifting cultivation and slash-and-burn method of land preparation are commonly used in Tanzania. Virgin land is opened up every season. Farmers believe this is the only way to maintain crop yields; and that shifting cultivation reduces weed pressure. In many cases, these practices have caused environmental degradation and may not be a sustainable farming system.

Importance of finger millet in Tanzania

Finger millet is a traditional crop in almost all regions of Tanzania. The main producing regions in Tanzania are Rukwa, Mbeya, Iringa, Ruvuma, Mara, Kigoma, Kilimanjaro, Singida, and Dodoma regions (Marandu and Ntundu 1995). It can grow in a wide range of climatic and soil conditions: rainfall from 350 to 800 mm (Rachie and Peters 1978); sea level to altitudes >1800 m; and under different temperature regimes (King and Mukuru 1995). It is adapted to a range of soil types, but grows better on red, light black or grayish loamy and sandy soils. It is reputed to tolerate degrees of alkalinity and acidity (Rachie and Peters 1978). In areas where there is adequate rainfall during the crop growth phases, finger millet can grow better in poor soils and produce reasonable yields as compared to sorghum and pearl millet (King and Mukuru 1994).

Finger millet production in Tanzania is generally low and has been decreasing over the years. For example, the Ministry of Agriculture and Food Security (MAFS) Crops Cultivation Report (2005) indicated that there has been a trend of decreasing area under cultivation for finger millet for 2001/2002 and 2002/2003 seasons from 171,800 hectares to 102,402 hectares, respectively (MAFS 2005). The national average yield is less than 500 kg ha^{-1}, mainly due to lack of improved varieties and poor agronomic recommendations and improved marketing systems. Finger millet can be stored for a long time without being damaged by storage insect pests. It is therefore ideal for food security for households who cannot afford to buy storage insecticides, and hence a popular crop among small-scale farmers.

More than half of Tanzania's finger millet production comes from the Southern Highlands, comprising Mbeya, Iringa, Ruvuma and Rukwa regions (Kisandu 1993, MAFS 2005). In the Southern Highlands, it is an important food and cash crop, ranking second to maize. The finger millet demands for local brewing industry from other regions where the crop is not grown traditionally also emphasize the importance of finger millet in the country. The common local brew prepared from finger millet malt is known as "*kimpumu*" in the Southern Highlands and "*mbege*" in the northern part of Tanzania. In Sumbawanga and part of Mbozi districts in the Southern Highlands, finger millet stiff porridge is a popular and important staple food. In Tanzania many farmers plant finger millet mainly as a cash crop, and maize for home consumption. Finger millet production costs are perceived to be lower than for maize, and market price of grain is higher although the local production practices (slash and burn) by farmers of finger millet, may have adverse effects on the environment. Finger millet produces excellent malt extract for brewing and other similar industries. It is an excellent source of calcium (seven times more than rice) and phosphorus (Rachie and Peters 1978). In many parts of Tanzania, it is a valuable food for nursing mothers, and children.

Finger millet research in Tanzania

Research on finger millet started in the early 1970s. The national research coordination centre was at Ilonga Agriculture Research Institute at Kilosa, Morogoro. Additional research was conducted at Uyole and Ukiriguru. The first focus was on farmers' agronomic problems. Field trials on agronomic practices of finger millet were initially conducted, but progress was limited by financial and policy support, as finger millet was considered a low priority crop. Owing to limitation of funding, the finger millet research program was closed at the end of the 1980s. Later, in 1991 the National Sorghum and Millets Improvement Programme (NSMIP) revitalised the program at the Agriculture Research Institute, Uyole in the Southern Highlands. The focus was on developing improved varieties. Initially, in the Southern Highlands, field trials were planted at Nkundi (Sumbawanga) and Mbimba (Mbozi), which are the main production areas. But again, progress was hampered by limited funding from the national as well as the international research centers.

As a strategy to promote finger millet germplasm conservation and utilization for plant breeding programs, a joint germplasm collection project was launched in 1993 by the National Plant Genetic Resource Center at Arusha, in collaboration with Uyole Agriculture Research Institute and the Southern Africa Plant Genetic Resources Centre (SPGRC) in Lusaka, Zambia. The objective was to collect and conserve the genetic diversity of available finger millet for future utilization in crop improvement program. Collection started in the Southern Highlands and was later extended to Mara, Kagera, Kilimanjaro, Singida and Dodoma regions. A total of 282 accessions were collected and conserved at the National Plant Genetic Resources Centre in Arusha.

Initial characterization of the germplasm was done in the collection areas, in order to capture the available variation existing among the accessions and their botanical descriptions within the traditional cultivation environment. In 1997, the Tanzania research department provided funds for further evaluation of the collected germplasm. The objectives were to:

- Further study genetic diversity in indigenous finger millet cultivars
- Study the genetic potential of the local collection, in comparison to introductions
- Identify landraces for future utilization in crop improvement and conservation.
- Identify promising finger millet materials for inclusion in national variety trials that could later be released or crossed and developed into improved varieties.

Screening and yield nurseries were established at Mbimba (Mbozi district) and Nkundi (Nkansi district) in the Southern Highlands. The screening nursery, with all collected accessions, was conducted in the first two years, in unreplicated 2-row plots of 0.4x3 m size. In the second year, promising accessions were also evaluated in the yield nursery on bigger plots, 2x3 m size. The evaluation was limited to morphological characters – ear shape, grain shape, grain color, ear size, growth habit, plant height, head blast disease and lodging susceptibility.

Morphological characteristics of the collected finger millet germplasm

Frequency distribution of morphological characters for accessions collected from Mara and Southern Highlands included in this study are summarized in Table 1. Four types of ear shapes namely open, droopy, semi-compact and compact were exhibited in the finger millet under study. The open type was the most frequent (39) followed by semi-compact (25) and droopy ear shape (11). Few accessions (3) had compact ear shape. Accessions from Kagera also showed a wider variation in ear shape, including the fist-type, which was not found in the Southern Highlands and Mara regions

Grain shape showed a considerable variation among the accessions studied. A large number (41) of the accessions had round grain shape, while (23) had reniform grain shape. Only (15) of the accessions studied had ovoid grain shape. A considerable variation existed in grain color among the characterized accessions. Thirty and 26 accessions had copper brown and purple brown grain color, respectively. Twenty-two (22) accessions had light brown grain. Only one (1) accession had white grain color. Two types of growth habit namely erect and decumbent were observed in the evaluated accessions. Erect types were the most frequent (76), while few (3) decumbent types were observed among the evaluated accessions. The evaluated germplasm also indicated a considerable range of plant height (39-95 cm). There was a great variation in resistance to head blast disease ranging from (0 - 8) and susceptibility to lodging ranging from (1-4).

Ear sizes were highly diverse, ranging from small to large. Of the 79 evaluated accessions 34 were observed to have intermediate ear size, 27 had large ear size and 18 were observed to have small ear size. Since ear size influences yield, it is anticipated that yields will also vary correspondingly. Finger millet was found in all regions visited during the collection. These included different farming systems and natural habitats – these varying ecological conditions would have contributed to the large genetic diversity obtained.

Table 1. Frequency distribution of morphological traits for 79 finger millet accessions collected from Mara and Southern Highlands.

Plant traits	Frequency
1. Ear shape	
Open	40
Droopy	11
Semi-compact	25
Compact	3
2.Grain shape	
Reniform	23
Round	41
Ovoid	15
3.Grain color	
Light brown	22
Copper brown	30
Purple brown	26
White	1
4. Ear Size	
Small	18
Intermediate	34
Large	27
5. Growth habit	
Erect	76
Decumbent	3
6. Plant height (cm)	39-95
7. Head blast disease (0-9)	0-8
8. Lodging score (0-9)	1-4

Yield potential of the collected germplasm

There was a great variation among accessions, with grain yield potential ranging from 800 to 4,450 kg ha^{-1} (mean 2,566 kg, Table 2). Yield potential was highly influenced by the number of grains per spikelet, ear size, and number of productive tillers per plant. Number of grains per spikelet ranged from low to high (4 to 8 grains).

Table 2. Performance of 21 finger millet landraces collected in Southern Highlands and Mara regions of Tanzania.

Characteristics	Range	Mean	SE±	Variance	CV (%)
Yield (kg ha^{-1})	800-4450	2566.2	50.123	625423.79	31
No. of grains per spikelet	3-7	5.0	0.163	2.052	29
Finger density per plant	5-7	5.8	0.113	0.975	17
No. of fingers per head	2-6	3.45	0.076	0.504	21
No. of productive tillers per plant	1-6	1.7	0.083	0.523	42

No. of grains per spikelet: 3 = low (4 grains), 5 = intermediate (6 grains), 7 = high (8 grains)
Finger density per plant: 3 = small, 5 = intermediate, 7 = large

Based on evaluation of morphological characters, 21 promising landraces were selected for yield assessment in comparison to introduced varieties (Table 3). The trials were conducted at two locations for three years. There were no significant differences in yield across seasons of testing at Mbimba, but a significant difference was observed at Nkundi, where yields were highest in 1999. Mean yields were higher at Mbimba than Nkundi (2270 vs 1724 kg ha^{-1}). Generally, yield means across locations, for the three years, indicated that Kalale, Usansha, Chikwelekwele (Acc. 85) and Nyego gave the highest yield – and only Kalale significantly out yielded the improved, high-yielding control lines. Yield performance of accessions differed with location.

Genetic erosion

Finger millet is threatened by competition from other crops which are available in all markets in the country. The base line survey findings for "Neglected and Underutilized Crops" across nine regions in Tanzania (Akonaay et al. 2004) indicated that the threat for genetic erosion for the neglected and underutilized crops differed among the nine survey regions. The interviewed farmers indicated that finger millet crop among others was disappearing in Dodoma, Kilimanjaro, Coast, Tabora and Tanga regions. Analysis of data from the respondents in the surveyed sites showed that lack of interest by farmers, replacement by other crops, and lack of agronomic recommendations and production inputs were by far the most important factors contributing to the disappearing of finger millet among other crops in the surveyed regions.

Change in farming systems, on the other hand, have gradually resulted in reduced number of crops by individual farmers, as a result, finger millet as a crop is further marginalised. From the results of the baseline survey, it is likely that there has been genetic erosion of finger millet among other neglected and underutilized crops, hence the urgency in collecting and conserving the remaining landraces.

Challenges for development of the finger millet subsector

Research and extension efforts must be increased. This will require a policy change, to increase emphasis on the crop. Finger millet was being cultivated in every area visited during the collection missions. Clearly, farmers value it greatly – but despite this, there is a severe lack of government support and an enabling policy environment

Technology adoption is poor: Despite the major position of finger millet as an important crop in the farming systems of some parts in Tanzania, little research efforts have been devoted to exploit the production potential of the existing landraces. The cultivars of finger millet that exist today in the country have arisen through selection from landraces. Neither improved varieties nor agronomic recommendations exist at farm level. Consequently, farmers in the country continue to use low-yielding landraces and traditional crop management practices, including shifting cultivation. Production can be improved by promoting agronomic packages already developed by research, such as fertilizer application, timely planting, and weeding – and discouraging shifting cultivation, which has proved to cause adverse effect to the environment.

The study showed that many landraces had narrow adaptation, with their performance differing by location. The challenge for researchers is to develop varieties with desirable traits that are stable over a wide range of environments.

Opportunities for development of finger millet

Some indigenous farmers' varieties – Usansha, Kalale, Nyego and Chikwelekwele (Acc. 85) – showed potential yields above 2 t ha^{-1}, which was higher than earlier selected varieties in the trial. This potential can be utilized to develop better varieties. These varieties should be included in the National Finger Millet Variety trial with a view to improvement and release. Availability of genetic variability is a vital aspect to plant breeders. The collections and evaluations showed that Tanzania has a considerable variability of finger millet landraces valuable for crop improvement program.

Conclusions

Based on the preliminary results of this study, finger millet displayed a considerable range of diversity for most of the evaluated morphological and agronomic traits. These traits may be exploited for genetic improvement of finger millet landraces. Further collections of finger millet germplasm to target the under represented (gap filling collections) agro-ecological zones is suggested for maximum diversity sampling. Future effective utilization of finger millet landraces may require a careful evaluation across the environments.

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Table 3. Yield (kg ha^{-1}) of the 21 collected accessions in the yield nursery at Mbimba and Nkundi, 1998-2000

Plot no	Name	Accession no.	1998		1999		2000		Location mean*		General mean*
			Mbimba	Nkundi	Mbimba	Nkundi	Mbimba	Nkundi	Mbimba	Nkundi	
1	Katila	207	1789	1290	2071	1264	1837	771	1899cde	1108ghi	1504c-f
2	Kahurunge nkulu	83	1985	1295	2141	1163	1970	340	2032b-e	933hi	1482def
3	Kahurunge nkulu	86	2054	1686	1743	2924	1344	1774	1714de	2128bcd	1921b-f
4	Chikwelekwele	85	3096	1928	2373	4030	2457	955	2642a-d	2304bc	2473ab
5	Chikwelekwele	128	1770	1340	1032	1362	1312	949	1371e	1217e-i	1294f
6	Kasasangwe	137	2686	1850	2326	3709	2426	760	2479a-d	2106bcd	2293bcd
7	Kalale	147	2591	2227	2273	5817	4450	1365	3105ab	3136a	3121a
8	Imangago	174	2136	1271	2336	1075	2316	1270	2263a-e	1205f-i	1734b-f
9	Nyego	194	2869	1523	2694	2614	3475	1073	3012abc	1737b-g	2375abc
10	Ntiswe	204	2103	1533	1409	2642	1450	1236	1654de	1804b-g	1729b-f
11	Ntiswe	215	1732	1626	1309	3417	2155	1808	1732de	2284bc	2008b-f
12	Usansha	260	3228	1790	3321	3953	1488	1082	2679a-d	2275bc	2477ab
13	Nyamweri gumwi	671	2509	1334	2043	1856	2934	1591	2495a-e	1594c-h	2045b-f
14	Nyamweri	679	1941	1540	1509	2747	2950	1425	2133b-e	1904b-f	2019b-f
15	Ndele	692	2326	1781	1661	4065	1754	1546	1914cde	2464b	2189b-f
16	Kesanda	696	2982	1516	2287	2641	2500	1795	2590a-d	1984b-e	2269bcd
17	Barikongo	699	1922	1456	2302	2072	1100	1430	1775de	1653b-h	1714b-f
18	Katila	156	3080	1127	3300	1475	2861	870	3080ab	1157f-i	2119b-f
19	Namankota	148	3315	1314	3850	1340	2781	1289	3315a	1314e-i	2315bcd
20	Makopelo	176	2328	1294	2600	1440	2056	1148	2326a-e	1294e-i	1811b-f
21	Mpiti	217	1790	1478	1781	1362	1800	1594	1790de	1478d-I	1634b-f
22	Makuru	Control	3259	764	2044	3393	2735	1087	2679a-d	1748b-g	2214b-e
23	P 388	Control	3494	906	1272	992	950	552	1905cde	817i	1361ef
24	L 580	Control	2507	885	1290	3289	1202	1136	1666de	1770b-g	1716b-f
25	SDFM 217	Control	1969	1069	2621	2495	2905	1521	2498a-e	1695c-g	2097b-f
	Mean		2458.4	1432.9	2070.6	2753.7	2339.5	1214.7	2270.1	1724.36	1997.2
	CV (%)		21.95	-	38.8	45.3	18.15	25.2	25.32	38.81	30.96
	$LSD_{0.05}$		231.47	149.00	1131.6	1767.9	636.64	421.2	944.5	642.4	706.5

*Numbers in the same column, followed by the same letter, are not significantly different at P=0.05

Finger Millet Blast in East Africa: Pathogen Diversity and Disease Management

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Abstract

Recognising the importance of finger millet and the constraint posed by the blast disease in East Africa, Project R8030 was funded by UK's Department for International Development – Crop Protection Programme (DFID-CPP) involving organizations based in East Africa and the UK. The major objectives were to: (1) gain an understanding of the pathogen diversity and epidemiology, (2) identify sources of resistance and (3) generate knowledge of the cropping practices, production constraints and the farmers' perception of the disease and its management. New knowledge of the blast pathogen biology has been generated through a range of experimental approaches. Indigenous blast populations were genetically distinct compared to those in Asia. However, the presence of a low level of the 'Asian type pathogen' was identified, potentially linked to germplasm exchanges. Pathogen typing using molecular markers revealed a large number of haplotypes, some of which were common to both Uganda and Kenya, while others were restricted to one country. Isolates from leaf, neck and panicle blasts did not form distinct clusters and some belonged to shared haplotypes suggesting that different forms of the disease are expressed under varying agro-ecological conditions. Blast pathogen populations were found to be highly fertile, based on laboratory crosses. A combination of molecular and pathological assays suggests a role for weed-derived and seed-borne pathogen in disease development. Pathogenicity tests revealed differences in aggressiveness showing the importance of quantitative polygenic resistance to blast in finger millet. Field trials led to the identification of a number of varieties possessing tolerance to blast and desired agronomic traits. Key information on finger millet cropping, utilization and production constraints has been generated and the farmers' needs identified through extensive PRA work.

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Further, research training and dissemination activities have contributed to local capacity strengthening. Building on the partnerships established, and with sustained support from DFID-CPP, Project R8445 was initiated to further promote the outputs so as to lay the basis for increased finger millet production and utilization, benefiting subsistence farmers and urban consumers in the East African region.

Introduction

Finger millet is not only important in the diets and economy of subsistence farmers but is also increasingly demanded as processed flour and porridge by urban consumers, in the semi-arid tropics of East Africa. Nutritionally, finger millet is equal or superior to other staple cereals, especially in minerals. This cereal is important for pregnant women, nursing mothers and children (National Research Council 1996) and could also help sustain malnourished people as it is recognized as an important dietary supplement for HIV positive people. Blast caused by *Magnaporthe grisea* (anamorph *Pyricularia grisea*) is a major constraint to finger millet production in the region. Blast affects finger millet at all stages of growth and most of the landraces and a number of other varieties are highly susceptible. Major gaps exist in our knowledge of the pathogen biology, epidemiology and its interactions with the host, impeding effective disease control (Sreenivasaprasad et al. 2005). The main objectives of the project R8030 funded by the UK Department for International Development (DFID) – Crop Protection Programme (CPP) were to (1) characterise the pathogen populations and use this information as a basis for epidemiological studies, (2) identify sources of host resistance and gain an understanding of the cropping practices and constraints to disease management and (3) build partnerships for promoting the outputs and to facilitate stakeholder interaction. Successful management of blast through new knowledge of the host-pathogen interaction, improved awareness of the farming community, and enhanced connectivity among stakeholders will substantially contribute to increasing finger millet production and utilization in East Africa.

Materials and Methods

Molecular characterization. Blast samples were collected from farmers' fields mainly in the northern and eastern regions, and also from western region in Uganda. Similarly, in western Kenya, samples were collected from farmers' fields in the key areas, and the blast screening nursery, Kenya

Agricultural Research Institute (KARI), Alupe. Field isolates were established from finger millet and weed samples on oatmeal agar (OMA) plates (Takan et al. 2004). Mono-conidial cultures prepared for every field isolate were used for further characterization. *M. grisea* isolates were preserved on filter paper discs (Latterell and Rossi 1986) and their details are available in the project datasets (Sreenivasaprasad et al. 2004). Cultures were grown in 2X Yeast Extract Glucose (2YEG) medium (Valent et al. 1991) and the mycelium was harvested, freeze-dried and stored at –20°C. Genomic DNA was extracted from 40 mg of freeze-dried mycelium using GenElute Plant Genomic DNA Miniprep Kit (Sigma, UK). *M. grisea* isolates were screened for the presence of the grasshopper (grh) DNA repeat element using PCR (polymerase chain reaction) primers designed from the grh sequence available in the EMBL database. Amplified fragment length polymorphism (AFLP) analysis was performed using a commercial kit (Invitrogen, UK). Fifteen *M. grisea* isolates were randomly selected and used for initial screening of a total of 64 primer combinations. Based on the number of bands and the level of variation, up to 15 primer combinations were selected for population analysis. For PCR based screening and the identification of *M. grisea* mating type alleles, MAT1-1 and MAT1-2, specific primer pairs were designed from gene sequences (provided by Dr S Kang, Penn State University, USA). For all forms of PCR referred above, genomic DNA (approx. 1 ng) and REDTaq Ready Mix (Sigma, UK) were used following standard procedures (Talhinhas et al. 2005).

Mating assays. To determine the fertility and mating compatibility of M. grisea, characterised isolates were crossed with testers of opposite mating type following standard procedures (Kumar et al. 1999). The testers used included previously described isolates 4136-4-3, TH 3 and I-R-22 for MAT1-1 and Guy 11, JP 15 and BR 62 for MAT1-2 (Notteghem and Silue 1992) and also a new tester K23/123 established in this project. The plates were observed under a microscope for the presence of the perithecia, approximately four weeks after crossing. Crushed perithecia were observed to determine the presence of asci and ascospores, and the germinability of ascospores was tested on water agar plates.

Pathogenicity testing. The following varieties were chosen based on previous field rating: (E11 and HPB-83-4 (susceptible), P665, OK/3 and INDAF 5 (moderately resistant) and SEREMI 1, SEREMI 2, SEREMI 3, PESE 1 and GULU E (resistant). *M. grisea* isolates representing the strategic sampling were tested with three replicates for each variety and isolate combination. Spore suspensions (40 ml of 1x105 spores/ml) were prepared from 15-day-old OMA cultures using 0.5% gelatin solution. Finger millet seedlings were grown in trays and maintained at 25-27°C. Each tray was isolated from its surroundings by placing it in a large autoclave bag and sprayed with 10 mls of the inoculum. After spraying, the tops of the bags were sealed and the plants were incubated at 25-27°C (under daylight bulbs) for seven days. The total number of blast lesions on the 4th leaf and the approximate percentage area covered by lesions were recorded. Pathogenicity of *M. grisea* on seed heads of mature finger millet plants was tested using six varieties (SEREMI 1, SEREMI 2, SEREMI 3, PESE 1, P665 and E11). Four week-old seedlings were transplanted into potting compost in 9-inch pots. A poly-grip bag with its bottom cut open was placed over a single seed head providing a contained environment in which to apply the inoculum. Ten pots per variety were prepared for each of the six varieties and replicated for each isolate. Fourteen days after inoculation, each seed head was classified as having no infection, partial infection (seed head showed signs of infection on some but not all of the fingers) or total infection (all the fingers in a seed head infected). The raw data were averaged between replicates and analyzed by Genstat.

Field trials. Epidemiological experiments on the role of seed-borne inoculum in blast development were conducted at SAARI, Uganda. Plots with a range of treatments from 0 to 10 % infected seed were established by mixing different batches of appropriate proportions of finger millet seed infected by *M. grisea.* The incidence of seedling blast was recorded six times starting at two weeks after emergence and at weekly intervals thereafter. In finger millet screening trials under natural blast infection, 65 farmer varieties plus 30 breeding lines from ICRISAT were tested at the Alupe station, KARI. The trial was planted in three replicates over two seasons, February-July 2002 long rainy season (LR) and August-December 2002 short rainy season (SR). Disease incidence was scored on a 0-9 scale, where 0= no disease and 9 = more than 75% leaf area covered for leaf blast (recorded at seedling and booting stages); and 0= no disease (all panicles have no disease on neck and finger) and 9 = 81-100% panicles severely infected for neck and finger blast (recorded at physiological maturity and harvest). Data on grain yield, days to 50% flowering, plant height, seedling vigor and agronomic performance were also collected.

Disease and Socio-economic surveys. Surveys were carried out in western Kenya and the northern and eastern regions in Uganda to record the blast disease levels across key cropping locations over different seasons and years and to collect blast samples from farmers' fields and screening sites. For assessing the disease, three 1m^2 quadrants were covered in every field. In each quadrant, total number of plants and the number of blast affected plants were recorded. In each quadrant, 10 heads were randomly selected to determine blast severity. For each head a proportion of spikelets affected by the disease was estimated. Values for the three quadrants were averaged. Participatory rural appraisal (PRA) studies with farmer groups were conducted in western Kenya, in Nambale and Butula divisions (Busia district), in Amukura and Amagoro divisions (Teso district) and in Masaba and Nyacheki divisions (Kisii district). In Uganda, sub-counties Kyere (Soroti district), Kapujan (Katakwi district) and Putiputi (Pallisa district) in the Teso and Bata and Adwari sub-counties (Lira district) and Chawente (Apac district) in the Lango were surveyed. A combination of PRA techniques, including focussed group discussions and key informant interviews, were employed through a semi-structured questionnaire.

Results and Discussion

Genetic diversity and relationships of Pathogen Populations. A range of PCR-based methods were used to characterise 328 *M. grisea* isolates collected from Uganda and Kenya, along with some reference isolates from other hosts and geographic locations. A PCR test developed in this study was used to show that the populations of *M. grisea* associated with finger millet blast in East Africa were genetically distinct to those in Asia, as 96 % of the 328 isolates did not contain a DNA repetitive element grasshopper (grh). This element has been shown to be commonly present in the pathogen isolates in Asia (Dobinson et al. 1993). Low level presence of the *M. grisea* isolates containing the grh element (4%) also suggests the recent introduction of these isolates linked to germplasm exchange. Initial AFLP analysis of the pathogen isolates with a limited number of primer combinations revealed a limited degree of diversity among the populations based on the profiles (DNA fingerprints, eg, Fig 1).

Extended analysis of the 328 M. grisea isolates with up to 15 primer combinations led to the identification of 243 haplotypes. Single haplotypes (unique DNA fingerprints) dominated the pathogen populations, as the 280 *M. grisea* isolates from surveys across multiple sites in Uganda and Kenya were partitioned into 160 single haplotypes and 35 shared haplotypes (identical DNA fingerprints). Similarly, 48 *M. grisea* isolates collected from nine finger millet varieties at a screening site in Uganda were all distinct single haplotypes. Cluster analysis of the haplotypes revealed continuous genetic variation pattern and a lack of clonal lineages among the blast pathogen populations associated with finger millet in East Africa. Some of the shared haplotypes identified were common to Uganda and Kenya, whilst others were restricted to one country (eg, Fig 1). Similarly, some of the shared haplotypes represented *M. grisea* isolates from different parts of finger millet indicating their genetic similarity and that these isolates are capable of causing different types of blast under suitable agro-ecological conditions. Further more, some of the shared haplotypes also represented *M. grisea* isolates from finger millet and wild millet suggesting their genetic similarity and that wild millet can serve as an alternate host in the field.

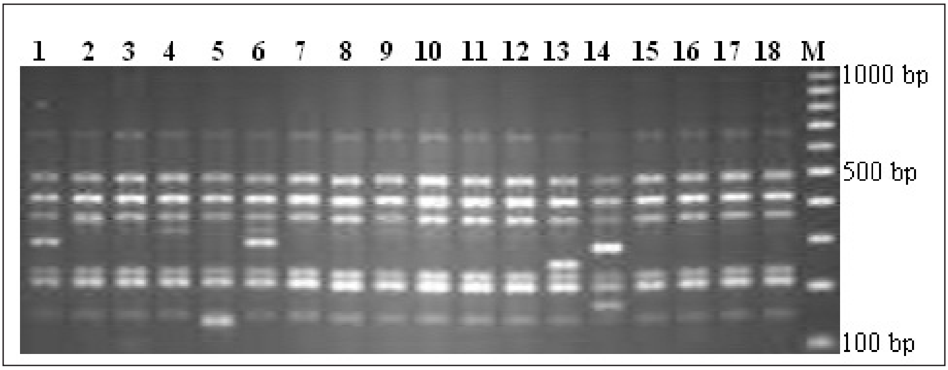

Figure 1. DNA fingerprint profiles of a set of the blast pathogen Magnaporthe grisea *isolates from Uganda and Kenya, generated using AFLP markers.*

Isolates 1-6, 9-15, 17 and 18 are from Uganda; isolates 7, 8 and 16 are from Kenya; M is a DNA size marker

Sexual reproductive potential of Blast Pathogen Populations. Reproduction of *M. grisea* on rice is predominantly asexual. However, high fertility of the pathogen isolates from finger millet in laboratory crosses has previously been observed (Yaegashi and Nishihara 1976). A PCR based assay developed was used to identify the mating type of the 328 blast pathogen isolates. This revealed a near equal distribution of the two mating types, MAT 1-1 and MAT 1-2, in general. In some locations, higher proportion of a particular mating type was also observed. Compatibility tests in dual culture crosses with standard tester strains demonstrated the high fertility status (86% – 88%) of the finger millet blast pathogen in East Africa. Among the fertile populations, hermaphrodites were dominant (67%), followed by males (27.2%) and females (5.8%), suggesting a gradual loss of female sex. *M. grisea* isolates from Eleusine spp. from the same district were also sexually compatible. These results strongly suggest a role for sexual reproduction and recombination in the continuous genetic variation pattern and non-clonality of *M. grisea* populations associated with finger millet blast in East Africa.

Pathogen Aggressiveness and Epidemiology. Pathogenicity tests were performed with a representative set of isolates that were characterised using molecular markers. A range of finger millet varieties (SEREMI 1, SEREMI 2 and SEREMI 3, PESE 1, Gulu E, INDAF 5, OK/3, P665, HPB-83-4 and E11) representing susceptible to resistant reactions based on previous field observations (ICRISAT and SAARI) were used in these assays under controlled conditions in the green house. Pathogenicity tests revealed that all *M. grisea* isolates caused susceptible blast reactions on finger millet varieties, with variation in aggressiveness both on a particular variety as well as in infecting different varieties (Fig 2).

