Agricultural Innovations for Sustainable Development

Contributions from the 2009/2010 African Women and Young Professionals in Science Competitions

Volume 3: Issue 2

FARA CTA NEPAD anafe AGRA RUFORUM

Agricultural Innovations for Sustainable Development

Contributions from the Finalists of the 2009/2010 Africa-wide Women and Young Professionals in Science Competitions

Volume 3 Issue 2

CTA
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FARA
Forum for Agricultural Research in Africa
12 Anmeda Street, Roman Ridge,
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Forum for Agricultural Research in Africa (FARA)

12 Anmeda Street, Roman Ridge

PMB CT 173, Accra, Ghana

Tel: +233 302 772823 / 302 779421

Fax: +233 302 773676

Email: info@fara-africa.org

Website: www.fara-africa.org

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Contents

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Finally, we wish to offer immense thanks to the editorial team for their steadfastness in ensuring that this publication is of a high standard.

Foreword

This publication came out of the second Africa-wide Women and Young Professionals in Science Competitions, and profiles the achievements of those who participated in the two competitions. It is a timely publication as Africa enters a promising decade of dynamic economic growth, where agriculture is playing a prominent role as a key driver of socio-economic development. Innovations, ideas and practical experiences are becoming increasingly important for decision-making, especially on investments in agriculture. FARA, CTA and the other co-organisers believe that information and knowledge, especially that generated from research on African problems, should be communicated to a range of audiences to catalyse further innovation and to buttress entrepreneurial ventures throughout the continent.

We are proud to share the 'winning' papers and addresses by promising and enterprising women and young professionals who contributed to the success of the 2009/2010 competitions. These are unique papers as they not only provide insights into the research that is being conducted to solve Africa's problems, but also demonstrate excellence and the ability of the winners to communicate their research findings. Most of the winners are working with farmers to solve the daily challenges the latter face concerning crop and livestock management, market access and agricultural mechanisation. The wide range of issues covered – from development of farmers' decision-support tools, through identifying genetic characteristics of crops, to improving agricultural waste management – shows the potential of African agricultural research to provide solutions to complex problems. The competitions also show that, within national systems, research and economic analysis are as important as providing effective and efficient farmer-support services. There is a need to balance research with interventions based on needs on the ground.

This publication includes the papers not only by the winners, but also by all the finalists. The diversity of papers is interesting as it goes beyond the usual breeding and genetic characterisation of commodities to include such topics as increasing the productivity of honeybee keepers and low-cost engineering designs to improve agricultural outputs.

For FARA, CTA and our regional and continental partners, this is a key publication, not only to encourage African women and young professionals in science, but also to underline the importance of investing in women and the future generations. With an enabling policy environment and mentoring by knowledgeable scientists and entrepreneurs, they can lead the African continent to the frontier of scientific excellence that responds to the needs and aspirations of its farmers.

Monty Jones
Executive Director
FARA

Michael Hailu
Director
CTA

Synthesis Report: Lessons Learned

Judith Ann Francis[1] and Myra Wopereis-Pura[2]

Excellence in science and innovation, and effectively communicating the results to achieve high impact, are important for enhancing agricultural performance and socio-development in Africa. The 2009/2010 Africa-wide Women and Young Professionals in Science Competitions sought to identify and give recognition to outstanding researchers who are engaged in communicating the outputs (knowledge, technologies, approaches) to farmers and other key agricultural stakeholders, as well as advocating for policy change to optimise the benefits from scientific and technological developments. The philosophical underpinning of the science competitions is that recognition and promotion of the achievements of women scientists and young professionals will motivate them to undertake more pioneering research to provide answers to the continent's problems and attract increased investment by African governments and the international community. The secondary goal is to increase the visibility of agricultural research as a valuable and promising career option.

In Sub-Saharan Africa, agriculture accounts for approximately 30% of the continent's gross domestic product (GDP) and 70–80% of employment. Investing in the agricultural sector is considered essential for stimulating African economies. This offers the best prospects not only for meeting food and nutrition security goals, but also for raising farm incomes and providing multiplier effects through value addition. The importance of enhanced agricultural performance to Africa's socio-economic development is well established, and recent evidence has shown the transformative impact of Africa's star performers, such as Ghana, Kenya, Malawi and Rwanda.

However, despite the potential of agriculture, both domestic and external funding for agricultural research have declined since the 1980s and remain stagnant in terms of national budgetary expenditure and direct foreign investment. Commitments to increase research funding have been made, but these have not been realised to the levels necessary to give African agriculture the big push it needs to make the quantum leap into the 21st century. Since agriculture is also considered a high-risk sector with low returns, private-sector investment in research and development is also low. Smallholder farmers – especially women, who are the biggest investors in Africa's agriculture – do not have adequate access to the knowledge and capital needed, and remain marginalised. The majority of Africa's youth do not see a viable future in agriculture.

1. Senior Programme Coordinator, Science & Technology Strategies, CTA, Wageningen, The Netherlands
2. Director, Access to Knowledge and Technologies, Forum for Agricultural Research in Africa (FARA), Accra, Ghana

That there is limited evidence available for either the potential or demonstrated impact of investing in science and technological innovations for improving the lives of farmers and rural communities, and thus reducing poverty, malnutrition and unemployment, contributes to the low level of national budgetary allocations to agricultural research. Weak organisation, human and technical deficiencies, and limited strategic foresight compound the problems. Yet agricultural research is taking place in Africa, and is making a difference.

Consequently, it is necessary to highlight the achievements and contributions to sustainable development of agricultural research and technological innovations in a cohesive manner and to provide national, continental and international coverage. Beginning in 2008, a consortium of African organisations and their international development partners initiated a collaboration to promote excellence in agricultural research, science and innovation by rewarding African women scientists and young professionals whose work demonstrates positive or potential impact on agriculture and rural livelihoods. The 2009/2010 competitions are the second in the series. Although various awards existed previously, this is the first dedicated process of promoting excellence in agricultural research by African women and young professionals based on criteria set by African institutions.

The goal of the 2009/2010 Africa-wide Women and Young Professionals in Science Competitions was to recognise and reward the hard work and excellence of women and young professionals who are engaged in innovative and pioneering research and communicating the outputs (knowledge, technologies, approaches) to improve agricultural productivity and the livelihoods of rural communities. The objectives were to:

- create awareness among women and young professionals of their potential to contribute to Africa's development and the opportunities to fulfil their personal goals and ambition through careers in science and agriculture;
- demonstrate the critical role of young professionals and women in science, technology and innovation at the community, national, regional and global levels;
- send strong signals to women and young professionals that their efforts and initiatives are gaining recognition;
- motivate women and young professionals and foster commitment to excellence in research, science, technology and innovation and to communication of the outputs for increasing the impact of research on socio-economic development.

The competitions were launched in August 2009. There were three stages of the evaluation process. Extended abstracts were solicited and reviewed by an expert panel drawn from CTA, FARA, AGRA, ANAFE and RUFORUM, followed by the submission and evaluation of full scientific papers that met the established criteria, and the oral defence of the top submissions before an independent jury. The full papers were also evaluated by an external consultant: Dr Fetien Abay Abera, Mekelle University.

A total of 100 abstracts were received in response to both science competitions from entrants attached to universities, research organisations, companies and non-governmental organisations from 15 African countries. Forty-one top entrants were selected to develop their abstracts into full papers following approved guidelines, and 27 were shortlisted (18 young professionals and nine women) to compete for the top five places in each category. The abstracts covered a

wide range of topics, including pest and disease management, morphological characterisation, biofuels, carbon sequestration, soil fertility, climate change, solar heaters, environmental impact assessments, economic analyses of interventions, and impact analysis of ICT usage. The research addressed critical challenges and technological developments, and contributed to improved technologies, increased productivity, enhancing knowledge on indigenous species, and better understanding of farmers' adaptation strategies.

The top 27 scientists who participated in the finals were required to make oral presentations, which were evaluated by an independent team of experienced, multi-disciplinary judges drawn from African universities and research organisations. The finals were held during the Fifth African Agriculture Science Week and FARA General Assembly in Burkina Faso, 19–20 July 2010.

The following criteria were used at all stages of the competitions:

- logic and content, including research design, statistical analysis and presentation of data, interpretation of results and conclusions;
- communication – written and oral presentations, and strategies used for sharing the outputs with key stakeholders, including farmers and policy-makers;
- impact (demonstrated or potential, on productivity, livelihoods, farmer empowerment, women and youth);
- innovation and originality.

The independent team of judges based their evaluations solely on the oral presentations made during the finals. The expert panel and external consultant based their evaluations solely on the written submissions – abstracts and full papers. The evaluation scores from the expert panel, external consultant and judges were then collated to select the overall winners for the top five prizes in each category.

The list of top winners is shown in Box 1. The distinction between the winners was based on the originality and innovation of their scientific endeavours, and their ability to communicate the results to intended users and policy-makers.

The most important lesson learned from the science competitions is that great diversity exists in approaches to development-oriented, basic and applied research for addressing the real problems that Africa faces. Creativity and clear justifications/elaborations of the original problem were displayed. Innovative research was presented on producing low-cost technologies, using ICTs, characterising agro-biodiversity (including indigenous resources), improving animal feed, and addressing climate change. Major variations were observed in the design, methodology and communication strategies.

Team work is a common concern in agricultural research, and an interdisciplinary approach is needed to address the interconnected problems that confront the agricultural sector. The challenge and the opportunity for good researchers in agricultural science is to create common ground for interdisciplinary work so that team members can come together around issues not only of individual interest, but also outside their own disciplines so that together they can achieve team goals. Some of the work presented demonstrated that multi-disciplinary research was being practised, but most projects were along disciplinary lines. During the oral presentation, except in a few cases (for example, the presentation of ENDSA by the first-place

Box 1. Top Winners of the 2009/2010 Africa-wide Science Competitions

Top Winners of the Women in Science Competition

1st Prize: Dr Sarah Lubanga Mubiru of Uganda for 'Development of 'Endiisa' decision support tool for improved feeding of dairy cattle in Uganda'

2nd Prize: Dr Theresia Luvuno Munga of Kenya for 'Breeding for Cassava Brown Streak Disease Resistance in Coastal Kenya'

3rd Prize: Ms Esperance Benedicte Zossou of Benin for 'Technological and institutional innovations triggered by farmer-to-farmer rice parboiling video in Central Benin'

4th Prize: Mrs Lalini Unmole of Mauritius for 'The sustainable approach for the management of the legume pod borer Maruca vitrata fabricius on bean in Mauritius'

5th Prize: Ms Eunice Wamuyu Githae of Kenya for 'Genetic diversity of gum Arabic-producing Acacia Senegal varieties in Kenya using inter-simple sequence repeats (ISSR) and chloroplast simple-sequence repeat markers'

Top Winners of the Young Professionals Competition

1st Prize: Ms Sandrine Nguiakam of Cameroon for 'Cours des matières premières, recettes budgétaires et croissance économique: Cas de la Cote d'Ivoire'

2nd Prize: Mr Kevin Zowe Mganga of Kenya for 'Reseeding – a gateway to rehabilitation success, food security and sustainable rural livelihoods in drylands Africa'

3rd Prize: Dr Aneeza Soobedar of Mauritius for 'Looking at wastes as valuable resources – an example from the sugarcane industry in Mauritius'

4th Prize: Dr Robert Kajobe of Uganda for 'Development of appropriate surveillance systems for honeybee pests and diseases for improved production of honey and other bee products in Uganda'

5th Prize: Mr Michael Kwabena Osei of Ghana for 'Morphological characterisation of African egg plant (Solanum species) in some African countries; and Ms Wendkhoumi Sabine Marie Flore Doamba of Burkina Faso for 'Variation de l'activité biologique dans les parcelles aménagées en cordons pierreux de la province du Kouritenga au Burkina Faso'

winner in the women's competition), the scientists were inclined to promote themselves. However, recognition must be given to team members' contributions to promote the benefits of developing inclusive and effective networks and to avoid ethical questions about ownership being raised. The opportunity provided for women and young scientists to be recognised at African level must be used to maintain contacts made, cross-train wherever possible, compete in teams in other competitions, and collaborate and network in joint research projects.

Experimental design and data analysis were seen as challenges for both women and young professionals. Many of the analyses were based on descriptive statistics. Better analytical skills were observed in the women's than in the young professionals' competition. Before beginning an experiment, researchers must decide on the research method and experimental design; the measurement scale to be used in quantifying the responses; and, ideally, the method of analysing and expressing the data obtained. These decisions are interconnected –the appropriate statistical methods for analysing the data depend on the measurement scale chosen and the experimental design. In fact, the chosen design may restrict which analyses are possible, and the measurement scale can determine which designs should be used. These capacities were found to be weak or missing in a few of the papers. Short-term training in research design and building capacity in biometrics and data analysis is therefore recommended as necessary and of strategic importance. Because of these problems, publication, dissemination and communication of results could be restricted.

Most young professionals and women researchers kept their work as unpublished outputs. The science competitions helped to raise awareness and provided a platform for sharing experiences and encouraging collaboration among African scientists. The informal interaction between participants, expert panel and judges was well appreciated, despite some language barriers between Francophone and Anglophone countries. The opportunity to have the papers scientifically edited, published and disseminated in print and electronic formats as outputs of the competitions contributes to building capacity and is an added benefit as it contributes to the African knowledge base.

Stricter guidelines need to be developed and adhered to when evaluating the communication strategy, especially with respect to determining how the research findings were shared with various stakeholders. Were the results communicated at the community level, with peers or policy-makers? Were they shared with local, national and international audiences, general or technical or both, and in what format? Was the strategy successful?

The diversity of the research topics presented in response to the competitions requires the judges and expert panel to have multi-disciplinary knowledge and skills. This was addressed to some extent in the second round of the competitions, but more can be done, and the expert panel should be expanded for future competitions. The strategy employed in engaging previous awardees of the first science competitions in the second round as mentors, keynote speakers, members of expert panels and judges was encouraging and appreciated, and should continue. The challenge remains how to strengthen the networking, keep it active and provide mentorship, especially for the young professionals and aspiring women scientists. It is also important that the winners themselves contribute to creating such connections and keeping them active.

In conclusion, the competitions provided an overview of current agricultural research and development activities across Africa. Africa's research could still benefit from improved team work among scientists across disciplines. Greater interaction and collaboration with scientists from the diaspora and international research institutions could contribute to improving standards and increasing visibility without losing autonomy. Collaboration enhances relevance and increases impact. However, African scientists must also be afforded the opportunities to build self-confidence and demonstrate their expertise and excellence in the various scientific spheres. The Fifth FARA General Assembly endorsed the science competitions as an integral part of its triennial African Agriculture Science Week.

Women in Science Competition

Keynote Paper: Strategic Repositioning of Agrobiodiversity in the Horticulture Sector for Sustainable Development in Africa

Professor Abukutsa Mary Oyiela Onyango[1]

Keywords: ***Africa, agricultural biodiversity, horticulture, repositioning, sustainable development***

Abstract

The year 2010 was declared the International Year of Biodiversity by the United Nations to celebrate the diversity of plants and animals. Horticultural biodiversity that used to form an integral part of African diets should have been part of this celebration. However, with the introduction of exotic temperate crops, indigenous green vegetables lost popularity in Africa and started to be regarded as 'weeds' and 'poor man's food'. With over 50% of the African population living below the poverty line, resulting in malnutrition and poor health, there is a need for a paradigm shift in food production patterns to harness the nutrition and economic potential of indigenous vegetables and fruits. Since the mid-1990s, Africans have seen an increase in diet-related ailments such as cardiovascular disease, diabetes and anaemia. Indigenous vegetables and fruits are micronutrient-rich, and could prove a powerful weapon in the fight against poverty and malnutrition as they are suited to local conditions. However, a number of factors have conspired against sustainable production and use of these indigenous crops, including negative perceptions, poor-quality seed, lack of technical packages, poor marketing, and high perishability, which have affected their strategic repositioning in the horticulture sector. Strategies that could be used to raise the status of agrobiodiversity include advocacy, capacity-building, development of dissemination materials, conservation, sustainable seed-supply systems, identifying potential markets, and development of acceptable products. In the future, there needs to be a focus on the development of good agricultural practices, efficient seed-delivery systems, breeding, conservation, commercialisation, processing, value addition and product development. Agrobiodiversity has a crucial part

1. Department of Horticulture, Jomo Kenyatta University of Agriculture & Technology, PO Box 62000, 00200 Nairobi, Kenya

to play in revolutionising the horticultural sector for food security, nutrition, income and sustainable development in Africa. It is therefore time to strategically reposition agrobiodiversity in the horticultural sector and restore its lost glory.

Introduction

Background

Agrobiodiversity is shorthand for 'agricultural biological diversity'. It embraces all components of biodiversity of relevance to food and agriculture. Agrobiodiversity has three levels: all cultivated and domesticated animal and plant species and their wild relatives that contribute to maintaining the key functions of agriculture; components of ecosystems (agro-ecosystems), such as bees for pollination or beneficial organisms to control pests; and managed stocks of wild animals and plants (FAO, 1999). Agrobiodiversity is the diversity of animals and plants that underpins agriculture, and is the result of the interaction between the environment, genetic resources, and management systems and practices used by culturally diverse peoples. It encompasses the variety and variability of animals, plants and micro-organisms that are necessary for sustaining the key functions of agro-ecosystems, including the structure and processes for, and in support of, food production and food security (FAO, 1999). The formal definition of agrobiodiversity is the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries (FAO, 1999). It comprises the diversity of genetic resources and species used for food, feed, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production and those in the wider environment that support agro-ecosystems.

There is an urgent need to exploit this diversity in food security, nutrition and economic development. The year 2010 was declared by the United Nations as International Year of Biodiversity. Agrobiodiversity is critical to human survival, but is significantly undervalued. There is a need to strategically reposition relevant agrobiodiversity in the horticulture sector. Horticulture is a rich and colourful discipline and sector that includes pomology (fruits), floriculture (flowers), ornamental horticulture and olericulture (vegetables) (Peter and Abraham, 2007). Indigenous horticultural plants must be repositioned in the horticulture sector for their full potential to be exploited (Abukutsa, 2010). Horticulture has grown to become the most vibrant foreign-exchange earner and employer in several African countries, yet the indigenous horticultural crops have not been exploited for existing export markets (HCDA, 2008). In Kenya, for example, in 2008 about 20% of horticultural produce was exported, and horticulture exports were valued at KES 74 billion (€740 million), of which 30–40% was from vegetables, but none of these were African indigenous vegetables (HCDA, 2008). Nearly half of the world's population live on less than $2 a day, and half the population in Africa live on less than $1 a day. Most malnourished and poor people are in Africa, and poverty is normally manifested in hunger, malnutrition and poor health (AICAD, 2003; Burke and Lobell, 2010). About 5.6 million people are food insecure in Kenya and 50% of under fives are malnourished, yet Africa is endowed with agricultural biodiversity (Schippers, 2002; Abukutsa, 2010). Repositioning involves changing the identity of a product, relative to the identity of competing products, in the collective mind of the target market. Strategic repositioning is seeking to exploit opportunities or deliberately influence audiences of significance without controlling them (Abukutsa, 2010).

Objectives

The objectives of this paper are to:

- discuss the position and current status of agrobiodiversity in the horticulture sector;
- explain major strategies for repositioning agrobiodiversity in the horticulture sector;
- discuss the role of agrobiodiversity and the significance of its repositioning in the horticulture sector.

Position and current status of agrobiodiversity in the horticulture sector

In the horticulture sector, agrobiodiversity is largely marginalised and most indigenous vegetables have been positioned as 'weeds', as reflected in their former names. For example, spiderplant (*Cleome gynandra*) was called 'spiderweed'; vegetable amaranths (*Amaranthus* species) were referred to as 'pigweed' and 'black jack'; 'obnoxious weed' (*Bidens pilosa*) is a delicacy in Zambia (Abukutsa-Onyango, 2009a).

Optimal production and utilisation of agrobiodiversity has been faced with several challenges, including neglect and stigmatisation, being referred to as 'weeds', 'poor man's crops' and 'orphan crops'; inadequate awareness of the value and potential of agrobiodiversity; lack of quality seed and of technical agronomic and utilisation packages; and poor marketing strategies, leading to low yields, production and consumption (Abukutsa-Onyango, 2009a).

African indigenous vegetables (AIVs) with nutritional and economic potential in Kenya, the East African region and Sub-Saharan Africa in general have been identified through a series of household, baseline and market surveys in various countries (Abukutsa, 2010). The identified AIVs include: pumpkin (*Cucurbita moschata*), jute mallow (*Corchorus olitorius*), cowpea (*Vigna unguiculata* – landraces used for their leaves), slenderleaf (*Crotalaria ochroleuca*), spiderplant (*Cleome gynandra*), vegetable amaranths (*Amaranthus blitum*), African nightshade (*Solanum scabrum*) and African kale (*Brassica carinata*).

Germplasm collection, evaluation and characterisation has been conducted for some promising indigenous horticultural crops. Morphological and molecular characterisation of some AIVs has been carried out. Inter- and intraspecific variations have been observed in African vegetable nightshade (*S. scabrum*): pronounced different ploidy levels (diploid, tetraploid and hexaploid) (Mwai *et al.*, 2007). Seed bulking, processing and agronomic investigations have been conducted on various indigenous fruits and vegetables, from which dissemination materials have been developed (Abukutsa-Onyango, 2009a).

Strategic repositioning of agrobiodiversity in the horticulture sector

One key to successful strategic repositioning of a technology or commodity is recognising that success involves innovative change and requires advocacy, capacity-building and marketing. This should involve as many players as possible in the value chain. In repositioning AIVs in the horticultural sector, the following strategies are vital: advocacy and promotion; capacity-building; a sustainable seed-supply system; conservation; marketing; and provision of technical information (Abukutsa, 2010).

Advocacy and Promotion Strategy

Advocacy and promotion are powerful tools in repositioning a commodity. This strategy has been used since 1999 to reposition agrobiodiversity in the horticulture sector. The main target groups should be chosen as strategic partners, including farmers, students, researchers, policy-makers and consumers. The objective is to let stakeholders know about the value and potential of agrobiodiversity and constraints hindering its optimal exploitation. Methodologies used should be diverse and user-friendly, and encourage participation. These include orature, song, dance and narratives; demonstration plots; print media, leaflets, posters and newspapers; lectures, seminars and workshops; exhibitions and shows, radio and TV, documentaries and cooking competitions (e.g. IRIN, 2009). These methods were used in an endeavour to sensitise and make a case for agrobiodiversity to all stakeholders.

Capacity-building in Horticulture

University students from agricultural faculties normally form the major human resources in research and extensions services in Kenya and other African countries. It is important to build the capacity of those who will undertake research on agrobiodiversity and those who will effectively disseminate information and transfer technology. At the university level, human resources development and expertise on agrobiodiversity have been achieved by restructuring undergraduate and postgraduate programmes at agricultural colleges and universities (Abukutsa, 2010).

Students on internships from overseas (Germany) have been trained for 3 months on AIVs and conservation of endangered tropical plants at Maseno University and Jomo Kenyatta University of Agriculture and Technology (JKUAT) (Herbst, 2007). Postgraduate research theses on agrobiodiversity have been completed in various public and private universities in Africa. Over 200 researchers and extension workers from all over Africa were trained on AIVs between 2002 and 2008, undertaking a 6-month diploma training course on vegetable crop production and research at AVRDC – The World Vegetable Center's Regional Center for Africa in Arusha, Tanzania.

To successfully reposition indigenous vegetables and crops, farmers are very important as they are the producers; so, apart from creating awareness, building their capacity and training them is vital. Farmers have been trained in Kenya and Tanzania on seed production of AIVs, and it is envisaged that these farmers can act as catalysts for the promotion and repositioning of AIVs at the grassroots level (Abukutsa-Onyango, 2009a).

Policy-makers are vital in promoting a commodity. Four policy-makers were nominated to attend 'The promotion of African indigenous vegetables in urban and peri-urban agriculture in African cities: a policy dialogue workshop' at Rhodes University in January 2003. These policy-makers were drawn from the Kenya Agricultural Research Institute, Ministry of Agriculture, National Council for Science and Technology, and Nairobi Municipality Council. This was funded by the European Union through the project 'Networking to promote the sustainable production and marketing of indigenous vegetables through urban and peri-urban agriculture in Sub-Saharan Africa' (the 'IndigenoVeg' project), which involved seven African countries and five European organisations.

Sustainable Quality Seed-supply Systems

The first step in promoting any crop is the provision of quality seed. Selections made from accessions collected have been multiplied, evaluated, bulked, packaged and distributed to farmers as a temporary stop-gap, as further breeding work to develop cultivars is planned. Seed-supply systems for indigenous vegetables were set up at Maseno University Botanic Garden and JKUAT Department of Horticulture as an intermediate measure for farmers to access quality seed (Abukutsa-Onyango, 2009b).

Conservation of Agrobiodiversity

In situ and *ex situ* conservation of AIVs was implemented from 2001. Maseno University Botanic Garden was established in 2001 and is home to 200 plant species, of which 20% are indigenous fruits and vegetables. The BIOTA project was funded by Federal Government of Germany, and the purpose of the garden was combined research, teaching, conservation and recreational use (Abukutsa-Onyango, 2009a).

Markets for Produce and Products

Market surveys indicate that the demand for indigenous vegetables is not fully met in Kenyan urban and peri-urban markets. Potential markets have been identified in Kisumu, Nairobi, elsewhere in East Africa and throughout Sub-Saharan Africa. Linking farmers to markets has been undertaken by our strategic partner Farm Concern International. Promoting a commodity with an assured market is vital for the commodity's success. There are potential urban, national, regional and international markets. People in the diaspora in the UK and USA have expressed a desire to have AIVs supplied to them. This would require preserving and some processing, and calls for research in this area.

Availability of Acceptable Recipes, Processing Technologies and Product Prototypes

Many consumers have expressed concern that traditional methods of preparation are time-consuming and tedious, especially for the younger generation. Traditional recipes were therefore collected and standardised. New recipes were also developed and evaluated. Product prototypes have been developed and are being evaluated, along with some of the recipes (Habwe *et al.*, 2009). To enhance consumption of AIVs, participatory selection and ranking of AIV recipes were carried out. Organoleptic and acceptability tests were conducted for recipes and prototype products in western Kenya and elsewhere in eastern Africa. Ranking was done on the basis of taste and appearance. Recipes prepared with traditional salt, lye[2], were significantly accepted by all testers in terms of appearance and taste. Participatory selection of the priority AIVs will also enhance acceptability (Musotsi *et al.*, 2005; Habwe *et al.*, 2009).

Development of Dissemination Materials

A diverse selection of effective dissemination materials would enhance the repositioning of AIVs for farmers and consumers. Simplified technical leaflets were developed on the production

2. Lye' is African traditional salt obtained by filtering ash from selected plants, and has been used for cooking for centuries; it is edible – not to be confused with sodium hydroxide!

of African nightshade, spiderplant, vegetable amaranths, jute mallow, slenderleaf, pumpkin leaves and African kale, and used in training and to disseminate technical information on AIVs (Abukutsa, 2010).

The role of agrobiodiversity and the significance of its repositioning in the horticulture sector

The Role of Agrobiodiversity

In 2010, the International Year of Biodiversity, people all over the world worked to safeguard this irreplaceable natural wealth and reduce biodiversity loss. This is vital for current and future human wellbeing. The International Year of Biodiversity was a unique opportunity to increase understanding of the vital role that biodiversity plays in sustaining life on Earth. Humans are an integral part of nature; our fate is tightly linked with biodiversity – the huge variety of other animals and plants, the places where they live, and their surrounding environments (Abukutsa, 2010). People rely on this diversity of life to provide the food, fuel, medicine and other essentials we simply cannot live without. Yet this rich diversity is being lost at a greatly accelerated rate because of human activities. This impoverishes us all and weakens the ability of the living systems, on which we depend, to resist growing threats such as climate change. Agricultural biodiversity is critical to human survival, but is significantly undervalued. The International Year of Biodiversity promised a wealth of opportunities for raising awareness of the role that biodiversity plays in the lives of people and the special importance of agricultural biodiversity. Climate change and increasing pressures on agricultural land are putting at risk the very tool that can help farmers adapt to these challenges: agricultural biodiversity. Bioversity International mounted a global awareness campaign – 'Diversity for Life' – which gained momentum during the year. Diversity for Life undertook a range of communication and educational activities targeting policy-makers, the media and schools in a number of countries around the world. The campaign provided an opportunity for consistent advocacy on the key objective that people should diversify their diets and that policy-makers should integrate the conservation and use of biodiversity into national poverty-reduction strategies and plans (Abukutsa, 2010).

Diversity for Life tells the stories of people whose passion for diversity is helping, in small and large ways, to create a healthier, more food-secure world. It focuses on the images and stories of the 'Guardians of Diversity': individuals who have dedicated their lives to safeguarding the diversity of plants and animals and making sure that it is used by people to improve their lives. Africa abounds with agricultural biodiversity resources – genetic resources, crop species, trees, fish, livestock, as well as microbes, pollinators and production environments. The story of what has been done on AIVs contributed to this celebration and offered some strategies for the African green revolution.

According to Thrupp (1997), experience and research have shown that agrobiodiversity can increase productivity, food security and economic returns; reduce the pressure of agriculture on fragile areas, forests and endangered species; make farming systems more stable, robust and sustainable; contribute to sound pest and disease management; conserve soil and increase natural soil fertility and health; contribute to sustainable intensification; diversify products and income opportunities; reduce the spread of risks to individuals and nations; help maximise the

effective use of resources and the environment; reduce dependence on external inputs; improve human nutrition (Ekesa *et al.*, 2008); provide sources of medicines and vitamins; and conserve ecosystem structure and the stability of species diversity. Furthermore, agrobiodiversity serves as a source for biotechnological applications.

Despite their stigmatisation, horticultural indigenous food crops have played a very important role in food security and nutrition on the African continent. There is an urgent need to strategically reposition indigenous vegetables and fruits in the horticultural sector, so that their potential can be fully exploited for food nutrition and income generation and contribute to achieving both Vision 2030 in Kenya and the Millennium Development Goals (MDGs).

The Significance and Impact of Repositioning Agrobiodiversity in the Horticulture Sector

- Increased number of students researching agrobiodiversity in Africa.
- Availability of quality seed of some indigenous vegetables and fruits in Africa.
- Increased yields and production of some priority indigenous vegetables and fruits in some African countries.
- Availability of dissemination materials and increased research and reference materials.
- Increased popularity, availability and consumption of indigenous vegetables and fruits.

Products, quality seed, and leaflets on indigenous vegetables and fruits have resulted in good crops for farmers, and availability of indigenous vegetables and fruits in supermarkets. A contribution was made to the livelihoods of people in Africa through the sustainable production and utilisation of indigenous fruits and vegetables, resulting in improved food security, nutrition and health; increased incomes and improved livelihoods; and sustainable development (Abukutsa, 2010).

Conclusions and recommendations

- Agrobiodiversity has value and potential that needs to be exploited in food security and nutrition in Africa.
- Horticultural biodiversity such as AIVs needs to be strategically repositioned to exploit its potential.
- Strategic repositioning will require a paradigm shift and must involve all players along the value chain.
- Researchers must actively engage policy-makers, the private sector and producers.
- Strategic repositioning of agrobiodiversity in the horticulture sector will greatly contribute to the achievement of Vision 2030 in Kenya, MDG1 on hunger, food insecurity and malnutrition, and MDG7 on ensuring environmental sustainability.