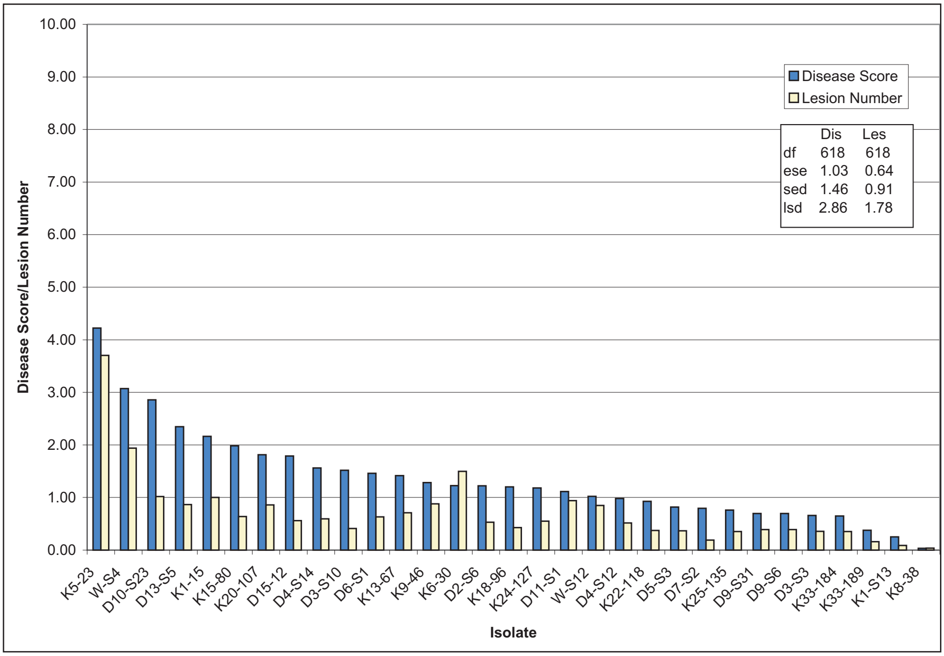

Figure 2. Aggressiveness of Magnaporthe grisea *isolates tested against 10 finger millet varieties averaged across varieties.*

For example, in a set of 35 blast isolates, most isolates showed the highest disease score on E11, but four of the isolates gave the highest disease score on PESE 1. None of the isolates tested, however, showed distinct compatibility and incompatibility reactions expected in gene-for-gene interaction systems involving major R genes. These results suggest that polygenic quantitative resistance is more common in the finger millet blast interaction. Pathogenicity tests were also carried out on seed heads of mature finger millet plants of varieties E11, SEREMI 1, SEREMI 2 and SEREMI 3, PESE1 and P665 using a set of eight *M. grisea* isolates. The apparent susceptibility of the finger millet varieties to seed head infection, with the exception of E11, appeared to differ from that in the seedling assays. For example, SEREMI 1, which was relatively resistant in the seedling experiments, appeared more susceptible with regard to seed head infection especially when inoculated with isolates from neck and seeds, and P665 was the least infected. This needs to be further investigated, as neck and panicle blast are particularly destructive, leading to major yield losses. Further, *M. grisea* isolates from weeds were pathogenic to finger millet, with some isolates being as aggressive as some of the isolates from finger millet. This is in agreement with the molecular analysis and suggests that the pathogen harboured by the wild millet can serve as an inoculum source. Similarly, results from the seed pathology experiments also showed that the pathogen present on finger millet seeds could play a role in the initial blast development in the field, as higher disease incidence was observed with seeds containing higher proportion of the pathogen.

Screening for Blast Resistance and Agronomic Traits. From the finger millet collections at ICRISAT, a range including 65 farmer varieties and 30 germplasm accessions were used in these trials. Finger millet varieties/accessions were tested for their reaction to blast under natural infection at Alupe, Teso district in Kenya linked to KARI. KNE 479 and KAT/FM1 were used as susceptible checks; KNE 620 and KNE 1034 were used as resistant checks and KNE 479 was used as infector rows. ICRISAT germplasm lines KNE 620, KNE 629, KNE 688, KNE 814 and KNE 1149, and farmer variety accessions 14, 29, 32 and 44 were identified with low blast levels and good agronomic performance (Sreenivasaprasad et al. 2004). There was a significant negative correlation between finger blast severity and grain yield during the long rainy season and some of the early-maturing varieties had high panicle blast incidence and severity. The varieties/lines identified can be utilized in breeding programs and some could be promoted for farmer production.

Disease and Socioeconomic Surveys. Disease surveys revealed blast as the most important and widespread disease in Busia, Teso and Kisii districts in Kenya, with grain yield losses estimated to be between 10 and 50%. Blast incidence (13 to 50%) and severity (24–68 %) varied considerably across main finger millet cultivated areas in the northern and eastern districts of Uganda. In both countries, the disease incidence and severity were higher during the first season (February-July) than in the second season (August-December). Varieties producing dark coloured seeds and compact heads were more blast resistant compared to white-seeded and open-headed varieties. Blast was frequently observed on weeds such as *Eleusine indica* (wild millet), *Digitaria spp*., *Dactyloctenium sp*. and Cyperus sp. commonly occurring in finger millet fields. Weed control, particularly wild millet, which is very common and difficult to distinguish from the crop at early stages, is a key issue in blast disease management.

Socioeconomic surveys conducted in western Kenya revealed that Enaikuru in Kisi, Emumware in Teso and Ikhulule in Busia were the most popular local varieties. The improved varieties Gulu E and P224, liked for their early maturity, were common in Busia although farmers rated them as moderately susceptible to blast. Farmers in Kisii rated Marege and Enyakundi as having some level of resistance to blast. In Busia, farmers have adopted row planting to reduce labour intensive weeding. In Uganda, five to eight varieties were grown depending on the location in the first season (February-July), whilst fewer varieties were grown in the second season (August-December). There is a need to develop innovative seed multiplication and distribution systems to promote the varieties identified, as a majority of farmers used own seed. Millet is commonly grown in mixed cropping, and the order of rotation varied, but some farmers, especially in Teso, were aware that millet should not follow sorghum (Sorghum bicolor) because of *Striga*. Most farmers were aware of blast symptoms (in Uganda described as Ebwetelele, Obapu and Kalajajwa - generally meaning 'dry heads' and known as egetabo in Kisii, Kenya) but were not aware of the cause, modes of transmission and control measures. Both in Kenya and Uganda, there is a general lack of crop pest and disease management information, which needs to be addressed urgently. It is also important to identify/develop blast resistant varieties with farmer preferred qualities (Table 1) to improve production and utilization.

Table 1. Farmer preferred characteristics of finger millet in the order of ranking

1	Early maturing
2	Drought tolerance
3	Uniformity in height
4	High tillering
5	Large heads, non-shattering and high yielding
6	Widely adaptable
7	Seeds easy to dry, clean and market
8	Resistance to diseases especially blast, lodging and pests
9	White seeded
10	Good palatability
11	Good brewing qualities
12	Good storability and viability

Conclusion and Perspectives

New knowledge on the blast pathogen genetic and pathogenic diversity and epidemiology has been generated and baseline data on finger millet production systems in East Africa including farmers' practices, blast disease incidence/severity and other constraints to production and the pattern of use of finger millet varieties has been established (Sreenivasaprasad et al. 2004, Takan et al. 2004). This information, along with the identification of blast resistant finger millet varieties and lines and the evidence that finger millet mainly contains quantitative resistance to blast provide a firm basis for developing a sound and sustainable finger millet blast management strategy in East Africa. Some of the varieties and lines identified are suitable for farmer promotion and others can be utilized in breeding programs. Opportunities exist for flexible approaches to the promotion of the improved varieties. For example, in Uganda, the government has identified millet as one of the priority crops to improve the livelihoods of internally displaced people and SAARI have previously been involved in releasing finger millet varieties. Moreover, the grain processing industry is proactively seeking wider linkages. Issues such as quality, standards, reliable supply and alternative uses have been the topic of on-going discussions between researchers, extension workers, farmers and grain processors in Kenya and Uganda. Improved communication among the key players is paramount to sustained growth in finger millet production in the region (Lenné et al. 2007). This regional workshop has provided an opportunity to further strengthen the partnerships and to initiate connectivity.

This provides an excellent platform to develop wider linkages and pathways for improving finger millet production and utilization in East Africa to the benefit of subsistence farmers and consumers.

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Overview and objectives of Finger Millet project R8445 on "Facilitating the Promotion of Improved and Blast resistant Finger Millet Varieties"

MA Mgonja[1]

Finger millet (*Eleusine coracana*), a widely grown cereal in semi-arid areas of East and southern Africa and South Asia, is a staple food and generates income for millions of poor people. It plays a key role in the livelihoods of smallholder farmers and their families and is an important food security crop. As production statistics for the nine cultivated millets are often combined, reliable estimates of the areas sown to individual species are difficult to find. It was recently estimated that finger millet accounts for 10% of 38 million ha sown to millets globally.

In East Africa, however, finger millet is the most important millet being cultivated over 50% of the area sown to millets, especially in Uganda, Tanzania and Kenya. In addition, finger millet production in East Africa has risen by 25% over the past 30 years, driven by domestic demand, growing regional trade, and higher market prices than other cereals. Nutritionally, finger millet is equal to or superior to other staple cereals, especially in minerals. It has more fiber and iron, and especially calcium that is 40 times that found in maize and rice and 10 times that in wheat.

Challenges in the finger millet industry:

The neglect of finger millet by mainstream research organizations and donors has contributed to a lack of realization of the potential productivity of finger millet. Increased production, utilization and trade of finger millet in East Africa is currently limited by a number of constraints that reduce yields to 0.5-0.75 t ha^{-1} from a realistic on-farm potential of 1.5-2.0 t ha^{-1}. The constraints are in the whole food supply chain from production to utilization.

At the production level, although a number of varieties are grown by farmers, no significant research has been done to characterise the varieties in terms of their adaptability to the various agro ecologies and recommendation domains and also in terms of their end use quality characteristics as required by consumers and the industry. Finger millet blast disease caused by the fungus *Magnaporthe grisea*, more commonly known as a rice disease is the most serious constraint. The disease affects finger millet at all growth

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stages. It is especially serious in the Busia, Teso and Kisii districts of Kenya and in the main finger millet areas in north and east Uganda. Many widely-grown landraces and genotypes are susceptible with losses of 10-50% being common. Other constraints include the high labor demand for weeding, under-developed seed systems, poor post-harvest handling which reduces grain quality, and an inefficient production – supply chain, poor husbandry, especially soil and crop management. It has also been noted that the demand for finger millet products far exceeds the grain marketed though the market and pricing systems are not very well developed and are also not explicit.

Until recently, limited information about blast disease and its management in East Africa was available. The UK Department for International Development (DFID) Crop Protection Programme (CPP) projects (R8030 "Pathogen diversity and disease management" and R8445 on "Facilitating the promotion of improved and blast resistant Finger millet varieties"), implemented in the past five years in Kenya and Uganda, have made a significant contribution to the development and promotion of sound blast disease management strategies. In this process, a firm foundation for increased finger millet production and utilization in East Africa has been established.

The outputs from project R8030 "Pathogen diversity and disease management" provided a justification for the new project R8445. These included:

1. Knowledge on finger millet blast pathogen diversity
2. Establishment of the weed blast isolated aggressiveness
3. Finger millet blast resistant and adapted varieties were identified and assembled
4. An understanding of the East Africa finger millet production systems and farmers perception of blast and its management
5. Capacity building needs in the finger millet sector were identified

Through a number of stakeholders interactions in the East Africa region, the justifications for a next phase ie, R8445 after R8330 were emphasised, particularly the work on variety promotion, improved farmers' awareness of the disease, pathogen spread and use of clean seed. Other recommendations included promotion of connectivity in production/supply chains and the research-extension farmer industry linkages. All these recommendations should be bound by favorable policy environment that is supportive of the finger millet sector.

The demand for the project R8445 is further supported by the following facts:

1. Area under finger millet production in Kenya, Tanzania and Uganda, which is approximately 100,000 ha, 200,000 ha and 400,000 ha respectively, and is showing an increasing trend
2. The farmers' and industry perspectives on the crop, including its nutritive value, especially for babies and nursing mothers, feeding AIDS patients, because it is high in methionine, iron and calcium, low in gluten and also its potential as forage and as an export crop
3. Results from the blast work need to be disseminated
4. The increasing number of research projects currently being developed and also those that are being implemented by various organizations both in the north and in the south. These include the "Collaborative Crop Research Program (CCRP), Comparative Genomics of the Chloridoid Cereals –Enhancing progress in Tef and Finger Millet" and also the characterization work by ICRISAT

Project 8445 is therefore on facilitating the promotion of improved and blast resistant finger millet varieties. The expected outputs from this project are:

1. Promotion/demonstration of the potential of improved and blast resistant varieties
2. Increased farmer awareness of the blast disease problems and management
3. Improve connectivity between finger millet production–supply chain and R&D/E workers–farmer-industry continuum

It is against this background on the expected project outputs and especially on connectivity between finger millet production-supply chain that this international workshop is organized to promote communications among finger millet stakeholders.

Finger Millet in East Africa: Importance, Blast Disease Management and Promotion of Identified Blast Resistant Varieties in Western and Nyanza Provinces of Kenya

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Abstract

Finger millet is an important food crop in the semi-arid regions of East Africa. Fundamental properties of finger millet underlie the nutritional benefits and wide adaptability. The most serious biotic constraint to finger millet is blast caused by the fungus *Magnaporthe grisea*. It can affect the crop at all growth stages, causing large yield losses. Researchers from National Agricultural Research System (NARS) of Uganda and Kenya, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the UK National Research Institute (NRI) had collated available germplasm, collected finger millet blast isolates and studied the epidemiology of the blast fungus and identified blast resistant genotypes. Based on the results, on-farm trials were conducted in Kenya's Western and Nyanza provinces in 2005, to evaluate and promote the identified blast-resistant varieties. Seven improved varieties were tested using the Mother-Baby Trial (MBT) approach, which comprised 5 researcher-managed and 81 farmer-managed trials covering four districts of Busia, Teso, Gucha and Kisii. Varieties KNE688, KNE1149, KNE814 and Acc.14 were suitable for Busia and Teso districts whereas varieties KNE814, KNE688 and Acc.14 were suitable for Kisii and Gucha districts. Farmer preferences for these varieties were based on grain quality (especially brown color), high yield potential, low blast disease levels and relative earliness. However, early maturing varieties seemed to be more susceptible to the blast disease than late maturing types. The variety KNE688 showed high yield and low blast incidence, and also responded well to good management, with mean yields of 1.37 and 1.85 t/ha under farmer- and researcher management, respectively. The variety P224 gave appreciable yield under good or poor management. These materials need to be evaluated more extensively to assess yield stability and GxE interactions. Field days were held in four districts to provide stakeholder interactions and to allow farmers to assess the varieties.

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Farmers valued the improved varieties for their yield and blast resistance, but also valued the dark brown color which is present in their local varieties. Breeders must therefore seek to combine high yield, blast resistance and brown grain color in future varieties. There is need for more investment in finger millet research, extension and market linkages for improved food and nutrition security and enhanced income.

Introduction

Among the small millets, finger millet (*Eleusine coracana*) is the most important. Its wide adaptability; from hill slopes and undulating fields to shallow and gravelly soils, makes it the most popular small millet in India, Africa and, to some extent, dry regions of Sri Lanka. Finger millet accounts for an 8% of planted area and 11% of production of all millets worldwide (Rachie and Peters 1977). Finger millet belongs to the family *Poaceae*. Its native home is presumed to be eastern/central Africa, specifically Uganda, from where it moved to the Indian subcontinent around 3000 BC. In Uganda, finger millet is the most important cereal, equaling the hectarage and production of all other cereals combined. It is a hardy crop, able to thrive in poor soil and limited moisture conditions. In eastern Africa, it is grown mainly in the lake regions and highland areas of Kenya, Uganda, Tanzania, Rwanda, Burundi and eastern Democratic Republic of Congo. Other producers include Ethiopia, Sudan, Somalia in eastern Africa; Malawi (Mnyenyembe 1993), Zambia (Agrawal et al. 1993) and Zimbabwe (Mushonga et al. 1993) in southern Africa.

Average grain yield on farmers' fields are low, ranging from 500kg/ha to 750 kg/ha (Mitaru et al. 1993). However, in spite of the low yields, the crop continues to be widely grown because of its high traditional values, and because of the high prices it fetches compared to other cereals (Obilana et al. 2002).

Being a C4 plant, it has a high production potential, reaching up to 4 t ha^{-1} under optimum conditions. Its wide adaptability to different rainfall zones, developmental plasticity and high nutritive value make it one of the most popular small millets. In Africa and India, it is grown in areas with 500-1200 mm rainfall. It can be grown throughout the middle-elevation areas of eastern and southern Africa. It is best suited to altitudes of 1000-1800 m. In Kenya, it is grown by small-scale farmers for both food and cash. About 65,000 ha are planted annually in Western, Nyanza and Eastern provinces (Mburu 1989) and about 500,000 ha in Uganda (Ekwamu 1991). There has been a decline in production area, largely attributed to its high labor requirement compared to maize and its lower yield per unit area.

Though often known as a crop for the poor, it is fast becoming a popular food crop among people of all wealth categories. It is recognized as being more nutritious than other cereals. It is rich in calcium, iron, manganese and fiber; and an excellent source of methionine – an amino acid lacking in the diets of millions of the poor who live on starchy foods such as cassava, plantain, polished rice, and maize meal (Obilana 2002). Finger millet protein contains a very good source of sulphur amino acids. In addition, it has the unique distinction of being the only cereal with over 300 mg/100g of calcium in the grain. *Source:* www.mcgill.ca/dataTables/dalit/3dalit grain data Tables. It is a good source of iron and micronutrients. It is recommended as the ideal food for diabetics, elderly, the sick and especially those affected by AIDS. In Kenya and Tanzania it is known as *wimbi* and *ulezi*, respectively. In these two countries as well as in Uganda it is used to make breakfast porridge and can be mixed with other energy sources to make stiff porridge popularly known as *ugali*; similarly known as *sadza* or *nsima* in Zimbabwe and Malawi /Zambia, respectively. Finger millet is also used to make local beers, for example, *bussa/ajono* in Kenya/Uganda and *mbege* in Kenya. Finger millet can be stored for long periods, a critical trait in ensuring food security for poor households in drought-prone areas. Stored seeds are seldom attacked by insects or molds.

Finger millet blast *(Magnaporthe grisea*), a very close relative of rice blast (*Pyricularia oryzae*) is the most serious and widely spread disease. Blast affects finger millet at all growth stages, from seedling stage (causing lesions and premature drying of young leaves) to affecting the panicle causing neck and/or finger blast. The latter is the most destructive phase of the disease and can prevent grain set and cause seeds to shrivel (Pande et al. 1992). Other diseases include *Helminthosporium*, which causes leaf-spots, seedling blight, and head blight. Control is through phytosanitary measures – uprooting and burning infected plants – as well as use of resistant varieties. The most important pests include grasshoppers and armyworms and the latter is particularly devastating during the early growth stages. It can wipe out the entire field, necessitating re-sowing. Other pests include shoot fly and stem borers. Birds can cause damage when the crop is ready for harvesting – but in many instances damage levels are low and do not warrant any intervention. Finger millet production is labor-intensive, especially for controlling weeds in broadcasted fields and especially wild finger millets. The crop is also severely affected by *Striga*, which is a parasitic weed most notorious on cereals. Weeding and harvesting account for approximately 25% and 14%, respectively, of the overall labor requirement (Nyende 2000). In areas with declining soil fertility and areas infested with prolific weeds, up to four weedings may be necessary in order to realize good yields. Row planting has often been advocated as a solution (Shakya et al. 1991). It may not necessarily reduce labor demand because manual row planting (most smallholders lack mechanized alternatives) is also labor intensive. However, row planting requires less labor, especially during weed control than in a broadcasted field (Nyende et al. 2001), and thus has the potential to significantly reduce the labor constraint and also improve yield.

Most finger millet landraces and a number of other genotypes are highly susceptible to blast. In view of the importance of the crop and the impact of the disease, the Department for International Development (DFID), UK, funded the project *Finger millet blast in East Africa: pathogen diversity and disease management* (R8030, Crop Protection Programme). The project was implemented during the period 2001 to 2004. Research under this project generated several outputs (Takan et al. 2004) summarized as follows:

- Characterized pathogen populations based on a baseline collection of over 300 isolates. The analyzes revealed that the pathogen was limited in genetic diversity but varied considerably in aggressiveness.
- Weed blast isolates were found to be capable of infecting finger millet; in particular, isolates from wild Eleusine were as aggressive as some of the finger millet blast isolates. Seedborne pathogen appeared to contribute to disease development, with higher blast levels in seed lots of susceptible varieties. This enables identification of disease intervention points and management strategies.
- An assemblage of finger millet varieties likely to be suitable for East Africa was screened and several resistant/tolerant varieties have been identified, with the potential for immediate promotion or incorporation into breeding programs.
- Baseline information has been generated on East African finger millet cropping systems and prevalence of blast, production constraints, and farmers' perception of blast disease; farmers' needs have been identified.
- The project contributed to local capacity development and dissemination of outputs to target beneficiaries to ameliorate the constraints posed by blast,

and also to develop sustainable disease and crop management methods through local and regional capacity building.

The results of the above project R8030 formed the basis for a new project R8445, specifically targeting the promotion of R8030 outputs. The previous project (T8030) laid a foundation for interventions – disease management, utilization of host resistance for enhanced finger millet production. The broad stakeholder interaction and Participatory Rural Appraisal (PRA) results clearly showed the need for further work to promote improved, blast-resistant varieties to increase productivity and bridge the huge gap between local supply and demand. The results also showed the need to enhance farmer awareness of the blast problem (pathogen spread, collection and use of clean seed) and of methods to improve post-harvest handling and grain quality, which could result in higher quality and better market opportunities. The policy makers and stakeholders in Kenya and Uganda that participated in R8030, also recognized the lack of connectivity, both in the production-supply-market chain and in the research-extension-farmer-industry continuum, which the new project aims to address. Policy makers and stakeholders in both countries also expressed their willingness to provide support for finger millet research, extension and linkages to markets.

The major objective of project R8445 was to further promote the outputs of project R8030 and thus contribute to increased production and utilization to benefit subsistence farmers as well as urban consumers in East Africa. The specific objectives were to:

- Demonstrate and promote through farmer participatory approaches, the potential of improved, blast-resistant finger millet varieties
- Increase farmer awareness of blast disease problems and management, harvest and use of clean seed, and improved grain quality
- Enhance connectivity along the production-to-supply chain and along the research-development-extension-farmers-industry continuum

Materials and Methods

Blast resistant finger millet varieties selected for promotion

Seven finger millet resistant lines selected for their low blast levels and good agronomic performance were used in this farmer participatory finger millet evaluation. The lines included three farmer varieties (Acc.14, Acc. 29 and Acc.32), three ICRISAT germplasm lines (KNE688, KNE814 and

KNE1149) and one commercial variety (P224). These were selected based on a blast reaction trial of finger millet varieties grown by farmers in four districts of Busia, Gucha, Kisii and Teso; using 65 farmer varieties collected from the four districts. These comprised 12 varieties from Busia, 25 from Teso, 16 from Kisii and six from Gucha. The 65 farmer varieties plus 30 ICRISAT germplasm lines of known reaction to blast were evaluated on-station at the Kenya Agricultural Research Institute (KARI) Alupe research centre in two rainy seasons, April-July 2002 and August-December 2002. The PRA carried out in 2002 in Busia, Teso, Kisii and Gucha districts in Kenya, had also indicated that most of the landraces had varying degrees of susceptibility to blast with yield loss estimates ranging from 10 to 50%. It was also evident that blast disease incidences were higher in Kisii than in Busia and Teso districts. This was attributed to the two seasons planting of finger millet in Kisii whereas in Busia and Teso the crop is mainly grown during the long rainy season only. Evaluation and selection of the finger millet for blast resistance was done jointly by KARI in Kenya, National Agricultural Research Organization (NARO) in Uganda, ICRISAT, and partners from the DFID finger millet project

***Promotion of improved blast-resistant varieties in Mother Baby Trial (MBT) design*:** The project was building on the contacts developed with the farming communities and local agricultural extension staff during earlier PRA and disease surveys in Kenya (conducted under the previous finger millet project in R8030). Variety demonstrations were established with participation from farmers, farmer group leaders and extension staff of the target districts. The MBT approach was used to demonstrate the potential of improved, blast-resistant varieties. This approach has been extensively used to test a range of technology options suited to a heterogeneous community (Snapp 2002). The MBT approach involves three components – mother trials, baby trials, and farmer experimentation. Mother trials are researcher-designed, researcher-managed and completely randomized, with two to four replications per site. They are designed to directly compare different 'best bet' technologies in the same field and the same year and over several years, allowing farmers to choose technologies most appropriate to their needs. Baby trials are located around mother trials, and consist of a few treatments chosen from the mother trial and run by the farmer. They are un-replicated, and may be managed by farmers (usually) or by researchers. Baby trials allow farmers to see for themselves the performance of treatments at different trial sites, and allow for faster, larger-scale (although somewhat less rigorous) testing at different locations under different management conditions. The third component is farmer experimentation, where farmers select and test technologies of their own choice – they develop their own methods to experiment, modify treatments where needed, share results with other farmers, and identify technologies that offer significant benefits. The finger millet activities reported here included only mother and baby trials.

Trials were established in selected villages in four districts – Kisii and Gucha districts in Nyanza province, Busia and Teso districts in Western province. The trials were hosted by a total of 81 farmers managing either mother or baby trials. A total of 5 mother trials and 81 baby trials were planted. Mother trials were planted at Busia (Alupe, Nambale and Butula divisions); Teso (Amagoro and Amukura); Kisii (Masimba) and Gucha (Nyacheki). Each mother trial was typically 'surrounded' by 12-15 baby trials. Each mother trial consisted of one local and seven improved varieties: KNE688, Acc.32, KNE814, P224 (commercial variety), KNE1149, Acc.14 and Acc.29. Each baby trial was managed by a farmer and consisted of four of the above varieties, including a farmers' local check variety and the commercial variety P224. Initial work on identifying sites and farmers/farmer groups and providing seed was done between January and March 2005. Trials were planted by April 2005 depending on the onset of rains.

Data collection and analysis

On the mother trials, data was collected on leaf, neck and finger blast, days to 50% flowering, agronomic scores, plant height, lodging, panicle weight, threshing percentage, 100-seed mass and grain yield. Data were analyzed for each mother trial and also combined across sites. A comparison was also made between researcher-managed versus farmer-managed mother trials.

Increasing farmer awareness of blast management and grain quality

Linkages were developed with local extension staff from the earliest stages, and they participated in the planning of the trial, planting, management and data collection. Project staff periodically visited the sites to work with farmers on plot management, and to discuss varietal performance under biotic stresses, especially blast. Farmer field days were conducted at physiological maturity to demonstrate the potential of the improved varieties in terms of blast resistance, yield and other attributes. Extension staff as well as local community-based organizations and NGOs worked with project staff to increase farmer awareness of blast management and encourage adoption of the new varieties. During field days, farmers visited the mother and baby trials and discussed the full range of issues from finger millet production to consumption and marketing. Feasibility of improved sowing methods (notably row planting) to manage weeds and reduce labor, as adopted by farmers in Busia, were discussed. During the field days, farmers also participated in selecting the best performers based on a number of criteria. Farmers' rankings of varieties were analyzed to better understand their needs and preferences.

Results and discussion

Due to logistical problems during the cropping season, data from only 4 mother and 46 baby trials were received. Even where data were received, especially for baby trials, only a few variables were recorded. Two mother trials were received from Busia, one each from Teso and Gucha and none from Kisii. Out of the 46 baby trials' results received, 15 were from Kisii, 15 from Gucha, 10 from Teso and 6 from Busia.

Teso district

Mother trials:

Data were recorded on grain yield, blast incidence (leaf, neck, finger, and overall blast reaction), days to 50% flowering, agronomic score, plant height and lodging score from one mother trial. Grain yields ranged from 1.065 to 1.852 t ha^{-1} (trial mean 1.580 t ha^{-1}, local control 1.34 t ha^{-1}). Varieties KNE688, Acc.32, KNE814, KNE1149 and P224 gave yields above the trial mean (Table 1) in the mother trial. All the varieties had a low blast reaction with incidence scores of $\leq$ 3.0 for leaf, neck, finger, and overall blast. The varieties KNE688, KNE814 and KNE1149 had the lowest blast incidences of <2.0. Acc.32 was the earliest to flower (68 days) but also had the highest blast incidence scores of 3.0. This reflects the susceptibility of early maturing varieties, as reported in previous finger blast screening research (Pande et al. 1995). Plant height varied from 104 to 119 cm and Acc.32, although the shortest, had a relatively high lodging score of 3.8, indicating that it has a weak stem. KNE 1149 had the best overall agronomic score (1.8) and Acc.32 and the local variety had the poorest (3.0).

Baby trials: Although the babies were planted later than the mother trial, yields were generally comparable. Variety P224 gave the highest grain yield (1.734 t/ha, averaged across the 10 farmers/babies and together with KNE688, KNE814 and KNE1149 had lowest blast incidence of $\leq$ 2.0 (Table 1). Some slight differences in varietal performance in baby and mother trials were observed. For example, P224 yielded 1.67 t ha^{-1} in mother trials, and 1.73 t ha^{-1} in baby trials. KNE688 gave the lowest grain yield in baby trials (1.37 t ha^{-1}) and the highest in mother trials (1.85 t ha^{-1}). Overall, the mean yield from the baby trials (1.516 t ha^{-1}) was fairly comparable to that of the mother trial (1.580 t ha^{-1}), an indication that in general, farmers managed the trials just as well and the disease score were also comparable.

Table 1: Grain yield, agronomic performance and blast scores for 8 finger millet accessions in one mother and 10 baby trials in Teso District.

	Mother trial						Mean of 10 Baby trials	
Variety	Yield (t ha^{-1})	Blast score (1-9)	Days to flowering	Plant ht (cm)	Agronomic score (1-best, 5-poor)	Lodging score (1-none, 5-highest)	Grain yield (t ha^{-1})	Disease score (1-9)
KNE 688	1.852	1.9	77	110	2.5	1.6	1.374	1.8
ACC 32	1.806	3	68	104	3.0	3.8	1.660	2.3
KNE 814	1.759	1.9	71	108	2.0	2.5	1.569	2.0
KNE 1149	1.713	1.9	80	114	1.8	1.6	1.454	1.3
P 224	1.671	2.3	71	109	2.0	1.5	1.734	1.8
ACC 14	1.440	1.9	74	109	2.0	1.5	1.437	2.2
LOCAL	1.343	2.8	75	108	3.0	1.4	-	2.8
ACC 29	1.065	2.1	79	119	2.5	1.6	1.383	2.4
Trial mean	1.580	2.2	74.31	110	2.34	1.94	1.516	2.075
SE	0.26	0.28	1.84	7.17	0.36	0.57	0.370	0.668
CV%	16.70	12.5	2.5	6.5	15.20	29.30	24.6	30.8

Table 2 shows a preliminary farmer rating based on overall agronomic score across the baby sites in Teso District (including Alupe). The most popular varieties appear to be Acc.14, Acc.29, KNE814, P224 and KNE1149, based on blast resistance, panicle size, grain color and grain yield.

Table 2: Farmers variety ratings in Teso District.

Variety	Reasons for preference
Acc 14	Big panicles/high yield, brown grain, low finger blast.
KNE 814	High yield, low finger blast
ACC 29	Grain color (dark brown), low finger blast
P 224	Big panicles, high yield
KNE1149	High yield
Local	Grain color

Busia district

Data were available from two mother and six baby trials established in the two divisions of Butula and Nambale. The trials in Nambale division were affected by a hailstorm at maturity, which caused substantial damage to the crop. Grain yields were therefore much lower ranging from 0.48 to 0.74 t ha^{-1} (Table 3) compared to 1.07-1.85 t ha^{-1} in Teso District (Table 4). Acc.14 and local variety (control) gave the highest and lowest yields, respectively. The performance of the mother trial at Butula was affected by moisture stress at the reproductive stage and bird damage due to late sowing. Grain yields ranged from 0.409 to 0.656 t/ha (mean 0.540 t ha^{-1}) and varietal performance trends were basically similar to those in Nambale with KNE688 giving the best yields (0.656 t ha^{-1}). Although the blast incidences were generally and relatively low, KNE688, KNE1149, and KNE814 recorded the lowest overall blast levels (Table 3). It was also evident that although grain yields were low in mother trials in Butula and Nambale, the performance of the varieties was relatively consistent. Yields in baby trials in Nambale division ranged from 0.419 t ha^{-1} (Acc.29) to 1.162 t ha^{-1} (KNE688). Six farmers with baby trials rated KNE688, KNE814, Acc.14 and local (Ikhulule) as the top four performers. Farmers selected the local variety because of its brown grain color, whereas the other varieties were selected for their high yields. This is a clear indication that researchers need to identify varieties with high yield potentials together with the desired grain color.