Research Direction, Perspectives and Engaging the Private Sector

- Seed production, processing, packaging and distribution could be taken on by seed distribution agents and community-based organisations.
- Product prototypes could be developed into business ventures.

- Recipes can be used in restaurants, hospitals, organisations and airlines.
- Curriculum development at agricultural universities should be focused on these developments.
- Strong collaboration will be needed with stakeholders from agriculture sector ministries, the private sector and grassroots organisations.

A Parting Shot

Agricultural biodiversity comprises high-profile commodities with nutritional and unrivalled health benefits. These commodities have a role to play in food security, nutrition, income and sustainable development in Africa and beyond – they are a gold mine to be harvested.

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Technological and Institutional Innovations Triggered by a Farmer-to-Farmer Rice Parboiling Video in Central Benin

Espérance Zossou[1]

Keywords: ***entrepreneurship, learning, rice video, social capital, training***

Abstract

In Africa, rice production and processing tasks are allocated on a gender basis, with women being responsible for much of the drudgery involved in processing. Parboiling rice is an important processing activity in the north and centre of Benin. Good parboiling reduces the breakage rate during milling and greatly enhances the nutritional quality of rice. Parboiling is mainly done by women in and around rice production areas, and is an important income-generating activity. The traditional rice parboiling method is still dominant but does not yield quality rice. To address this, an improved rice parboiling technology was introduced in central Benin through two training methods: conventional training workshops and farmer-to-farmer video (initiated by the Africa Rice Center). To compare these two methods of changing women's rice processing practices, we interviewed 160 women and 17 women's groups who had been exposed to one or both of the learning approaches in 16 villages. In addition, we interviewed 40 women processors in four control villages that had received no intervention at all. The video was well appreciated by both the non-governmental organisations (NGOs) and the target population as a good learning tool in rural areas, and had reached three times more women than the conventional training workshops. While conventional training was biased by participant selection, stakes in per diem payment and monopoly by the elite class, video helped to overcome local power structures and reduced conflict at the community level. Women who watched the video enhanced their creativity and adapted the learning to their environment by developing appropriate technologies. They improved their rice parboiling, leading to better-quality rice. As well as triggering local NGOs to improve their training methodology, farmer-to-farmer video also strengthened NGOs' relations with rural communities, and relationships between the women rice processors and input and output markets.

Introduction

The Training and Visit (T&V) system was the principal agricultural extension approach in Benin from 1985 to 1999. This approach was based on producing large amounts of purely technical advice, using standardised, detailed and rigorously monitored schedules of contact farmer visits and staff training sessions. T&V drew heavily on the adoption and diffusion of innovation (Leeuwis, 2004). However, farmers were dissatisfied with these extension activities because

1. Africa Rice Center (AfricaRice) / ULg, Gembloux Agro-Bio Tech, 01 BP 2031, Cotonou, Benin.

their real needs were not taken into account (Moumouni, 2005), and there were calls for changes in the traditional public extension systems, which were seen as outdated, top-down, paternalistic, inflexible, bureaucratic and inefficient, and therefore less able to cope with the dynamic demands of modern agriculture (Rivera and Zijp, 2002).

The success of any sustainable development programme is determined largely by the level of farmers' participation (Axinn, 1997). As extension systems are increasingly decentralised and fragmented, non-governmental organisations (NGOs) and the private sector are redefining their roles to fill certain niches. To strengthen rural learning and support the multitude of existing and emerging service providers, the Africa Rice Center (AfricaRice) has developed a series of farmer-to-farmer videos according to the zooming-in, zooming-out (ZIZO)[2] approach, which leads to locally appropriate and regionally relevant videos (Van Mele, 2006). The video 'Cashing In with Parboiled Rice' was developed according to the ZIZO approach in collaboration with women rice processors in Benin, who were primarily involved in participatory technology development on parboiling.

From 2005 onwards, four local NGOs used a conventional methodology that consisted of 2-day community workshops, during which experts demonstrated the process for improved parboiling to women. In addition to workshops, with technical and financial support from AfricaRice, NGOs organised public screenings of the parboiling video, followed by facilitated group discussions, in 80 villages in late 2006 in central Benin.

In this paper, we compare the effectiveness of conventional training and video as rural learning approaches, and discuss the challenges of such videos in creating technological and institutional changes among service providers and rural entrepreneurs.

Materials and methods

Field surveys were conducted from November 2007 to May 2008 in five municipalities in the Collines Department of Benin, where local NGOs (Castor, LDLD, Rabemar and Un Monde) operate to strengthen the rice sector. The surveys covered 16 villages where the video had been shown in late 2006 and where conventional training was carried out once between 2005 and 2007, plus four control villages where no intervention had taken place. In total, 200 women rice-parboilers (10 per village) and 17 women's groups were interviewed. The villages and the women were selected randomly. Local artisans trained in making the parboilers and NGOs staff were also interviewed.

Both qualitative and quantitative methodologies were used. Qualitative data were collected through focus-group discussions (to obtain an idea about the role of parboiling at the village level); participant observation (to analyse how the women applied the learning gathered from the video in practice); photography (to illustrate and discuss the technological innovations); and semi-structured interviews (e.g. to understand various social dimensions influencing parboiling as a rural enterprise). Quantitative data were collected through structured questionnaires

2. ZIZO is a method of video-making that evolves around five guiding principles: (i) identify generic topic of regional relevance; (ii) learn about context diversity through participatory research; (iii) develop videos with local actors; (iv) test videos in various contexts and fine-tune them; (v) scale-up and scale-out.

with 200 women. Women's motivation for rice parboiling was assessed by both a subjective measure of the interest with which women spoke about parboiled rice and a self-ranking organised by women to classify themselves according to their degree of motivation to parboil rice. Behavioural changes towards parboiling were assessed by the ratio of parboiled rice to paddy produced or purchased per cropping season by each woman, in order to gain an idea of the women's entrepreneurial mindset.

To understand how social cohesion was built and strengthened, some indicators – such as the level of the women's participation in group work, as well as the level of collaboration between women, NGOs, formal and informal credit institutions and traders in parboiled rice – were assessed through regular observations of women's activities, focus groups and interviews.

Quantitative data were analysed using analysis of variance (ANOVA), logistic binomial regression models, Wilcoxon and chi-square tests. Three months after these initial investigations, the results were validated during a workshop at AfricaRice with NGO field staff and scientific colleagues. This provided additional feedback and stimulated learning between partners.

Results

Effectiveness of Conventional Training and Video

Conventional training involved NGO field staff, who directly trained a few selected women (26% of women surveyed) in a central village and hoped they would share their learning with others when they returned to their villages. Participation was affected by the provision of a per diem, and the fact that leaders of existing farmers' groups typically chose friends or relatives to take part in the training, ignoring the actual target women. Most of the women who participated in the training workshops were mainly interested in receiving a per diem (81%). As the selection of women to take part in training was not based on motivation to promote rice parboiling in their localities, nearly two-thirds of the women surveyed did not even know that conventional training workshops had taken place.

Video-mediated learning helped to overcome participant selection bias through local power structures, and reduced conflict at the community level. However, other factors may have influenced whether women could take part in the video shows. Therefore we introduced some socio-economic factors (ethnic group, age, number of dependents in the household, educational level of women, importance of rice parboiling activity, experience, religion, membership of a farmers' organisation, awareness of the importance of rice parboiling, and their motivation for the activity) in a logistic binomial regression model (Table 1) to better appreciate which factors could affect participation in public video screenings at the village level. Analysis showed that none of these factors influenced the viewing (P>0.1).

Women in villages had an equal chance to watch the video, confirming the democratic character of community-based, video-mediated learning. Video reached 74% of surveyed women and was well appreciated by both the NGOs and the target populations as a good way to disseminate the technology widely and to entertain rural communities.

Table 1. Socio-economic factors considered likely to influence the viewing of the video in villages*

Variable	Estimated parameters	Standard error	Probability
Ethnic group	–0.049	0.054	0.362
Age	–0.003	0.024	0.903
Number of dependents in household	–0.009	0.099	0.926
Woman's educational level	0.139	0.104	0.181
Importance of rice parboiling activity	–0.172	0.251	0.493
Experience	0.042	0.039	0.279
Religion	–0.084	0.218	0.702
Membership of farmers' organisation	0.303	0.404	0.453
Awareness of the importance of rice parboiling activity	0.303	1.108	0.235
Motivation of women	0.315	1.098	0.774

*As determined by the logistic binomial regression model.

Technological Innovations Triggered by the Video

In villages where the video had not been shown, the improved parboiler was not used. In those where the local NGOs had intervened and facilitated access to the improved parboiler, 58% of the women started to use the improved equipment, individually (24%) and in groups (56%; that is, 22% used the equipment both individually *and* in groups). Some 72% of those who had watched the video but did not have access to the equipment innovated creatively using local resources, compared with 19% of those who learned through training. Video screening also encouraged women pay attention to reducing the loss of steam and using local resources innovatively to conserve energy during parboiling (Box 1). Future research will need to address the practicality of seeing the technology on video without practising it if intermediaries are not able to facilitate access to the technology.

Apart from enhancing women's creativity, the parboiling video influenced women's behaviour to deliver good-quality rice by improving rice handling practices (before and after the rice is parboiled).

Box 1. Technological innovations made by women for parboiling rice (*n* = 160)*

Innovations based on the principle of parboiling paddy with steam			
1	***2***	***3***	***4***
Women adapted a perforated base to their pan to pre-cook the paddy with steam (17.5%)	Women who cook local couscous with steam started to use the same equipment to parboil their rice (2.5%)	Women put wooden sticks in the pot and covered these with a bag before putting in paddy for parboiling (10.0%)	Women put yam fibres between wooden sticks and bag before putting in the paddy (1.2%)
5	***6***	***7***	***8***
Women put a bowl upside down in a pot with a little water and placed a bag on top of the bowl before adding paddy (10.0%)	Women put paddy in a locally sold sieve, placed on top of the pot with water (2.5%)	Women used a basket adapted to the pot so that the basket did not touch the water in the bottom of the pot (13.7%)	Women placed wire in the bottom of the pot containing a little water; a bag was put on the wire before rice was added (1.2%)

Innovations to seal the junction between pot and parboiling equipment for steam conservation				
1	*2*	*3*	*4*	*5*
A mixture of cassava flour and water applied at the junction (11.9%)	A mixture of cooked maize flour with water or *akassa* (local meal) (26.2%)	A mixture of ash from firewood with water (3.1%)	A mixture of clay and water (6.2%)	Use of clothes to close the junction (58.1%)
*Some women combined innovations.				

Entrepreneurial Mindset Triggered by the Video

The parboiling video influenced women's awareness of the importance of improved rice parboiling to deliver good-quality rice. Consequently, women became more motivated and became increasingly involved in rice production and parboiling (Table 2).

Some women left their primary activity to take up rice production and parboiling, which they considered more profitable, as the story of Mrs T. Prisca from Awaya village in Dassa shows. Although a dressmaker at first, after the video shows she left this activity and began parboiling rice. She became president of a women's rice-parboiling group in her village. She said that rice-parboiling income allowed her to pay for her children's education.

Table 2. Motivation and behavioural changes (%) towards rice parboiling after watching the video*

Changes		Before watching video	After watching video
Women's motivation to parboil rice†	Low	32.8 a	0.0 b
	Moderate	66.4 a	27.7 b
	High	0.8 a	72.3 b
Rice parboiling level‡	Less than half of the rice parboiled	33.6 a	0.0 b
	Over half of the rice parboiled	64.7 a	30.3 b
	All the rice parboiled	1.7 a	69.7 b

**n* = 119: number of women who watched the video in villages where it was shown.

†Values in rows with a different letter are significantly different at the 1% level by Wilcoxon test. ***Z*** = –10.490; two-tailed asymptotic significance = 0.000.

‡Values in rows with a different letter are significantly different at the 1% level by Wilcoxon test. ***Z*** = –10.479; two-tailed asymptotic significance = 0.000.

More women who watched the video parboiled rice for sale (88.2%) than did so for household consumption only (11.8%). Subsequently, larger quantities of parboiled rice could be found in local markets, of better quality and fetching a 35% higher price than traditionally parboiled rice.

Behavioural and Institutional Changes Triggered by the Video

The video motivated women to start parboiling in groups (Table 3) and to formulate group-based requests for credit and training, for example on the development of improved stoves. Most of the women surveyed (88%) improved their collaboration with NGO staff by meeting them at least once a month to discuss rice processing. NGOs, impressed by women's entrepreneurial spirit and the improved quality of rice, helped women to link up with input and output markets.

Table 3. Percentage of women who parboiled rice individually or in a group in villages where the video was shown

Parboiling activity	Women who didn't watch the video (n = 41)	Women who watched the video (n = 119)
Individual	48.8 a	19.3 b
Group	51.2 a	80.7 b

Pearson's chi-square = 11.544, df = 1, P = 0.001.

As the women gained experience and built confidence, they began to sell their services in parboiling to NGOs and traders, who started to promote their parboiled rice in urban areas. Responding to women's requests after the video show, NGO facilitators helped to strengthen their marketing capacities (processing, packaging, labelling and commercialisation).

The local NGOs started to facilitate women's access to micro-finance institutions and to informal credit providers, who proved more responsive due to the trust being created. Rice producers who attended video shows became more willing to sell rice on credit to women.

Strengthening their role as facilitators, NGO staff also supported women to organise themselves better. The experience with the video made them realise the power of pictures, so they modified their conventional training to include videos, pictures and diagrams.

Discussion and conclusion

Video-mediated learning has allowed wide dissemination of the technology, as the images really caught the target groups' attention. Significantly more women who watched the video used the technology, confirming a study by Gandhi *et al.* (2008) in which video increased the adoption of certain practices sevenfold over a classical training approach.

Farmer's innovations are often shaped by capital limitations, and mainly rely on locally available resources, among which knowledge is key. Sustainable agriculture must take into account farmers' creative ability to adapt basic principles of new technologies to local realities. Farmer-to-farmer videos are ideally suited to illustrate these principles, to expose rural people to new ideas and practices, and to encourage them to create their own innovations.

In many rural settings, development interventions are male-biased because women farmers are restricted by social norms in communicating with men outside their families (Katungi *et al*., 2008). Public video screenings helped to overcome this bias, because they give an equal chance to all community members, men and women, to learn. Another advantage of video is to dilute the negativity that can be associated with information ownership, because all the community can receive the information at the same time in the villages.

Moreover, video-mediated learning has strengthened the social capital among women's groups and improved the trust between actors in the rice value chain – a key weakness of markets in Africa (Fafchamps, 2004). Many organisational and institutional changes have taken place among women and intermediaries, and have led to improved collaboration between them and the input and output markets. Well made, high-quality videos showing functional technologies and their underlying principles can help a good part of the audience to adopt and adapt these technologies, much more easily and probably more cheaply than face-to-

face extension. 'Innovative farmer information systems are a blended learning process in which face-to-face interaction, learning by doing, learning through evaluation and experience, participatory research, etc. convert the generic information into location specific knowledge and then empower its members through horizontal transfer of knowledge' (Gakuru *et al.*, 2009). Farmer-to-farmer video learning is an excellent way to strengthen rural extension in developing countries.

The results of this research have already led to three publications: Zossou *et al.* (2009a, 2009b, 2010).

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The role of communication tools and strategies used by various knowledge intermediaries, and the impact on rural livelihoods and markets, is part of my ongoing PhD programme.