Table 3. Mean performance of varieties in 2 Mother and 6 Baby Trials in Busia District.

	Mother trials						Baby trials Nambale	
Variety	Grain yield (t ha1) Butula	Grain weight (t ha1) Nambale	Grain yield Across Nambale/ Butula	Overall disease score (1=none, 2=low, 3=average, 4=high)- across Nambale/Butula	Agronomic score-Butula (1-5)	Threshing %- across Butula/ Nambale	Grain weight (t ha1)	Farmer rating
KNE 688	0.656	0.735	0.652	1.0	2.3	55.1	1.162	1
KNE 1149	0.649	0.645	0.592	1.0	2.3	55.7	0.457	
ACC 29	0.600	0.631	0.644	3.0	3.3	66.0	0.419	
ACC 14	0.568	0.62	0.515	3.0	3.3	61.0	0.668	3
P 224	0.538	0.601	0.625	3.5	3.5	60.1	0.545	
LOCAL	0.479	0.588	0.506	3.0	3.5	66.4	0.455	4
ACC 32	0.424	0.514	0.557	4.0	3.3	63.4	0.597	
KNE 814	0.409	0.476	0.478	1.5	1.5	59.2	0.923	2
Grand mean	0.540	0.601	0.571	2.6	2.8	60.9	0.653	
SE±	0.227	0.1289	0.178	0.603	0.784	9.045	0.089	
CV %	42.0	21.4	31.7	23.5	27.6	14.8	15.6	

When performance of the varieties was considered across the districts of Busia and Teso, varieties KNE688, KNE1149 and KNE814 were the best in terms of grain yield and low blast incidence in mother trials. However, in the baby trials, varieties P224, KNE814 KNE688 and Acc.32 had the best yield performance and lowest blast incidence (Table 4).

Table 4. Agronomic performance of varieties in Mother and Baby trials across Busia and Teso Districts.

	Mother trials				Baby trials	
Variety	Grain yield/t ha^{-1}	Overall disease score (1=none, 2=low, 3=average, 4=high)	Agronomic score (1-best, 5-poorest)	Threshing%	Grain yield (t ha^{-1})	Overall disease score (1=none, 2=low, 3=average, 4=high)
KNE 688	1.046	1.4	2	64	1.365	1.8
KNE 1149	0.988	1.4	1	60	1.061	1.3
ACC 29	0.726	2.6	2	58	1.181	2.4
ACC 14	0.914	2.4	2	56	1.308	2.2
P 224	0.951	2.9	2	56	2.015	1.8
LOCAL	0.766	2.9	3	59	0.455	2.8
ACC 32	0.939	3.8	2	64	1.500	2.3
KNE 814	0.930	1.7	1	59	1.487	2.0
Grand mean	0.9075	2.3875	1.9	59.5	1.297	2.1
SE±	0.251	0.672	0.664	8.754	0.454	0.668
CV %	27.7	28.2	25.6	14.7	36.8	30.8

Farmers' Field Day – Busia District

A farmers' field day was held on 3 September 2005, at one of the mother trial sites planted by Bulindo PLAR group in Butula Division. The objective was to enable the farmers participating in the demonstrations, as well as those in the neighborhood, to appreciate the blast resistant varieties and improved crop husbandry techniques, and assist in varietal evaluation and selection. The field day was organized by the frontline Ministry of Agriculture staff involved in the on-farm activities, KARI and ICRISAT. A total of 72 people attended. The invitees included Agricultural Extension Officers from the neighboring divisions/districts, NGOs, community-based organizations, farmer groups, and a representative from Technoserve-Nairobi (an NGO specializing in building market linkages). The field day proved a good forum for exchange of ideas between extensionists, farmers, researchers and marketing experts. Key issues that emerged from this interaction were:

- Farmers appreciated row planting as a means to minimize drudgery at weeding
- Farmers appreciated the yield, blast and bird resistance potentials of some of the test varieties
- Farmers valued the storability of finger millet grain
- Both producers and consumers (market demand) attach a high value to finger millet
- Farmers appreciated that improved grain quality and higher volumes (more production) would enhance market prospects
- Farmers agreed on the need to enhance soil fertility for increased productivity
- Farmers recognized the need to form producer marketing groups to facilitate market access.

Variety selection: During the field day, farmers were divided into four groups and asked to assess the test varieties (agronomic evaluation). Each group evaluated one replication and selected the top three varieties from the replication. Scores were pooled to determine the best varieties overall. The top four were, in order of preference, KNE1149, KNE814, P224 and Acc.29. The reasons for preference were similar for all varieties: high yield potential, good grain color (brown), blast resistance and low bird damage.

Kisii district in Nyanza province

Due to difficulties in accessing baby trials sites, yield data were not available, although a few farmer rankings and scores were taken. Data were also taken on blast incidence and maturity duration. Blast incidence was scored on a 1-4 scale where 1= no disease and 4= high disease. Maturity duration was recorded on a 1-3 scale where 1=early, 3=late maturing. Farmers were involved in disease data collection with technical backstopping from ICRISAT, Ministry of Agriculture and KARI Kisii. Results showed high significant differences between farms with regard to blast incidence, whereas the difference was small between treatments. This might be a result of different farmer practices in each farm, especially in planting dates. Varieties KNE814 and KNE1149 showed the lowest blast incidence score of 1.9 and 2.2 respectively (Table 5) with trial mean 2.4, while the local variety blast score was as high as 2.9. All early maturing varieties had the highest blast incidence. This relationship between earliness and susceptibility confirms results from earlier work on blast screening. However, there is need to assess the relative risk of blast incidence versus susceptibility to terminal drought (late maturity). Farmers ranked KNE814, KNE688 and Acc.14 as the best three varieties.

Table 5. Mean performance of varieties in 6 Baby Trials in Kisii District.

Variety	Overall disease score (1=none, 2=low, 3=average, 4=high)	Maturity (1=early,2= medium, 3=late)	Yield rating (1-High, 2-Average, 3-Poor)	Preference ranking (1=best, 4=least preferred)
KNE 814	1.9	2.7	1	1.0
KNE 1149	2.2	2.4	3	4.0
KNE 688	2.4	2.5	1.5	2.0
ACC 32	2.4	2.1	2.5	3.0
ACC 29	2.5	2.2	2.0	2.3
P 224	2.6	1.9	2.0	2.8
ACC 14	2.6	1.9	3.0	2.0
Local	2.9	1.7	1.8	2.3
Mean	2.44	2.22	2.1	2.43
SE	0.50	0.62	0.718	1.278
CV %	19.75	30.07	35.9	51.1

Gucha district

In both mother and baby trials, data were collected on disease damage, maturity duration, farmers' yield rating and preference ranking. Disease levels were relatively low on farmers' fields and farmer rating of the varieties based on yield potential and blast resistance placed P224, Acc.32 and KNE814 as the best three varieties. Acc.32 was particularly singled out for its grain quality, which was comparable to the local variety. Mother trial results however showed Acc.14, P224, Acc.32 and Acc.29 to have best yield potential with yield ranging from 0.855 to 1.522 t ha^{-1} (Table 6).

There was missing information from the baby trials on yield rating for the variety KNE1149 and on grain color for KNE688 and KNE1149.

Table 6. Mean performance of varieties in 1 Mother and 15 Baby trials in Gucha District.

	Mother trial		Baby Trials			
Variety	1000 seed mass (g)	Grain yield t ha^{-1}	Disease score (1=none, 2=low, 3=average, 4=high)	Maturity (1-early, 2-medium, 3-late)	Yield rating (1-High, 2-Average, 3-Poor)	Grain color preference (1-Good, 2-Fair, 3-Poor).
ACC 14	3.40	1.522	2.0	3.0	2.5	2.0
P 224	3.40	1.418	2.0	2.0	1.7	2.5
ACC 32	3.38	1.186	2.0	3.0	1.0	1.0
ACC 29	3.40	1.087	2.5	2.5	3.0	2.0
LOCAL	3.35	1.011	2.2	1.6	2.0	1.0
KNE 688	3.38	0.959	2.0	2.0	3.0	-
KNE 1149	3.33	0.943	2.0	2.0	-	-
KNE 814	3.25	0.855	2.0	1.5	2.0	2.0
Grand mean	3.36	1.123	2.1	2.2	2.2	1.8
SE	0.22	0.298	0.284	0.528	0.745	0.500
CV%	6.6	26.6	13.5	25.1	35.8	28.6

Note: - missing data

Conclusion

Based on results from this study, potential finger millet varieties with high productivity and low blast reaction on farmers' fields were identified for western Kenya finger millet producing areas. Varieties KNE688, KNE1149, KNE814 and Acc.14 were suitable for Busia and Teso districts whereas varieties KNE814, KNE688 and Acc.14 were suitable for Kisii and Gucha districts. Farmer preferences for these varieties were based on grain quality (preference for brown color), high yield potential, low blast disease levels and relative earliness. Other than identifying suitable varieties, farmers were also able to appreciate the need to integrate appropriate agronomic practices to improve productivity and also the right post-harvest handling of the produce for increased grain quality and cleanliness, hence improve market value for their produce. There is need for further promotion of these varieties and accompanying agronomic packages, especially in areas not covered, in order to reach more farmers for enhanced production and productivity.

With anticipated uptake of the varieties identified and adoption of productivity enhancing technologies (row planting and seed selection), finger millet yields are apt to move from the current 0.5 -0.75 t ha^{-1} to a realistic on-farm potential of 1.5-2.0 t ha^{-1}. Sustainable production will, however, largely depend on linking the farmers to the markets for their produce. This therefore calls for strong partnerships across the production-supply value chain bearing in mind the need of each stakeholder involved. Future field days should strive to bring farmers and processors together for a better understanding of issues limiting grain quality to enable improvement at farm level. There is also need to impress on policy makers to reposition finger millet as an important food and nutrition security crop as well as a crop with great potentials for income generation

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Facilitating the Promotion of Improved and Blast Resistant Finger Millet Varieties to Enhance Production

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Introduction

Among the cereal crops grown in Uganda, finger millet (*Eleusine coracana* (L.) Gaertn) ranks second to maize in terms of total national production. During the 1994 commodity ranking exercise, finger millet emerged as the nations top priority with respect to food crops. It was ranked a priority crop for the Teso and Lango farming systems (NARO/DFID, 1998). The following major constraints to finger millet production were identified for research: lack of improved varieties, blast diseases, drought stress and *Striga*. Finger millet grain is a staple diet of many subsistence farmers and rural workers in Uganda, especially in the eastern and northern regions of the country, and is an important source of calories and protein. Finger millet is increasingly becoming a major cash crop. The grain can be sold directly for cash at local markets or shops soon after harvest or may be stored until the market conditions become favorable. Often the grain is brewed and the beer sold for cash. The grain may be used as a means of payment for labor wages either directly or in the form of beer or used in the barter exchange for other commodities like meat, livestock or chicken (Esele 1986).

Research on finger millet began in 1965, with the ultimate objective being to raise the yield and grain quality and stabilize yields by generating technology appropriate to the specific farming communities. The cereals program at Serere Agricultural and Animal Production Research Institute (SAARI) under the National Agricultural Research Organization (NARO) has the mandate to carry out research on finger millet, pearl millet and sorghum. Over the years, the cereals program has released improved finger millet varieties, namely, ENGENY, GULU E, SERERE 1, PESE 1, SEREMI 1, SEREMI 2, and SEREMI 3. Three more varieties are on restricted release, namely, SX 8, SEC 915, and SEC 394. Several agronomic recommendations have also been made to improve the farmers' yields: use of proper rotational system (Koma-Alimu 1985), seed bed preparation, timely planting, row planting, and use of farm-yard manure (Oryokot 1985).

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Although there has been some effort to transfer these technologies, adoption has been inadequate. Use of improved or modern varieties of finger millet in the Lango and Teso systems is very low. In a study conducted by Longley et al., 2002, only 28% of the farmers interviewed in Lira use, modern varieties and 0% was recorded in the Teso system. A survey on finger millet blast (Takan 2003) also showed that farmers still largely grow un-improved varieties. The source of seed for planting was 50% farmer-to-farmer, 36% farmer to grain market and 14% from other sources. Of the released varieties of finger millet, only PESE 1 was reported being used by farmers. Lack of awareness by farmers of new varieties was given as a reason for non-adoption. Low yields in farmers' fields are usually the result of poor crop husbandry, use of un-improved and un-adapted varieties, and low soil fertility. Oryokot (1985) addressed in length the reasons for limited transfer and adoption at that time. The situation does not appear to have changed much to date. Farmers still get inadequate extension services, have limited access to improved seed as well as other improved technologies (Longley et al. 2002), have serious labor bottle-necks due to lack of (or limited) mechanization and no formal market for their produce.

Blast caused by *Magnaporthe grisea* (anamorph *Pyricularia grisea*) has been identified as one the highest priority constraints to finger millet production in Uganda. Blast affects finger millet at all stages of growth and most of the landraces and a number of other genotypes are highly susceptible. Certain forms of blast can cause failure of the grain to set and seeds to shrivel resulting in major yield losses. R8030, which was finished by November 2004, addressed the constraints. R8030 achieved a number of key outputs – strategic knowledge on pathogen diversity, epidemiology, identification of farmers' needs, capability strengthening and identification of promising varieties.

However, the PRA work carried out in the project with farmer groups and communities in Uganda, as well as development and extension groups and interaction with industry clearly showed the need for further work to promote the potential of the improved and blast resistant varieties to bridge the huge gap between local supply and demand. It also highlighted the need to enhance farmer awareness of the disease problems, pathogen spread, collection and use of clean seed, improved post-harvest/grain quality as well as the potential of the improved blast resistant varieties. There is also a lack of connectivity in the production and supply chain and research – extension

– farmer – industry continuum. This project is building on previous work and responding to local demand identified in R8030.

The specific outputs and associated activities to address these needs are:

1. Potential of improved and blast resistant finger millet varieties demonstrated/promoted.
2. Farmer community awareness about blast problems and management issues enhanced through direct interaction and wider dissemination through leaflet/pamphlet distribution.
3. Connectivity between finger millet production-supply chain and R&D/E workers-farmers-industry continuum improved through a regional workshop and distribution of proceedings to R&D/E organizations, policy makers, and donors.

Progress towards outputs 1 and 2 will be reported in this paper while output 3 will be handled elsewhere.

Materials and Methods

Contacts with farmer groups, extension staff, and CBOs were revived in March and April 2005. At the same time, materials for on-farm work were being prepared. The varieties which were used in this project included Gulu E, PESE1/P224, Seremi 1, Seremi 2/U15, SX 8, SEC 915 and local variety specific for each site. These varieties have various attributes such as blast resistance, high yield, good grain quality and early maturity. Farmer group leaders were identified to participate in the varietal demonstration activity. Existing established groups were used. The composition of the farmer groups is given in Table 1. Five sites were targeted for placing the demonstrations for promotional work. Three sites were planted in the villages of Angalibu, Angaro, and Oselel of Anyara sub-county of the newly formed district of Kaberamaido; one site was planted in Kujju, Katakwi district; and one site was planted in Kikota village, Serere sub-county, Soroti district. The kind of entry used as a local check (variety) was left to the discretion of the farmer groups. The trails were planted on the 11^{th} and 12^{th} of May, 2005. The trials were planted in randomized block design provided with four replications following the Mother-Baby trial approach provided by ICRISAT. In all trials, the five demonstration plots were laid using the Mother design.

The gross plot size recommended was six rows, each 5 meters long, with row spacing of 30 cm and thinned to 10 cm between plants in a row. No fertilizer was applied at any of the sites.

Farmers were requested to record data on days to 50% flowering, blast disease scores (Table 2), plant height (cm), number of primary tillers, harvest plant count in the net plot and grain yield (g/plot). In addition, a general note on the growing conditions of the trial was requested. To obtain data in a uniform manner over the locations, cooperators were supplied with a set of guidelines and recording pro-forma. Data was analyzed using SAS statistical system (SAS 1992). Data based on counts and percentages was transformed using the square root transformation before analysis.

Processors too were contacted and a number of them were identified as potential collaborators. Among those identified were Maganjo Grain Millers Ltd., Family Diet, SESACO, East African Basic Foods Ltd. This was done between July and August 2005.

Focused consultations with representatives of farmer groups and industry prior to the workshop were also made during late August to early September 2005.

For output 2, dissemination materials were prepared on blast management and finger millet production. These will be translated into local languages when funds become available. No farmer field days were held during the reporting period as planned.

Results and Discussion

Data were returned from four sites (Angalibu, Angaro, Kikota and Oselel). Kujju farmers experienced some insecurity problems and because of this they hurriedly harvested the trial and divided the materials amongst themselves, so no data are available for that location. The trial was planted late and suffered a bit of terminal drought. This had some effect on some of the results obtained.

Whole plots per replication were harvested and weighed. Data on 50% flowering and plant population at harvest were not recorded by collaborating farmers.

Plant height was reported from the four sites that returned data (Table 3). The mean plant height for the trial over four sites was 69.3 cm. Maximum height for the trial was recorded at Kikota village (77.8 cm) and minimum at Oselel (59.1 cm). There were highly significant differences for plant height ($p < .001$) for sites and varieties. The interaction between sites and variety was not significant.

Grain yield of individual varieties over locations is presented in Table 3. The mean grain yield over locations was 2.39 t/ha. The highest mean of the trial was recorded at Kikota village (3.09 t/ha) and lowest at Oselel (1.59 t/ha). The highest yielding variety was Gulu E (3.02 t/ha) and lowest were the local varieties (1.44 t/ha).

The mean performance of the varieties over locations is given in Table 4.

Disease incidence

Farmers were requested to record blast disease incidence with the assistance of our technicians using the standard scale (Table 2) if it occurred in the trial. In view of the widespread occurrence and potential importance of finger millet blast in all millet growing areas, data for this disease requires detailed comment. Head blast was reported from four sites. The mean incidence ranged from 2 percent to 42 percent at Kikota. The incidences from the four sites are presented in Table 3.

Maximum incidence was at Kikota (25.2 percent) under natural infection. The varieties with least overall incidence of head blast were Seremi 1 and SX 8. Seremi 2, the earliest maturing variety, showed least resistance to blast (33.9%) at three locations, Angaro, Kikota and Agalibu.

Contrasting reactions were observed at Angalibu and Angaro villages and Kikota and Oselel for variety Gulu E. An incidence of 32% was recorded at Angaro and 18% at Kikota for the same variety. These kinds of reactions indicate location specific resistance and emphasise the need for continued testing in many sites to identify stable resistance to blast.

Conclusion

Good performance was given by the improved varieties, Gulu E, SX 8, PESE 1, SEC 915, Seremi 1 and Seremi 2. The trial was planted late but after struggling with terminal drought, the entries gave reasonable yields, which have impressed the farming community involved in this project. Seremi 1 and

SX 8 particularly showed high levels of resistance to blast at the four sites. Farmers selected Seremi 2 for earliness. SX 8 and Seremi 1 were selected for yield and cleanliness (free from blast attack) in the field.

No attempt has been made to analyze stability of grain over the locations for this trial at this time. An observation that has been made in this trial is that finger millet genotypes exhibited contrasting reactions to blast at different sites. Seremi 1 and SX 8 were found to have a relatively stable resistance across locations. Contrasting responses observed between locations would mean that multilocational testing should be continued in order to identify stable and durable resistance and investigation into the genetics of blast resistance (of the host) and physiologic specialization of the pathogen is needed.

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Annex 1

Table 1. Composition of farmer groups involved in project.

Site No.	Village	District	No. female farmers	No. male farmers	Total
1	Angalibu	Kaberamaido	10	15	25
2.	Angaro	Kaberamaido	0	1	1
3.	Oselel	Kaberamaido	8	8	16
4.	Kujju	Amuria	13	15	28
5.	Kikota	Soroti	9	16	25

Table 2. Standard evaluating system for finger millet blast.

Tillers with blast (%)	Reaction
0-20% infected	Resistant
21-40% infected	Moderately resistant
41-60% infected	Moderately susceptible
61-80% infected	Susceptible
81-100% infected	Highly susceptible

Table 3. Mean disease score (Finger blast, Head blast), number of primary tillers, Plant height, and Yield at four locations in Uganda.

Parameter	Angalibu	Angaro	Kikota	Oselel
Finger blast (%)	14.5_{b}	16.9_{b}	22.2_{a}	24.9_{a}
Head blast (%)	15.1_{b}	15.6_{b}	25.2_{a}	20.9_{ab}
Number of primary tillers	0.14_{c}	0.64_{b}	1.39_{a}	0.25_{c}
Plant height (cm)	69.3_{b}	71.1_{b}	77.8_{a}	59.1_{c}
Yield (kg/ha)	1.93_{b}	2.98_{a}	3.08_{a}	1.58_{c}

Means in the same row bearing the same subscript are not statically different. Means based on seven lines of finger millet viz: Gulu E, PESE 1, SEC 915, Seremi 1, Seremi 2, SX 8 and local checks.

Table 4. Mean performance of individual varieties of the on-farm trials over 4 sites.

VARIETY	Primary tillers	Plant height	Finger blast	Head blast	Yield
GULU E	0.68_a	68.8_c	24.9_{ab}	24.3_{bc}	3.02_a
LOCAL	0.56_a	62.6_d	17.6_{bc}	23.6_{bc}	1.45_c
PESE 1	0.56_a	79.1_a	25.6_{ab}	25.7_{ab}	2.44_a
SEC 915	0.75_a	58.7_e	20.1_{bc}	15.1_{cd}	2.39_b
SEREMI 1	0.56_a	$76.6a_b$	8.0_d	7.6_{de}	2.23_b
SEREMI 2	0.5_a	64.3_d	29.8_a	33.9_a	2.32_b
SX 8	0.62_a	75.3_b	11.1_d	4.1_e	2.93_a
Site Mean	0.61	69.3	19.6	19.2	2.39
CV % (0.5)	23.1	8.2	22.4	45.0	16.2

Weed Management in Groundnuts: Farmers' Experience in Ox-drawn Weeders in North Eastern Uganda and Implications for Finger Millet

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Abstract

This paper describes a process of Participatory Technology Development that took place in the Teso Farming System (TFS), northeast Uganda between 1998 and 2005. The main objective of the research/extension was to alleviate labor constraints and drudgery associated with weeding annual crops and to reduce costs and improve returns to these enterprises. The benefits of using draught animal power (DAP), however, are not fully realized until animals are used for weeding and other tasks (planting, groundnut lifting and potato ridging). Although only 50% of households own oxen, 90% use them for ploughing, including some of the poorest households, as it is cheaper to hire oxen than to employ manual labor. Hand weeding is mainly undertaken by women and children resulting in drudgery, withdrawal of children from school during the weeding seasons, high costs if labor is hired to undertake the task, reduced yields (in poorly weeded fields) and poor returns (gross margins). Weeder evaluation (4 designs) by farmers on their own farms took place during 2000 and 2001 in sorghum and groundnut crops. For sorghum DAP weeding made little impact on yield but reduced the time needed for hand weeding from 157 hours to 34 hours per hectare. Hand weeding costs were reduced from 47,000 Ush to 10,000 Ush per hectare. For groundnuts, DAP weeding gave higher yields (not significant) and reduced the time needed for hand weeding from 73 hours to 31 hours per hectare. Hand weeding costs were reduced from 30,700 Ush to 13,700 Ush per hectare. At the end of the study, farmers concluded that ox-drawn weeders reduced the labor and costs required for weeding groundnuts and improved gross margins. They also found out that ox-drawn weeders are a practical and effective alternative to hand weeding and may improve groundnut yields and also be utilized in other field crops for example, finger millet especially when planted in rows.

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Introduction

Weed management is one of the most expensive farming activities faced by farmers in north-eastern Uganda. It is labor demanding in terms of human labor or cash and if is not properly done, or on time, it can lead to crop yield losses of up to 100% (Akwang et al. 1998). In almost all sub-Sahara countries, weeding has been cited as one of the main constraints in crop production for resource poor farmers and crop losses of 30–70% have been recorded because of poor weeding (Croon et al. 1984). Weeding normally takes up to 50% of the available season time and accounts for 40–55% of the total labor input.

Weeds are a major constraint to crop production in the Teso Farming System of Eastern Uganda and weeding labor constraint severely limits the area that a household can sow to arable crops. To increase production, there are two options; namely, increase acreage or intensify production by increasing yield/unit area. To succeed with either of these strategies, it will be essential to manage weed populations on farmers' fields. It has been reported that weeding using oxen can play a very important role in improving agricultural productivity and alleviating the labor shortages experienced during weeding operations (Lekezime 1988). Weeding with oxen is a much faster and less tiring operation compared to hand weeding. This can allow timely weeding, which in turn can subsequently lead to better yields per hectare (Kwiligwa et al. 1992).

Weeding by hand demands a lot of labor and if it is not done well and on time it causes a high crop yield loss. Therefore, the main objective of the research/extension was to alleviate labor constraints and drudgery associated with weeding annual crops (in an area where the presence of HIV is reducing the numbers of economically active people available for agricultural labor) and to reduce costs and improve returns to these enterprises.

Methodology

This work was conducted in nine sites (Abalang, Kachede, Kaler, Kibale, Koritok, Obule, Obur, Orungo, and Pingire parishes in Soroti, Kumi, Kaberamaido, Katakwi and Pallisa districts). Trials were carried out in farmers' fields and they were farmer managed.

Farmers were trained at the beginning of the study on weeder adjustments and how to use oxen for weeding.

Farmers in a site were considered as replications and the plots measured 40x10 m. Groundnut was planted at a spacing of 45x10 cm, while sorghum was planted at a spacing of 60x20 cm. No fertilizer and pest control method was applied.

At maturity, all the plants in the plot were harvested and the plot yields were used to calculate yield per hectare. Data was also collected on weeder performance and farmers' comments on weeders. In addition, economic analysis was carried out to assess the profitability of weeding groundnuts using oxen. In this analysis, variable costs for each weeder and hand weeding were computed and these deducted from the gross income. Groundnut market price at the time (in 2000) was used in the calculations. The data collected was then subjected to analysis of variance (ANOVA) using Genstat computer package.

Weed data were collected from each plot using a quadrant measuring 33x 33 cm (0.11 m^2). The quadrant was randomly thrown 10 times in each plot and the weeds inside the quadrant were counted. Weeds were categorized as perennial grasses, annual grasses, sedges and broad-leafed annuals. Data on weeds were collected before (a) first weeding, (b) second weeding, and (c) at maturity (ie, at harvest time).

Efficiencies of the different methods of weeding were calculated using the formula:

Weeding efficiency (%) = $100 - \{[(W_0 - W_1)/W_0] \times 100\}$

Where W_0 = weed density immediately before weeding and W_1 = weed density immediately after weeding

Assessments of weeders:

Two assessments were conducted to allow farmers to articulate their experience on use of oxen in weeding. The assessment was carried out in all nine sites by the farmers. The technique used was a Strength, Weakness, Opportunity and Threats (SWOT) approach for data collection and analysis. The farmers were asked to assess the efficiency and effectiveness of weeders against hand weeding (farmer practice). Farmers were facilitated to identify a set of criteria that they deemed relevant for ranking the two weeders that they had used (SAARI and AEATRI). The criteria developed were then scored using a score range of 0–5, for worst and best performance, respectively. Prior to scoring, reasons for the choice of particular criteria were examined and the comparative performance of each weeder against the identified criteria evaluated.

Farmer-to-farmer extension

Following weeder evaluation a farmer-to-farmer extension system was established to promote DAP weeding technology. Links were developed between farmers and manufacturers of agricultural implements (weeders) to ensure that these tools match their requirements and to ensure future sustainable supplies of appropriate equipment.

Farmers were then trained on how to train fellow farmers on use of oxen for weeding.

Results and discussions

Effect of weeder and hand weeding on weed densities at farmers' fields

Throughout the nine sites, the highest population of weeds was the broad-leafed annual category (Figure 1), possibly due to their high seed rate, viability and easy dispersal. These data indicate the commonest categories of weeds in the north-eastern Uganda (Teso Farming System) but not necessarily the most important.

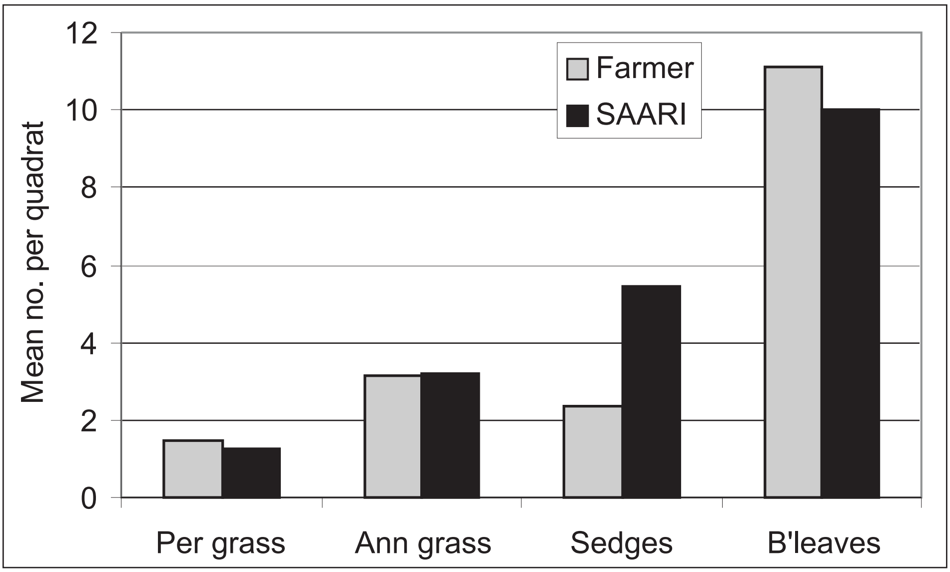

Figure 1. Weed densities (no. per 0.11 m^2 quadrant) on farms at 2^{nd} weeding.

The SAARI weeder was very effective in controlling annual weeds, possibly because they were completely buried by the deep digging and burying action of this weeder. By contrast, the farmers' practice of hand-weeding was better for controlling perennial grasses and sedges because the reproductive parts were pulled out of the soil by hand. The preliminary results from this study indicate that continuous use of a SAARI weeder could lead to the build up of a population of sedges and other perennial grass weeds as the population of annual weeds is reduced.

Weeding efficiencies (%) against annual and perennial weeds
The SAARI weeder gave the highest weeding efficiency (95%) for annual weeds, while hand-weeding resulted in the highest weeding efficiency (82%) for perennial weeds (Figure. 2).