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Insect Fauna of Fallow Legumes

N.J.M. Kouakam[1], M. Tindo[2], I.A. Parh[3] and I. Nchoutnji[4]

Keywords: collection, identification, insect damage, leaf loss, order

Abstract

Legume-improved fallow is an alternative to slash-and-burn cultivation. This study was conducted to evaluate the potential of multi-purpose legume herbs and shrubs in a wet forest ecological zone. As these legumes are hosts to insects, their entomological status was investigated. The legumes were *Cajanus cajan*, *Centrosema pubescens*, *Mucuna pruriens* var. *utilis, Pueraria phaseoloides* and *Tephrosia candida*. The study aimed to conduct an insect collection, ascertain the relative abundance of insect orders, identify actual and potential pests, and evaluate damage to the legumes. All five legumes were attacked by insects. Insects from nine orders were collected. Pod borers were found in *C. cajan* pods. Many aphids found on *C. pubescens* were associated with ants. Alydids actively pierced and sucked the sap of *M. pruriens* leaves. Many orthoptera, such as *Zonocerus variegatus*, chewed leaves of *P. phaseoloides.* Pod borers and *Anoplocnemis* spp. were found on *T. candida*. In terms of damage, tunnels were visible on the pods of *C. cajan*; and 80–100% of *C. pubescens* leaves were shrivelled, possibly due to a virus transmitted by aphids. Thrips were found on flowering plants. Most of the insect species found on these legumes are also pests of cultivated legumes such as soya bean, common bean and cowpea. This knowledge may be valuable for crop rotation in fallow management.

Introduction

Slash-and-burn agriculture, practised in the wet forest region, demands long fallow periods (up to 25 years) to restore soil fertility (Russell, 1993). However, with rapid population increase, pressure on arable land is also increasing, and this cropping system is no longer practicable (Slaats, 1992) because farmers quickly move back to the fallow areas (Young, 1987). Five years is the current average fallow period in the wet forest zone (Duguma *et al.*, 1998). In the benchmark zone of the International Institute of Tropical Agriculture (IITA), fallows are longer in low population-pressure locations in the south of the zone (average of 7.5 years in Ebolowa). The fallow period is shorter in Yaoundé (3.9 years), and intermediate in Mbalmayo (5.4 years), where the demographic pressure is average (Tiki Manga and Weise, 1995). These reduced fallow periods are causing a serious soil-depletion problem. With population increase and shorter

1. Institute of Agricultural Research for Development, Station of Dschang, PO Box 44 Dschang, Cameroon.
2. University of Douala, Cameroon.
3. University of Dschang, Department of Plant Protection, PO Box 222 Dschang, Cameroon.
4. Institute of Agricultural Research for Development, Station of Garoua, Cameroon.

fallow periods, new cropping methods are the only way forward for maintaining soil fertility. To meet this need, IITA and its stakeholders proposed an improved fallow technology (Young, 1987; Abegbehin and Igboanugo, 1990; Balasubramanian and Sekayange, 1992).

Improved fallow helps to restore soil fertility rapidly and to control weeds. Improved fallow uses cover plants or multi-purpose tree plants, which are mainly legumes. IITA has therefore embarked on a large-scale evaluation of multi-purpose legumes, including *Cajanus cajan*, *Centrosema pubescens*, *Mucana pruriens* var. *utilis*, *Pueraria phaseoloides* and *Tephrosia candida*, with a view to introducing them into fallows. These legumes have not been included in any previous research activity on fallows, yet they can host both insect parasites and pest populations. Hence this work aimed to show the entomological status of these legumes. The study involved an insect collection; an evaluation of the relative abundance of insect orders hosted by the legumes; an identification of insect species responsible for leaf and pod loss; and an evaluation of the damage caused by these insects.

Materials and methods

The work was conducted in Mbalmayo, Cameroon, located at 30°30′ to 30°31′ N, 11°29′ to 11°31′ E, 600–700 m above sea level (Santoir, 1995). Average annual precipitation varies between 1600 and 1700 mm. The minimal and maximal temperatures are, respectively, 18 and 27°C for Yaoundé, and 19 and 28°C for Ebolowa (Suchel and Tsalefac, 1995).

Total *C. cajan* area was 25.5 m^2 with 47 shrubs; *T. candida* 11 m^2 with 18 shrubs; *P. phaseoloides* had a total area of 24 m^2; *M. pruriens* 510 m^2; and *C. pubescens* 4,010 m^2. *Cajanus cajan*, *T. candida*, *P. phaseoloides* and *M. pruriens* were grown in three replicates, each covering one-third of the total surface area for the legume species concerned. The whole surface of the plots of these four species was explored on each data-recording visit. For *C. pubescens,* 1 m in the central vertical line was examined for 100 m length of rows, for four rows each visit – thus a surface area of 400 m^2 was examined each visit.

At the beginning of observations, *C. cajan*, *T. candida*, *P. phaseoloides* and *C. pubescens* had flowered and were covered with pods, while *M. pruriens* was at the vegetative stage (and did not flower throughout the observation period). All the above-soil plant parts were investigated. Insect capturing was both visual and non-visual. Non-visual capture was performed using an insect sweep net. The leaf surfaces were quickly explored and scraped with the net. All insects, except butterflies, were collected in tubes containing 50% alcohol. The insects were later removed, dried and pinned into collection boxes. Butterflies were killed by pinching their thoraxes, and then placed into wrappers. Each week the insects were sorted in a laboratory and classified.

To identify the insects, insect identification keys of Delvare and Aberlenc (1989) were used. In addition to morphological characters, ecology and diet were also used in identification, on the basis of descriptions in COPR (1981).

The relative abundance of insect orders on all the plants was evaluated from insects captured on the plots over the study period, as the number of captured individuals of one order compared with the total number of captured individuals. Damage to plant parts (organs) was

assessed by eye (perforated leaves, shrivelled leaves, bored pods). Damage was recorded as an index of proportion of organs damaged per plot: 0: no damage; 1: 1–20% damage; 2: 20–40%; 3: 40–60%; 4: 60–80%; 5: 80–100% damage.

Insects' status as monophagous (feeds on a single species of plant); oligophagous (feeds on two or more plants from the same family); or polyphagous (feeds on many plants from different families) was determined.

The chi-square (χ^2) test was used for statistical analysis.

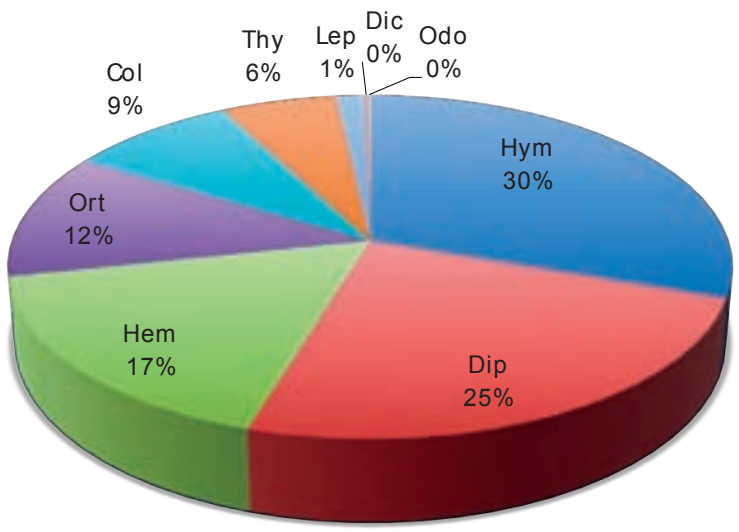
Results

All five legumes were attacked by the insects sampled. The insect collection is kept at the IITA insectarium at the Humid Forest Ecoregional Centre, station of Yaoundé-Nkolbisson.

Nine insect orders were identified – in decreasing order of abundance: Hymenoptera, Diptera, Hemiptera, Orthoptera, Coleoptera, Thysanoptera, Lepidoptera, Dictyoptera, Odonata (Fig. 1). There was a significant difference ($P < 0.05$, $\chi^2_{cal} = 85.10 > \chi^2_{th}$) between the proportions of abundance of insect orders.

Pod borers were found in the pods of *C. cajan*. Many aphids were seen on *C. pubescens*, and were associated with ants (Hymenoptera: Formicidae). Insects belonging to the family Alydidae (Hemiptera) were seen actively piercing and sucking the sap of *M. pruriens* leaves. Many Orthoptera, including *Zonocerus variegatus*, were found chewing *P. phaseoloides* leaves (Table 1). Pod borers and species of *Anoplocnemis* were found on *T. candida*.

Figure 1. *Relative abundance of insect orders*



Hym: Hymenoptera; Dip: Diptera; Hem: Hemiptera; Ort: Orthoptera;
Col: Coleoptera; Thy: Thysanoptera; Lep: Lepidoptera; Dic: Dictyoptera; Odo: Odonata.

Table 1. Major insects captured, identified and sampled

Scientific name	Family	Order*	Plant*	Damage
Riptortus dentipes	Alydidae	Hem	*Cc Cp Pp Tc*	Pierces and sucks sap of pods
UID†	Alydidae	Hem	*Mu*	Pierces and sucks sap of leaves
Anoplocnemis curvipes	Coreidae	Hem	*Cc Tc*	Pierces and sucks sap of leaves
Acanthomia tomentosicollis	Coreidae	Hem	*Cc Tc*	Pierces and sucks sap
Clavigralla sp.	Coreidae	Hem	*Cc Tc*	Pierces and sucks sap
Nezara viridula	Pentatomidae	Hem	*Cc Cp Mu Tc*	Just passing (?)‡
UID	Aphididae	Hem	*Cp*	Shrivelled leaves
Zonocerus variegatus	Pyrgomorphidae	Ort	*Cc Cp Mu Pp Tc*	Chews the leaves
UID	Grillidae	Ort	*Cc Cp Mu Pp*	Cuts parts, plants (?)

*Hem: Hemiptera; Ort: Orthoptera; *Cc*: *C. cajan; Cp*: *C. pubescens*; *Mu*: *M. pruriens*; *Pp*: *P. phaseoloides*; *Tc: T. candida.*

†UID: Unidentified species.

‡(?): Question asked.

Table 2. Damage to legumes*

Symptoms	C. cajan	C. pubescens	M. pruriens	P. phaseoloides	T. candida
Eaten leaves	0	0	2	4	0
Shrivelled leaves	0	5	0	0	0
Bored pods	1	0	0	0	1

*As percentage of plant organs per plot showing damage: 0: no damage; 1: 1–20% damage; 2: 20–40%; 3: 40–60%; 4: 60–80%; 5: 80–100% damage.

In terms of the damage caused by these insects, tunnels were seen in the pods of *C. cajan*; 80–100% of the leaves of *C. pubescens* were shrivelled, possibly due to a virus transmitted by aphids. Less than 20% of the leaves of *M. pruriens* were eaten, while leaf loss was severe on *P. phaseoloides* (60–80%) (Table 2). Thrips were found on the flowering plants.

Discussion and conclusion

The Centre for Overseas Pest Research states that pod borers, thrips and Diptera belonging to the Agromizidae family are major legume insects (COPR, 1981). Thrips were found on the flowering plants in this study. The symptoms found on *C. pubescens* were those of a virus disease. *Centrosema pubescens* is very sensitive to virus diseases, especially to *Cowpea mosaic virus* (Comovirus), Centrosema mosaic potexvirus and *Passion fruit woodiness virus* (Potyvirus) (Koizumi, 1995; ICTVdB, 2006). Carriers of these viruses are *Aphis gossypii* and *Mysus persicae* (Hemiptera: Aphididae). Tindo (2001) found that Coreidae (Hemiptera) such as *Cletus* sp. feed on the flower base of *T. candida* and could cause seed sterility.

The aphid species (*Aphis* spp.) found were monophagous (fed only on a single plant species). The other species identified were oligophagous (fed on many plants from the same family – in this particular case from the Leguminosae). *Riptortus dentipes* was the most oligophagous species among the hemipteran insects, feeding on all four of the legume species that flowered in this experiment.

Riptortus dentipes, *Anoplocnemis curvipes*, *Ancanthomia tomentosicollis* and *Clavigralla* sp. are major cowpea (*Vigna unguiculata*), common bean and soya bean pests (COPR, 1981; Koona *et al.*, 2001). *Nezara viridula* is a major soya bean pest. Thrips are among the major cowpea pests (Bottenberg *et al.*, 1997). *Zonocerus variegatus* is phytophagous and polyphagous (Foahom, 2002). Most of the insects identified on the five legumes are major pests of cultivated legumes (common bean, soya bean and cowpea). It will therefore be better to avoid sowing these legume crops immediately after improved fallow using multi-purpose legumes. This knowledge must be fed into and guide fallow management, crop rotation and successive cropping systems.

Improved fallow technology using legumes offers a promising alternative to slash-and-burn agriculture. This innovation will contribute to revitalising farming in Cameroon and other countries with similar agro-ecologies. Introducing multi-purpose fallow legume herbs and shrubs addresses the major concern about restoring soil fertility, which is basic in farm production. This innovation is also a meaningful environmental protection method. The use of legumes in this way helps to significantly increase not only farm yields, but also farmers' incomes. The results of this research will therefore help to reduce crop yield losses and poverty.

Acknowledgement

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Genetic Diversity of Gum Arabic-producing Acacia senegal Varieties in Kenya using Inter-Simple Sequence Repeat (ISSR) and Chloroplast Simple Sequence Repeat (cpSSR) Markers

Eunice W. Githae[1], C.K.K. Gachene[1], J.T. Njoka[1], D.W. Odee[2] and S.F. Omondi[2]

Keywords: conservation, gene flow, molecular markers, variation

Abstract

Acacia senegal is a drought-tolerant, multi-purpose tree species, highly valued for gum arabic production and increasingly being used in agro-forestry in Sub-Saharan Africa. Despite its long history of use, there has not been exhaustive genetic evaluation of the extant genetic resource base of *A. senegal* in Kenya for genetic improvement of the species. Inter-simple sequence repeat (ISSR) and chloroplast microsatellite (cpSSR) markers were used to study genetic diversity among seven Kenyan populations of *A. senegal* embracing three putative varieties: *kerensis*, *leiorhachis* and *senegal*. The two marker types detected similar levels of Nei's gene diversity (H_{ISSR} = 0.211, H_{cpSSR} = 0.212) among the *A. senegal* populations. *Acacia senegal* var. *kerensis* exhibited the highest diversity using ISSR markers (H_{ISSR} = 0.248), followed by varieties *leiorhachis* (H_{ISSR} = 0.218) and *senegal* (H_{ISSR} = 0.151). Analysis of molecular variance (AMOVA) detected significant genetic variations within and among populations ($P < 0.001$ and $P < 0.01$ for ISSR and cpSSR, respectively). Based on the unweighted pair group method with arithmetic mean (UPGMA) dendrogram of the seven populations, two regions were differentiated (north and south). Both markers demonstrated their potential for delineating population structure at local and regional levels, and infra-specific relations within the species, hence their potential as tools for conservation, improvement programmes and sustainable use of the species. This study provides baseline genetic information for the domestication of *A. senegal* varieties in Kenya.