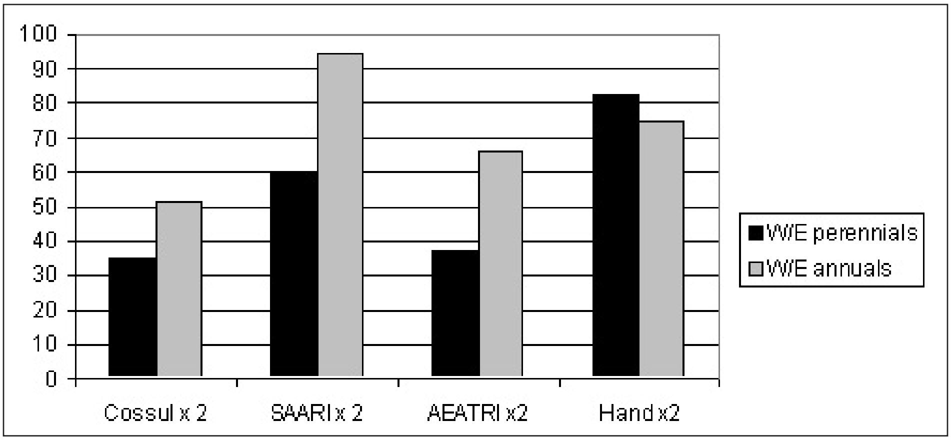

Figure 2. Weeding efficiencies of DAP weeders and hand weeding against annual and perennial weeds at 2nd weeding of 2nd rainy season, 2000

Effect of SAARI weeder and farmers' practice on groundnut yields on farmers' fields during first rains 2000
In all the nine sites, the highest yields were recorded in plots where the SAARI weeder had been used (Table 1). The probable explanation is that the SAARI weeder cuts deeper into the soil than the hand hoe, creating ridges beneath the groundnut crop that encourages pegging. The furrow created between rows could collect water when it rained and also prevented water runoff. Stevens (1994) in his studies reported that weeding using draft animal power gives a better tillage effect with deeper loosening of soil leading to better infiltration of rain water. Variations in yields obtained at different sites could be attributed to differences in soil fertility and rainfall.

The abnormally low yields obtained from Pingire and Kaler were due to the prolonged dry spell experienced at these sites. In some instances, no yields were obtained from farmers' fields.

Table 1. Effect of the SAARI weeder and farmers' practice on groundnut yield during the first rainy season of 2000 (kg/ha).

Site	*Treatments*	
	SAARI weeder	***Farmer's practice***
Abalang	1200	738
Kachede	1138	874
Kaler	299	290
Kibale	338	302
Koritok	1821	158
Obule	1949	1583
Obur	1358	547
Orung	1042	589
Pingire	92	68
Mean	1135	691
SED	*418*	
CV	*37.7%*	

Economic profitability of ox-weeding

The use of ox-drawn weeders reduced the hand labor required for weeding from 157 hours/ha to approximately 34.5 hours/ha (Figure 2). This is in agreement with what Kwiligwa reported that average time for hand hoe weeding was 230 work hours per hectare as against 50 working hours per hectare when weeding with oxen (Kwiligwa et al. 1994). This is also almost the same as what Chatizwa and Nazare reported that there was an overall reduction of working hours of 20 – 70% when weeding with animal power compared to hand weeding. There were no significant statistical differences in the performance of the two ox-drawn weeders in terms of their impact on the amount of hand labor required for weeding (Table 2). Hand weeding costs (at the prevailing market rate) are significantly reduced to around Ush 10,000/ha compared with Ush 45,000/ha for farmer practice (Table 2).

Table 2. Labor use, costs and margins on-farm, season 2, 2000.			
	SAARI Weeder	*AEATRI Weeder*	*Farmer practice (hand weeding)*
Yield (kg/ha)	1016.61	776.82	833.74
Hand weeding (hours/ha)	32.19	37.05	157.81
Cost of hand weeding (Ush/ha)	9656	11114	45657
Hand weeding costs as % of total	12.44	13.88	51.34
Total costs (Ush/ha)	76657	73506	82603
Gross Margin (Ush/ha)	25004	4176	771
Returns to hand weeding (Ush/day)	21978	16911	3735
Number of observations	21	22	23

Hand weeding costs as a percentage of total costs are reduced from more than 50% to 13% (Table 2). Total costs are also reduced but by a much smaller margin. This can be accounted for by increased costs associated with planting in lines 94 hours/ha as opposed to broadcasting and covering seed (30 hours/ha) and the costs associated with using oxen for weeding (hire rates). Gross maegins were highest with the SAARI weder (Table 2 and Figure 3)

Farmers' assessment of weeders

The SWOT analysis

Strengths

- Germination rates and vigor in the planted crops were superior to the broadcast ones
- Line planting takes less seed compared to broadcasting

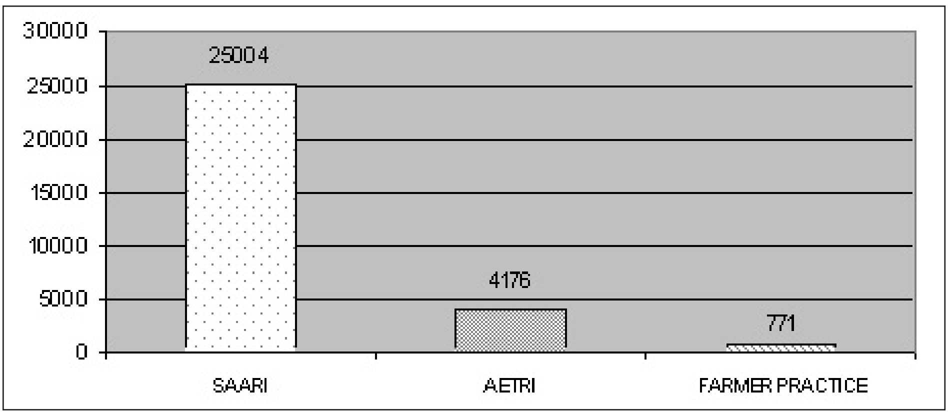

Figure 3. GROSS MARGINS (Ush/ha) on-farm season 2, 2000.

- The incidence and control of insect pests and diseases is easier in row-planted crops. This was particularly the case with groundnut rosette
- Yields were superior in the row-planted plots

Weaknesses

- Labor required for land preparation, marking and planting cultivated crops is high and may act as an initial deterrent
- It takes time and skill to train both the oxen and the farmers on the basics of ox weeding

Opportunities

- There is increasing trend towards line planting as opposed to broadcasting crops in the farming community
- Women participated in the study. This has helped demystify the notion that DAP is a preserve for men
- Farmers were increasingly row-planting their own fields (gardens) other than the experimental ones with the aim of ox weeding
- In most of the DAP project sites, input suppliers like AT-Uganda agents are within easy reach
- Some farmers are already taking on the role of farmer trainers
- The beam of the SAARI weeder can be adjusted to accommodate a ploughing function (the blades of the SAARI weeder can easily be fitted on the locally available plough beam)

Threats

- The initial high labor demand for land preparation, marking and planting might act as a serious drawback, especially because aggregate labor requirements at the onset of the rainy season tend to be high
- A possible conflict of interest between use of oxen for ploughing on one hand and weeding on the other might arise. This has in built gender implications since ploughing is traditionally a male activity and weeding is a female one.
- The cost of the technology may well be beyond the financial ability of most farmers, especially the resource poor ones, who are expected to be the main beneficiaries

- Spares are not readily available
- In some of the sites, oxen have not been nose-punched. This makes harnessing and control more difficult

Farmer-to-farmer extension

Following weeder evaluation, a farmer-to-farmer extension system was established to promote DAP weeding technology and more than 2,500 farmers have been trained in this way. Links have been developed between farmers and manufacturers of agricultural implements (weeders) to ensure that these tools match their requirements and to ensure future sustainable supplies of appropriate equipment. Staff of NGOs working in Teso are being trained to ensure that DAP weeding extension continues post project. Recent training has not been restricted to weeding only, with the addition of ridging (using a plough), planting (marking lined with a weeder) and groundnut lifting using a plough (minus mouldboard) as an important part of the labor reducing DAP package. Ridging of sweet potatoes and groundnut lifting has been particularly well received by farmers and widely adopted in those communities receiving training. The mechanization of potato ridging reduces labor costs from Ush 123,000 to Ush 24,000 per hectare (and drudgery) of this operation. In some communities this has allowed area expansion (as labor availability and costs formerly restricted the area cultivated), improved food security and incomes.

Impact on livelihoods

The introduction of DAP weeding has made women feel less oppressed and men have become involved in this task as it is mechanized and a great reduction in drudgery is reported along with improved food security and higher incomes. Women are now able to pursue more rewarding activities and are experiencing a better quality of life. Children are no longer withdrawn from school during the weeding seasons (April-May and October-November). Farmer-to-farmer extension may be one of the more effective means of effecting rapid adoption of technology; as most farmers in rural Africa have little contact with formal extension services. Their main source of information and knowledge – which they trust – and the results of which they can easily observe, are the activities of neighboring farmers. It is anticipated that in the longer-term, even the poorest of economically active households will benefit from mechanization as hire markets develop for DAP services (weeding, groundnut lifting and potato ridging) – they already exist for ploughing and to a limited extent weeding.

Conclusions

Use of oxen in weeding has a big role to play in reducing drudgery, making farming attractive and improving the income of resource-poor farmers in North Eastern Uganda (Teso Farming System). Weeding using oxen can improve crop production and alleviate the labor shortages experienced during weeding in the Teso Farming System. Significant differences in performance between the use of oxen-drawn weeders and the traditional practice of hand weeding were found for certain relatively simple parameters (eg, time taken to weed experimental plot). The main advantages associated with the use of oxen-drawn weeders in Teso Farming System were: higher yields, greater returns, and reduced drudgery.

Acknowledgement

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Evaluation of Finger Millet as a European Forage Crop: Plant Growth, Weed Control, and Seed Pelleting

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Abstract

With its high nutritional qualities, finger millet (*Eleusine coracana*) could be a valuable forage crop for cattle in the moister regions of Northern Europe. To this end, trials have been initiated to evaluate the agronomy, productivity and composition of *E. coracana* grown in Northern Ireland. A preliminary trial sown with naked seed in June 2003, showed that *E. coracana* will germinate and grow satisfactorily in the relatively cool, moist conditions. The plants remained growing throughout the summer without flowering until they were killed by frost in early October 2003. Trials sown in June 2004 and June 2005 were designed to establish the optimum seed rate, the benefits of pelleting seed, and to find a suitable herbicide for weed control. The best seed rate in terms of plant development and tillering was 1 g m^{-2} (10 kg ha^{-1}). Two pelleting materials were tested: one, which only increased seed size to facilitate drilling, and another, which also contained a water-absorbing material. The latter appears to have much improved germination. Four herbicides were compared, applied at recommended rates: atrazine, sprayed immediately after sowing; MCPA, nicosulfuron, and MCPA + isoproturon sprayed post-emergence. Atrazine gave the best weed control resulting in the best foliar growth. The other three herbicides did not satisfactorily control all weeds. The outstanding treatment in the current season (2005) is the combination of water-absorbing pelleted seed and atrazine herbicide.

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Introduction

Finger millet (*Eleusine coracana*) is found in many warm, temperate regions of the world, but primarily in East Africa and southern India, where it is a staple food for millions of people. It is a versatile grain crop, used in many different types of food and for brewing beer. The grain is considered to be more nutritious than any other major cereal species. It has high levels of methionine, an amino acid which is lacking in the diets of poor people who live on starchy foods (Anon 1996). The phosphorus, calcium, iron and vitamin B contents are particularly valuable in the diets of young children and pregnant or lactating women. Finger millet straw makes good animal fodder, containing up to 60% total digestible nutrients (Anon 1996).

E. coracana thrives under hot conditions, but also tolerates cool climates. It appears, however, to be photoperiod sensitive, the optimum being 12 h. Problems of photoperiod sensitivity were encountered in the crop which otherwise grew successfully in the USA as far north as Davis, California (Anon 1996). It can be grown in any soil type, but requires rainfall of at least 800 mm per annum (Van Wyk and Gericke 2000), and will not tolerate flooding. It is less susceptible to pests and diseases than other grain crops, blast being the only major disease, but it has a poor ability to compete with weeds.

The cold tolerance of *E. coracana* and its requirement for rainfall spread over the growing season, suggest that it could be grown successfully in Northern Ireland – not as a grain crop, but as a forage crop for cattle. The long daylight hours of summer at this latitude should suppress flowering and it is possible that finger millet could give high forage yield without the drop in digestibility that occurs with headed grass plants. If the protein in the leaves has the same high methionine content as the grain, this would make a much more nutritious silage feed for cattle than ensiled maize. It would also grow faster than maize, producing a large tonnage per acre, and could be harvested much earlier than maize (which is often harvested in the cold, wet conditions of late autumn).

The objective of this study was to evaluate the agronomy, productivity and composition of *E. coracana* grown in Northern Ireland. The initial trials reported here were established to determine how best to sow seed and control weeds.

Materials and methods

Plant growth. Finger millet seeds were produced and sent from ICRISAT-Nairobi, with the kind assistance of Eric Manyasa. The trials were established in field plots at the Department of Agriculture & Rural Development, Belfast, UK. Seeds were sown in prepared plots (1 mx4 m). In 2003 and 2004, seeds were mixed in moist sand (1 kg per plot) and broadcast at varying seed rates in 8 and 48 randomized plots, respectively. In 2005, naked and pelleted seeds were drilled in rows 10 cm apart. Two types of pelleted seed (produced by Germain's Technical Group, Norfolk, UK) were sown. One type of pelleted material simply increased the size of the seed to facilitate drilling, the second pelleting material also possessed water-absorbing properties. The trials were established in 60 randomized plots: two finger millet varieties sown as naked seed and two types of pelleted seed, with five treatments (4 herbicides plus untreated control).

Herbicides were used at recommended rates:

- atrazine (2.2 g L^{-1} as 'Atrazol', Sipcam, 500 g L^{-1} SC)
- MCPA (2 g L^{-1} as 'Agritox 50', Nufarm UK, 500 g L^{-1} SL)
- nicosulfuron (0.08 g L^{-1} as 'Samson', Syngenta, 40 g L^{-1} SC)
- MCPA (2 g L^{-1} as 'Agritox 50', Nufarm UK, 500 g L^{-1} SL) + isoproturon (2 g L^{-1} as 'Primer', AgriGuard, 500 g L^{-1} SC)

Results and discussion

Growth potential. A preliminary trial was established to determine if finger millet would germinate and grow under Northern Ireland conditions. Four varieties (Lanet Local, 6BK-027189, FMB19/01/wk and KNE 1034) were sown by broadcasting on 8 July 2003 at two seed rates, 4.2 and 11.5 g m^{-2}, in eight randomized plots. The first emergence occurred after one week. The plots were hand-weeded. Visual observation indicated that the lower seed rate produced better plants. The plants remained growing throughout the summer without flowering until they were killed by frost in early October 2003. This frost sensitivity means finger millet can only be sown after the period of spring frosts and must be harvested before the autumn frosts.

Seed rate and herbicide treatment. A more extensive trial was established in 2004, to further assess the effect of seed rate on plant growth and to evaluate the efficacy of the weed killer atrazine on plant development. Seed of varieties Lanet Local, 6BK-027189, FMB19/01/wk and KNE 1034 were sown again by broadcasting at rates of 1, 2 and 3 g m^{-2} in randomized plots on 3 June 2004. Treatments to assess the benefit of herbicide application comprised:

1. control (no herbicide spray)
2. spray application at sowing
3. spray application and raked over at sowing
4. spray application at the cotyledon stage

The seed rate of 1 g m^{-2} (equivalent to 10 kg ha^{-1}) gave the best plant growth and tillering; and Lanet Local was much the best variety under Northern Ireland conditions. Herbicide treatment 2 (spray application at sowing) gave the best weed control and best foliar development. Treatment 3 was less effective, probably because raking broke the herbicide seal over the soil surface and distributed the atrazine deeper into the soil. Treatment 4 resulted in damaged foliage and hence reduced plant growth. At the time of harvest flowering had not occurred.

Pelleted seed, herbicide treatment. In the current (2005) season, a randomized trial using two varieties, Lanet Local and Ex-GBK 027/89 Lanet, has been established to assess the effect of seed pelleting on germination and also to compare three post-emergence herbicide treatments with atrazine. This trial is still in progress. Naked seed, seeds pelleted to increase their size, and seeds pelleted with a water-absorbing material were sown at the equivalent of 1 g m^{-2} on 11 May 2005. Atrazine plots were treated immediately after sowing. The post-emergence herbicides were applied on 23 June 2005. From visual assessment, the outstanding treatment is the one with water-absorbing pelleted seed and atrazine herbicide. These plots are free of weeds and the plants are growing well and tillering at 10-12 stalks per plant. No post-emergence herbicide adequately controlled all weeds. Nicosulfuron suppressed grasses, but did not control C*henopodium album* or *Polygonum aviculare*. Isoproturon + MCPA gave more effective broad-leaved weed control than either herbicide alone but only checked, rather than killed, grass growth. Finger millet plant populations were lower in post-emergence treatments than in atrazine-treated plots. Unfortunately, atrazine will lose UK government approval in December 2007, but a new Syngenta herbicide, mesotrione ('Callisto') combined with nicosulfuron, for weed control in maize, will be trialled in 2006.

The pelleting material that only increased the size of the seed apparently soon broke away, leaving a naked seed to germinate. The water-absorbing pelleting material appeared to offer two-fold benefits. It increased the size of the seed, facilitating drilling; and also maintained a moist coating around the seed, encouraging germination. Another potential advantage of pelleting seed for tropical countries: it could allow the incorporation of a fungicide to control seed-borne blast infection. This study did not examine the cost implications of pelleting, which was done on an experimental basis by a private firm, for no charge. However, returns from pelleting are likely to be higher if improved management methods (eg, row planting) are used.

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Genetic Resources Diversity of Finger Millet – a Global Perspective

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Abstract

Finger millet is a traditional grain cereal in Africa and South Asia. The crop has a wide range of adaptation, can withstand adverse soil and weather conditions, and is grown at altitudes from sea level to about 2,400 m. The grain yield potential is good, and the grain is highly nutritious, particularly rich in methionine, iron and calcium. However, finger millet has been neglected by mainstream research. One way to boost production and productivity and enhance acceptability is to assemble diverse germplasm resources, characterise them to identify traits of agronomic importance, and use them to breed superior varieties. ICRISAT's genebank in Patancheru, India, holds 5,949 germplasm accessions from 23 countries. Of the six races of finger millet, *Vulgaris* is the most predominant (61% of the total collections). The accessions have been characterised for five qualitative and 14 quantitative traits. The quantitative data show that the race *Africana* is more distinct than other races, and had the highest means for 10 out of 14 traits measured. To overcome the problems of managing a large collection and to enhance the use of germplasm in crop improvement, ICRISAT has developed a core collection containing 622 accessions (10% of the entire collection) based on geographical origin and quantitative traits. The core collection was evaluated in 2004 and a further mini-core collection (10% of the core or 1% of the entire collection) was constituted, with 65 accessions. In addition, a composite set of germplasm comprising 1,000 accessions has been developed under the Generation Challenge Program. This set is being characterised; microsatellite markers will be used to access the genes for beneficial traits.

Introduction

Finger millet [*Eleusine coracana* (L.) Gaertn.] is a traditional grain cereal cultivated in Africa and South Asia. The crop has a wide range of adaptation. It is cultivated from sea level in parts of Andhra Pradesh and Tamil Nadu in India to about 2,400 meters above sea level in hilly areas in northern India;

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and similarly at high altitudes in Nepal, Uganda, Kenya and Ethiopia. Its requirements for soil, water and climate are similar to upland paddy; but it can survive adverse soil and weather conditions better than most other food-grain crops. The reported grain yield potential is high, for example, 4,265 kg ha^{-1} in Uganda (Odelle 1993), 6,060 kg ha^{-1} in Zimbabwe (Mushonga et al. 1993), 3,700 kg ha^{-1} in Ethiopia (Mulatu and Kebebe 1993), and 4,789 kg ha^{-1} in India (Bondale 1993). The grain is highly nutritious. Protein content is about 7.4%, which is comparable to rice. Calcium content in whole seed is 0.34% compared to 0.01-0.06% in most cereals (Kurien et al. 1959). Iron content is also exceptionally high, 46 mg kg^{-1} (Serna-Saldivar and Rooney 1995), much higher than wheat or rice.

Precise data on area under finger millet are not available, because it is frequently reported with other millets including pearl millet (as in the FAO database). However, the Consultative Group on International Agricultural Research (CGIAR) assumes that of the total global millet area of 34.6 million ha (FAO 2004), 10% is finger millet. Information is available for some countries, for example, 1.68 million ha in India in 2001-02 (CMIE 2004). Other countries with large finger millet areas are China, Democratic Republic of Congo, Ethiopia, Eritrea, Kenya, Myanmar, Nepal, Uganda, Tanzania and Rwanda.

The ICRISAT genebank at Patancheru, India, holds 5,949 finger millet accessions from 23 countries. This paper describes how this collection was established, and strategies to enhance its use in crop improvement.

Assembly of finger millet germplasm

As finger millet is an important food crop, national research programs in several countries have assembled germplasm collections, for example, 4,490 accessions in India (Seetharam 1989), 778 in Nepal (Sherchan and Baniya 1993) and over 2,000 in Uganda (Odelle 1983), where finger millet is the number one cereal crop. ICRISAT began assembling germplasm in 1976. The collection now holds 5,949 accessions, of which 4,077 were received through donations and 1,872 were collected accessions. The germplasm collection represents 23 countries (Table 1).

Table 1. Finger millet germplasm accessions in the genebank at ICRISAT, Patancheru, India, Aug 2005.

Country	No. of accessions	Country	No. of accessions
Burundi	15 (0.25)*	Pakistan	1 (0.02)
Cameroon	8 (0.13)	Senegal	5 (0.08)
Ethiopia	31 (0.52)	South Africa	1 (0.02)
Germany	1 (0.02)	Sri Lanka	18 (0.30)
India	1365 (22.95)	Tanzania	42 (0.71)
Italy	7 (0.12)	Uganda	959 (16.12)
Kenya	946 (15.90)	UK	14 (0.24)
Malawi	252 (4.24)	USA	7 (0.12)
Maldives	4 (0.07)	Zaire	2 (0.03)
Mozambique	1 (0.02)	Zambia	136 (2.29)
Nepal	780 (13.11)	Zimbabwe	1154 (19.40)
Nigeria	19 (0.32)	Unknown	181 (3.04)
		Total	5949 (100)

* Figures in parentheses show accessions as a percentage of the entire collection

The genepool of finger millet germplasm consists of four cultivated races (*Compacta*, *Elongata*, *Plana and Vulgaris*) and two wild races (*Africana* and *Spontanea*). Race Vulgaris is most prevalent in the collection (61%) followed by race *Plana* (17%), *Compacta* (11%), *Elongata* (9%), *Spontanea* (2%), and *Africana* (<1%). The collection includes 136 better yielding selections from the landraces, 50 breeding lines, 5,658 landraces, and 105 wild accessions. Seeds are conserved in medium-term storage (4^0C, 30%RH, in airtight aluminum containers) and long-term-storage (-20^0C, in vacuumized aluminum foil). Seed viability is monitored at regular intervals, and the collection is safe and secure (Table 2). Accessions showing low germination are regenerated and the old seeds replaced with fresh, healthy seeds.

Table 2. Germination rates of finger millet germplasm conserved in the genebank at ICRISAT Patancheru, Aug 2005.

Germination %	No. of accessions
<75%	59
75-80%	36
81-85%	81
86-90%	202
91-95%	853
> 95%	3779
Accessions tested	5010

Characterization of germplasm resources

To facilitate its utilization by plant breeders, germplasm must be characterized for qualitative and quantitative traits of agronomic importance. Characterization should be done in standard and commonly understood language so that researchers in different institutes and countries can use this information easily and effectively. An expert committee sponsored by the then International Board for Plant Genetic Resources (IBPGR) formulated a list of Descriptors for Finger Millet (IBPGR 1985). This includes 30 passport data, 45 morphological data, and resistance to 32 stress factors (5 abiotic, 27 biotic) for describing finger millet germplasm accessions.

ICRISAT's large collection could not be characterized completely in one year. Accessions were therefore characterized in batches over the years at the ICRISAT research farm at Patancheru, India, during the rainy seasons. The site is located at 18^0N, 78^0E, altitude of 545 m, about 600 km inland. Annual rainfall is about 750 mm, most of which occurs between June and September. During the finger millet crop season, July to October, temperatures are 28-32^0C maximum and 20-22^0C minimum. Germplasm accessions were sown on red soil (alfisols) fields (pH about 7.0) on ridges, spacing 60x10 cm. Each accession was a single row of 4 m length. Basal fertilizer of 18 kg N and 46 kg P, and top dressing of 46 kg N ha^{-1} were applied. Sowing was in July every year using an augmented block design, with blocks of 30 plots that included 27 test accessions and three check cultivars; the latter were sown after each set of nine test accessions. The crop was protected from weeds and irrigated if needed. Data were recorded on five qualitative traits (description in discrete classes) and 14 quantitative traits (continuous variation) following the Descriptors of

Finger Millet (IBPGR 1985). Qualitative traits (plant pigmentation, growth habit, inflorescence compactness, lodging, overall plant aspect) and two quantitative traits (days to flowering, grain yield) were recorded on a plot basis. Number of basal tillers was measured from five representative plants per plot. The remaining 12 quantitative traits (plant height, number of culm branches, flag leaf blade length, flag leaf blade width, flag leaf sheath length, peduncle length, panicle exsertion, inflorescence length, inflorescence width, longest finger length, longest finger width and number of panicle branches) were measured on main culms of the five representative plants per plot. During field evaluation, accessions were also classified into six botanical races (*Africana*, *Spontanea*, C*ompacta*, *Elongata*, *Plana* and *Vulgaris*) following Prasada Rao et al. (1993).

Qualitative traits. Three plant colors were found: green is most common, followed by purple, and violet plant color was of rare occurrence. Of the three growth habit classes, erect was predominant, followed by decumbent trait; prostrate growth habit was of rare occurrence. Grain color was recorded in four classes; dark brown, light brown, reddish brown and white. Light brown was most common, followed by reddish brown, dark brown and white. Lodging occurs in finger millet and there were differences between accessions. The proportion of accessions with no lodging, slight lodging or medium lodging was similar in all races. In about 3% of accessions, plant foliage remained fully green until grain maturity – a valuable trait if the crop is to be used for fodder. The trends in plant color, grain color, and distribution of accessions among different growth habits, lodging, and frequency of the staygreen trait, was similar in all races.

Spike shape and compactness was recorded in eight classes: compact, fisty, incurved, top-curved, short-open, long-open, pendulous and lax. In the entire collection, a large number of accessions had incurved spike, followed by top-curved. The remaining six spike types occurred less frequently. The formation of races is based primarily on spike type.

- Race C*ompacta* – high proportion of fisty, compact, and incurved spikes
- Race *Elongata* – high proportion of long-open, pendulous and top-curved spikes
- Race *Plana* – mostly top-curved spikes
- Races *Spontanea* and *Vulgaris* – incurved or top-curved spikes.

Glume status is the distinguishing trait between cultivated and wild races.

The two wild races (*Africana* and *Spontanea*) had mostly prominent glume, while all three classes – prominent, non-prominent, medium – were found in cultivated races.

Quantitative traits. The mean of quantitative traits calculated across races indicated that *Africana* was more distinct compared to other races. It also had the highest means for all traits except days to flowering, flag leaf blade length and width, and width of longest finger (Table 3). The latter two parameters were highest in race *Plana*. *Compacta* had lowest means for eight out of the 14 quantitative traits estimated. In general, *Vulgaris* was the earliest to flower (short crop duration) and *Elongata* flowered last (longer crop duration).

Table 3. Means of quantitative traits in finger millet germplasm of different races, ICRISAT Patancheru.

	Entire collection	Africana	Compacta	Elongata	Plana	Spontanea	Vulgaris
Days to flowering	80.41	63.17	80.59	83.69	81.02	80.15	79.78
Plant height (cm)	100.66	115.00	100.37	101.44	107.50	96.68	98.80
No. of basal tillers	5.19	18.17	4.46	5.71	4.73	9.21	5.24
No. of culm branches	2.30	3.67	2.13	2.43	2.10	2.23	2.36
Flag leaf blade length (mm)	358.10	303.33	364.91	348.62	384.19	308.32	352.46
Flag leaf blade width (mm)	12.65	7.67	13.11	12.54	13.20	12.68	12.44
Flag leaf sheath length (mm)	102.53	143.33	98.88	104.92	99.91	111.82	103.26
Peduncle length (mm)	215.45	368.33	208.10	218.13	215.03	236.68	215.69
Panicle exsertion (mm)	113.47	183.33	111.84	113.14	112.95	124.49	113.52
Inflorescence length (mm)	93.12	181.67	82.60	116.86	104.86	95.75	88.29
Inflorescence width (mm)	78.41	112.33	69.04	105.56	83.03	96.45	74.50
Longest finger length (mm)	72.63	146.67	64.28	92.93	82.02	80.37	68.39
Longest finger width (mm)	11.58	2.83	11.96	11.07	12.06	9.46	11.52
Panicle branches number	7.74	10.67	7.67	8.00	7.56	7.79	7.76

Cluster analysis of races was performed on the first two principal components (95% variation). Three clusters were found. *Africana* was most distinct compared to the other races and formed its own cluster. *Spontanea* and Elongata formed a second cluster; *Plana*, C*ompacta* and *Vulgaris* shared some similarities and formed the third cluster (Figure 1).

Developing a core collection for finger millet

Frequently, basic germplasm accessions are not adequately utilized in crop improvement. One of the main reasons is the large number of collections, and inability to evaluate a large number of accessions in replicated multi-locational trials, to identify traits of agronomic importance for utilization in breeding programs. The ICRISAT genebank at Patancheru holds 5,949 finger millet accessions – replicated multi-locational evaluations of this entire collection would be costly. To overcome this problem, Frankel (1984) proposed sampling of the collection to form a 'core collection' of manageable size. A core collection contains a subset of accessions from the entire collection but captures most of the diversity in the larger collection (Brown 1989). We have developed a core collection of 622 finger millet germplasm accessions, based on origin and data on 14 quantitative traits (Upadhyaya et al. 2006). Comparisons of means, variances, frequency distribution, Shannon diversity index (H`) and phenotypic correlations indicated that the core collection represented >85% diversity of the entire collection (Upadhyaya et al. 2006).

Identifying useful accessions from the core collection. The core collection was evaluated in an augmented design using three control cultivars during the 2004 rainy season. Genotypic variance was significant for 12 of the 15 quantitative traits. Genotypic variance was non-significant for number of basal tillers, culm branching, and flag leaf sheath length (Table 4). We identified five accessions (IEs 2288, 3280, 3952, 5066, 5179) for high grain yield (2.06-2.15 t ha^{-1} vs 2.08 t ha^{-1} for control cultivar), five accessions (IEs 501, 2322, 2957, 4759, 6013) for early flowering (49-52 days vs 68 days for control), and five accessions (IEs 2039, 4443, 4476, 4709, 6890) for high basal tillers (4.3-4.7 vs 4.2 tillers in control).

Table 4. Genotypic variance and heritability in finger millet core collection at ICRISAT Patancheru, 2004 rainy season.

	Genotype		Race				
	Variance	se	Wald statics	df	wald/df	x^2 probability	h^2
Days to flowering	64.41	4.11	49.94	5	9.99	<0.001	99.59
Plant height (cm)	242.72	20.17	61.91	5	12.38	<0.001	98.98
No. of basal tillers	0.06	0.06	116.25	5	23.25	<0.001	69.64
Culm branching	0.00	0.03	54.15	5	10.83	<0.001	0.24
Flag leaf blade length (mm)	1717.00	518.00	18.42	5	3.68	0.002	93.26
Flag leaf blade width (mm)	2.46	0.31	38.23	5	7.65	<0.001	97.83
Peduncle length (mm)	1012.00	149.20	7.68	5	1.54	0.175	97.12
Exsertion (mm)	831.70	111.20	4.59	5	0.92	0.468	97.43
Inflorescence length (mm)	445.30	40.30	184.15	5	36.83	<0.001	98.69
Inflorescence width (mm)	155.15	21.20	82.51	5	16.50	<0.001	97.53
Length of longest finger (mm)	406.93	28.48	223.59	5	44.72	<0.001	99.40
Width of longest finger (mm)	7.95	0.71	37.36	5	7.47	<0.001	98.77
Panicle branch number	1.13	0.19	11.08	5	2.22	0.05	96.68
Yield (kg ha^{-1})	104578.00	32443.00	17.58	4	4.40	0.001	93.21

We identified 20 high-yielding accessions (relative to yield of the control cultivars PR 202 and Kalyani). Cluster analysis based on the first five principal components (69.5% variation) resulted in four clusters, indicating diversity of the selected accessions compared to the controls (Figure 2). This work will facilitate use of these accessions in breeding programs to develop high-yielding cultivars with a broad genetic base.

A mini-core collection. When the entire collection is very large, even a core collection becomes unwieldy for evaluation by breeders. To overcome this, ICRISAT developed a 'mini-core' collection, which consists of 10% of accessions from the core collection, ie, 1% of the entire collection

(Upadhyaya and Ortiz 2001). This mini-core subset still represents the diversity of the core collection, and was developed in two stages. First, a representative core subset (about 10%) was developed from the entire collection, using information on origin and geographical distribution, as well as characterization and evaluation data. This core subset was then evaluated for various morphological, agronomic, and quality traits, and a further subset of about 10% of accessions was selected. At both stages, standard clustering procedures should be used to separate groups of similar accessions.

The size of our core collection (622 accessions) is not large. But considering the low priority given to finger millet in most breeding programs, it will be too large for breeders to conveniently exploit. We therefore developed a mini-core collection of 65 accessions following the approach of Upadhyaya and Ortiz (2001).

Developing a composite set of germplasm

We have developed a composite set of finger millet germplasm under the Generation Challenge Program. This set comprises 1,000 accessions selected using various criteria: representation in ICRISAT core collection and in Indian NARS collections, major agronomic traits, resistance to insect and diseases, etc (Table 5). Phenotypic and genotypic characterization of this composite set will help identify useful and unique germplasm resources, and greatly increase the scope and effectiveness of utilization in crop improvement.

Table 5. Composite set of finger millet germplasm developed for Generation Challenge Program.

	No. of accessions
From ICRISAT core	508
Selected for agronomic traits	222
One each from 114 clusters in ICRISAT core	114
Representing Indian NARS core	50
Selected for resistance to stresses	85
Selected for grain nutrition traits	12
Selected for genetic diversity	9
Total	1000

In the past, genetic improvement in finger millet has been very limited. The crop has several merits (eg, competitive in marginal environments, good yield potential, high dietary value), and deserves more attention. Finger millet could be made competitive by broadening the genetic base and increasing the productivity of the cultivars developed. Useful germplasm for breeding could be identified using two approaches: (i) identifying biological races in which accessions are more genetically diverse, and also have higher means for desired traits, (ii) systematically characterizing the core and mini-core collections. In the present study, we found that race *Africana* is very rich for several economic traits, namely plant height, basal tillers, number of culm and panicle branches, peduncle length, inflorescence length, and length of longest finger. The finger millet crop at ICRISAT Patancheru generally remains free from disease or insect damage. However, the crop is known to be affected by diseases such as blast (*Pyricularia grisea)*, leaf blight (*Helminthosporium* sp), and leaf spot (C*ercospora eleusine)* in Nepal, Kenya, Uganda and other countries. Germplasm accessions were screened against these diseases and resistant sources were found (Sherchan and Baniya 1993, Esele 1993). The availability of male sterility could be very useful to breeding programs, and one such line was produced recently through artificial mutation (Gupta et al. 1997). At ICRISAT, a number of accessions with desired agronomic traits have been selected using the core collection approach. These value-added germplasm lines, which are freely available to researchers, could form a good base for breeding programs in both Asia and Africa.

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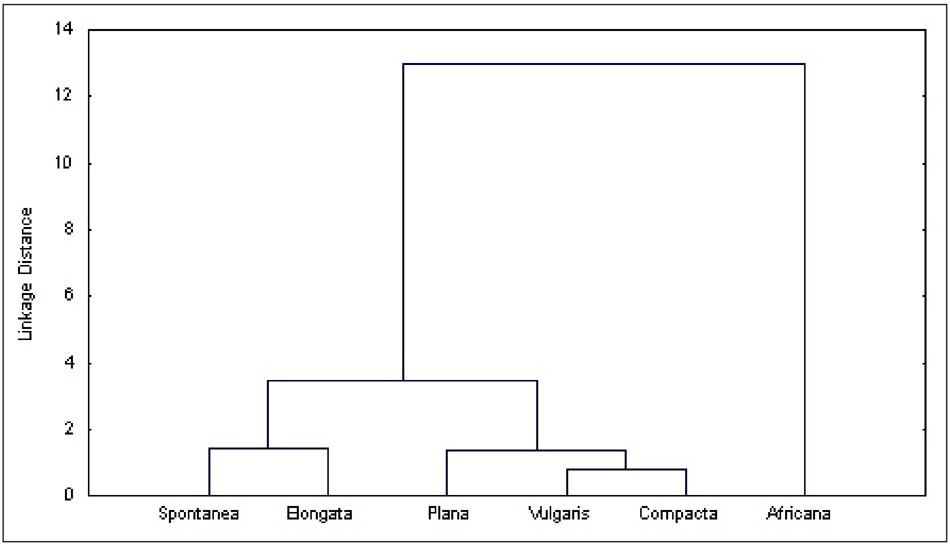

Figure 1. Dendrogram based on first two principal components of races in finger millet entire collection at ICRISAT Patancheru (variation captured 95%).

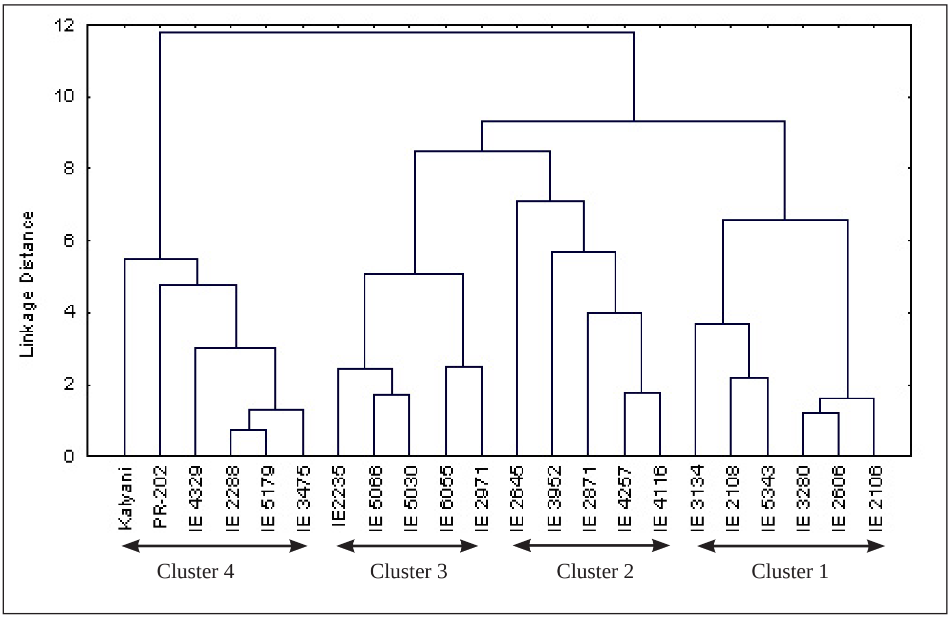

Figure 2. Dendrogram based on first five principal components (69.5% variation) of 20 High-yielding finger millet accessions (from core collection) and two control cultivars.

Importance and Characteristics of Finger Millet Processing in Uganda

Julius Okwadi[1]

Abstract

This paper presents the result of a reconnaissance survey conducted among the key actors in the finger millet processing chain in Uganda aimed at understanding the salient characteristics of and constraints to finger millet processing. A semi-structured checklist was administered to processors, millers/traders and producers of *"Ajon"*. This was complemented by visits to key market outlets within Kampala. A Strengths, Weaknesses, Opportunities and Constraints framework was used to analyze the data. Finger millet is processed by the households, traders/millers and processors. There is limited product variability and diversification and the process is highly labor intensive. It is a leading source of income for the urban and rural poor women who brew *"Ajon"* and are employed to clean finger millet. There is a growing demand for finger millet and its products propelled by the increase in population, increasing recognition of the high nutritional value of the product, growing interest in the crop by a wide array of stakeholders and the aggressive marketing strategies employed, mostly by the processors. Processing is constrained by low production and productivity of the crop, mistrust and suspicion among the actors and unscrupulous activities like adding soil/stones to finger millet, tampering with weights and measures and adulterating products with undeclared mixtures. There is need to enhance connectivity among the key actors in the chain and to develop and harmonize policies and standards that will regulate and promote the sector both nationally and regionally.

Introduction

Finger millet, *Eleusine coracana* L. (*wimbi* in Swahili) is the sixth most important grain in the world. It sustains a third of the world's population and, in the ECA region, it is only surpassed by maize as a major cereal. Global production is estimated at 4.5 million metric tons per annum, and in the ECA region Uganda is the leading producer with yields averaging about 700,000 metric tons per annum on approximately 412,000 ha (FAO

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2005). The current yield level of 1,555 kg ha^{-1}, that is typical of smallholder harvests in ECA region, however, is still much lower than the real potential of 3,000 kg ha^{-1} (Oryokot 2001, FAO 2005). The leading finger millet growing areas in Uganda are the East, North and West. In these regions, finger millet doubles both as a subsistence food crop and a source of income particularly for the urban and rural poor women. Currently, the demand for finger millet outstrips production and this is projected to continue, unless productivity enhancing options are developed and adapted.

Finger millet production, processing and utilization in the ECA region is characterized by predominance of traditional practices that entail planting of farmers' home-saved seeds, harvesting of mature panicles using thumb knives, open sun drying on bare ground, rocks, or mats; threshing by beating dried panicles with sticks, winnowing using flat trays and dehulling using mortar and pestle; and narrow utilization base of value-added products in the form of thin or thick porridge and alcoholic beverages. The practices are considered inappropriate, laborious, time consuming, unhealthy and uneconomical. The problems are further exacerbated by asymmetrical information on markets, prices, technologies, and lack of organized marketing and pricing systems. Oryokot (2001) observed that finger millet marketing in Uganda is informal, although several avenues exist for the farmer to market his produce, such as bartering between farmers at the farm level; brewing and selling at farm/ family level; local markets where local produce dealers purchase the grain.

In Uganda, the responsibility for finger millet improvement is vested in the Serere Agricultural and Animal Production Research Institute (SAARI), one of the research centers under the auspices of the National Agricultural Research Organization (NARO). Recent work on finger millet, in collaboration with the Warwick HRI/University of Warwick and supported by the Department for International Development (DFID) has focussed on enhancing finger millet production and utilization through improved blast management and stakeholder connectivity. In addition to this, was a follow-on project on facilitating the promotion of improved blast resistant finger millet varieties to enhance finger millet production in Eastern Africa. Understanding the mutual needs of the finger millet industry was identified as a key activity and in this paper, the results from a scoping study aimed at identifying the importance and characteristics of finger millet processing in Uganda are presented.

Methodology

A rapid reconnaissance survey was conducted among the key actors in the finger millet value chain. The actors visited were large-scale processors, millers and traders and brewers of *"Ajon"*, a local brew made from finger millet. Market outlets like supermarkets, shops and market stalls were also visited to determine the range of finger millet products available and to try to get a feel about customer preferences. A semi-structured checklist was used to capture information on the pertinent issues regarding finger millet processing. Information and data generated were analyzed using a Strengths, Weaknesses, Opportunities and Constraints (SWOC) framework.

Results

Finger millet Processing

Finger millet is processed at household level, by the millers who at times double as traders and stockists and by the processors. At household level, processing involves post harvest handling (drying, threshing, winnowing, sorting and storing) and developing products like flour for porridge, flour for Atap (Finger millet and cassava), yeast and *"Ajon"*. With the exception of milling, which can also be done manually, most of the other activities are labor intensive and almost exclusively done by women.

The millers who offer the trading role buy finger millet, sort, clean it further and either transport it to other market outlets or sell it in their stores. Some mill it and sell it as either pure finger millet flour or mixed with cassava flour. Millers also offer services to farmers or other actors in the industry who want to mill. Most millers visited in Kampala employ women to clean and sort the finger millet to suit the needs of the various clients.

Processors purchase either milled flour, or clean finger millet grain from the traders, which they then use as an input in their subsequent operations. None of the processors visited had a cleaning facility, although they all showed interest in acquiring it. The main products are flour for porridge, flour for food and finger millet soya flour. Earlier studies indicated that some of the bakeries were also using finger millet.

From the above, it is clear that most of the operations are manual, the range of products is still limited, with the exception of *"Ajon"*, produced at household level or finger millet soya flour, produced by the processors. The innovation is mainly in the efficiency of the process. The challenge is two fold: how can the processors support commercialization of *"Ajon"*, and how can capacity be built at farm level to propel diversification of finger millet and its products?

The SWOC Analysis

Strengths

Finger millet processing is highly labor intensive, employing mainly the urban and rural poor women, thus providing a source of income to them. Results from several diagnostic studies in the rural areas in Northern and Eastern Uganda reveal that brewing local beer *"Ajon"* is a leading source of income mainly for the women. It is estimated that gross income from the sale of *"Ajon"* is more than twice the cost of the raw finger millet. Similarly, the women involved in cleaning finger millet in the peri-urban areas of Kampala can clean up to 3 bags a day, earning the equivalent of US$ 5 a day[2].

There is a high demand for finger millet and finger millet products year round. Finger millet, especially from Lira is preferred by the local brew industry, and although the statistics are not readily available, there is sufficient evidence to bear out the fact that this industry is steadily growing. A visit to the market outlets indicated that customers preferred finger millet and soya products, followed by pure finger millet for porridge. In terms of source, customers (market outlets) seem to prefer products from the bigger processors like Maganjo and East African Basic Foods. Although reasons for this preference were not exhaustively explored, it is reasonable to attribute it to the fact that they produce on a relatively larger scale, they have stayed longer in the business, perhaps have a more aggressive marketing strategy and customer loyalty, since taste and preferences do not change over night. Nonetheless, the market share commanded by other processors like Family Diet, Seseko and Yellow Star is steadily growing. Overall, there is increased awareness among the consumers of the high nutritional value of finger millet and finger millet products like finger millet and soya flour, thus providing a cheaper source of nutrients that also conform to the eating habits of the consumer. High demand can be attributed to increase in population especially in the peri-urban areas, occasioned largely by the rural urban migration, particularly

[2] Households living below the poverty line are those who subsist on less than US$1 per day.

from North and Eastern Uganda[3], partly resulting from the civil strife but also the high national population growth rate of 3.3%. Added to this is the fact that processors are proactively looking for markets for their products. This has taken the form of advertisements through the various media, participation in local, national, regional and international trade fairs and exhibitions and door-to-door sales promotions and awareness campaigns. In some cases, contractual arrangements have been put in place to supply fixed quantities of particular products to super markets and other customers like the Tuberculosis unit of Mulago hospital. Family Diet and Maganjo millers have market outlets in the United Kingdom. Indeed, one of the processors visited expressed interest and willingness to participate in this workshop at their own cost.

Some of the processors visited have initiated linkages with some of the other stakeholders, like the Department of Food Science, Makerere University for purposes of ascertaining the nutritional content of their products. Another processor had established linkages with a farmers' co-operative in Kibale. Under this arrangement, the processor availed one ton of finger millet seed to the farmers and expects to purchase at least one ton of finger millet from each of the 300 farmers at a guaranteed price of Ush 450/kg. Similarly, another processor is willing to link up with farmers but only if he can acquire machinery or a more efficient way of cleaning finger millet. This particular processor was worried about establishing the linkage then failing to absorb the excess finger millet produced due to poor mechanisms for cleaning finger millet.

Weaknesses

The labor intensive nature of the processing operations implies that it exerts high demand on labor, time and costs. Urbanization worldwide often results in shortage of labor and therefore high costs of the available options. Although some of the big processors expressed interest in controlling especially the cleaning operations, lack of alternative equipment and high costs especially of the de-stoner in countries like Brazil and India present a real constraint.

There is also an atmosphere of mutual mistrust and suspicion among and between some of the actors in the sector. The farmers believe that the traders always want to "cheat" them by either offering low prices or using tampered weights and measures. Traders, on the other hand, believe that the farmers

[3] Finger millet is a key staple in North and Eastern Uganda. These are equally among the principle finger millet growing areas.

are not sincere and deliberately add stones and sand to the finger millet so as to make it heavy. High incidence of soil and stones in finger millet leads to significant losses, sometimes up to 20 kg per bag. Some of the large-scale processors believe that finger millet, especially ground finger millet, is not pure finger millet. Indeed some of the small-scale finger millet processors were selling clean finger millet grain at a higher price than the ground finger millet flour. Under such circumstances, it is reasonable to conclude that this finger millet flour is adulterated with other cheaper coarse grains like sorghum. Consumers of the various products expressed reservations as to the extent of honesty by some processors and therefore purity of the said products. Although the Uganda National Bureau of Standards (UNBS) is mandated to develop, test and ensure application of standards, it has not done much with respect to finger millet. The only mandatory requirements from the bureau are that processors should state the expiry date, weight and that it is food for human consumption. The real issues like stones, dust, and adulteration of the products are yet to be tackled. This mistrust is further aggravated by the fact that finger millet is largely processed in the suburbs, places in which water and sanitation facilities are poor and other support infrastructure is lacking.

The range of processed finger millet products is still narrow, limited to flour for porridge, and finger millet bread. Beyond packing, labeling and cleaning, the level of innovation in most products is developing composite products. There are limited attempts to enhance forward and backward linkages and connectivity both within and between processors. Finger millet for porridge, finger millet/cassava for bread is not significantly different from what is produced at farmers' level.

Opportunities

Several opportunities have been identified that if taken advantage of can greatly propel the finger millet industry to greater heights. To begin with, finger millet, compared to other coarse cereals like sorghum and maize, is not susceptible to most post harvest pests and diseases. As such, it has a much longer shelf life, implying those agents/organizations with the requisite capital and appropriate storage structures can purchase it in bulk during times of plenty, store and either sell or process at the appropriate time. Moreover, fresh finger millet is not liked, compared to the "older" grain and as such attracts a lower premium in the market.

There is a high and growing demand for processed finger millet products. All the processors visited acknowledged that the main problem is how to meet the needs of the growing market. Some of them had reservations on venturing into new market avenues, especially the big super markets, for fear that they will fail to cope with the demand. The Super Market Uchumi in Nairobi had placed an order for a regular monthly supply of 1,000 kg per month, for a start, but the processors contacted failed to venture into this market, without even satisfying the domestic one. In the same token, there is a lot of cross border trade in finger millet. For example, while Arua is a major source of finger millet for the Kampala traders, most of it originates from the Democratic Republic of Congo. Similarly, although Eastern Uganda is a major finger millet producing area, it is not a significant source of finger millet for the Kampala traders since most of it ends up in Kenya.

At the national level, a supportive macro-economic policy framework exists, as outlined in the Plan for the Modernization of Agriculture(PMA). The PMA seeks to transform the agricultural sector from a predominantly subsistence one to a commercial one through a multi-sectoral approach. In line with other government policies, it seeks to redefine the role of the state from an active service provider to one that ensures a conducive environment for private sector engagement in agriculture. In keeping with the above, a number of public-private organizations with a stake in the finger millet sector have emerged. NARO through her institute, SAARI, holds the remit for finger millet research and improvement and has developed a number of high yielding, early maturing, pest and disease resistant varieties. These varieties were developed by the farmers. What has been lacking is involving the processors and the consumers of processed finger millet products in the research and development process. The UNBS has a pivotal role to play in developing, harmonizing and enforcing standards. Agricultural extension services are provided under the National Agricultural Advisory Services (NAADS). Unfortunately, very little has been done to provide advisory services for finger millet because the philosophy of NAADS is that farmers should identify and prioritize enterprises and finger millet has not significantly featured as a priority enterprise in most of the areas. Nonetheless, since NAADS emphasizes producing for the market, the current thrust to commercialize finger millet is likely to alter the current prioritization of the enterprises at farm-level and attract advisory services for finger millet under the NAADS program. The private sector and private sector organizations present a great opportunity for commercialization of the enterprise and linkages to sources of credit. Indeed, some of the processors had accessed credit and business development skills and services through the Uganda Small Scale Industrialists Association (USSIA). Against this background, is growing donor interest in promoting finger millet. This framework presents an excellent opportunity for dialogue, demand articulation and for enhanced stakeholder connectivity and commercialization of the enterprise.

Constraints

Finger millet processing is greatly constrained by the low production and productivity at farm level. This has an obvious limitation on the marketable quantities, pushes the price of finger millet through the roof and limits the ability of the processors and other actors to enjoy economies of scale and scope. Added to this are the poor perceptions of most actors towards finger millet. To some, it is an inferior commodity, while to others, promoting finger millet impacts negatively on food security, since a lot of it is consumed as *"Ajon"*. At higher levels, there have been minimal attempts to support/ promote the crop, as is the case with others that receive special attention through projects like strategic interventions.

Within the finger millet chain, there is no umbrella organization under which the actors are organized and therefore can lobby and advocate. As such, most activities tend to be restricted to either promoting sections within the chain or specific actors. For example, while a lot of advertising has been done by the processors, in reality they only promote their products and company name. Advertisement often leads to increase in sale of products, which may or may not result in increase in farm-level production that would in turn respond to the increase in demand.

Conclusion

Although there are significant constraints and weaknesses in finger millet processing, overall, the future of the sector appears to be promising. For this to be realized, it is pertinent that a platform for increased connectivity among the actors should be established. This platform could serve as an avenue through which stakeholders' needs are periodically articulated and appropriate action points designed. This forum would act as a platform through which progress against agreed criteria is periodically evaluated. Existing legislation including policies and standards needs to be reviewed and appropriate policies and standards designed and harmonized regionally. Such standards would both regulate and promote the sector.

Acknowledgements

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Annex 1: Strengths, Weaknesses, Opportunities and Constraints of Finger millet Processing.

Strengths	Weaknesses	Opportunities	Constraints
• Finger millet processing is labor intensive and employs mostly women • Technology used is simple and easily adaptable • Provides a source of income to, especially poor women • Products of high nutritional value are produced • Higher demand for processed products than raw finger millet • Processors are proactively seeking for markets for their produce • Linkages have been established with some actors like Food science department, Makerere, and Farmer groups. Another developed a contractual arrangement with a farmer co-operative.	• High demand on time, labor and cost • Other technological options are not easily accessible • Mutual mistrust among the actors (Traders Vs farmers; Small-scale processors Vs large-scale processors) • Unscrupulous behavior-mixing stones, adding sorghum and selling as finger millet flour • Product base available in the market is still limited • Most processing is conducted in the peri-urban areas that have poor infrastructure like water and sanitation	• Finger millet is not as perishable as other coarse cereals like sorghum and maize • High and growing demand for finger millet products • Regional trade in finger millet, especially DR Congo and Kenya • Conducive policy framework PMA, USSIA • Institutions with mandate on various aspects of finger millet-NARO, UNBS, Private sector, Makerere, Donors, micro-finance, eg, ADF • Increased recognition of the need to tackle quality issues particularly stone and dust	• Low farm level production, resulting in high price fluctuation • Poor perceptions towards potential of finger millet • Absence of an umbrella organization that brings together actors in processing • Lack of policies and standards governing finger millet processing • Inadequate connectivity among the actors

Issues and Constraints Faced by Finger Millet Processors in Uganda

Issa Wamala[1]

Abstract

In Uganda, finger millet production is still at a very low level of commercialization with the largest processing plant hardly close to 20 tons per day. In spite of the huge potential to increase finger millet processing, this potential is hampered by several economic, biophysical, cultural, technological and policy constraints. Though Family Diet Ltd is still a young firm, it is determined to provide a ready market to small-scale farmers in Uganda and process finger millet grain into products for both domestic and export markets.

Introduction

Family Diet Ltd is a relatively young firm in Uganda, specializing in grain products, including millet, maize, soya, rice and cassava flour. We commenced production in 2001. Our vision is to provide a ready market to small-scale farmers, and to process and sell the grain to domestic and export markets.

With particular reference to finger millet we also aim to

- Start up model 'Farmers Pilot Projects' in the major finger millet growing districts in Uganda
- Increase public awareness of the high iron content in finger millet

Finger millet production and processing in Uganda is still at a very low level of commercialization, and caters only to the domestic market. Rarely do you find a farm with more than 10 ha under millet. The largest processing plant handles less than 20 tons per day.

Issues and constraints

Processors in Uganda face a range of constraints: economic, biophysical, cultural (these three are the most serious), and issues related to administration, infrastructure, policy and technology. These are summarized below.

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Economic constraints:
Finger millet is grown as a food crop, not a cash crop. Farmers are not very interested in scaling-up production. Thus, processors are unable to procure a steady supply of grain. The marketing chain depends on exploitative middlemen who often add dust and stones to increase weight of grain; hoard supplies to create artificial shortages; or inflate transport costs from farm gate to processor. Small-scale processors lack capital: they are rarely able to access government grants or soft loans. Instead, they pay bank interest rates as high as 35%. Electricity supply is irregular, while generators and fuel are expensive, thus increasing production costs. Land factory construction is expensive. Since printing is expensive, processors are forced to use cheap, unattractive packaging. Finally, consumers lack purchasing power and buy cheaper but poor quality products. All these problems have led to reduction in the size of the market for quality products.

Biophysical constraints: Variable climatic conditions cause numerous problems, for example, delayed maturity causes farmers to harvest too early, and deliver immature grain to processors. Rains can make roads impassable, disrupting transport and production. Another problem is that difference in soil type leads to differences in taste of the milled product.

Cultural constraints: Literacy levels are low, hampering extension efforts and adoption of modern technology – and also leading to poor awareness of the nutritional benefits of finger millet. There are popular misconceptions about finger millet, for example, that it is a food only for certain tribes, which greatly reduces the size of the market.

Administrative issues: Many processing firms are badly managed. For example, use of untrained staff to reduce costs, lack of basic office equipment (computers, internet, email, etc), lack of proper administrative structure, nepotism and dependency on relatives and family members as managers, and poor record keeping. There are no research or technology upgrading programs. Instead, companies use trial-and-error methods of processing. They produce the same products year in, year out, with no product diversification. Staff working conditions are often poor, with no insurance, no proper working gear (face masks, gloves, boots), etc.

Infrastructure and policy issues: Processors receive no protection from government, and are vulnerable to imports of high-quality, well-packaged foreign brands. There is no association of finger millet growers or processors, hence capacity to lobby for policy change is limited. Agricultural infrastructure is poor, for example, lack of affordable trucks/tractors at district level as well as bad roads and no rail system, reducing the opportunities for commercial production. In general, the threat of war or political instability has discouraged investors. There is a lack of educational programs about health and nutrition, whether from government or NGOs; people remain unaware of the health benefits of finger millet.

Technology issues: Many processors have no access to modern processing technology, using primitive methods that are inefficient and ultimately costly. Storage facilities are poor, exacerbating contamination by dust and stones. Companies lack access to information on new research findings, newly developed finger millet varieties, and new food products. A recent problem is the use of certain weed control chemicals which damage soil productivity, eventually reducing production and supply.

Conclusions

Despite these problems, experience has shown that a large potential market exists. If consumers and producers are sensitized about the health benefits of finger millet, production and processing can expand rapidly.

Finger Millet Processing in Uganda -The Case of Maganjo Grain Millers Ltd

Mary Tamale[1]

Abstract

Finger millet is a traditional cereal crop grown in parts of Uganda for food and beverage products. Its popularity is hinged on its nutritional qualities that surpass those of other cereals, for example it has relatively higher contents of iron 12.6 mg, calcium 410 mg, and fibre 3.6 mg compared to maize which is at 2.3 mg, 26.0 mg and 2.8 mg per 100 gm, respectively. Processing of finger millet in Uganda is done at household, small and medium, as well as large-scale levels. There are relatively large numbers of small-scale processors that can process between 500 kg and 20 metric tons per month.

Maganjo Grain Millers Ltd (MGM Ltd), founded in 1984, is one of the large-scale processors, using modern grain cleaning equipment, and is involved in R&D mainly for product development. Finger millet milling techniques are similar across all scales of processing. However, large-scale millers like MGM Ltd are also involved in packaging and marketing of the value-added products across the country and beyond national borders. Through its corporate social responsibility and to help promote its products, MGM Ltd is linked with different stakeholder groups such as faith groups and national leaders, and supports sports and youth activities and also avails its facilities to learning institutions for training. While opportunities for increasing finger millet production and utilization are enormous, there are a number of challenges. These include contamination of grain with soil/stone particles, unreliable supplies, inconsistency in product quality, poor market linkages and information. To alleviate these challenges, MGM Ltd proposes several approaches. Of highest priority is the formation of an umbrella organization for the farmers, processors, consumers, and researchers and close collaboration with NGOs working in partnership with the government for creating favorable policy environments. The role of research for development is instrumental in developing and disseminating improved finger millet varieties, improved post-harvest technologies and other technologies across the whole value chain. The objective is to make finger millet a viable and sustainable sector to address issues of nutrition, health and income to improve livelihoods.

[1] Managing Director, Maganjo Grain Millers Ltd., PO Box 6738, Kampala, Uganda.

Introduction

Finger millet is a traditional cereal crop grown in some parts of Uganda. Many tribes have for a long time used finger millet for food, as porridge, meal food, brew, or drink. Various programs have been initiated to promote the finger millet sector. The focus is to strengthen the performance of both the farmer and the finger millet processor both on the small/medium scale and on the large scale in order to build capacity for growth of the finger millet sector in the East and Central Africa region.