Introduction

Acacia senegal (L.) Willd. (Mimosodeae) is a drought-tolerant, multi-purpose tree/shrub legume that is widely distributed in drylands of Sub-Saharan Africa, extending to the Arabian Peninsula, Pakistan and India. The species is known for its exudate, named 'gum arabic', used and traded globally for the food and medical industries. The species is known to be highly variable in growth form (Brenan, 1983). Three varieties are currently recognised in Kenya: *A. senegal* var. *senegal* Schweinf., var. *kerensis* Schweinf. and var. *leiorhachis* Brenan (Fagg and Allison, 2004). They are differentiated on natural distribution and morphological characteristics. While this variation is desirable in terms of adaptability and potential for genetic improvement, its management

1. Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi, PO Box 29053-00625, Nairobi, Kenya.
2. Kenya Forestry Research Institute, PO Box 20412-00200, Nairobi, Kenya.

and the sustainable use of *A. senegal* in Kenya are constrained by, among other factors, poor delimitation of the varieties (Brenan, 1983; Maundu and Tengnäs, 2005), and inconsistency in production and low quality of gum arabic (Chretin *et al.*, 2008). Despite its long history of use, there has not been any exhaustive genetic evaluation of the extant genetic resource base of *A. senegal* in Kenya for genetic improvement of the species. Several studies have been conducted using isoenzymes (Fagg and Allison, 2004) and different molecular markers (Chiveu *et al.*, 2008; Assoumane *et al.*, 2009; Omondi *et al.*, 2009). However, most of these studies have used small populations, and few describe the varieties used. Efforts to conserve *A. senegal* germplasm would be useful for effective use of the resources and in order to improve gum production and quality. The present study was undertaken to evaluate the genetic diversity of populations of *A. senegal* varieties in Kenya using inter-simple sequence repeat (ISSR) and chloroplast microsatellite (cpSSR) markers, which will be crucial in developing appropriate strategies for improvement, sustainable use and conservation of the genetic resources.

Materials and methods

Seven populations were selected to represent Kenyan populations in terms of putative variety, potential gum production and altitude (Fig. 1). Thirty samples per population were selected for ISSR and eight samples per population for cpSSR, giving a total of 210 and 56 individual trees, respectively. Total genomic DNA was isolated using a modified cetyltrimethylammonium bromide (CTAB) method as described by Fernández *et al.* (2000).

Fifteen ISSR primers were screened initially and the best seven polymorphic primers were selected. Reactions were carried out in a 25 µl volume consisting of approximately 20 ng of DNA and 10 µm of primer in puReTaq Ready-To-Go PCR Beads (GE Healthcare, Buckinghamshire, UK). Amplifications were performed using a TECHNE TC-412 thermal cycler (Bibby Scientific Ltd, Staffordshire, UK) with the following conditions: 94°C for 5 min, 94°C for 30 s, 52°C for 45 s, 72°C for 2 min (42 cycles), with a final extension at 72°C for 10 min. Electrophoresis was carried out on 2% agarose gels using Tris borate ethylenediaminetetraacetic acid (EDTA) buffer (0.5×). The gels were photographed using Gel LOGIC 200 imaging system (Kodak MI SE, Rochester, New York, USA) and the fragments estimated against a 100 bp DNA ladder.

Chloroplast microsatellite loci developed by Weising and Gardner (1999) were used to genotype the populations. After initial screening with several primer pairs, only two universal primer pairs produced clear amplicons of the expected sizes across the populations. Amplifications were performed in a 13 µl volume containing 0.3 µM of each primer, 1 U *Taq* DNA polymerase (Gibco, Invitrogen), 200 µM of each dNTP, 1 x reaction buffer, 3.25 µg of bovine serum albumin and 10.0 ng of template DNA. Amplifications were performed using a TECHNE TC-412 thermal cycler (Bibby) with the following conditions: 96°C for 2 min, 94°C for 1 min, 56°C for 1 min, 72°C for 1 min (30 cycles), with a final extension at 72°C for 30 min. Electrophoresis was carried out on 8% non-denaturing polyacrylamide gels in a Hoefer SE600 electrophoresis unit (Leicestershire, UK) using Tris borate EDTA buffer (1x). All individuals were characterised for cpDNA haplotype at both loci against a 1 kb standard (Microzone, Buckinghamshire, UK).

The bands were used to assign loci for each primer, and scored as present (1) or absent (0). Genetic parameters for each population were derived using POPGENE 3.2 software

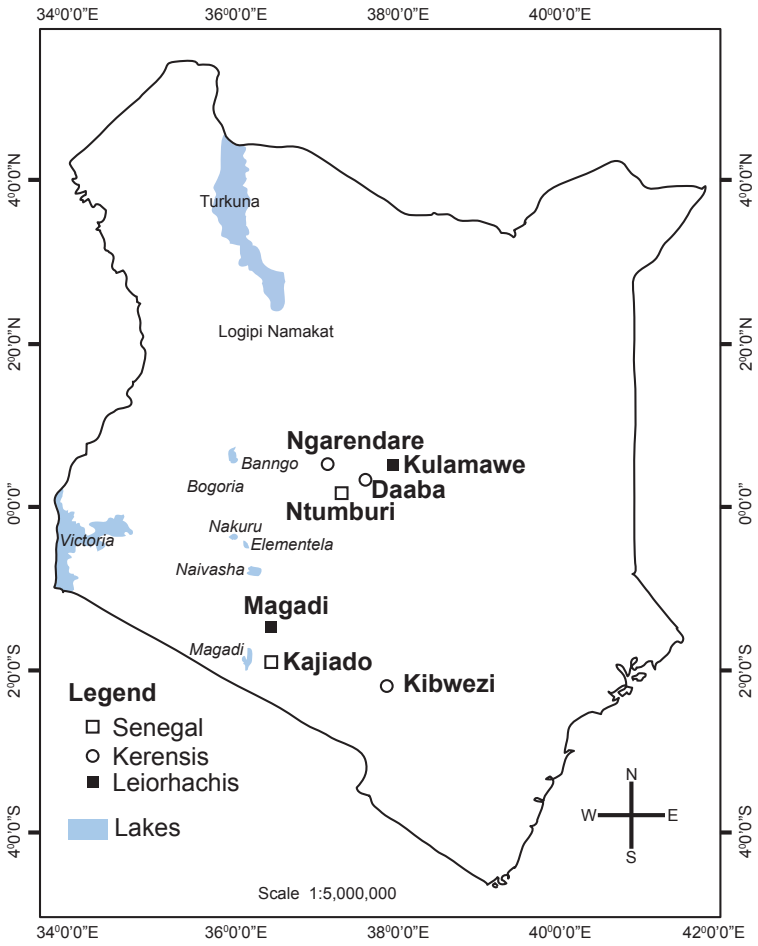


Figure 1. *Locations of the seven study sites representing A. senegal varieties in Kenya*

(Yeh *et al.*, 1999) assuming Hardy–Weinberg equilibrium. The genetic distance matrix was used to generate the diversity trees using the unweighted pair group method with arithmetic mean (UPGMA) method (Yeh *et al.*, 1999). Analysis of molecular variance (AMOVA) was performed using GenALEx version 6 (Peakall and Smouse, 2006).

Results

The seven ISSR primers produced a total of 203 scorable fragments of between 200 and 1,450 bp, of which 56.53% were polymorphic across the 210 trees. The mean Nei's gene diversity (*H*) (Nei, 1973) for all the populations using ISSR was 0.211, with mean percentage polymorphism of 70.80% (Table 1). The highest genetic diversity and number of polymorphic loci was exhibited by the Ngarendare, Kibwezi and Daaba populations – all representing variety *kerensis*, while the lowest diversity was exhibited by Ntumburi and Kajiado populations, both representing variety *senegal*.

The two cpSSR primers detected intraspecific polymorphism for phylo-geography analysis. The mean Nei's gene diversity for all the populations using cpSSR was 0.212 (Table 1). The highest genetic diversity was shown by the Magadi and Kajido populations representing varieties *leiorhachis* and *senegal*, respectively. These two populations are geographically close to each other. Daaba and Kulamawe populations are also geographically close to each other, and both showed no detectable diversity.

AMOVA detected significant genetic variations within and among populations for both marker types (Table 2). The ISSR marker demonstrated higher genetic diversity within than among populations, while the cpSSR marker showed higher diversity among than within populations. The shortest genetic distance was observed between Ngarendare and Daaba populations, both representing variety *kerensis*, while the most distant populations were Kajiado and Kulamawe, representing varieties *senegal* and *leiorhachis*, respectively (Table 3). Cluster analysis based on UPGMA clustered the populations into two regions: north and south (Fig. 2). Ngarendare and Daaba populations were clustered together by principal components analysis (PCA), confirming the results obtained by pairwise analysis (Fig. 3).

Table 1. Genetic values for the seven populations of *A. senegal* varieties for ISSR and cpSSR markers

		ISSR*				cpSSR	
Population	**Variety**	**N_P**	**$\%N_P$**	**A**	**H**	**Haplotype (count)**	**H**
Kibwezi	*kerensis*	173	85.22	1.852	0.250	8 (6), 11 (1), 12 (1)	0.203
Ngarendare	*kerensis*	172	84.73	1.847	0.255	4 (6), 5 (1), 7 (1)	0.219
Daaba	*kerensis*	160	78.82	1.788	0.238	4 (8)	0.000
Magadi	*leiorhachis*	149	73.40	1.734	0.218	6 (3), 7 (2), 9 (2), 10 (1)	0.469
Kulamawe	*leiorhachis*	133	65.52	1.655	0.218	3 (8)	0.000
Kajiado	*senegal*	107	52.72	1.527	0.155	10 (4), 9 (3), 7 (1)	0.344
Ntumburi	*senegal*	112	55.17	1.552	0.146	4 (4), 4 (4)	0.250
Mean		**144**	**70.80**	**1.708**	**0.211**		**0.212**

*N_P = number of polymorphic loci; $\%N_P$ = percentage polymorphic loci; *A* = mean number of alleles; *H* = Nei's gene diversity.

Table 2 AMOVA of the seven populations of *A. senegal* for ISSR and cpSSR markers

	ISSR*				cpSSR*			
Source of variation	**df**	**MS**	**%*V***	***P***	**df**	**MS**	**%*V***	***P***
Among regions	1	1162.033	16	<0.001	1	8.086	21	<0.01
Among populations	5	450.814	33	<0.001	5	3.454	49	<0.01
Within populations	203	22.175	51	<0.001	49	0.242	30	<0.01
Total	**209**	**1635.022**	**100**		**55**	**11.783**	**100**	

*df = degrees of freedom; MS = mean sum of squares; %V = percentage variance.

Table 3. Pairwise population matrix of Nei's unbiased genetic distance (*D*) of the seven populations of *A. senegal* in Kenya using ISSR markers

	Kulamawe	Ngarendare	Daaba	Ntumburi	Kibwezi	Magadi	Kajiado
Kulamawe	0.000						
Ngarendare	0.286	0.000					
Daaba	0.261	0.030	0.000				
Ntumburi	0.321	0.261	0.242	0.000			
Kibwezi	0.357	0.204	0.181	0.319	0.000		
Magadi	0.245	0.355	0.333	0.425	0.139	0.000	
Kajiado	0.464	0.345	0.343	0.249	0.143	0.237	0.000

Figure 2. *UPGMA dendrogram of the seven populations of* A. senegal

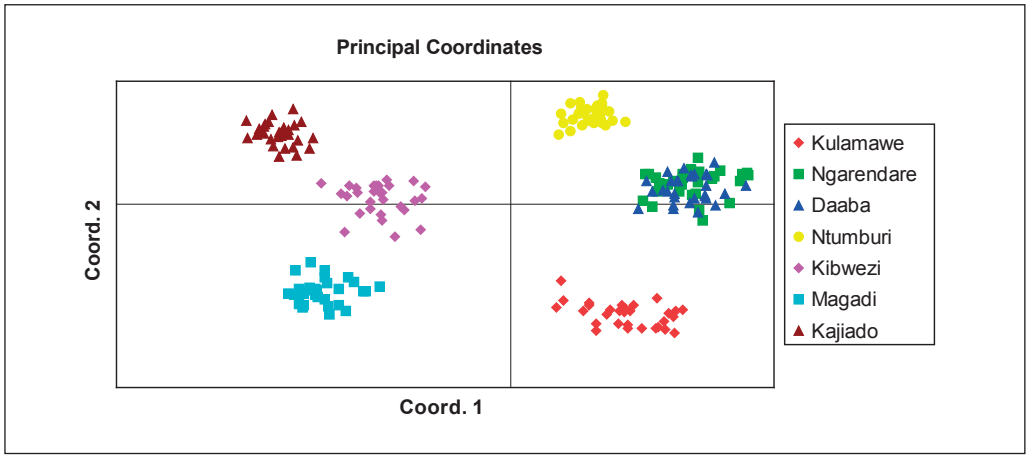
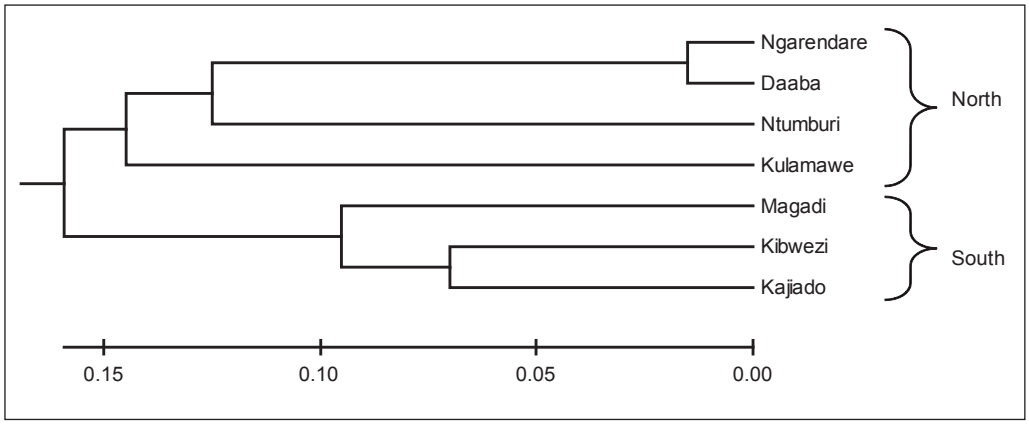


Figure 3. *Cluster analysis of the seven populations of* A. senegal *using PCA analysis*



Discussion

Seven populations of *Acacia senegal* showed high genetic diversity (H_{ISSR} = 0.211, H_{cpSSR} = 0.212). This diversity is higher than that reported for isoenzyme markers of *A. senegal* populations from seven countries, which ranged from 0.17 to 0.175 (Fagg and Allison, 2004). The high level of genetic diversity observed in this study is consistent with the wide geographical distribution of the species in Kenya. However, this diversity is lower than that reported by Chiveu *et al.* (2008): mean diversity of 0.283, but without discriminating the varieties used.

Although current differences among *A. senegal* varieties are based on variation in natural distribution and morphological characteristics (Fagg and Allison, 2004), variety *kerensis* showed a high genetic diversity compared with the other two varieties studied. This is in agreement with a recent study by Omondi *et al.* (2009). This variety is the main source of commercial gum arabic in Kenya, and its gum also shows high variability in physico-chemical properties (Chikamai and Banks, 1993). *Acacia senegal* var. *leiorhachis* had the highest genetic distance with the largest number of private alleles. This suggests genetic isolation of this variety, which should be considered in conservation. The lack of chloroplast diversity among Daaba and Ngarendare populations (both representing variety *kerensis*) suggests that they may have originated from a single lineage.

AMOVA detected significant differences within and among populations. Greater genetic diversity demonstrated within than among populations is a characteristic of long-lived perennial tree species with wide geographical distribution. This is brought about by exclusive out-crossing mating systems which do not allow the species to self-pollinate. Studies have shown that *A. senegal* is an exclusively out-crossing species with self-incompatibility traits; the high diversity within a population can be brought about by efficient and effective gene flow between populations through pollen transfer (Omondi *et al*., 2009). The UPGMA dendrogram of the seven populations revealed two groups of populations: north and south regions in Kenya. This was in agreement with the geographical distribution of the species, with the geographically close populations having a short genetic distance. This indicates gene flow between populations that are at proximate geographical locations.

This study shows that there is genetic diversity and variation among and within the three indigenous varieties of *A. senegal* in Kenya. However, domestication of these varieties may prove effective in identifying their environmental adaptation. This should be directed by assessing the better performing provenances that have good gum arabic production, as well as potential for rehabilitation of degraded lands. The study also demonstrates the ability of ISSR and cpSSR markers to delineate the population structure and infraspecific relationships among Kenyan *A. senegal* populations. This study provides baseline genetic information for the domestication of *A. senegal* varieties in Kenya, and may prove vital for the conservation and sustainable use of the species in the region.