This case is to highlight trends in finger millet processing in Uganda. However, before we take a look at finger millet growth in Uganda , it is appropriate to provide an overview of Maganjo Grain Millers (MGM) Company Ltd. The company is located 10 kms from Kampala on the Kampala-Gulu Highway (Bombo Rd). It is Uganda's leading grain processing company. It was registered as a private limited company in 1984 in the food processing industry. MGM has attained a reputation as the largest and longest-surviving private company in this line of trade.

Mission

"Committed to producing highly nutritious, affordable and quality products that are available at all times in a way of exhibiting a leading culture of providing customer oriented services, while protecting and supporting the environment around in our quest for feeding nations"

Vision

"To be a leading food processing firm in East and Central Africa ethically recognized by the authorities"

Finger millet processing in Uganda can be grouped under three broad categories of processing:

1. Household level
2. Small- and medium-scale level
3. Large-scale level

1. Household Level

Finger millet processing at household level has rarely been studied. It is understood that after direct harvest from the small home garden, the finger millet is threshed, winnowed and locally ground. If funds allow, this small household farmer could take his/her finger millet to a nearby milling facility to have his/her finger millet milled to flour.

2. Small- & Medium-scale level

Uganda has a number of small-scale finger millet processors. These can process between 500 kg and 20 metric tons per month. The majority of Uganda's finger millet processing falls in this category.

3. Large-scale

Very few processors produce an average of 20 to 100 metric tons per month. Such large-scale processors are to some extent involved in R&D, mainly for product development.

Our contribution

We contribute to this industry directly through:

1. Supporting the local and commercial farmer by buying his/her finger millet grain
2. Processing of finger millet by adding value as saleable finger millet-based products, for example, finger millet blended porridges
3. Purchasing finger millet from middle men and traders who also make money by moving the grain from the farmers to the processors

At processing level

In large scale processing firms, advanced technology is used for processing the finger millet grain as soon as it is received from the stores. Using equipment such as de-stoners, finger millet grains can be graded into varying grain sizes and separated from the stones and all dust particles to produce a fine, clean, and uniform size of finger millet grain depending on the processors requirements.

Milling to add value

Milling adds value to the finger millet cereal. Milling is the industrial process of turning a cereal/coarse particles into a fine flour. By milling, the processor is adding value to the finger millet in terms of its marketability, acceptability, and profitability. The process of milling is common both in the small and the large-scale processors, however only the large-scale processors use a de-stoner to remove physical contaminants.

Packing of finished products/Loading to the Market

Depending on their market strategies and customers' demands, different processors in Uganda pack their finger millet-based products differently. A range of finger millet based flours are produced.

Part of MGM corporate responsibility

The MGM Company engages in a number of public interactions in the interest of promotion, opening opportunities for our brands, and also sharing profits with our communities as part of our corporate responsibility. The company interacts with the government, other institutions, the public at large and is associated with religious leaders. National leaders extend an ear to MGM and these have included the wife of the South African President, the wife of Uganda's President and the Executive Director of the Uganda Investment Authority. MGM also sponsors football and netball games in Uganda.

MGM has a long-term corporate responsibility strategy and initiates the younger generation into the technicalities of food production. A number of schools (primary and secondary) and universities use the MGM factory as a learning facility.

Why does the Ugandan processor venture into finger millet processing?

1. There is growing demand for processed finger millet as compared to the raw material form.

	Year			
	2002	2003	2004	2005
Production (tons/year)	570	575	575	580
Consumption (tons/year)	570	575	575	580

2. Finger millet is of a high nutritional value.

	Contents per 100gms				
	Iron	Calcium	Fiber	Protein	Energy
Finger millet	12.6mg	410mg	3.6gm	7gm	328Kcal
Maize	2.3mg	26mg	2.8gm	9gm	342Kcal

3. Finger millet is a good bakery/confectionery blend/mix

Finger millet produces a good blend with wheat flour once blended in recommended proportions. It produces quality bread, cakes, and buns. In Uganda, one of the leading bakeries promoted finger millet based bread (Finger millet or Health bread).

4. Finger millet flour has a long shelf life

Although milling finger millet grain reduces its shelf life, it has a comparatively longer shelf life than other competing cereal flours like wheat, maize and soya.

5. Finger millet has less than 2% by-products

Compared to other cereals during the processing stage, finger millet by-products in terms of bran and husks are far less compared to those from maize, soya, etc. In addition, finger millet residue(s) are/can be used in the production of local brew and are used in the feed mills to produce animal feed.

Challenges to using finger millet

Disadvantages of using finger millet in processing compared to competing cereals:

1. Since much of the finger millet that is brought in from the farms is contaminated with soil/stone particles, processing can be very laborious
2. There is unreliability in supply of the finger millet grain from the farmers (undermining existing markets)
3. Lack of markets and product specification information
4. Poor organization of farmers and processors, which has caused the market to face the problem of inconsistency in product quality
5. Finger millet is small in size

Way Forward

There is need for:

1. A uniting body, for example, a Uganda Finger Millet Processors Association.

   This would provide cohesion for the interests of finger millet consumers and processors to enable continued growth of finger millet processing and consumption.
2. NGOs working in partnership with the governments to set favorable policies to enable finger millet promotion (enabling and supporting the building of linkages).
3. NGOs to work with the farmers and farmer groups to enable them to produce quality finger millet.
4. An umbrella organization for the farmers, processors, consumers, and researchers.
5. Research/researchers to develop improved finger millet varieties with desirable end use traits together with improved post-harvest technologies. For example, the Food and Agriculture Organization of the United Nations (FAO) has been a lead in supporting post–harvest initiatives which would enable production of improved products through improved post-harvest technologies (see Beyond Agriculture-Making markets work for the poor. Pg 46).
6. Development programs to support awareness of new finger millet varieties and support new finger millet products, for example, finger millet flakes, baby/infant formulas. This would include partial support in acquiring technology to produce new finger millet based products.

7. Processors to link with donors and researchers to educate the public about the nutritional benefits of finger millet over other cereals.
8. Supporting the growing finger millet processor to access his/her product to the market. This would involve sensitizations in particular forums or seminars on issues that would be required by the market, for example, packaging and branding, efficiency.

Summary

There is great opportunity for increasing finger millet grain production and consumption of finger millet-based products because of its nutritional advantages over other cereals. MGM, on behalf of other Ugandan finger millet processors, acknowledges the importance of this partnership that seeks to bring together stakeholders to address issues of linkages and to spearhead development of the finger millet industry in the Eastern and Central Africa (ECA) region.

Collaboration between the research and the donor community is critical in strengthening economies of scale for the large-scale farmers and processors and in improving the performance of the small/medium-scale farmers/processors in the ECA region.

Sources of information

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5. Dr Maggie Kigozi: Executive Director, Uganda Investment Authority (Investment opportunities in Uganda)

Building Market Linkages: Experiences from Commercialization of Smallholder Production

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Abstract

This paper investigates the potential of farmer organizations to remedy pervasive market imperfections in rural sub-Saharan Africa by drawing on the experiences of producer marketing groups (PMGs) and farm households in semi-arid eastern Kenya. The analysis shows that the functioning of markets is constrained by high transaction costs and coordination problems along the supply chain, but PMGs could provide new opportunities for small producers through vertical and horizontal coordination of production and marketing functions. The effectiveness of groups is determined by levels of participatory decision making, member contributions and their initial start-up capital. The benefits of membership are directly related to the amount marketed through groups and hence farmers with larger marketed surplus gain higher benefits. Along with failure to pay on delivery for cash constrained farmers, lack of access to credit and finance is a major constraint that stifles the competitiveness of marketing groups. In addition, exogenous climatic shocks and policy constraints that limit group marketing and hinder sustainable transition of farmer groups into cooperatives require policy interventions and investments in complementary institutions. While competitive markets require reliable supplies of high quality products, the limited responsiveness of rural markets to grain quality differentials also discourage farmers from improving the quality of the grain. This problem can however be addressed if market linkages are strengthened allowing farmers to market their grains to identified buyers which could eventually develop into coordinated value chains.

Key words – commercialization, rural markets, transaction costs, institutions, collective action, producer marketing groups.

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1. Introduction

Many sub-Saharan countries have liberalized their economies and developed poverty reduction strategies aimed at opening up new market-led opportunities for economic growth. The results have, however, been mixed (Winter-Nelson and Temu 2002, Dorward and Kydd 2004, Fafchamps 2004). A large number of smallholder farmers continue to engage in subsistence agriculture and are therefore unable to benefit from liberalized markets. Structural problems of poor infrastructure (Kydd and Dorward 2004 Dorward et al. 2005) and lack of market institutions (World Bank 2002 and 2003) continue to characterise the subsector with high transaction costs, coordination failure and pervasive market imperfections. Moreover, partial implementation of reforms and policy reversals have tended to mute the positive effects of liberalization (Jayne et al. 2002). Although opportunities afforded by liberalization have not been fully exploited, the expectation that removing state marketing boards would open opportunities for the private sector to take over these functions has not been fully realized in many areas. However, avenues exist in market institutions that make use of collective action to compliment government and private sector responses for enhanced coordination in rural commodity markets. This is because individual marketing of produce may not make economic sense due to small quantities, large spatial distances from input and output markets and subsequently the associated high transportation costs, all characteristics of small-scale production, especially in the semi-arid areas. Underdevelopment of market infrastructure in these areas makes them less favored for business development by the private sector.

This paper aims to analyze the role that institutional and organizational innovations can play in improving the performance of rural markets in less favored areas lacking in terms of desired market infrastructure. With a case study of producer marketing groups (PMGs) in Eastern Kenya, the paper identifies potentials and constraints of rural institutions in providing market services for small-scale producers of staple and cash crops. Marketing outcomes and the potential sources of differential success of marketing groups in relation to marketing and other stated functions are highlighted. The rest of the paper is organized as follows. Section 2 reviews market institutions and their emerging roles in remedying market imperfections in rural areas. Section 3 outlines the methodological approach used in the case study. Section 4 presents the main results, followed by a summary of the key findings and policy implications in the concluding section.

2. Role of Institutions for Improving Rural Markets

2.1. Institutions and market imperfection

According to North (1990), institutions constitute formal constraints (ie, rules, laws, constitutions), informal constraints (ie, norms of behavior, conventions, and self-imposed codes of conduct) that structure human interactions, and their enforcement characteristics. Along the same line, World Bank (2002) defines institutions as rules, enforcement mechanisms and organizations that promote market transactions. These definitions show that institutions provide multiple functions to markets: they transmit information, mediate transactions, facilitate the transfer and enforcement of property rights and contracts, and manage the degree of competition. They can therefore be used to address market failure problems.

Market failures are due to asymmetric information, high transaction costs and imperfectly specified property rights. They tend to be more pronounced in rural areas with under-developed road and communication networks and other market infrastructure. Without supporting market institutions, rural markets in these areas tend to be thin and imperfect, leading to high marketing and transaction costs. These costs undermine the exchange process (Kranton 1996, Gabre-Madhin 2001) leading to atomized rural markets with little rural-urban linkages (Chowdhury et al. 2005). Given such market arrangements, households respond by producing a limited range of goods and services for own consumption, especially when social protection for food security is not provided through markets and government interventions (de Janvry et al. 1991). Further, important market players fail to undertake profitable investments (due to the absence of complementary investments) leading to coordination failures that hinder market functions (Dorward et al. 2005, Poulton et al. 2006). Associated shocks and vulnerabilities to production risk (ie, weather, pests and sickness) and market risk also exacerbate market imperfections and transaction failures (Dorward and Kydd 2004). Institutional innovations that reduce transaction costs and enhance coordination of marketing functions in rural markets - such as PMGs that make use of collective action - can be instrumental in overcoming some of these problems.

2.2. Farmer organizations for improving markets

Farmer organizations have a potential to mitigate the effects of imperfect markets by enabling contractual links to input and output markets (Coulter et al. 1999) and by promoting economic coordination in liberalized markets (Rondot and Collion 1999) upon which market functions for smallholder farmers can be leveraged. The realization of this potential lies on their ability in conveying market information; coordinating marketing functions; defining and enforcing property rights and contracts; and more critically in enhancing competitiveness and mobilizing the membership to engage in markets.

Efforts aimed at promoting PMGs backed by innovative mechanisms for supporting market functions will need to consider development of a new generation of farmer cooperatives as business oriented enterprises for promoting market participation and income growth in rural areas. The legacy of farmer cooperatives in Africa has not been exemplary in providing business opportunities and marketing services to small producers (Hussi et al. 1993, Akwabi-Ameyaw 1997). The lessons indicate that farmer organizations can succeed if farmers are allowed to manage them autonomously with minimal government interference, participate actively in decision-making at every stage of the process, and if collective action reduces transaction costs and improves competitiveness. This implies that a new set of policies and institutional reforms would be desirable to facilitate their evolution as private sector enterprises with clear business plans, instead of their past role as public sector service providers, which contributed to their poor performance. Such institutional arrangements seem to raise hopes for rural areas affected by pervasive market imperfections to benefit from market integration and commercialization of production.

PMGs have the potential to enhance market opportunities for small producers through facilitated access to better markets, reduced marketing costs, and synchronized buying and selling practices to seasonal price conditions. Yet, collective action is a critical factor in realizing this potential. Participation in collective action will depend on the magnitude of expected benefits and associated costs. Collective action is likely to occur if the gains in terms of reduced transaction costs, better input and/or product prices, empowerment and capacity enhancement outweigh the associated costs of complying with collective rules and norms.

3. Data and Methods

Two sets of data that were obtained from a baseline in 2003 and a follow-up survey in 2005 are used in this study. The surveys were conducted in Mbeere and Makueni districts of semi-arid Eastern Kenya, where poverty is pervasive and smallholders face frequent drought-induced shocks. These districts were targeted by ICRISAT as potential areas where dryland legumes like pigeonpea and chickpea could be exploited to reduce poverty and vulnerability. The two districts are located in part of the larger semi-arid lands characterised by low density paved roads and limited access to major marketing centers. Farmers produce limited marketable surplus. Despite climatic variability and recurrent droughts, smallholder agriculture is almost entirely dependent on rains.

The baseline survey of 400 households (240 in Mbeere and 160 in Makueni) was undertaken in 2003 before the PMGs were formed as part of an ICRISAT-led research project that aimed to pilot alternative institutional innovations for improving market access for smallholders. The households were randomly sampled from a list of all households in the target villages. Farmers were sensitized and assisted to form PMGs[4]. Interested farmers voluntarily established five PMGs in each district. The groups got formally registered and were provided a certificate of legal constitution as welfare societies (self-help groups) issued by the Ministry of Gender, Sports, Culture and Social Services. Some of the households that had initially expressed interest in joining the group subsequently decided not to join. From the initial sample of 400 households, the distribution of members and non-members was decided later after the PMGs were established on the basis of committed and paid up members. Information on poverty indicators, agricultural production, market participation, and adoption of agricultural technologies was collected from the respondents.

During a follow-up survey conducted in 2005 in the same districts, data were collected at several layers: the community or village, the PMG and at the farm household levels. At the community or village level, 20 communities (two from each PMG) were purposively selected for the survey based on villages that had the highest number of registered members in their respective PMGs. A group of about nine gender-balanced key informants were selected from each village based on peer perception and the village chief's advice on their ability

[4] The form of assistance provided included mobilizing farmers to discuss production and marketing strategies for dryland legumes, training in quality seed production and marketing, and provision of information in organizing marketing groups. No direct subsidies or incentives were provided to farmers

to provide quality information about socioeconomic profiles of the village economy. At the PMG level, all the 10 PMGs were surveyed separately. The key informants about the PMG activities included five to seven respondents selected from the PMG management and ordinary members. Data obtained included objectives and aspirations of the groups, group characteristics, asset ownership, credit access, grading and quality control, bulking and marketing, governance, and major constraints to collective marketing. Lastly, at the household level data were collected from 400 randomly selected households (210 from Mbeere and 190 from Makueni districts) in the PMG villages, comprising of 250 members and 150 non-members. This sub-sample consists of 150 households re-sampled from 235 baseline households that had remained PMG members and 100 households re-sampled from 165 households that had remained non-PMG members. Information obtained included data on socioeconomic characteristics, assets, credit and savings, production, buying and selling, and participation in collective marketing.

The primary data were subjected to qualitative and quantitative analyzes. Simple descriptive statistics were used to analyze the socioeconomic and biophysical profiles of the PMG villages. The PMG data was used to determine constraints to collective marketing, identify indicators of collective action and to assess performance of marketing groups. Household data were used to examine the marketing channels and market actors along the value chain, and to establish the market shares, volumes and prices received by farmers. A simple OLS specification was used to identify factors that influence unit price of point transactions and to test whether PMGs pay higher prices to farmers than other buyers.

4. Results

4.1. Grain markets and marketing channels

Analysis of the market structure in terms of transactions (number of sells and volume) by distance and market participants during 2003/2004 show that rural wholesalers accounted for 45% of transactions and 49% of the volume traded while brokers/assemblers accounted for 38% of the transactions and of the traded volume (Table 1). Hence rural wholesalers and assemblers jointly control more than 80% of the transactions and traded volumes. This is because they are well organized and have the necessary capital and mobility to buy directly from dispersed farmers. PMGs accounted for 4% of the sales and 2% of the volume and rural consumers (ie, deficit producers) accounted for less than 10% of the sales and volume purchased from farmers. Further, 45% of the traded volume and 36% of the transactions were conducted at the farmgate.

A review of the relation between spatial distances and market engagement reveal that about 34% of the transactions (accounting for 25% of the traded volume), were conducted within 3 km of the farmgate. Generally, with increasing distance from the farmgate, the number of transactions and volumes traded by market participants declined. This can be attributed to increasing transportation and transaction costs for the small quantities marketed as distance increases, which is consistent with the findings by Fafchamps and Hill (2005). The prices also varied significantly over time – increasing gradually as local supplies decline and declining again as local produce reaches local markets after harvest. This illustrates potential business opportunities for PMGs through bulk marketing and spatial and temporal arbitrage.

However, the drought situation that prevailed during the 2004/05 production season significantly depressed the marketed surplus and the number of transactions in 2005. The effect of the drought-induced shock on pigeonpea marketing and the market shares and prices paid by different buyers are shown in Table 2. As a result of the drought, the latter declined from 243 in 2003 to just 50 in 2005 as the traded volume plummeted from about 41 tons to 4.7 tons. The total volume purchased by the PMGs (all crops) declined from over 60 tons in 2004 to about 15 tons the following year. Such a drastic change in market participation is significant given that pigeonpea is one of the most drought-tolerant crops grown in these areas. The results also show that the farmgate prices paid by the PMGs (Ksh 27/kg) were generally higher than other participants who offered Ksh 23-25/kg.

4.2 Collective marketing and its outcomes

A key objective of collective marketing is to reduce transaction costs and improve farmgate prices for producers. In some cases, reducing the volatility of local markets and reducing the price risks could be an important benefit to small producers. Testing the latter hypothesis, however, requires panel seasonal price data for different buyers. We therefore use cross-sectional grain sales data to test whether PMGs indeed pay significantly higher price than other buyers. In order to test this hypothesis, we estimated a linear regression model for actual prices received by farmers. The model dependent variable was the actual unit price received by farmers for different crops. A description of the model explanatory variables is summarized in Table 3.

The estimated model was significant ($P<0.001$) and explained about 61% of the variation ($R^2=0.612$). The model results show that farmer grain prices are significantly determined by the distance to the point of transaction, the type of crop sold, location by district, buyer type (particularly consumers, PMGs and schools) and the season the grain is sold. Unit prices were positively correlated with distance (Table 4). Specifically, prices seem to increase by about Ksh 0.2 for every 10 km traveled from the farmgate ($P<0.1$). The effect of distance is interesting: while prices seem to increase as distance increases, the price change for the range of distances covered in this study (less than 10 km) does not seem to be sufficient to create incentives for farmers to travel long distances for grain marketing. The small price gain is likely to be muted by the associated transportation costs unless the quantity sold is large enough to exploit economies of scale. This seems to explain why most farmers prefer to sell the grain at the farmgate (Tables 1 and 2). After controlling for the crop type, season, quality and type of buyer, amount sold does not seem to have a significant effect on prices received by farmers.

Prices vary significantly across crops ($P<0.01$). In relation to maize (reference crop), the price variation ranges from Ksh 4/kg for cowpea to about Ksh 15/kg for beans. Pigeonpea and greengram – two predominant cash crops in the study districts – sell at Ksh 12/kg over and above the price for maize while chickpea fetches about Ksh 14/kg more than maize. An interesting result is that grain quality does not seem to matter in price determination (the price differential between above-average quality and average quality grain is insignificant). This is a reflection of the classic case of asymmetric information (Akerlof 1970) where buyers take the quality of a good to be uncertain and consider only average quality of a good with the implication that suppliers of superior produce will be driven out of the market.

Indicating some differences in price across districts, farmers in Makueni district receive Ksh 2/kg less ($P<0.01$) than those in Mbeere. This may be due to the relative proximity of Mbeere district to Nairobi. When we look at the different marketing channels, consumers, PMGs and schools respectively paid about Ksh 7, Ksh 6, and about Ksh 4 over and above the prices paid by brokers/assemblers ($P<0.01$). This shows that PMGs can be attractive market outlets for small producers. The school feeding programs (captured by the school variable) also seem to provide an alternative market outlet for farmers at significantly higher prices ($P<0.01$).

Controlling for crop type, market outlet distances, location, and the type of grain buyer, farmers selling their produce at harvest (Season1) would lose about Ksh 1.5/kg compared to those who can afford to delay selling for 4-5 months (reference season) after harvest ($P<0.1$). However, the price differential for a 2-3 months delay after harvest (Season2) was not significant, indicating the time lag in seasonal price changes. This, however, shows that PMGs could exploit seasonal price differentials through temporal arbitrage involving bulking and storage. This confirms why the PMGs often store their grain for several months in anticipation of better prices.

A simulation analyzes using these econometric results shows that rices paid by the PMGs to the member farmers - after having covered operational costs - are about 22 to 24% higher than the prices paid by middlemen, the major competitors in rural areas (Table 5). However, this gain comes at a cost of delayed payments to grain sellers (on average for 5 weeks). In contrast, other competing buyers paid on delivery or shortly thereafter. This explains why cash-constrained farmers opt to sell through other channels, even at the cost of lower prices. As we discuss later, capital constraints and lack of access to credit are major constraints to the growth and expansion of PMGs in Kenya.

Is the observed price differential sufficient to provide economic incentives for smallholders to join marketing groups? What is the additional income that farmers gain from group membership after having paid the associated fees and indirect costs? A simple cost benefit analysis of grain marketing using two prices - offered by brokers and PMGs at the farmgate - can show these gains. Using the 24% farmgate price differentials for selling immediately after harvest (Table 5), Table 6 presents (first half) the estimated gains for members by selling through the PMG as compared to using the broker channel. The associated average costs of membership (annualized joining fee and annual contributions) and the opportunity cost of capital for delayed payments are included as costs of collective action. The average income gain is about Ksh 678 per household, but varies across household groups depending on the amount marketed. While the income gain per unit sold is constant, farmers with larger marketed surplus obtain higher benefits. In our case, this varied from Ksh 152 for the bottom one-third to Ksh 1,133 for the upper one-third of the farm size classes.[5] These income gains are modest for two reasons: (a) the average amount marketed was severely reduced because of the drought

[5] Higher rates of time preference and hence higher opportunity cost of capital will lower the gains from using the groups. For example, the income gains to lower and upper farm size groups decrease to Ksh 132 and 1,070, respectively, if a higher annual rate of interest (15%) is used to value the cost of delayed payments (for five weeks).

that prevailed during the 2004/05 production season, and (b) about 60% of the member farmers chose to sell through non-PMG channels partly because: (i) these buyers paid promptly, hence meeting the immediate cash needs of resource poor farmers, and (ii) some larger farmers faced lower transaction costs and opted to market the grain individually outside the village.

4.3 Performance of collective marketing groups

One major difficulty in collective action studies is to identify metrics for measuring the level of collective action and lack of evidence on how such group action contributes to final performance outcomes. Generally there are no standardized measures or indicators that can be used to assess the level, viability and effectiveness (performance) of collective action (eg, Place et al. 2002). However, depending on the situation, certain indicators may be identified as proxies for the differential level of collective action and the degree of effectiveness of such action in attaining stated group objectives. We used the PMG survey data to identify some indicators for the levels of cooperation and its effectiveness (performance) in attaining certain marketing outcomes. Accordingly, six indicators of collective action were identified: the number of elections since formation, share of members respecting the bylaws, attendance of meetings, annual member contributions to the group, cash capital and agreed annual subscription fees. In order to facilitate comparison across groups, the indicators were standardized in per capita or in percentage values. In relation to the effectiveness of collective marketing, the PMGs were compared on the basis of two outcome indicators: total assets built over time and total volume of grains traded (both standardized per member). The PMGs were then ranked according to their performance on each of the selected indicators. An aggregate mean rank for all the indicators of both the level and effectiveness of collective action is then used to evaluate the overall performance of PMGs. While the assumption of equal weights for the six indicators is unlikely to hold for all groups, it was sufficient to show the relative ordering of the different groups on a scale of collective action indicators.

The aggregate rankings across the three effectiveness indicators (ie, combining assets built over time and crop sales per capita) show that Kathonzweni (1.3), Kalamba (3.3) and Makima (3.5) performed much better than others (Table 7). The mean rankings for the six selected indicators of the level of collective action (not shown separately due to space limitations) show that these same groups performed best, namely Kalamba (3.0), Makima (3.2), and Kathonzweni (4.3). A non-parametric test – Spearman's rank correlation – was used to check the consistency on how the PMGs were ranked on the basis of level of CA and its effectiveness indicators. The average ranks were strongly correlated (r=0.985) which shows that groups that did well in terms of the different aspects of collective action were also the groups that performed better in terms of achieving their collective marketing functions. This confirms that higher effectiveness in group marketing functions is closely correlated with higher levels of collective action, a result consistent with field observations on the level of group action and its effectiveness.

4.4 Constraints to collective marketing

If the farmer marketing groups offer new opportunities to make markets work for small producers, what are the external limiting factors for their growth and expansion? The study attempted to identity the key perceived constraints to PMG performance. The median rank for the three most important constraints to collective marketing was given as: lack of credit (1), price variability (3) and low volumes (3) (Table 8). Other less important operational constraints to PMG performance and effectiveness include lack of buyers (4) and low business skills (6). In order to exploit the full potential of PMGs, future policies need to address these constraints.

The prominence of lack of credit as a major constraint is consistent with the pervasive financial market imperfections in rural areas (eg, Poulton et al. 1998, Kelly et al. 2003) and the wide recognition of what this service can play in marketing and enterprise development (Kirkpatrick and Maimbo 2002, Bingen et al. 2003). Credit constraints may be addressed through rural micro-credit facilities, contract or outgrower schemes and inventory credit arrangements. With a lead model demonstrated by the Grameen bank in Bangladesh, there are now several successful examples of micro-finance schemes across Africa. The disadvantage of such schemes is that their operations are normally subsidized such that the sustainability is not guaranteed in the long term. In addition, the size of loans may be small to provide capital required for buying large volumes of grain as needed to attain economies of scale. Selective subsidies may, however, be needed to 'kick-start' agricultural markets as they play an important role in relieving critical seasonal and cash constraints, and reducing market and input supply uncertainties (Dorward et al. 2004a).

Processors, exporters and supermarkets that need consistent and timely supply of high quality products may also provide financial resources and key inputs to farmers, through contractual or out-grower arrangements, with the latter undertaking to supply grain under pre-harvest formal or informal agreements that often specify volumes, prices and timing. The production loans can then be settled against the value of the grain supplied to the end-users. Farmer organizations and PMGs can play a vital role in facilitating such contractual arrangements with the private sector in a manner that would be mutually beneficial to farmers and contractors. The viability of such an arrangement would however depend on three factors: i) the extent to which they would be able to produce quality products in the desired quantity and time, ii) the ability of the groups to coordinate production and marketing activities of their members, and iii) the legal and institutional framework for contract formation and enforcement. The latter is critical as many contract farming arrangements suffer from non-binding contracts and lack of arbitration and enforcement mechanisms.

An inventory credit (also called warehouse credit) system is another option for providing credit services to PMGs. There are three players involved in this arrangement: the farmer, the PMG and a bank. The warehouse, which can also be operated by a PMG or a third party, can be used to store grain supplied by farmers with a formal bank lending the PMG the capital needed to pay farmers at least a certain percentage of the grain value at the time of delivery. The PMG will settle the bank loans later after selling the grain through temporal or spatial arbitrage. This option could be particularly attractive as the logistics are relatively simple and it is widely practiced in Africa. However, the success of such an arrangement will depend on the legal status of the PMGs, the willingness of the banks to lend against inventories, availability of secure and well-managed warehouse systems, and the legal framework to prevent loan defaults.

The problem of price variability can be attributed to supply fluctuations and weak market linkages with outlying areas. With limited local demand, covariate risk leads to negative correlation between local supply and prices. Production and supply in rainfed systems are often caused by changes in rainfall and its distribution. Sometimes, farmers could turn such seasonal price changes to their advantage through temporal arbitrage. Nevertheless, the challenge of low volumes can only be addressed through increasing crop productivity or procuring produce over a wider catchment area. The latter however implies coordinating the marketing activities of multiple PMGs to enable spreading and sharing of fixed marketing costs, which calls for organization of PMGs at a higher level of aggregation.

These results suggest that given the low level of market development and lack of service providers in many rural areas, the PMGs are unlikely to prosper in a "business as usual" policy environment. There is a need for conducive policies that support PMG growth and their gradual transition to business enterprises. This would include an enabling legal framework, improved access to market information, support to enhance business skills, and access to essential finance and credit facilities. The current status of PMGs in Kenya as self-help groups (SHGs) means that many such groups across the country lack legal status as business enterprises. This restricts their ability to access essential credit and finance from formal financial institutions.

An important corollary about the future of PMGs is a legal framework that facilitates their transition to a cooperative society. While the Kenya Cooperative Societies amendment bill (Republic of Kenya 2004) would appear to provide for a stronger regulatory framework within which cooperative societies can operate (Manyara 2003, Argwings-Kodhek 2004), it fails to provide sufficient mechanism for nascent farmer organizations, now registered as welfare groups, to develop fully and transit into cooperative societies. The current regulatory framework stipulated in the act may inhibit further development and competitiveness of nascent farmer groups and organizations and fail to provide sufficient mechanisms to facilitate and support such groups develop into farmer-owned effective business enterprises[2].