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Cassava: Adding Value for Africa – Gender and Diversity as a Driving Force

Petra Abdulsalam-Saghir[1]

Keywords: gender mainstreaming, cassava farmer, village processors, vulnerable groups

Abstract

The Cassava: Adding Value for Africa (C:AVA) Project explores the strategic and practical gender needs of major actors in the cassava value chain in Nigeria, analyses gender roles, explores access to and control of resources, and is influencing social relation factors (e.g. gender role reversal) along the value chain. The data were analysed qualitatively using brainstorming sessions, descriptive statistics and discussions within a multidisciplinary group. Women's participation in the project has increased from fewer than 10% (of female farmers and processors) at the beginning to more than 85% at all levels of the value chain. The ability of men and women to access resources in the cassava value chain differs in many locations. Opportunities and financial benefits from cassava production and processing are contributing to changes in gender roles and responsibilities, with a financial increase of over £50 (€60) per month for both men and women as a result of C:AVA capacity enhancement. The study concluded that, for successful project intervention and transformation of smallholder farmers and their households, interventions need to be gender-inclusive because gender-based constraints affect the structure and relationships of value chains. The project is therefore helping vulnerable groups to prioritise in terms of opportunities for older women in polygamous marriages as well as women-headed households, widows, youth and men in project activities.

Introduction

The Cassava: Adding Value for Africa (C:AVA) Project, funded by the Bill and Melinda Gates Foundation, started in Nigeria in May 2008 and will run until 2012. It seeks to develop value chains for high-quality cassava flour (HQCF) to provide ample opportunities for interconnectivity of market access, gender and smallholder farming enterprises and in micro-, small- and medium-scale enterprises. C:AVA focuses on three key intervention points in the value chain: (1) ensuring a consistent supply of raw materials; (2) developing viable intermediaries acting as secondary processors or bulking agents in value chains; and (3) driving market demand and building market share (in, for example, the bakery industry and components of traditional foods or plywood/paperboard applications). C:AVA strategies identify the participation of smallholder farmers as a critical feature of agricultural development, success and sustainability by recognising that women comprise the vast majority of smallholder farmers and food producers, given their dual responsibilities/roles in reproduction and production in rural households, which are not formally recognised or acknowledged (Kabeer and Subrahmanian, 1999).

1. Natural Resources Institute, University of Greenwich, Chatham, ME4 4TB, Kent, UK.

C:AVA also believes that in order to achieve dramatic and sustainable improvements in the lives and wellbeing of smallholder farmers, it must offer innovative and transformative approaches to development challenges that engage, empower and invest in women and the disadvantaged for the long term, especially where control, ownership and management of resources are defined by cultural and context specific gender roles (Bill & Melinda Gates Foundation, 2008).

The study was conducted by specialists from the Natural Resources Institute, University of Greenwich, UK in collaboration with University of Agriculture, Abeokuta, Nigeria and the International Institute of Tropical Agriculture (IITA).

Materials and methods

At the conceptualisation stage, the multidisciplinary team (including a social development expert, agricultural economists, value-chain experts, food scientists, agronomists, agricultural extension officers and a gender specialist) decided to mainstream the gender study along with the value-chain analysis and scoping studies to fully exploit the natural interactions along the value chain and recognise the intricacies inherent in the system. The gender and diversity components of the value-chain analysis commenced between 19 June and 4 July 2008, and were carried out within the scoping study from 17 to 31 August 2008; the gender audit took place in September 2009, and the baseline study was ongoing at the time of writing (August 2010).

Primary data were collected on the strategic and practical gender needs of respondents; gender roles; access to and control of resources; and social relations along the value chain. Collection methods were participatory rural appraisal and rapid market assessment, focus group discussions, one-to-one interviews with key informants in the cassava sub-sector, and self-assessment questionnaires with an interview guide. The study covered three main cassava-processing states in south-west Nigeria – Ogun, Oyo and Ondo states.

In each state, the local government areas with the highest level of involvement in the cassava value chain were identified in collaboration with local partners. Subsequently, the villages and market centres where most cassava processing and marketing took place were identified with local extension officers and staff of relevant non-governmental organisations (NGOs). In each study location, interviews were carried out with all available small and medium-sized enterprises (SMEs), processors, men and women farmers' groups, service providers, micro-processors (who are all women), village processing units (VPUs – these are mainly men who operate graters and other mechanical processing equipment in the village), farmers' associations and local leaders.

In the case of women and men farmers and processors, the interviews were carried out in groups of 10–20. The data were then analysed with the use of descriptive and qualitative analysis, using brainstorming sessions within the multidisciplinary group that conducted the study.

Results and discussion

Strategic and Practical Gender Needs of Farmers and Processors

The major stakeholders in the cassava value chain are farmers, processors, SMEs that own HQCF dryers, processors, VPUs and various levels of local leadership (Table 1). Cassava is a

Table 1. Major stakeholder categories, their roles and location

	Number of respondents			
Stakeholder category	**Ogun**	**Ondo**	**Oyo**	**Overall**
SME (owner of dryers)	2	2	1	5
Men farmers' group	9	14	1	24
Women farmers' group	8	5	1	14
Service provider	8	4	0	12
Micro-processor (women)	8	6	1	13
VPU	1	2	1	4
Farmers' association	0	1	2	3
Male and female youth	0	1	0	1
Local leader	2	1	0	3

priority crop for food security and income generation for all the smallholder farmers (men and women) in the selected states. The high intensity of cassava cultivation is a response to high demand for cassava products such as *gaari*, *fufu*, *lafun* and *pupuru*, and more recently to the high and regular demand by existing and emerging starch, ethanol and HQCF factories. Farmers ranked cassava first among food and cash crops in communities that have easy access to the *gaari* markets and in areas with low soil fertility. The only exceptions were Ita Ogbolu and Elere Adubi villages, where cassava was ranked second after yam. It was ranked second in the forest and forest-transition belt, where cocoa and yams are the dominant income generators.

In general, there are economic (indicated by 95% of participants), cultural (70%) and social (70%) barriers to the participation of women and the poor in cassava value-adding activities. The main constraints are financial (85%), time availability (80%, especially for women with small children, who are limited to dealing in local markets for their produce rather than marketing in the larger urban centres), technologies that are uncomfortable to use (90%, e.g. traditional *gaari* roasters), limited capital to purchase raw materials (92%), and lack of credit facilities to invest in improved equipment (85%). Most women in the study had very low levels of formal education. A further factor is that innovations with potential to generate a significant cash flow attract local elites and often become dominated by men (men had access to formal credit facilities because they had collateral, such as land property, and could easily find guarantors for loans). The strength of the current system is that women village-level processors are relatively autonomous, can integrate production and processing, can work at their own pace and can retain the income from the sale of their products. Due to a variety of push and pull factors, youths leave for major cities and towns for better opportunities. This adds to the vulnerability of elderly women and men.

Gender Roles According to Productive, Reproductive and Social/Community Roles

The cassava value chain reflects different gender roles for men and women in production and processing activities. Due to their position in the labour market, women are typically found in low-status work and at the bottom of the value chain. Women are responsible for the majority of cassava harvesting, processing and transportation, while men are often associated

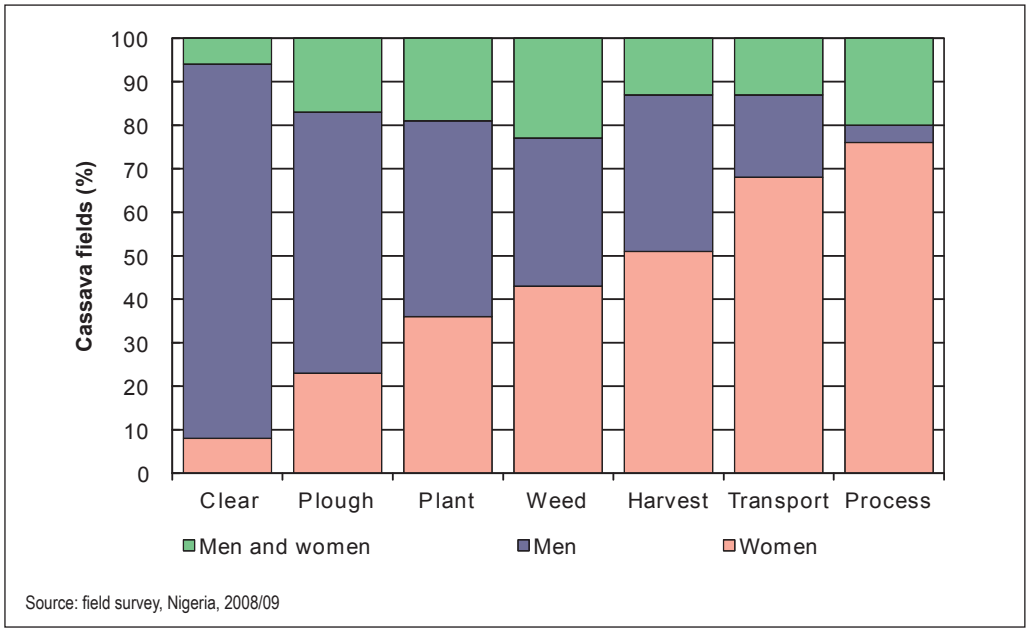

Figure 1 *Percentage gender division of labour in cassava production and processing*

with the farming (Fig. 1). Women's role in cassava processing is highly labour intensive and largely non-mechanised. However, men's involvement increases as processing becomes more mechanised and commercialised.

Opportunities and financial benefits from cassava production and processing are contributing to changes in gender roles and responsibilities. Women are more empowered financially and are doing many things that were traditionally seen to be men's responsibilities – for example, they have more money available for household needs, and they even lend money to their husbands. More negotiation takes place around allocation of responsibility for household activities, such as men looking after the children when women are engaged in processing (although this is not frequent).

A great concern among women is that their husbands will spend any increase in their income in acquiring an additional wife, with the consequence that his financial support to the established unit will be reduced, or that the first wife will be abandoned. An increase in men's real income could come about either through men accessing women's income or, more commonly, the substitution of women's earnings from cassava processing for men's expenditure on household needs and children's education.

> "Women are under the authority of their husbands and their extended families. They [husband's extended family] see her as 'my' wife as much as her husband, and she must respect them. We have tried skilfully to tell them that all of us are equal, especially in order to improve the quality of life and that they should not be surprised that females can excel. There is gender discrimination, but at least women are now saying they can do things for themselves."
> (Male extension agent).

The dimensions of vulnerability not only include gender- and age-related factors as described above, but also poverty, disability and poor health for both women and men. Old men and women are also vulnerable when they can no longer work. Differentiation in relation to poverty was not immediately apparent within the villages visited. When asked what characterises the poorest members of the village, women replied that "someone who is poor usually cannot come out and say they are poor; you can tell by their clothing and health. They are also socially withdrawn – if there is no money you cannot meet up with your friends socially."

However, women attributed the causes of poverty to unwillingness or inability to work, or to wasting money:

> "There's no other way out of poverty aside from working. As your husband works, you also must match that and meet society. With that you will be respected."

Gender Differences in Access to and Control of Resources and Factors Influencing Social Relations

Access to and control of land, information, technologies, human resources, social capital and financial resources is central to the success of any business endeavour. The ability of men and women to access these resources in the cassava value chain differs in many locations. Specific instances are explained below.

- Land was widely considered to be physically available in all the communities visited. However, there were some variations at both state and individual levels. For example, in Ogun State, the ability of men to access land was very high compared with that of women, who depended on their spouses to access land, or hired land from men at a price that may not be affordable. In Ondo State and Akufo in Oyo State, many farmers leased land for agricultural purposes, and there was less of a divide between women's and men's abilities to access land.
- Mobile phones, radio and television provide opportunities to access information from outside farmers' communities. Radio ownership was very common, while TVs were much less available but were found in some of the communities visited. Mobile phones were becoming increasingly common: about 70% of participants (men) owned mobile phones. Men had more access to information than women because they were more socially mobile than women.
- The shortage of youths and the high cost of labour were common to most, if not all, the communities visited. Women hired labour and also engaged themselves in cassava production just like men, but men engaged the labour of their spouses and children.
- Men had more access to technology than women because most of the technologies available were not women-friendly in terms of handling.
- Knowledge and decision-making ability appeared to differ between men and women, and their analytical skills were used differently, leading to differences in motivation and actions. A major concern of most of the women consulted was the need to make enough money to sustain their families. Women in Owe Village, in Abeokuta explained that they "Cannot put a value on the total income, but when we sell *fufu, gaari* and *lafun* we tend to meet our family's needs and you can never be poor." Though discussions and negotiations

on livelihood issues took place between husband and wife, men often took final decisions on matters concerning health, production, processing and proceeds from sales.

- Women as well as men were often highly organised and involved in group formation in order to meet their social needs and those of their group. However, these skills in group formation did not appear to be applied very frequently in cassava production, processing or marketing because of the role of intermediaries.
- Ability to access financial capital (e.g. formal and informal credit) was very limited. Men appeared to have more access to formal credit than women because they were the owners of collateral. On the other hand, access to informal credit was balanced for men and women, as the value of a group loan is a function of how much each member of the group has contributed into the common purse.

The C:AVA project impacts were spreading from Ogun and Ondo States to the neighbouring states of Ekiti and Oyo. About 5,000 individual farmers were benefitting (by August 2010) and the multiplier effect of that was becoming more evident among and within households (all stakeholders). Farmers and farmer–processors were supported in production, primary processing activities and capacity building. Incomes of smallholder households had increased significantly by £50 (€60) per month (additional earnings realised through value addition) and women's participation in the project had soared from fewer than 10% at the beginning to more than 85% at all levels of the value chain. Additional benefits of C:AVA intervention included youth employment at the village and intermediary levels, reduction in raw material costs for end users, reduction in the need to import wheat (particularly relevant with increasing prices), development of the capacity to upgrade other similar food-ingredient value chains, and, where comparative advantage existed, the opportunity to export HQCF and legislation to include 10% HQCF in wheat to form composite flour. The project had also increased agricultural productivity through diffusion of high-yielding, disease-resistant cassava stems, and enhanced the opportunities for new entrants into cassava processing via the use of user- and women-friendly equipment. Rural livelihoods were guaranteed through access to sustained markets for raw materials of HQCF (producers benefit), wet cassava cakes, dry chips and suppliers of HQCF (processors benefit).

The concept of gender was understood in more practical terms, instead of taking the more strategic approach that emphasises challenging gender roles and reducing structural gender inequalities. A common split was between production activities for men and processing activities for women. However, this ignores the other roles women play in agriculture, such as planting, weeding and harvesting. In addition, because women generally have control over activities on their own plots, it makes more sense also to expose them to activities in agricultural production other than processing, and to enhance their capacities along the whole cassava value chain.

Conclusion

The C:AVA Project in Nigeria has had successes because it has factored into its programme a more gender-equitable development system, by recognising that gender is not about women alone, but is about recognising specific gender roles and needs in programme effectiveness.

As cassava production is expanding from food-production to income-generating activities, it is important to recognise specific roles of men and women in its value chain. The project is therefore helping vulnerable groups to prioritise in terms of opportunities, to include older women in polygamous marriages, and to include women-headed households, widows, youths and men in project activities.

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Development of Endiisa Decision Support Tool for Improved Feeding of Dairy Cattle in Uganda

Sarah L. Mubiru[1], Peter Wakholi[2], Annuciate Nakiganda[3], Harriet Ndagire Sempebwa[4], Agnes Namagemebe[3], Jimmy Semakula[5], Ali Lule[6] and Peter Kazibwe[7]

Keywords: crude protein (CP), feed combinations, metabolisable energy (ME), milk production, nutritional requirements

Abstract

Efforts to improve livestock feeding in Uganda have made great strides in identifying nutritious feed resources for cattle. These feed resources include pasture grasses and legumes, leguminous shrubs and multi-purpose trees, crop residues and agro-industrial by-products. Despite this knowledge and, in some cases, use of the appropriate feed resources, milk production on dairy farms has remained low, in the range of 2–5 L per cow per day. This poor performance indicates a gap in the knowledge disseminated to farmers with regard to cattle feeding. One major knowledge gap in Uganda was that farmers did not know the quantities of feeds that would adequately meet the nutritional requirements of their animals. As a result, the farmers only provided 59 and 36% of the required metabolisable energy and crude protein, respectively, to their animals. Thus it was necessary to develop a mechanism by which farmers could establish adequate nutritional feed quantities for their cattle even when they combine a variety of feeds. One practical means of achieving this was through the use of a decision-support tool (DST), which was one of the major outputs of this research. In conclusion, the study provided information on the low status of dairy cattle feeding in the central zone. The DST that was developed and tested led to improved cattle feeding status, and increased milk production by 24%. The tool, available on the website of the National Agricultural Research Organisation (NARO-Uganda), should be recommended for use by farmers, researchers, trainers and policy-makers. A mechanism should be established for regular updating of the DST to include new feed resources and incorporate emerging information.

1. National Livestock Resources Research Institute (NaLIRRI), PO 96, Tororo, Uganda (current address: Association for Strengthening Agricultural Research in Eastern and Central Africa [ASARECA], PO Box 765, Entebbe, Uganda).
2. Faculty of Computing and Information Technology (CIT), Makerere University, PO Box 7062, Kampala, Uganda.
3. NaLIRRI, PO 96, Tororo, Uganda.
4. Kulika Charitable Trust, Uganda.
5. Mukono Zonal Agricultural Research and Development Institute (MuZARDI), Uganda.
6. National Agricultural Advisory Services (NAADS) Coordinator, Kayunga District Local Government, Uganda.
7. NAADS Coordinator, Luwero District Local Government, Uganda.

Introduction

Dairy production makes a significant contribution to incomes, nutrition and general livelihoods for a large number of households in Uganda. It contributes 54–98% of household incomes for mixed crop–dairy farms in the Lake Victoria crescent (Mubiru *et al.*, 2007). However, milk production was found to be very low – averaging about 2,400 kg per cow per lactation from cross-bred (Holstein Friesian × Small East African Zebu) cows, which is approximately 50% of their milk production potential. Previous studies showed that farmers provided only 59 and 36% of the minimum required metabolisable energy (ME) and crude protein (CP), respectively, to their dairy cattle (Mubiru *et al.*, 2003). Poor cattle nutrition resulting from inadequate feeding was a major contributor to the low levels of milk production. A stakeholder meeting with farmer participation identified the major source of the under-feeding problem as a lack of clear information on how to feed dairy cattle. Farmers indicated knowledge of the high-value cattle feed resources; however, they had no knowledge of the quantities to feed. The major intervention deemed appropriate to respond to this was the development of a mechanism that would assist farmers in knowing the appropriate quantities of feeds to offer to their cattle in order to, at least, meet their minimum nutritional requirements.

Materials and methods

Through a brainstorming process, a team of scientists (four female and four male) from the National Livestock Resources Research Institute (NaLIRRI), Makerere University, Kulika Charitable Trust–Uganda, Mukono Zonal Agricultural Research and Development Centre (MuZARDI) and the National Agricultural Advisory Services (NAADS) agreed that the prudent solution would be to develop a computer-based decision-support tool (DST). The team also agreed that the DST should have the capacity to generate least-cost feed combinations for farmers on the basis of available feed resources to enable profit maximisation. The DST would benefit dairy farmers through three main channels:

- farmers who had access to computers and were computer-literate would, using the DST, carry out proper planning of the feeding of their dairy cattle – this would be an option not only for farmers with personal computers, but also for those living in close proximity to farmers' resource centres, numbers of which are growing in Uganda;
- extension advisors (government and NGO) would receive information from farmers on their cattle types and available feed resources, and use this information in the DST to generate cattle-feeding schedules for the farmers;
- researchers could incorporate all new feed resources and strategies into the DST to evaluate mechanisms for their use.

The team embarked on a process in two dairying districts of Uganda: Kayunga and Luwero. The four-stage process involved: (i) a baseline study; (ii) DST development; (iii) DST testing; and (iv) uploading the DST onto the NARO website and collecting stakeholder feedback. The baseline study covered 106 representative dairy farms, and used a structured questionnaire to collect data on household characteristics and production inputs and outputs, with major focus on dairy. Of the study households, 84% were male-headed with a husband and wife, the rest

were female-headed households. Data collected from the baseline study were analysed using GenStat (Discovery Edition, version 3) to establish the proportion of farmers providing less than the required ME and CP to their dairy cows. In addition, *t*-tests were used to study differences in milk production where feeding was adequate compared with situations where feeding was inadequate. Simple linear regression was used to study the effects of ME and CP, separately, on milk production. In this case, milk production (L per cow per day) was the dependent variable, and the proportions (%) of the daily requirement of ME and CP provided were the independent variables.

Data from the baseline survey were also partly used in developing the DST. This incorporated information on feed resources used in the study area. Cattle feed requirements and feed nutritional values in terms of ME and CP were obtained from information generated from previous research in Uganda. The DST was uploaded on the NARO-Uganda website prior to the testing phase. This was done to obtain ideas for improvement of the DST before its release to the general public. Testing of the DST was carried out on six farms selected from those where data were collected during the baseline study. This was done to evaluate selected feed combinations generated from the DST: the ability of the cows to consume all the feed, and the effect on milk production. Data on milk production were collected before and after implementation of the feeding regime developed from the DST, and tested using paired *t*-tests in Genstat. After the testing phase, the DST was revised and two stakeholder feedback workshops were held, one in each of the districts of Kayunga and Luwero. The workshops – which were largely attended by farmers, extension advisors and policy-makers – aimed at dissemination of the DST, explaining its mode of use, describing the benefits that could be realised through its use, and obtaining stakeholders' views on it.

Results

Survey

The baseline survey showed that only 24 and 28% of farms in the study area were providing dairy cows with their daily minimum ME and CP requirement, respectively. Where the nutrition was inadequate, on average only 49% of the minimum ME and 52% of the minimum CP requirement was being provided to the dairy cattle. Milk production was 26% higher where feed offered provided the minimum nutritional requirement compared with farms where it did not. The regression analysis showed that the effects of both ME and CP on milk production were positive, with closely related levels (Table 1). Metabolisable energy and CP each accounted for about 14% ($P < 0.1$) of the variation in milk production on the farms.

Table 1. Effects of quantities of ME and CP provided to dairy cattle on milk production in Kayunga and Luwero districts, Uganda*

Variable	Regression coefficient	R^2	*F*
Proportion of daily requirement of ME	0.51	14.0	0.07
Proportion of daily requirement of CP	0.54	14.3	0.07

*ME, metabolisable energy; CP, crude protein.

Decision-support tool

A DST was developed with the capacity to generate feed combinations from 22 types of feed resources commonly used by dairy farmers. Feed combinations and their costs could be generated for lactating cows of weight 350 kg and above. The DST, which was named 'Endiisa' by the research team, generates feed combinations based on the specific cow CP and ME requirements and the CP and ME contents of the feed resources. The word '*endiisa*' means 'feeding' in Luganda, which is the most widely spoken local language in Uganda. The DST can be accessed and used via the internet (Mubiru *et al.*, nd).

Two of the feed combinations generated from the DST and fed to the test cows are shown in Table 2. These were developed for a daily ration for a lactating cow of 4–6 lactations in its early stage of lactation (1–3 months) and weighing 450 kg.

Table 2. Feed combinations generated from the decision-support tool for cows of four to six lactations weighing 450 kg and in the early stage (1–3 months) of the lactation cycle

Sample feed option 1	Quantity of feed component	Sample feed option 2	Quantity of feed component
Elephant grass (kg)	53.3	Elephant grass (kg)	53.5
Maize bran (kg)	2.5	Banana peel (kg)	23.5
Lablab (kg)	23	Lablab (kg)	23
Total (kg)	79	Total (kg)	100
Cost of formulation (UShs)	1,515	Cost of formulation (UShs)	1,000

Overall feeding of the DST-calculated feed combination to cross-bred (Zebu × Friesian) cows in the early lactation period (1–3 months) of four to six lactations increased daily milk production by 3.6 L per cow (24% increase; $P < 0.05$).

Stakeholder workshops

The stakeholder feedback workshops in the two districts were attended by 120 participants. These included farmers, extension advisors, NGOs, researchers and policy-makers. During these workshops, presentations were made on the research findings and description of the Endiisa DST, and comments and questions from participants were received and, where possible, addressed.

Dissemination

For further dissemination of the DST, the following activities were carried out:

- an article was published in the Ugandan print media – *The New Vision* daily (Nyapendi, 2009);
- a leaflet on Endiisa was produced;
- a booklet summarising the research was produced and the results, including the use of Endiisa, were also circulated;

- the DST was put on computer storage media (USB drives), which were circulated in the major dairying districts where internet access is still a challenge.

Discussion and conclusions

Much of the dairy cattle feeding in the Central zone of Uganda is inappropriate, with most farmers offering feed providing less than the minimum nutritional requirement for dairy cows; as a result, milk production is low. Metabolisable energy is a critical source of energy for maintenance and production, and CP contributes greatly to milk production. Metabolisable energy and CP each account for about 14% of the variation observed in milk production. It is expected that the rest of the variation is caused by other factors, such as cattle breed, age, lactation stage and other nutritional components. If available feed resources are acquired and fed in the appropriate quantities, the required CP and ME can be provided to dairy cattle, and this will lead to an increase in milk production.

The Endiisa DST, developed as one of the outputs of this project, is a tool for the development of feed formulations/mixtures that provide the required nutrition for dairy cows at least cost in Uganda and similar agro-ecological zones, particularly in parts of eastern and central Africa. Endiisa is a valuable tool for policy-making with regard to feeding dairy cattle. Currently, Endiisa can be used only for milking cows weighing 350 kg and above. The tool will be improved over time to handle more applications, using inputs provided by users who take the time to post their comments on the website.

The tool will also:

- reduce time wastage through uncertainty about the quantities of feeds to prepare for dairy cows;
- enable conservation of feed when feed resources are in excess, for use in the dry season;
- enable development of long-term feeding plans and programmes;
- control feeding disorders, such as bloat, that result from feeding excess protein.

Endiisa, being computer based, will be particularly attractive to the younger generation of farmers, and will provide an incentive for older farmers to develop computer skills. In addition, the tool has prospects for incorporation into a mobile (cell) phone mechanism whereby farmers can receive feedback regarding least-cost feeding options based on information they send to farmers' resource centres or extension staff on their available feed types and cattle characteristics. This system, using short messaging service (SMS), would increase access to the DST, as most farmers have mobile phones.

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Contribution of Rice and Vegetable Value Chains to Food Security and Incomes in the Inland Valleys of Southern Benin and Mali: Farmers' Perceptions

A. Sounkoura[1], C. Ousmane[1], S. Eric[1], D. Urbain[2] , A. Soule[3], P. Sonia[1] and H. Joel[4]

Keywords: Benin, cropping systems, financial profitability, Mali, productivity, rice–vegetable, value chains

Abstract

The intensification and diversification of rice and vegetable cropping systems in inland valleys contributes to food security and significant incomes. Major problems for the sustainable use of inland valleys are the degradation of natural resources and increased pollution related to population growth; insect pests and plant diseases; and poor access to input and product markets for intensification. Intensifying inland-valley systems will require the promotion of a high-value commodity-chain system involving rice and vegetables, with increased productivity and low per-unit cost of production and natural resources. The Africa Rice Center project reported here fits well into this framework of promoting rice and vegetable value chains while protecting natural resources. This study identified production systems, assessed their constraints, and analysed the profitability of best-bet rice and vegetable cropping systems. A sample of 235 producers was selected in Benin and Mali according to input use and access to product markets. Four main value-chain stakeholders operate in the inland valleys: producers, processors, traders and consumers. This study focuses on producers. The major constraints reported by farmers were attacks by insects and birds, poor access to product markets, and the unavailability of key inputs (seeds, pesticides, small equipment) in both countries. Other constraints were high costs of transport, post-harvest losses, and poor conservation of fresh vegetables and tubers. The most profitable systems in the inland valleys were those based on rice and a vegetable (*gboma*, a *Solanum* species) using improved seeds, followed by the system containing rice and *gboma* using improved varieties of rice such as NERICA, plus chemical fertilisers and herbicides. Rice associated with improved varieties of potato and mineral fertilisers was more profitable in Mali. Rice as sole crop is not profitable in Benin, mainly in Vovokanmey. Women are more involved in the sole cropping of rice in Mali.

1. International Institute of Tropical Agriculture, Cotonou, Benin.
2. Institute of Rural Economy, Sikasso, Mali.
3. National Agricultural Research Institute, Benin, Agricultural Policy Analysis Programme, Porto-Novo, Benin.
4. Africa Rice Center, Cotonou, Benin.

Introduction

Background and Rationale

In Sub-Saharan Africa, inland valleys account for a substantial amount of the land capital for development and intensification of agricultural production. However, food and nutritional insecurity and rural poverty are increasing, aggravated by the decline in soil fertility linked to the degradation of natural resources in the inland valleys. Furthermore, rapid population growth without accompanying agricultural technologies has increased the pressure on arable lands. This has led to the shortening of fallow cycles and reclamation of marginal lands, particularly in densely populated regions (Adégbola, 1997). Despite the efforts of research institutions in Benin and Mali to deal with this problem through research and dissemination of a vast number of fertility-management technologies, adoption and dissemination have not followed. Less than 10% of the inland valleys and floodplains is being developed (Adégbola *et al.*, 2006).

Developing inland valleys through intensification and diversification increases the productivity of rice-based and vegetable systems, and contributes to food and nutritional security and substantial increases in agricultural and non-agricultural incomes. Case studies of the inland valleys in Benin and Mali reveal that they have potentially available arable lands estimated at 205,000 and 300,000 ha, respectively. In Benin, since the 1990s the degradation of rainfed agricultural lands and demographic pressure on land have encouraged a movement towards the diversification and intensification of the inland valleys. Rice and vegetable farming are attractive income options for small-scale farmers, as they can be integrated and complementary in the inland valleys, depending on the climatic conditions and market signals (FAFA, 2009). In southern Mali, inland valleys account for 11% of national paddy rice production, a substantial proportion of fruit production (mango, citrus and banana), vegetables and tubers (sweetpotato and cassava), and almost all of the region's annual crop of 50,000 t of potato. During the dry season, an increasing number of cattle use the inland valleys for grazing and watering (Ahmadi and Teme, 1996; Dacko *et al*., 2006). Previous studies indicate that 16 and 6% of available lands are cultivated in Benin and Mali, respectively (Adégbola *et al*., 2006; Dacko *et al*., 2006). Rice production and vegetable farming are income-generating activities for producers, especially women, in rural and urban communities in southern Mali.

Objectives

The general objective of this study was to promote value chains based on the most profitable farming systems with a low environmental cost in southern Benin and Mali.

Specifically, this study was intended to:

- identify and classify various people involved in rice and vegetable value chains (both existing and potential);
- identify the main farming systems in inland valleys;
- identify the constraints and opportunities linked with intensifying systems and promoting innovation in inland valleys;
- evaluate the financial profitability of rice and vegetable farming systems.