4.5 Lessons from commercialization

There are numerous constraints that inhibit smallholder grain farmers to commercialize despite their potential to do so. The most important ones identified in this study included low productivity, poor grain quality and limited market access. For these smallholder farmers to successfully commercialize, they need to be competitive by addressing these constraints. Low productivity limits the marketable surplus of smallholder farmers. Productivity constraints have been caused by limited use of available yield enhancing technologies either due to unavailability of such technologies to farmers or many farmers simply lack the cash to buy the improved seeds. Commercialization also requires that the new varieties embody preferred market traits that meet the

[2] Among other things, the framework requires that societies elect annually new office bearers and maintain financial statements that meet international standards. Failure to meet these requirements may lead to dissolution.

preferences of different end users. Small producers also need to overcome the high marketing costs, typical characteristics of isolated rural markets. The high marketing costs coupled with low productivity and poor grain quality make smallholder produce unattractive to potential buyers. The issues of productivity, limited surplus, reliability of supply, grain quality and market access have to be resolved to accelerate commercialization.

The productivity and grain quality issues remain squarely in the realm of farmers and crop breeders. While breeding takes the lead in improving productivity and market traits, grain quality is very much affected by farmer management practices. Breeders need to direct their efforts in generating not only high yielding varieties (drought and pest tolerant and disease resistant) but also varieties with market-preferred traits that meet the different end-user needs. Table 9 summarizes the market-preferred traits for dryland legumes and cereals. The market-preferred traits are very dynamic and there is a need to undertake market assessments to update these preferences. Similarly, different markets need different traits, for example, demand for food (on-farm and processed), feed (dairy, poultry, swine, etc) and industrial (biofuel, breweries, starch, etc). It is therefore imperative that target market traits are incorporated in the crop breeding programs. The potential for concurrently addressing multiple traits for multiple uses may vary from one crop to another and need to be factored in making breeding priorities. The minimal set of complimentary traits that matter most for markets (eg, grain size and color) need to be present for viable commercialization.

Once these varieties are developed in close partnership with scientists, access to supportive marketing and financial services is critical for farmers to adopt the new varieties. But, underdeveloped seed delivery systems and poor market access continue to stifle technology uptake and crop commercialization. The underlying causes for poor market access range from poor infrastructure in terms of road networks, to storage facilities and credit access. The underdeveloped seed systems – shared between legumes and open pollinated cereal crops – emanate from anticipated low effective demand as farmers often recycle the seeds. Poor market information and problems of addressing seed quality issues also limit the development of rural seed delivery systems. Producer Marketing Groups (PMGs) and rural agro-dealers offer good opportunities in addressing the limitations in both input and output value chains.

The innovative institutions that have been put in place to tackle these market access problems, for example, PMGs, have yielded impressive results in eastern Kenya. The farming households belonging to these PMGs have been able to access both input and output markets that they were unable to access before. They have been able to access seed of improved high yielding varieties for selected legume and cereal crops both on cash and credit terms. These PMGs have also been the entry points for training farmers on various aspects of farming. On the output market, PMGs have been able to sell grains collected from member farmers to urban traders and processors, hence helping small producers overcome the spatial market access barriers. These urban buyers offered a price that was over 20% of the rural prices. The potential of these PMGs is even larger if the identified institutional and policy constraints were tackled to improve access to credit and better coordinate production and marketing functions through legally supported marketing cooperatives.

On the basis of experiences in the region on commercialization of both cereals and legumes, the following critical lessons are identified. These lessons could be made useful for efforts targeting commercialization of high value crops like finger millets.

- Low volumes and limited market surplus are key market constraints
- Seed and technology delivery systems are needed to enhance technology adoption and improve productivity
- Crop breeding needs to target market traits for alternative uses
    - Food (on-farm and processed foods)
    - Stock feed (dairy, poultry, swine)
    - Industrial (breweries, starch, alcohol, biofuel)
- Price competitiveness with substitutes in the target markets are important (eg, maize with sorghum and millets)
- Grain quality is important for competitiveness in regional and international markets
- Reliability of supply and seasonality need to be considered
- Technological and institutional innovations are needed to improve competitiveness and create market linkages for smallholder producers

5. Conclusions and Policy Implications

Market liberalization is a necessary but not sufficient condition for increasing access to markets by smallholder farmers in many countries of sub-Saharan Africa. The expected economic growth from the market reform policies and the liberalization strategy has therefore largely remained unrealized. With imperfect markets and limited institutions to support market functions, the liberalization strategies were bound to fail in integrating smallholder farmers in less favored areas into the market system. In the absence of the necessary market infrastructure, producer organizations and collective marketing groups provide alternative institutional innovations to enhance the uptake of market-oriented and productivity-enhancing technologies, to link farmers to markets, and foster market participation and commercialization of smallholder production.

The analysis presented here has shown that PMGs were able to pay higher prices to members and hence improve opportunities for resource poor farmers to benefit from markets. While marketing channels in the study areas are characterised by long and complex marketing chains and high transaction costs, which considerably lower the farmers' share of the consumer price, PMGs improved market opportunities for small producers by bulking, storage, grading, sorting, and selling the produce directly to buyers at the upper end of the value chain. The links to secondary and tertiary markets were enhanced through better coordination of production and marketing activities. There was no evidence that the PMGs benefited only the wealthier and resource-rich farmers. On the contrary, the incentive for joining collective marketing groups seems to be higher for those with smaller farmland.

Nevertheless, only relatively successful PMGs were able to exploit this potential. The challenge is to mobilize farmers in participatory governance, provision of start-up capital to PMGs coupled with training of managers and members in business skills in running PMGs as business enterprises. In addition, the PMGs need to be supported to transition into legal business entities and not to remain as self-help groups, which restricts their ability to access essential financial and other services from the formal sector. The effectiveness of the PMGs was hampered by their lack of cash capital to pay in time for produce deliveries by farmers. Cash constrained farmers found it very difficult to defer payments, even when future prices would be significantly higher. The ability of the PMGs to access working capital through access to financial credit is therefore critical. One strategy would be to explore the use of crop inventory as collateral for financial credit and to subsequently encourage formal financial institutions to extend ware-house or inventory credit services to organized farmer groups. Another option would be to pay farmers a portion of the grain value at the time of delivery so that they would be in a position to meet immediate needs and also benefit from better prices by delaying full payments for some time. Many farmers expressed interest in such a policy.

In addition, the establishment of a legally recognized union of PMGs for expanding horizontal and vertical coordination of production and marketing activities may help in addressing the problem of low volumes, price variability and make the groups economically attractive to financial institutions. The seasonal price differentials may also be exploited further through bulking and storage during periods of excess supply and selling when prices improve. But this needs advanced analyzes of price trends and market functions to better understand their implications on policy. These strategies should be pursued together with alternative options for smoothing supply through investments in drought mitigating and water harvesting techniques that would enable farmers in drought-prone areas manage production risk more effectively.

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Table 1: Total transactions (number of sales) and volumes (tons) in 2004/05 (all crops) (n = 624).

Buyer	Total		Share (%)		Farmgate		< 3 km		3 - 5 km		> 5 km	
	Sales	Volume	Sales	Volume	Sales	Volume	Sales	Volume	Sales	Volume	Sales	Volume
Consumer	33	6.5	5	3	21	4.7	6	0.7	3	0.5	3	0.7
PMG	27	3.7	4	2	4	0.8	10	0.7	12	2.2	1	0.1
Rural wholesaler	283	101.8	45	49	25	27.5	167	43.3	82	29.9	9	1.0
Broker/assemblers	237	77.7	38	38	175	60.0	24	5.2	16	2.9	22	9.7
Urban wholesaler	13	6.4	2	3	1	0.0	3	0.2	3	0.2	6	6.1
Cotton ginnery	12	4.7	2	2	-	-	2	0.4	9	4.1	1	0.2
School	19	4.9	3	2	-	-	2	0.7	10	2.1	7	2.0
Total	624	205.7	100	100	226	93.0	214	51.1	135	41.9	49	19.7
Share (%)					36	45	34	25	22	20	8	10

Table 2: Pigeonpea marketed volumes, transactions and channel utilization by participant and distance to markets.

Buyer	Traded volume (tons)		Volume share (%)		Number of transactions		Distance from farmgate: Farmgate		<3 km		3 – 5 km		>5 km		Mean price (Ksh/kg	
	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005	2003	2005
Consumer	2.0	0.36	5	8	23	3	20	0	2	1	1	2	0	0	22	25
PMG	-	0.35	-	7	-	7	-	1	-	3	-	3	-	0		27
Rural wholesaler	11.9	1.65	24.6	35	93	22	9	2	56	12	22	6	6	2	15.3	23
Broker/assembler	24.6	2.06	60	44	110	15	76	10	14	1	5	1	15	3	18.6	25
Urban grain trader	2.8	0.29	7	6	17	3	3	0	3	1	0	1	11	1	24.8	24
Total	41.3	4.68	100	100	243	50	108	13	75	18	28	13	32	6	18.1	25
Share (%)	-	-	-	-	-	-	44	26	31	36	12	26	13	12		

Table 3: Description of regression model variables (n = 624) [a].

Variable name	Description	Mean	Minimum	Maximum
Price (dependent)	Unit price (Ksh/kg)	19.24	6	50
Sold	Amount sold (kg)	324.95	3	6000
Sold squared	Amount sold squared (1000 kg)	439	0.009	36,000
Distance	Distance to sales point (km)	4.6	0	400
Maize (reference)	Maize (1 = maize, 0 = otherwise)	0.46	0	1
Beans	Beans (1 = beans, 0 = otherwise)	0.06	0	1
Pigeonpea	Pigeonpea grain (1 = pigeonpea grain, 0 = otherwise)	0.08	0	1
Chickpea	Chickpea (1 = chickpea, 0 = otherwise)	0.03	0	1
Greengram	Greengram (1 = greengram, 0 = otherwise)	0.27	0	1
Cowpea	Cowpea (1 = cowpea, 0 = otherwise)	0.03	0	1
Cotton	Cotton (1 = cotton, 0 = otherwise)	0.04	0	1
Vegetables	Vegetables (1 = vegetables, 0 = otherwise)	0.04	0	1
Quality1 (reference)	Quality of the crop sold (1 = above average, 0 = average)	0.08	0	1
Quality2	Quality of the crop sold (1 = average, 0 = above average)	0.92	0	1
District	District (1 = Makueni, 0 = Mbeere)	0.16	0	1
District (reference)	District (1 = Mbeere, 0 = Makueni)	0.84	0	1
Broker (reference)	Broker/assembler buyer (1 = broker/assembler, 0 = otherwise)	0.38	0	1
Consumer	Consumer buyer (1 = consumer, 0 = otherwise)	0.05	0	1
PMG	PMG buyer (1 = PMG, 0 = otherwise)	0.04	0	1
Rural wholesaler	Rural wholesaler buyer (1 = Rural wholesaler, 0 = otherwise)	0.45	0	1
Urban trader	Urban trader buyer (1 = urban trader, 0 = otherwise)	0.02	0	1
Cotton ginnery	Cotton ginnery buyer (1 = cotton ginnery, 0 = otherwise)	0.02	0	1
School	School buyer (1 = schools, 0 = otherwise)	0.03	0	1

Variable name	Description	Mean	Minimum	Maximum
Season1	Harvest season (1 = harvest, 0 = otherwise)	0.71	0	1
Season2	Some 2-3 months after harvest (1 = Yes, 0 = otherwise)	0.19	0	1
Season3 (reference)	Some 4-5 months after harvest (1 = Yes, 0 = otherwise)	0.11	0	1
Gender	Gender of household head (1 = Male, 0 = Female)	0.84	0	1
Education	Education of household head (Years)	6.79	0	14
Own ICT[b]	Household owns ICT (1 = Yes, 0 = No)	0.82	0	1

[a]n = 624 is the number of point transactions;

[b] Information and Communication Technology (ICT) assets include radio, television and mobile phone.

Source: Household survey, 2005

Table 4: Determinants of grain prices received by farmers.		
Variable[a]	Coefficient	t-ratio[b]
Sold	-0.001	-0.97
Sold squared	$3.34x10^{-8}$	0.16
Distance	0.023	1.97**
Beans	15.163	14.99***
Pigeonpea	11.275	12.06***
Chickpea	13.512	9.31***
Greengram	12.321	19.45***
Cowpea	4.061	2.99***
Cotton	7.760	4.77***
Vegetables	7.421	5.51***
Quality	0.222	0.26
District	-2.194	-2.97***
Consumer	6.757	6.02***
PMG	5.950	5.04***
Rural wholesaler	-0.614	-1.20
Urban trader	0.988	0.52
Cotton ginnery	1.017	0.49
School	3.570	2.66***
Season1	-1.491	-1.96**
Season2	-1.173	-1.33
Gender	0.553	0.81
Education	-0.032	-0.49
Own ICT	0.056	0.09
Constant	13.914	9.79***
N	624	
F(23,600)	41.09	
R^2	0.612	

[a] Reference variables include: crop price = maize; quality = above average; district = Mbeere district; buyer = broker/assembler; season = 4-5 months after harvest.

[b] Significance levels as follows: ***=1%; **=5%; and *=10%

Table 5: The effect of collective marketing on pigeonpea prices in eastern Kenya.

Buyer	Season	Point of sale	Price (Ksh/kg)	PMG price advantage (%)
PMG	Immediately after harvest	Farmgate	29.81	24.00
Brokers/assemblers			24.04	
PMG		5 km	29.93	23.88
Brokers/assemblers			24.16	
PMG	4–5 months after harvest	Farmgate	31.16	22.72
Brokers/assemblers			25.39	
PMG		5 km	31.29	22.62
Brokers/assemblers			25.52	

Table 6: Income effects associated with selling through marketing groups.

Value of grain sold (Ksh)	Income gain from using groups by farm size class (N=23)[b]				Member lost income by not using groups by farm size class (N=150)			
	Small	*Medium*	*Large*	*Total*	*Small*	*Medium*	*Large*	*Total*
Using PMG price	2303	5387	7418	5155	14381	19284	22452	18705
Using broker price	1872	4413	5988	4188	10518	14407	16743	13889
Difference	431	974	1429	967	3862	4877	5708	4816
Cost of collective action[a]	279	290	296	289	314	330	339	328
Net gain/lost income	152	684	1133	678	3548	4547	5369	4488

[a] The cost of collective action includes the annualized costs of joining fee, annual subscription fee and the opportunity cost of delayed payments calculated using the annual interest rate of 4.3% on savings by the commercial banks in Kenya.

[b] The farm size classes represent the lower, medium and upper one-third household groups.

Table 7: Selected indicators of performance of marketing groups.[a]

PMG	Per capita assets built over time (Ksh/member)	Per capita sales volume (kg/member)		Per capita total sales volume (kg/member)	Mean rank for performance indicators	Mean rank for collective action indicators
		2003*	2004	2003-2004		
Kathonzweni	6393	212	30	242	1.3	4.3
Kalamba	3130	46	8	54	3.3	3.0
Makima	301	-	123	123	3.5	3.2
Kilia	177	34	23	57	5.3	6.8
Kamwiyendeyi	333	192	0	192	5.3	6.3
Wango	63	-	8	8	6.5	4.8
Emali	268	92	0	92	6.7	6.0
Thavu	395	3	0	3	6.7	5.2
KYM	335	10	0	10	6.7	6.5
Nthingini	34	-	7	7	7.5	5.7

[a] Missing data indicates that PMGs were established later in 2003 and did not sell during that year.

Table 8: Rankings of PMG collective marketing constraints (1=most important)[b].

Constraint	Mbeere (n=5)	Makueni (n=5)	Total (n=10)
Lack of credit	1.4(1)	1.2(1)	1.3(1)
Price variability	4.6(5)	2.6(2)	3.6(3)
Low volumes	4.8(3)	3.2(3)	4.0(3)
Lack of buyers	5.4(4)	4.0(4)	4.7(4)
Low business skills	4.8(6)	6.0(6)	5.4(6)
Low quality	7.2(7)	6.2(6)	6.7(7)
Storage pests	7.6(8)	7.6(7)	7.6(7.5)
Internal conflicts	8.0(8)	8.2(8)	8.1(8)
Poor leadership	7.8(9)	9.6(10)	8.7(9)
Lack of storage	11.3(12)	8.2(7)	9.4(10)
Theft in storage	10.8(11)	11.2(12)	11.0(11)

[b] Figures in parenthesis are medians.

Table 9: Market preferred traits for selected dryland crops.

Crop	Traits
Pigeonpea	Large-seeded, cream-colored, uniform, clean, good for dhal making
Chickpea	Large size (>8 mm), cream (kabuli), brown (desi), clean and uniform
Groundnut (confectionary)	Red or tan, medium to large size, low oil content, suitable for blanching & roasting, low aflatoxin (0-4 mg/kg)
Groundnut (oil extraction)	Red or tan, small to large size, high oil content, low aflatoxin (<20 mg/kg)
Sesame	White or cream, clean, small to large, high oil content
Cereals for food	Nutritional quality, grain color, taste, processing and storability
Cereals for feed	High energy values, low in tannins, low in mycotoxins and ease of processing
Other industrial uses	Flexible maturity, year-round supply, high fermentable sugar and ethanol yields for biofuel industries

Priorities for Millet Research in East and Central Africa

BN Mitaru[1] and SM Githiri[2]

Abstract

The Eastern and Central Africa (ECA) region covers an estimated area of 8 million km^2.

The millets (pearl and finger) are major crops grown in localized areas of this region where the low rainfall received does not permit reliable production of the preferred cereals such as sorghum and maize. More than 95% of the millet grains are consumed as food in the main production areas and only small quantities are commercially processed or marketed. As the countries become more urbanized and disposable incomes increase, commercial agro-processing is bound to be stimulated. However, for commercialization to occur, increased production and productivity are a pre-requisite.

This paper reports the continuing importance of millets in the semi-arid and drought-prone areas of ECA, trends in millet production and productivity over time and factors contributing to the observed trend. It will also look at identified production and productivity enhancing constraints and strategies that have been put in place to address the same.

Introduction

The Eastern and Central Africa (ECA) region has a population of approximately 250 million people. The region covers an area estimated at 8 million square kilometers. About 80% of the population live in the rural areas and derive their livelihood from agriculture. Forty percent of this population lives in the arid and semi-arid areas where sorghum and millets (finger and pearl) are the major crops cultivated. Sorghum is grown on approximately 10 million ha and millets on about 3 million ha (Table 1), mainly by small-scale farmers. Approximately 60% of sorghum and millets production is consumed at farm level and the remaining 40% is sold, largely in local markets.

[1] Eastern and Central Africa Sorghum and Millet Network (ECARSAM) and

[2] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Table 1. Production area for sorghum and millets.

Crop	World	Africa	ECA*
Sorghum	46	26	10
Millets**	36	21	3

* Account for 56% of area covered by cereals and 41% of total cereals production

** Finger millet and Pearl millet

Sorghum and millet are crucial to the worlds' and Africa's food economy. Specifically in the ECA, these crops are vital because of their dominance in the food economy of the poorest and most food insecure population living in arid and semi-arid areas. More than 70% sorghum and 95% millet are consumed as food in the main producing areas in Africa. A large proportion of farm households aim to produce enough grain to meet household requirements. However, many often fail to meet even this limited goal (FAO, 1996).

It is clear that increased production and productivity is a pre-requisite for commercialization and hence for a sustained contribution to economic growth and improved livelihoods. It is the object of this paper to provide an assessment of millet production and productivity in the ECA region. Although often discussed together, it is the intention of this paper to, as much as possible, separate the millets into finger millet and pearl millet. The paper will look specifically at the continuing importance of the crops in the semi-arid and drought-prone areas of ECA, trends in millet production and productivity over time and factors contributing to the observed trend. It will also look at identified production and productivity enhancing challenges and strategies that have been put in place to address the same and probable impacts.

Importance of millets in the ECA region

The intensity of recurrent droughts in the ECA region has increased the urgency with which national policymakers are considering drought-tolerant crops. Systems for agricultural research in many African countries would have to strengthen their programs to improve the millets to address this challenge. The millets offer viable options in harsh environments where other crops do poorly.

Pearl Millet

Pearl millet is a niche crop in ECA, grown in localized areas where normal rainfall does not permit reliable production of the preferred dry land cereals such as sorghum and maize. The crop is widely grown in a belt covering Sudan and bordering areas of Ethiopia and Eritrea. It is also grown in the low altitude areas of eastern Kenya and the central plateau of Tanzania. Pearl millet yields are usually much lower than those of other cereals (which are grown under more favorable conditions). Furthermore, yields are highly variable from one season to another.

Finger Millet

Finger millet (*Eleusine coracana*) plays a key role in the livelihoods of smallholder farmers and their families and is an important food security crop. As production statistics for the nine cultivated millets are often combined, reliable estimates of the areas sown to individual species are difficult to find. It was recently estimated that finger millet accounts for 10% of 38 million ha sown to millets globally (www.cgiar.org/impact/research/millet.html).

In the ECA region, finger millet is the most important millet, being cultivated in over 50% of the area sown to millets (Obilana, 2002), especially in Uganda, Tanzania and Kenya. Finger millet production in East Africa has risen by 25% over the past 30 years, driven by domestic demand, growing regional trade, and higher market prices than other cereals. The crop has outstanding properties as a subsistence food crop: Its small grains can be stored safely for many years without insect damage; the grains are an excellent dietary source of calcium, iron, manganese, and methionine, an amino acid lacking in the diets of hundreds of millions of the poor who live on starchy foods such as cassava, plantain, polished rice, and maize meal. Finger millet is also productive in a wide range of environments and growing conditions, throughout the middle-elevation areas of ECA.

Trends in millet production in the ECA region

The global area under millets has shown a slight decline from 38.1 million ha in 1981 to 37.6 million ha in the mid 1990s (FAO, 2004). Despite this global decline, Africa's acreage has shown a slight increase and the continent has now become the world's leading producer of millet. Between 1970 and 2000, millet production in Africa increased by 22%, whereas other regions registered substantial declines. Within the ECA region, finger millet is most important in Uganda considering its share in the total cereal production while acreage under pearl millet production is highest in Sudan. Other important millet producing countries include Ethiopia, Eritrea, Tanzania and Kenya.

In the ECA region, millet production was stagnant between 1992 and 2002. In recent years, production has expanded mainly through an increase in crop area. However, productivity has failed to increase, or has even declined. This is because production is being pushed into more marginal areas and poorer soils, even in those areas that are already drought-prone. Seasonal variation in agro-climatic factors, particularly rainfall, has resulted in big seasonal disparities in production leading to price fluctuations and hence, unwillingness of producers to invest in commercial production. These agro-climatic factors have also constrained adoption of improved technologies. Moreover, discriminative agricultural policies against millets relative to those for other cereals and poor marketing infrastructure have exacerbated the slow productivity growth and low producer prices resulting in low competitiveness of these crops (FAO/WFP 2000).

It is positive to note that a growing proportion of farmers are beginning to adopt new varieties. This is because only a small investment is required to acquire improved seed. However, they are less willing to allocate more resources to purchase chemical fertilizers. Allocation of capital and family labor required to improve water and nutrient availability to the crop are also limited because of the perception of higher returns from competing alternative farm and non farm enterprises. Rising labor costs have also affected most farm operations in millets. Furthermore, changing food habits in favor of other cereals, presence of bird pests, diseases and insect pests, among others, are also threatening millet production.

Research efforts made in the past have generated significant results to reduce these negative impacts. However, the rate of adoption of improved technologies is not encouraging owing to poor linkages between producers, consumers, processors, researchers and development workers. Moreover, the resource poor condition of majority of farmers in the semi-arid growing environments has aggravated the problems of millet production as an enterprise.

Potentials and opportunities for millets in the ECA region

Despite the relative importance of millets in the food systems of many countries, only small quantities of this crop are commercially processed or marketed. As the countries become more urbanized and disposable incomes increase, commercial agro-processing is bound to be stimulated. The actual level of utilization of any grain will depend on its relative competitiveness as food, feed and as an industrial input.

Industrial methods of processing millets are not as well developed as those for maize, wheat and rice. Finger millet is readily milled into acceptable flour (Obilana 2002). A growing number of small, medium and large commercial grain millers and processors in East Africa each mill 10–800 tons of finger millet per month, producing both pure finger millet flour or composite flour and porridge mixtures, mainly for the domestic market.

Nutritionally, finger millet is equal to or superior to other staple cereals, especially in minerals (Table 2). Its exceptionally high calcium content makes it an important food for pregnant women, nursing mothers and children (Obilana, 2002). In addition, it is being increasingly recognized as a quality food for people with HIV/AIDS and diabetes. In East Africa, particularly Kenya and Tanzania, finger millet is primarily consumed as a thick porridge known as *ugali*, and as a thin porridge known as *uji*. It also has excellent malting properties and is used to make local beers. Therefore, there is great potential for further product diversification.

Constraints in millet production and utilization in the ECA region

Constraints to millet production and utilization in the region were derived from stakeholders responses to the country millets status questionnaire, review of national, regional and international reports and personal communication with scientists, partners and collaborators. The results indicated that average productivity estimates for sorghum and millets in Africa are very low (about 800 kg/ha) compared to those found in other parts of the world (1200 kg/ha in Asia, 4000 kg/ha in America and 5000 kg/ha in Europe). Seven major constraints were identified in the production to consumption chain of millets in ECA as:

- Low productivity
- High post-harvest handling losses
- Limited processing and utilization
- Limited marketing
- Unfavorable policies
- Limited capacity building and institutional development
- Limited knowledge and information exchange

Most of the identified constraints are common to all countries in the ECA region and can be solved by generating and using demand-driven technologies/innovations and policies. However, national agricultural research systems (NARS) in the region have limited resources and capacity to tackle these problems on their own and hence the need to pool resources.

Networking on sorghum and millet research in the ECA region

The Eastern and Central Africa Regional Sorghum and Millet Network (ECARSAM) was initiated in 2003, building on the achievements of the former network, the Eastern Africa Regional Sorghum and Millet network (EARSAM), which ran from 1982 to 1993. ECARSAM covers eight of the 10 Association for Strengthening Agricultural Research in the Eastern and Central Africa (ASARECA) member countries, namely, Burundi, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda.

The principal goal of the network is to increase economic growth and improved livelihoods in the ECA while enhancing the quality of the environment. Its purpose is to enhance sustainable productivity, value added and competitiveness of the regional sorghum and millet system. The network strives to eliminate some of the bottlenecks to increased production of sorghum and millets and their utilization in value addition processing at farm and village levels. It encourages the adoption of available sorghum and millet production technologies (improved cultivars, fertilizer use, crop protection) through on-farm trials and other extension interventions to enhance productivity and overall production. The network aims at stimulating the use of sorghum and millets for small-scale processing and utilization at farm and village level, and large-scale industrial processing through demonstration of appropriate value addition and labor-reduction technologies.

ECARSAM's Strategic Objectives

The critical strategic issues facing the sorghum and millet sub-sectors in the ECA region have been rationalized into the following four strategic objectives to achieve ECARSAM's purpose:

i. Demand driven sorghum and millet technologies/innovations generated and promoted;
ii. Enabling regional and national policy options for transformation of sorghum and millet systems facilitated;

iii. Regional and national capacity for integrated agricultural research for development in sorghum and millet systems strengthened; and,
iv. Availability of information on sorghum and millet research and development enhanced.

In order to achieve its objectives, ECARSAM links and collaborates closely with appropriate stakeholders – those that generate technologies, including universities; advanced research institutes, such as the International Sorghum and Millet Collaborative Research Support Program (INTSORMIL); the International Centre of Insect Physiology and Ecology (ICIPE); and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Network Programmes and Projects (NPPs) of ASARECA and similar networks in other regions of Africa. The network also collaborates with stakeholders to disseminate technology. These stakeholders include extension departments of ministries of agriculture and NGOs; service providers, such as seed producers, agro-chemical distributors, transport sector and credit facilities; and agro-processors including breweries and feed and food processors.

Priority setting process for millet research and development in th ECA region

ECARSAM was formed to efficiently use limited financial and scientific skills by sharing research responsibilities and technologies in the region. Considering that resources are limited, it is difficult to address the many constraints affecting millet production-consumption continuum chain. Priority setting, therefore, is important in determining rankings of research for development agenda to allocate resources judiciously. The research themes and sub-themes are ranked so as to identify projects that will have the highest impact in bettering the sorghum and millet sub-sectors, and in essence give an indication on the sequence by which they are to be implemented. This was done by the stakeholders' priority setting workshop (ECARSAM, 2005).

To set priorities, the network followed a seven-step process in the ASARECA Guidelines for priority setting. A priority setting committee (PSC) was established (Step 1) to review the research domain (Step 2), evaluate existing research results (Step 3), and develop/identify the list of individual constraints supplied by national programmes (Step 4) into a set of research alternatives consolidated into research for development (R4D) themes and sub-themes for intervention (Step 5). This was then followed by a priority setting workshop (Step 6) involving stakeholders representing participating

NARIs, private sector, other ASARECA networks (NPPs) and collaborators, and preparation of a final report of recommendations (Step 7).

The stakeholders evaluated and ranked themes and sub-themes by using assigned sub-criteria weights and other relevant documents. The criteria were set to reflect the following potential impacts:

(i) economic growth

(ii) social welfare

(iii) environmental quality

(iv) capacity building

(v) regionality

After calculating and weighting individual scores, the diverse mix of major stakeholders in the millets sub-sector in ECA assigned priority to seven themes namely: (i) production, (ii) policy, (iii) processing, (iv) post-harvest, (v) marketing, (vi) capacity, and (vii) information and knowledge in a descending order. The seven themes were further sub-divided into 14 sub-themes and also ranked and prioritized. It is apparent that projects addressing production constraints dominate the other themes in the ranking process. However, during this period, ECARSAM recognizes that the implementation of the prioritized projects should be such that the whole production-consumption chain is given attention. For example, dwelling on production issues alone may lead to increase in output for which there may be no market. It was thus thought prudent that selected projects under each theme be implemented simultaneously so as to foster sustainable development of the sorghum and millet sub-sectors. This will enable wholesome addressing of constraints facing the production-consumption continuum and hence effectively achieve the network objectives. A mix of projects from each theme was thus prepared and categorized as having high, medium, and low implementation priority, based on weights that were assigned by stakeholders (Table 2). The high priority projects were recommended for immediate implementation depending on funding, while the medium and low priority ones will follow later.

Table 2: Level of priority for implementation of millet projects in the ECA region.

Theme	Project title	Implementation Priority
Production	Development, dissemination and promotion of integrated water management practices for increased productivity and livelihoods in drought stressed areas	High
	Participatory development, dissemination and promotion of high yielding millet varieties for specific end-use for different agro-ecologies	
	Participatory development, dissemination and promotion of integrated *Striga* management option	
Processing	Product diversification and promotion to enhance commercialization of sorghum and millets	
Post-harvest	Development, dissemination and promotion of integrated post harvest technologies for increased incomes and food security	
Policy	Explore innovative approaches to strengthen and sustain institutional capacity	
Market	Enterprise development to establish and strengthen supply chain linkages for sorghums and millets	
Production	Development, dissemination and promotion of integrated nutrient management practices in sorghum and millets for increased productivity and income	Medium
	Participatory development, dissemination and promotion of integrated disease management options for millets	
Processing	Develop, adopt and disseminate processing and utilization technologies related to total quality assurance	
Capacity	Explore innovative approaches to strengthen and sustain institutional capacity	
Information and knowledge base	Assess and establish regional sorghum and millets information database to support development and dissemination of demand driven technologies for food security and commercialization	
Marketing	Conduct market research to identify and characterize existing and potential markets for a diverse range of sorghum and millets products	
Production	Develop farmer responsive seed production and supply systems to promote adoption of sorghum and millets technologies for specified end-uses	

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Group and Plenary Discussions and Recommendations

Challenges in the Finger Millet sector

The neglect of finger millet by mainstream research organizations and donors has contributed to a lack of realization of the potential productivity of this crop. Increased production, utilization and trade of finger millet in East Africa is currently limited by a number of constraints that reduce yields to levels of 0.5-0.75 t ha^{-1} from a realistic on-farm potential of 1.5-2.0 t ha^{-1}. The constraints are in the whole food supply chain from production to utilization.

At the productivity level, although a number of varieties are grown by farmers, no significant research has been done to characterise the varieties in terms of their adaptability to the various agro ecologies and recommendation domains and also in terms of their end use quality characteristics as required by consumers and the industry. The most serious constraints are those related to productivity enhancement, especially varieties that are resistant to blast disease caused by the fungus *Magnaporthe grisea*, more commonly known as a rice disease. Blast affects finger millet at all growth stages. It is especially serious in the Busia, Teso and Kisii districts of Kenya and in the main finger millet areas in north and east Uganda. Many widely-grown landraces and genotypes are susceptible with losses of 10-50% being common. Other constraints include the high labor demand for weeding, under-developed seed systems, poor post-harvest handling which reduces grain quality, product development and an inefficient production–supply chain.

Stakeholder Perspectives on Finger Millet development

A series of presentations covered various topics – findings of earlier and ongoing DFID-funded projects; research progress and future R&D needs in Kenya, Uganda and Tanzania; management of blast disease; genetic resources; processing and marketing; weed and crop management; new niches for finger millet; and the role of regional networks in promoting the crop.

The second day was devoted to working group discussions. Most workshops have one set of break-away sessions. This one had two. First, participants broke up by area of specialization or interest – farmers/extension/community, research, and industry (trade, processing). This allowed participants to discuss issues in depth, and identify specific problem areas. With this background, participants regrouped into another set of brainstorming sessions on a random basis to identify problems and solutions. Each group discussed constraints and opportunities to/for finger millet development from their particular perspectives. These findings were later presented and discussed in plenary. This process allowed the meeting to consider a wide variety of views in detail, and provided a strong base for discussions on a regional action plan.

Researchers Group

Constraints

1. Genetic resources

- Germplasm (assembly, resources and enhancement, breeding): There are important gaps in the region's germplasm collections, in cultivated varieties as well as wild species. The available germplasm also needs to be more fully characterised and utilized in breeding programs.
- Improved varieties (availability, promotion and dissemination): We must continue to develop new, improved varieties adapted to specific production zones.
- Seed production and distribution: Lack of seed of adapted varieties is a major constraint to adoption.

2. Production and productivity

- Weeds – *Striga* and others, especially wild *Eleusine*
- Pests (shootfly and stem borer) and diseases, eg, blast
- Birds
- Drought
- Poor soil fertility: fertilizer and other amendments rarely applied on finger millet
- High labor demand for land preparation, planting and weeding
- Post-harvest quality and management

These constraints lead to reduced productivity; as a result, farmers are not interested in expanding or commercializing finger millet cultivation, preferring to grow the crop on small plots for household consumption.

3. Policy

- Inadequate awareness on the importance of the crop among policy makers
- Lack of enabling policy environment
- Low funding for R&D
- Price fluctuation linked to production variability
- Competition from other crops

4. Other issues

Limited product range: few finger millet based foods are available in urban markets, reducing sales and promotional prospects.

Key constraints: lack of new varieties: improved varieties need to be developed and promoted, associated with adequate seed supply

Opportunities

1. Genetic resources

- Varieties with high yield, local adaptation and blast resistance are available – already identified and tested, or in the final stages of testing
- Seeds systems models are available, and have been successfully used for seed production and distribution in other small-grained cereal crops
- A regional program for testing and promotion of new varieties can be established, using networks and linkages already in place for sorghum and pearl millet
- Germplasm assembly, evaluation, utilization can be enhanced through partnerships between countries, facilitated by ICRISAT and regional bodies

2. Production

- Integrated pest and disease management in finger millet has been well studied. Crop management 'packages' are available for diseases (including blast), weeds (eg, row planting, and control using animal draft power), and water and soil fertility management
- Tools and methodologies are available for pathogen studies and resistance screening

- Synergies can be exploited for further progress – with other crops, and among various research institutions in the region

3. Post-harvest grain quality
- Information is available on post-harvest grain quality management. Potential low-cost technologies and interventions have been identified.
- Strong links already established between farmers and processors in some areas and for some crops. These can be extended to finger millet.

4. Policy environment
- NARO - Uganda's approach to finger millet involves close interaction between R&D agencies and policy makers. This could serve as a model for other countries.
- Donor interest in finger millet is increasing (because of its nutritive value); opportunities for increased R&D funding.
- Links between research, NGOs and extension already exist, but can be strengthened to promote finger millet.
- ECARSAM, as an established regional network, can lead or facilitate policy advocacy.

Industry Group

Constraints

1. Poor grain quality
- Grain delivered to processors is usually of poor quality
- Grain is contaminated by foreign matter (stones, dust, sand, husk)
- High moisture content caused by poor drying and or poor storage
- Immature grain because the crop is harvested too early
- Mixed with other grain (eg, sorghum) either accidentally or deliberately

2. Low, irregular supply
- Grain supplies are low and irregular because of low and variable production and lack of an efficient marketing chain. This increases processors' cost of production, thus reducing profits.
- Processors are unable to maintain regular supplies to urban markets, and lose customers

3. Packaging

- Packaging of processed foods (flour, meal) is expensive; lower-cost packaging does not give adequate shelf life
- Packaging is not targeted/segmented at consumers

4. Limited product diversification

- No research on processing and development of new food products
- Poor linkages between research-processor-consumer, hence lack of feedback on consumer demands and market opportunities

5. Weak processor associations

- Finger millet processors are not well organized (unlike other crops); hence limited capacity for policy advocacy or for strengthening markets, supply chain, etc

6. Policy issues

- Lack of official product standards or quality grades; reduces incentive to improve quality
- No enabling policy, finger millet remains low priority for policy makers

Key constraint: Poor grain quality associated with a weak marketing chain

Opportunities

1. Grain quality can be improved by

- Increasing awareness of the quality concerns by farmers and traders
- Aggressive promotion of production practices, eg, improved threshing methods
- Establishing price incentives based on quality

2. Regularity of Grain supplies can be improved through

- Better market information systems for grain buyers and sellers
- Better grain collection systems, eg, bulking at collection centers
- Improved processor-farmer chain

3. Product diversification

Availability of a wider range of products will increase utilization. Accordingly, we need to:

- Stimulate research interest in development of new products
- Improve processor-consumer linkages to better identify and service consumer needs
- Improve access to information: new products/technologies for processors, product availability, price, advantages, etc, for consumers

Farmers' Group

Constraints

Finger millet is grown primarily on a small scale, for household consumption. Production suffers from various constraints:

- Low prices
- Low yields due to various factors – soil fertility, lack of improved varieties, pests, weeds, diseases, labor shortages, poor technology adoption, lack of timeliness in farm operations
- Unavailability of seed of improved varieties
- Lack of information on household utilization, crop husbandry, post-harvest technology, markets
- Lack of credit facilities

In particular, research/development interventions are needed to improve soil fertility and seed availability.

Other major constraints

- Farmers are not involved in decision making – traders, processors and policy makers make all decisions
- Negative community attitude – finger millet is considered an inferior food
- Unofficial cross-border trade creates opportunities for Ugandan producers, but Kenyan farmers are out-competed by imports

Key constraints: Farmers are not involved in decision making; low yields; negative community attitude towards finger millet

Opportunities

1. Labor saving operations, for example, row planting and use of draft power can reduce production costs and also improve yields by improving timeliness of operations

Seed availability can be improved in various ways:

- Establish farm demonstrations, and distribute a portion of the harvested grain/seed to other farmers
- Promote pre-released varieties, where seed production for local sale/exchange is permitted by law
- Establish community seed banks
- The community must appreciate and enforce collective ownership of initial seed, ie, recipients of seed from NGOs or extension programs must share with other farmers

2. Soil fertility improvement:

- Education, training on use of manure and inorganic fertilizer
- Planting agro-forestry trees; training and seedlings may be needed
- Use of legume crops in rotation and or other associations
- Interventions to improve availability and reduce cost of fertilizer

3. Other opportunities for promoting the crop:

- Inclusion of finger millet in food relief programs will create market opportunities for local producers
- Publicity and awareness campaigns will help remove the common perception that finger millet is inferior to wheat or maize
- Networking and formation of farmer groups will help improve production, and access to inputs and markets

Promotion of Finger Millet: Constraints and Opportunities

Groups were given another opportunity to discuss constraints and opportunities related to the promotion of finger millet. Participants formed three groups each of which considered four questions:

- What are the major constraints to the promotion of finger millet in East Africa?

- What are the opportunities to resolve these constraints?
- Which stakeholders should be involved?
- Who should pay?

The three groups independently reached broadly similar conclusions, which are summarized below.

Constraints

Policy

- Low government priority for finger millet (except in Uganda), extremely low funding for research and extension, hence poor technology development and dissemination.
- Different countries have different tax regimes, import/export procedures, certification and phytosanitary standards, etc. This reduces trade opportunities and hinders the creation of a single regional market large enough to attract private investment.
- No policy framework to encourage utilization in specific areas where potential exists, eg, baking, brewing

Awareness

- Lack of awareness among all stakeholders, including policy makers
- Most rural communities are unaware of its nutritive value, and consider it inferior to maize, rice or wheat

Production

- Producers are scattered across outlying areas; not organized into larger, more effective groups. Hence highly variable production, fluctuations in grain supplies, quality and price
- Poor linkages between farmers and processors
- Lack of quality control systems, or standards/prices based on crop quality
- Lack of credit facilities to enable farmers to expand production
- Lack of seed of improved varieties

Marketing

- Long and inefficient marketing chain with numerous middlemen; no formal, organized marketing structures
- Poor infrastructure (roads, communications)
- Producers lack market information, market access - simultaneously, buyers lack information on crop availability, quality and price
- Limited product range, especially convenience foods, hence poor sales in urban areas despite potential demand

Opportunities

Policy

- Detailed analyzes have been or can be conducted on policy issues; opportunity for regional bodies like ECARSAM, ECAPAPA to lobby for favorable legislation
- Influence policy makers to harmonize tax regimes at local and regional levels
- Include finger millet in strategic grain reserves, also in school feeding programs, food relief
- Review policy on specific products, eg, use of finger millet in bread, opaque beer
- Establish finger millet committee within ECARSAM, to coordinate and lead promotional and lobbying efforts

Awareness

- Technical information is available on many aspects, including utilization, nutrition, value-added products. Package and disseminate this information to different stakeholder groups: policy makers, consumers and other potential users, eg, schools, prisons
- Raise profile of the crop through local media: radio, TV, press. This will improve public awareness of the importance of the crop, and eventually result in more funding for R&D.
- Spread nutrition awareness by working with Ministries of Health, Education

- Build on and exploit linkages already established, to eventually develop a coalition/platform to promote finger millet. ECARSAM could help increase the profile of the crop, and establish a separate identity, not clubbed together with pearl millet

Production

- Appropriate, low-cost technologies are available in Asia and elsewhere, to improve production and processing. ICRISAT could act as a channel to bring in these technologies
- Examine successful models used for other crops in the region, for (i) quality control system, price/grading standards, (ii) mechanisms to intensify production, eg, contract farming
- NGOs, community-based and church organizations could provide resources (including staff and local experience) to supplement government extension services
- Facilitate formation of Producer Marketing Groups (PMGs), strengthen existing groups, to increase production and marketing
- Establish collection centers, encourage farmer groups to bulk up produce
- Provide credit through micro-finance institutions, which are available in many areas
- Promote finger millet in non-traditional areas, ie, outside high-rainfall or cooler sones

Marketing

- Use PMGs as the focus of intensified marketing efforts; PMGs can also manage collection centers and disseminate market information to group members
- Disseminate market information (price, location) through farming radio programs and government extension channels
- Include finger millet in existing market information channels, eg, KACE in Kenya, Foodnet in Uganda
- Good business opportunities for the private sector, eg, demand for value-added (eg, fortified) finger millet products; high-value niche market for finger millet as an organic product exported to Europe

Price fluctuations

Price fluctuations harm both producers and buyers (processors). Fluctuations can be reduced by schemes that will enable farmers to wait until prices rise, not sell immediately at harvest. They can be implemented at PMG level. Options include:

- Micro-finance credit, ie, loan from a financial institution against stocks
- Inventory credit, where farmers place crop in joint storage and receive credit from an NGO

Seed availability

Appropriate high-yielding, disease-resistant varieties are available for multiplication. Seed shortages can be resolved by:

- Promoting alternative models for seed production and delivery, eg, community based production
- Linking seed producers to private sector, eg, seed company contracts small-scale farmers to produce ‘certified’ seed
- Farmer training on seed production techniques and seed quality control
- Liberalizing the seed sector, particularly for subsistence food crops such as finger millet; harmonizing seed policies across region, eg, phytosanitary, registration, certification

Which stakeholders should be involved?

To promote finger millet effectively, the full range of stakeholders must be involved:

- Farmers
- Researchers
- Extension
- NGOs, community-based organizations, churches
- National governments
- Government ministries: Policy makers, planning, education, food, health, industry
- Private sector – small traders to large processing or trading firms
- Market information agencies such as KACE, Foodnet

- Financial institutions, eg, micro-credit and banks
- National Bureau of Standards in each country
- Seed companies
- Seed regulatory bodies
- Media
- Consumer bodies

Who should pay?

All stakeholders must be willing to contribute resources, in cash or kind. For example, national extension staff provide time, vehicles. Farmers provide land and labor. Industry provides facilities, use of equipment.

- Regional bodies (ECAPAPA, ECARSAM, ASARECA), especially for harmonization efforts
- DFID, FAO, UN agencies
- Other donors: Gates Foundation (nutrition, AIDS aspects), McKnight foundation (plant breeding, crop management), Rockefeller Foundation, DANIDA, Sasakawa Global 2000
- Industry
- Farmers
- Artisans (*jua kali*) for fabricating household or village-level processing equipment

Finger Millet Workshop Recommendations

Genetic resources: Tanzania is poorly represented in the global germplasm collections. Additional collection missions need to be organized, especially since East Africa is the center of origin. There is considerable potential for identifying sources of blast resistance; and also for enlarging collections of the races *Africana* and *Spontanea* (wild relatives), which are severely under-represented in all collections and are being genetically eroded. Both NARS and IARCs must increase their investments in germplasm collection and maintenance in Tanzania.

Status of variety development: Most of the 'improved' varieties in Uganda are only selections made from local germplasm collections. In Tanzania, germplasm and improved material developed by ICRISAT, was supplied to the national program through EARSAM. However, this material was not screened because of lack of funds; and the finger millet research program has essentially been closed since 1994. Similarly in ICRISAT, the breeding program ended in the early 1990s, although ICRISAT continued to maintain the germplasm collection. In this situation, a first priority should be to transfer blast resistance into popularly grown varieties (whether landraces or improved).

Variety release procedures and dissemination of new varieties: In Kenya, the national variety release system has not functioned effectively for nearly 15 years; releases were not always based on data, and were mostly restricted to maize and wheat. However, the committee has now been resuscitated, and the following procedure established:

- A prospective new variety has been tested for two years in KARI trials. If performance is good, it can be advanced to national trials conducted by the Kenya Plant Health Inspectorate (KEPHIS). The breeder/institution is required to pay a fee of Ksh 40,000 per variety for these trials
- KEPHIS trials last for four seasons: 2 long rains and 2 short rains
- Subject to good performance, the variety is then considered for release by the national variety release committee
- These procedures are for Scheduled Crops only, and do not cover finger millet

Throughout the region, official release procedures are too slow, especially for minor crops such as finger millet, where the returns may not justify the expense and effort needed to fast-track release of a new variety. However, on-farm trials offer the opportunity for rapid dissemination. Varieties at this stage are considered 'pre-release' and informal exchange or sale at community level is permitted (although commercial sale of branded or labeled seed is illegal). Seed harvested from on-farm trials can be distributed to other farmers in the community. Within three seasons after the first trials, sufficient seed of cereals can be multiplied and exchanged to meet local requirements, and even produce a surplus for sale to neighboring communities.

For this to happen, farmers must cooperate with each other, freely sharing seed and agronomic knowledge about the new varieties. Unfortunately, farmers who host trials are often reluctant. Researchers must make it clear to trial participants that seed must be shared; and the community must help enforce this.

Other semi-formal channels are also available. Under a DFID-funded project in Kenya, kale seed is produced at community level, inspected by KEPHIS (through special arrangement), and successfully sold to neighboring communities. In Tanzania, the government allows "Quality Declared seed", ie, seed produced by farmers for sale to the community, and labeled as such. This does not require formal inspection or certification.

The participants noted that in many cases the key issue is not slow variety release procedures but unavailability of seed – even of varieties released several years previously. This is a major reason for poor adoption of improved varieties.

Adaptation: Finger millet area in the major production zones is declining or stagnating. However, if widely adapted varieties can be developed, there is a huge potential for a huge increase in area. For example, the crop is now restricted to high-rainfall areas. Availability of drought-tolerant varieties would lead to significant expansion. Likewise, frost tolerance would enable expansion into highland areas, and even into Europe (as a forage crop).

ICRISAT intends to map zones of adaptation of specific finger millet varieties using GIS tools (as it has done for sorghum and pearl millet). Mapping – mainly on the basis of rainfall, min/max temperatures and length of growing season – will help target new varieties to areas where they are best adapted, and identify non-traditional areas with suitable environments, where finger millet can be introduced.

Traits for end use: Finger millet is not suitable for confectionery (baked) products because of its low gluten content. However, the national programs will not be able to screen accessions for high gluten, in view of the large number of accessions and the limited resources available. In addition, low gluten is an advantage in some ways, for example, for those who have problems with food products that contain gluten. It is important to identify a few priority traits where screening and breeding efforts can be concentrated.

Fodder and stove: Finger millet is rarely used for stover or silage in East Africa. The reason: in smallholder systems, harvested fields are traditionally considered a common resource, and animals are allowed to graze freely on residues. However, good genetic material is available, identified or developed at ICRISAT-Zimbabwe in the 1990s. Two finger millet lines have been released for forage use in Zimbabwe, and are being successfully promoted as a source of dry-season fodder.

Post-harvest operations: The milling industry is concerned about grain cleanliness. This may be caused by adulteration and/or poor post-harvest handling. Several participants felt that grain from the farm was fairly clean. However, stones, sand and small quantities of cheaper sorghum grain – were largely introduced by middlemen and traders, to increase weight of the product when delivered to millers. However, farm-level handling methods also need to be improved. Finger millet is threshed, and later sun-dried, on the ground. Use of cemented threshing and drying floors would greatly reduce contamination. So would mechanized threshing: inexpensive machines are available, suitable for community use.

Processing: Processors are the key to expanding cultivation, and must be involved more closely in R&D. National and international research institutes must give processors samples of all new varieties, for testing grain quality, traits, and suitability for industrial use.

Grades and standards: Contamination can be reduced by a grading system with differential prices. This is being done to a limited extent by millers in Kenya and Uganda. For some traits (eg, presence of foreign matter), the miller may stipulate a progressive reduction in price. For other traits (eg, moisture) there may be no price differential, but the consignment is completely rejected if found beyond acceptable limits.

One difficulty is poor communication. Grades, standards and prices can be clearly established between millers and their suppliers, but this information is not being passed on to farmers, or to all traders in the bulking-up chain.

Producer marketing groups (PMGs): Farmers organized in groups have numerous advantages over individuals. They can negotiate better prices for both inputs and outputs; and enforce quality and grading standards (eg, contamination) among their members, and thus obtain higher farmgate prices. The PMGs are also a good entry point for development interventions, for example, new varieties or mechanized threshing. Pay-offs from innovations will be higher with a PMG, compared to individual farmers. Market linkages are also easier to develop. For example, successful technology adoption by a PMG will attract interest from – and subsequently investment by – a private firm, especially when a third party such as an NGO, facilitates the process. PMGs also improve financial viability. For example, a group – but not an individual – could afford to pay for transport (direct to miller, higher prices); if NGO support is still required, it is easier to administer and recover loans through the group.

Middlemen and traders: Traders are often accused of exploiting small-scale farmers. However, in most outlying communities, and for many crops, the trader is the only link to the market. He buys small quantities from many scattered producers, incurring the risk and cost involved in bulking up quantities to sell to larger traders. At least in the middle term, smallholder farmers in Africa cannot survive without traders and middlemen. It would be useful to bring them into the development partnership through training, awareness, and technical and/or financial support. This process, if well managed, will lead to a win-win situation. Traders can maintain their profits while system efficiency, quality, and farmgate prices can all improve.

Policy environment: The key issue is low government priority for the crop in Kenya and Tanzania, although finger millet has a higher priority in Uganda. This affects production and marketing. Some legislation that apparently 'discriminates' against finger millet also needs to be changed. For example, the national Bureau of Standards specifies that bread can only be made from wheat. Another important policy change would be to legalize opaque beer – this would unlock a large market for finger millet. Interestingly, in Kenya, opaque beer powder is legal, and at least one brand has been certified by the Bureau of Standards – but beer made from the powder is liable to be confiscated by the police.

Information and lobbying: Policymakers should be lobbied to enact more supportive policies; but lobbyists will require hard information to strengthen their case. Stakeholders must aim to collect and provide such information. This will include:

- Use of finger millet in composite flours; demonstrate technical and financial viability
- Costs and benefits of regional (as opposed to national) registration/release of new finger millet varieties
- Adoption data; consumption levels, especially among the rural poor

Distinct identity for finger millet: It is important to establish a distinct identity for finger millet – and information on crop production, utilization and market trends, etc, is an important prerequisite. But such information is scarce. In published statistical data, millets are usually presented as one commodity; in some cases, all small-grained cereals – ie, sorghum and millets- are published as a 'single' commodity. Stakeholders must work together to ensure that crop-specific information is collected in the future.

However, it is already possible to obtain some crop-specific data. Most millet data from Uganda refer to finger millet; almost all data from Tanzania and Sudan refer to pearl millet. In Kenya, differentiation is possible, from 1995 onwards. Millet data from Western Province is entirely finger millet; data from other provinces is mainly pearl millet.

Funding for R&D: In the future, an increasing proportion of donor funds will be channeled through governments; direct funding to NGOs and district or community-level projects will fall. This is likely to reduce funding for finger millet, since donor funds will be spent on areas or crops that enjoy government priority. It is therefore important to disseminate information and sensitize policy makers quickly, in order to increase funding support for finger millet.

Role of ECARSAM: The East and Central Africa Research Network for Sorghum and Millet (ECARSAM) can play a key role in promoting finger millet. Various possibilities were suggested:

- ECARSAM has committees for specific crops. A new committee should be established for finger millet, to facilitate research and promotion. Based on the research priorities identified at this meeting, the committee could develop a proposal seeking donor funding specifically for the crop, for example, establishing competitive research grants system for finger millet in the region. This was agreed in principle, but the modalities need to be worked out
- ECARSAM has a system of competitive grants for various crops; adding finger millet to this list would allow funding for small research projects

Closing Session

The closing remarks were made by representatives from the different stakeholder groups and institutions. The remarks mainly reflected how the workshop was organized, the timing, the issues covered and also how it successfully achieved its objectives. The remarks also covered how the team will forge ahead in terms of developing a road map for a more rigorous finger millet research for development initiative. In support of the R for D initiative, remarks were given on how to explore additional and new funding sources for continued work. Key to achieving the overall goal is the art of forging a strategic partnership that will result in transforming the finger millet sector into a dependable, economically-viable and sustainable sector to improve farmers' health, nutrition and livelihood.

The workshop outputs exceeded expectations and included:

- commitment from all three participating NARS to strengthen finger millet research and extension, and improve consumer awareness of its unique nutritional value;
- key constraints to expanded production, processing and trade identified and research opportunities identified and prioritized; and
- clearly defined elements of a future R&D agenda, jointly by all stakeholders – NARS, farmers, extension, the private sector, development investors, and others.

Closing remarks

S Sreenivasaprasad:

Research Group Leader, University of Warwick, UK

The workshop has successfully met its three main objectives. The first was to increase 'connectivity' and establish partnerships among finger millet stakeholders across the region. The base has been laid, and we now need to continue these interactions. The second objective was to identify and prioritize the challenges and opportunities before us, and thus plan the way forward. This too has been done. Thanks to valuable inputs from each stakeholder group, we have consensus on what targets we should set for ourselves. A third objective was documentation: publication of the workshop proceedings, and preparation of a policy paper to be shared with stakeholders and donors. The policy paper is being circulated as a separate document.

The next step is to consult DFID and other agencies, to seek funding for future activities; and to work with the ministries of agriculture, health and education in Kenya, Tanzania and Uganda, to promote utilization of finger millet.

On behalf of all stakeholders I would like to thank the DFID Crop Protection Programme (represented here by Andrew Ward) for their strong support through the years; S Mary Mgonja and her team for organizing the workshop; and Said Silim, ICRISAT Regional Director, for his support to this initiative.

Jillian Lenné

DFID Crop Protection Programme consultant and project facilitator, UK

The workshop has exceeded expectations. It has been participatory, inclusive, productive – and good fun. Over the past two days we have built and widened partnerships, and laid the foundation for continued work to promote finger millet in East Africa.

The timing of the workshop was ideal. The DFID project has three months to run; this gives time to plan and begin work on some areas highlighted by this meeting; and to look for new projects with DFID and others. We must continually explore new research opportunities and look for investment partners, in order to generate the level of support that will be needed.

Mary Mgonja

Principal Scientist (Breeding), ICRISAT, Kenya

I must first thank the participants for their support. We have had participation from the three East African countries, and from India and the UK. Without exception, every invitee was present – which is highly unusual for a workshop of this size. It shows the importance of finger millet in the region, and the depth of commitment from so many individuals and institutions, to promoting the crop.

I would also like to thank the support team – Eric Manyasa, Joseph Kibuka, Peter Kaloki, Philip Ndungu, Lynette Bwire and others – who stayed in the background but ensured that everything went smoothly.

Mary Tamale

Managing Director, Maganjo Grain Millers Ltd, Uganda

My thanks to everyone: the workshop organizers, participants, and the sponsors, ie, DFID. I am sure we are all encouraged by KARI's strong support for finger millet, as shown by the opening address by their Deputy Director (Research). With this kind of commitment from the national research program, we will be able to move forward quickly.

I am glad that three large processing firms are represented here. The industry now knows about the DFID project, and the research findings. This meeting has given us other valuable information that we did not have – the background and priorities of various stakeholders (research, extension, NGOs, donors), major areas of concern, and future plans. As industry representatives, we will now sensitize other processors, and work with farmers to promote both cultivation and utilization of finger millet.

Our common goal is to promote finger millet across the region. To achieve this, we must work together. For example, the industry could organize a workshop highlighting its nutritional qualities; researchers must participate and provide support. Researchers might work on developing new products – for which the industry can provide equipment, facilities and skills.

The workshop lasted only two days, but we were able to successfully complete the agenda without skimping on the quality of debate – the discussions were exhaustive, comprehensive, and led to clear conclusions and recommendations.

Ambrose Agona

Head, National Post-harvest Research Program, Uganda

The workshop title was 'Blast disease of finger millet', followed by a scientific name… I was somewhat intimidated. But the discussions have been more wide-ranging, and more relevant to many of us, than a purely technical discussion on plant pathology. We have shared experiences about profitability and income of finger millet cultivation, about socio-economic aspects, post-harvest issues, marketing, etc.

The discussions led to clear priorities and recommendations. The next step is to translate these to concrete action. How best do we operationalize the promotion of finger millet? What time frame do we give ourselves? We must work fast enough to gain the confidence of all stakeholders; farmers, extension, processors, donors. Business as usual will not do.

This is the first workshop of its kind in East Africa, focusing exclusively on finger millet. We are starting out to build on a new regional initiative, sharing knowledge, experience and resources. We have all been involved in this initiative together, from Day One. Our success will be ours, our failures will be ours – we will have no excuses.

Let us give finger millet a chance. We need to show devotion and commitment to what has been agreed at this meeting. We need to work together; if you have a problem, talk to another stakeholder, and solve it together.

I was weaned on *wimbi* porridge. If you want to look like me, eat finger millet[1].

Ben Kanyenji

Coordinator, National Sorghum and Pearl Millet Program, Kenya

This is the First Regional Finger Millet Workshop for the Eastern Africa region. When was the First Regional Maize Workshop held? In other words, a great deal of work on cereals has been done, and substantial investments made in research, training, and field and laboratory facilities. Many of the resulting advances can be directly or indirectly applied to finger millet.

Consider the finger millet farmer who is unable to make enough profits to pay his children's school fees... or the processor who has to close his plant because he cannot compete with maize millers… their future depends on how well we work, and how seriously we take the commitments made at this meeting.

We are not 'challenging' maize or wheat, but simply remembering a traditional but partly forgotten crop that has much to offer. We are in a historic position – the first ever, best ever collection of skills and expertise on finger millet.

Between us, we have enough skills and experience with small-grain production. We need to develop research proposals to resolve technical constraints, and interventions to promote finger millet more aggressively. If we clearly assign responsibilities and work together, we can make the finger millet industry a success. The future is within reach.

Andrew Ward

Deputy Program Manager, Crop Protection Programme, Department for International Development, UK

My earlier contact with finger millet was only through project reports; but this workshop has helped things sink in. The results reported here are highly impressive. Clearly, finger millet is a crop with great potential for improving nutrition and alleviating poverty; but it has not received the priority it deserves.

The DFID's Crop Protection Programme, which funds this project, will close in 2006. Subsequently, DFID will continue to fund research through regional bodies and international agricultural research institutes such as ICRISAT. We must ensure that finger millet is included in national and regional priorities. DFID may also provide funding to help promote or popularize outputs from currently funded projects. The criteria will include: use of innovative methods to spread and apply existing knowledge, strong capacity building component, and strong South input (from governments, regional bodies, professional or industry associations, etc). The finger millet work meets these criteria, and will be well placed to compete for funds. Efforts should be made to develop funding proposals at the appropriate time.

In addition to external donors, we also need to look for funding from national governments and other sources of support. Elsewhere, the private sector funds research and training, and this avenue should be explored. A start has already been made: private milling companies at this meeting have offered to contribute facilities and resources towards product development.

Ultimately, our goal is not finger millet promotion per se, but poverty alleviation through the promotion of finger millet. Poverty is still the biggest challenge for development agencies, and DFID will continue to work with partners in Africa to find sustainable solutions.

R8445 - Finger Millet Workshop, 13-14 September, 2005, Nairobi Safari Club, Nairobi, Kenya

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