Methodology

This study was carried out in Benin and Mali, where inland valleys represent significant potential for the intensification and diversification of farming (rice, vegetable and cotton cultivation, and fish farming). The sample of people involved in the value chains represented four categories: producers, rice processors, traders, and consumers of products from the inland valleys in southern Benin and Mali. Two hundred and thirty-five people were selected, including 17 rice processors, 37 traders and 134 consumers. The value chains were analysed to determine the potential for adding value in each segment of the chain (for rice, potato and vegetable production systems), with a view to enhancing the contribution of the chains in improving food and nutritional security and reducing poverty (through income generation while preserving natural resources). Descriptive statistical methods were used (frequency, averages and standard deviations), including economic analysis. The descriptive analysis helped to characterise the farming systems. The economic analysis revealed the current levels of profitability of the farming systems. Costs of production and some economic indices (gross output, added value and operational results) were calculated.

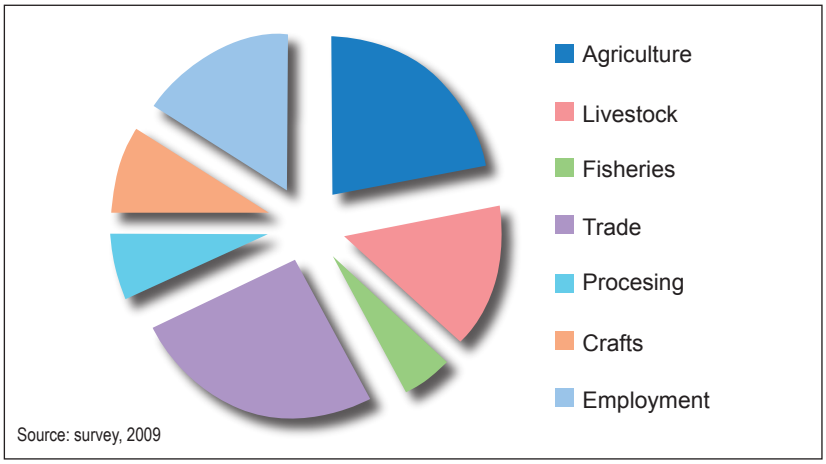
Results and discussion

Socio-economic Characteristics

The findings showed five groups of people who play a key role in the value chains: input suppliers (seeds, pesticides, fertilisers, etc.), producers, processing enterprises, traders, and consumers (Fig. 1).

The main producers are the rice, potato and vegetable farmers, fisherfolk, cattle farmers and tree growers. The processing activities are carried out by men, women, old and young people in Mali (Sidibé, 2008). There are few traders in inland-valley production systems in either country, showing the limited role of the private sector, which needs to be strengthened for promotion of the value-chain systems through intensification. Four types of traders were identified in the inland valleys: wholesalers, retailers, primary collectors and secondary collectors.

Figure 1. *Activities carried out in the inland valleys in Benin and Mali*



Financial Profitability of Farming Systems in Inland Valleys in Benin and Mali

Among the systems identified (Table 1), in Mali the system based on rice monoculture, followed by the system based on rice and potato using inorganic fertiliser (compost at 150 kg ha^{-1}), and then by a system based on rice and potato combined, were the most profitable in the inland valleys. In Benin, the rice–vegetable system (*gboma*, *Solanum* sp.) using improved seeds, followed by the rice-based system and *gboma* using NERICA-type[5] improved rice varieties (plus chemical fertilisers and herbicides for rice), were the most profitable systems. The rice monoculture system with inorganic fertiliser and herbicides was the least profitable in Benin, as a greater quantity of the rice produced is sold uncut because of cash-flow problems. These results agree with those obtained by Chalabi (1994) for Faranah production units in inland valleys in Guinea.

The production is purchased by a trader who, in turn, provides seasonal credit to the producer. Women engage in rice farming during the rainy season and vegetable growing during the off-season. In Benin, the most commonly used systems are: rice–vegetable farming system using improved NERICA rice varieties, improved *gboma* variety, fertilisers and herbicides; and rice and *gboma* (unimproved *gboma* variety), using improved NERICA varieties with chemical fertilisers and herbicides for the rice. Meanwhile, sole cropping of rice (recorded in one season only) was financially less profitable for producers in the sites of Benin.

Table 1. Financial profitability of rice and vegetable farming systems in Benin and Mali

Country	Farming system (basis of)	Net margin
Benin	Rice–*gboma* (improved *gboma* variety + NERICA + fertilisers + herbicide)	642,640
	Rice and *gboma*	617,028
	Rice–*gboma* (local variety)	211,433
	Crincrin and rice	182,286
	Rice monoculture	–134,025
Mali	Rice monoculture	428,971
	Rice–potato (improved potato variety + inorganic fertiliser)	425,886
	Rice and potato	414,174
	Rice and potato, associated with sweet potato	352,648
	Rice and potato, associated with eggplant	18,563

Source: survey, 2009.

Constraints and Opportunities Linked with Farming in Inland Valleys

The main constraints mentioned by the producers in inland valleys in Benin and Mali were the strenuousness of farming activities; attacks by birds on rice and potatoes, and by insect pests on vegetables; the difficulty of storing rice and potatoes; poor access to agricultural credit for purchasing inputs and the payment of labourers' salaries; and lack of market opportunities from the inland valleys (Fig. 2). However, the frequency of these constraints differed between the countries: difficulty of farming work was by far the most common constraint in Benin, followed by lack of commercial outlets to sell the products, and attacks by rodents (mainly mice). Poor

5. NERICA – "New Rice for Africa": interspecific progeny of the two domesticated rice species (*Oryza sativa* and *O. glaberrima*), originally developed by the Africa Rice Center.

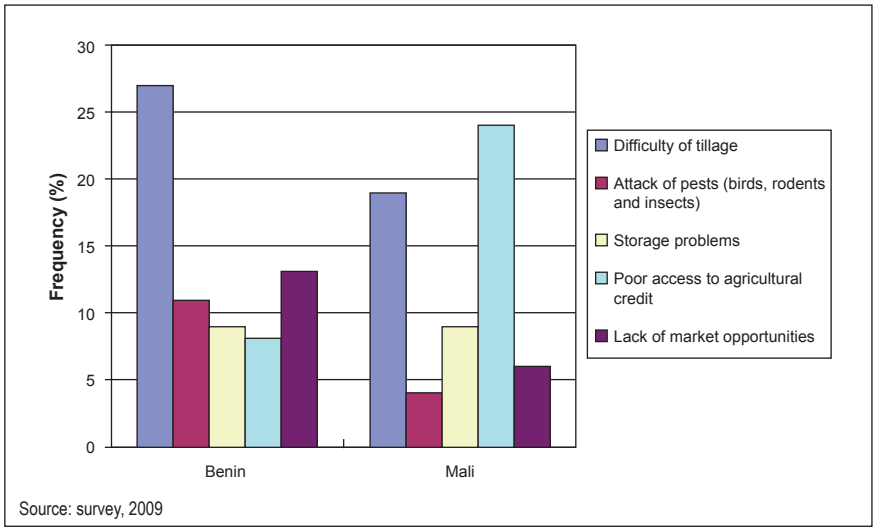


Figure 2. *Constraints faced by producers in Benin and Mali*

access to credit facilities was emphasised by the producers in Mali. Storage difficulties, equally prevalent in the two countries, result from inadequate facilities for drying and the unnecessarily long period of drying, leading to the products becoming mouldy or being contaminated by fungi. It was observed that technical monitoring and capacity building were very low among vegetable producers in the study locations.

Conclusion

The four categories of people involved in the value chains in the inland valleys of the two countries are: producers, processing firms, traders and consumers.

The economic analyses of the different farming systems showed that in Benin, the farming systems geared towards the production of rice and *Solanum* were the most profitable, and the use of inputs (pesticides, herbicides) enhanced the profitability of these systems. In Mali, the rice monoculture system was the most profitable, followed by the rice–potato system with inorganic fertiliser. The monoculture rice system was the least profitable in Benin, mainly Vovokanmey. In Mali, rice monoculture is undertaken solely by women during periods of flooding. In Benin, women have limited resources and limited leverage in terms of their capacity to access inputs and credit. Solutions must be sought to address these constraints by way of innovations for producers through research for development and capacity building. This could also be done through mechanisms for dissemination of information and knowledge through information and communications technology (ICT) and farmers' forums for demonstration of technological and organisational innovations.

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Breeding for Cassava Brown Streak Disease Resistance in Coastal Kenya

T.L. Munga[1]

Keywords: combining ability, grafting, inoculation

Abstract

Cassava (*Manihot esculenta* Crantz subsp. *esculenta*) productivity in coastal Kenya is low, partly due to susceptibility of the popular varieties to cassava brown streak disease (CBSD). Host resistance is the most economical method to control CBSD. However, breeding acceptable, high-yielding and CBSD-resistant varieties is hampered by limited information on farmers' preferences in cassava varieties and lack of an effective *Cassava brown streak virus* (CBSV) inoculation technique. Information on the inheritance of CBSD resistance, root yield, percentage dry matter (DM%) and root cyanide is also lacking. Results of a survey conducted in three districts of coastal Kenya indicated that early maturity followed by high DM content and yield were the most important characteristics preferred by farmers. Evaluation of five CBSV inoculation techniques showed that plants inoculated with CBSV by grafting infected scions had highest percentage of plants with CBSD leaf symptoms and fewest number of days to first appearance of the symptoms. An analysis of the F_1 progeny of 9 × 9 diallel crosses showed highly significant general (GCA) and specific (SCA) combining ability effects for the incidence of CBSD and root yield at the seedling stage. Both GCA and SCA effects were significant for all the traits evaluated at the clonal stage, but additive effects were more important than non-additive effects (except for DM%). The parents Kaleso followed by Gushe had the most significant and negative GCA effects for CBSD resistance. Kibiriti-mweusi had the most positive and significant GCA effect for root yield. Thirty CBSD-resistant hybrids yielding over 40 t ha^{-1} were identified. Thirty-six scientists from eight countries were trained to wedge graft-infected scions onto cassava plants.

Introduction

Statement of the Problem

Cassava is the second most important food crop and a source of income for rural communities in the coastal region of Kenya. The crop is also important in alleviating food insecurity. The low yield of 5–9 t ha^{-1} realised in the region is partly due to the low yield potential of the local cassava landraces and susceptibility to cassava brown streak disease (CBSD). The disease causes root necrosis, which renders the roots unfit for human or livestock consumption. Yield loss of up to 74% has been associated with the disease (Muhana *et al.*, 2004). To boost yield and enhance

1. KARI Mtwapa, Box 16, Mtwapa-80109, Kenya.

the role of cassava as a food-security crop, high-yielding CBSD-resistant varieties that combine farmers' preferred characteristics are required. However, lack of information on farmers' cassava variety preferences, effective inoculation technique(s) for *Cassava brown streak virus* (CBSV) and the inheritance of CBSD resistance, root yield, root percentage dry matter (DM%) and root cyanide content are hampering breeding for acceptable improved varieties.

Literature Review

Cassava brown streak disease can be controlled by roguing, selecting healthy planting materials and early harvesting (Hillocks, 2003), but host-plant resistance is the most effective and realistic control method because it allows cassava to be left in the field to achieve maximum yield potential and to be harvested piecemeal. Breeding for host-plant resistance in coastal Kenya has focused mainly on selection for yield and resistance to diseases and pests. This has led to low adoption of CBSD-resistant varieties such as 46016/27, because it is late maturing and has poor taste. Sweet varieties are often preferred where cassava is used without processing (Nweke, 2005) to avoid poisoning, as sweet taste is associated with low root cyanide. In semi-arid zones of Ghana, Nigeria and Chad, early maturing, high-yielding, sweet and drought-resistant varieties are preferred (Kormawa *et al.*, 2003). These reports suggest that farmers consider a range of characteristics, which need to be incorporated in new improved varieties if adoption is to be enhanced.

Screening for CBSD resistance has relied on natural spread, which is variable and dependent on the variety and whitefly population (Hillocks *et al.*, 2001; Maruthi *et al.*, 2005). Some plants may escape infection, leading to false field resistance. Rubbing infected sap, grafting (Storey, 1936) and whitefly (Maruthi *et al.*, 2005) transmit CBSV, but infection rates are low and the grafting procedure is not well defined. However, a 100% transmission of the *Piper yellow mottle virus* in black pepper plants (*Piper nigrum*) by cleft-grafting infected scions was reported in Sri Lanka (Silva *et al.*, 2002). Therefore identification of an effective CBSV inoculation technique is paramount to improve efficiency in screening for CBSD resistance.

Selecting parents in breeding for CBSD resistance is based on their performance – many progeny are evaluated over several generations before identifying a few desired varieties – which is expensive. Selecting parents in a crossing block, based on their combining ability for CBSD resistance, would increase the probability of identifying varieties with desirable traits (Ceballos *et al.*, 2004). However, this is not possible due to limited and conflicting information on CBSD inheritance. Kanju *et al.* (2003) suggest that CBSD inheritance is controlled by a few recessive genes linked to the gene controlling the zigzag stem habit. However, Hillocks and Jennings (2003) propose that additive genetic factors are involved in the inheritance of CBSD, because continuous variation was observed in the expression of the disease among varieties. Therefore understanding the inheritance of CBSD will help in designing the most effective breeding scheme for acceptable CBSD-resistant varieties.

Scope and Purpose of the Research

A survey was carried out in three major cassava-growing divisions in Kilifi, Kwale and Malindi Districts to identify farmers' preferences in new CBSD-resistant varieties in 2005. In 2006, five CBSV inoculation techniques were evaluated for their efficiency to transmit CBSV in cassava cultivar (cv.) KME. First-generation (F_1) progeny of 9 × 9 diallel crosses were evaluated in seedling

and clonal trials at the Kenya Agricultural Research Institute (KARI) Mtwapa farm between March 2006 and August 2007. The objectives of this study were to determine the general (GCA) and specific (SCA) combining ability for CBSD resistance, DM% and root cyanide, and to identify parents and hybrids with CBSD resistance, high root yield and DM%, and low root cyanide.

Materials and methods

Farmers' Preferences in Cassava Variety Characteristics in Coastal Kenya

A survey was conducted in Chonyi, Kaloleni and Kikambala (Kilifi District); Kubo, Lungalunga and Msambweni (Kwale District); and Magarini, Malindi and Marafa (Malindi District) Divisions. A purposive sampling technique was used to select districts and divisions. A total of 90 cassava farms, 10 in each division, along the major routes were selected at 10 km intervals using a systematic sampling technique. If cassava was absent within the 10 km interval, the next farm was sampled. Data on preferred characteristics of new CBSD-resistant varieties were listed and ranked during individual farmer interviews.

Evaluation of CBSV Inoculation Techniques

Five inoculation techniques were evaluated for their efficiency in transmitting CBSV in cassava cv. KME. The techniques were soaking cassava cuttings in infected sap for 12 h overnight, grafting infected scions, topping and spraying, injecting, and rubbing with CBSV-infected sap at 2 months after planting (MAP). A control consisting of soaking cuttings in water for 12 h overnight before planting was included. Fifty plants for each inoculation technique were grown in a screenhouse. Two months after inoculation, data were recorded on the percentage of plants expressing leaf chlorosis or vein clearing; the time (number of days) to first appearance of symptoms was also recorded. Data collected were analysed using GENSTAT version 11.1.

Analysis of Diallel Crosses for CBSD Resistance and Yield Components

Nine parents – Kibandameno, Ambari, Gushe, Kibiriti-mweusi, Kaleso, Guzo, Mshelisheli, KME and Kalulu – were selected on the basis of their levels of resistance to CBSD, other diseases and pests, DM%, cyanogenic potential (HCN), fibre content, yield, and ability to flower. The parents were crossed using the half-diallel mating design. A total of 36 families (treatments) were generated. Thirty F_1 progeny from each family in a replication were evaluated in a seedling-evaluation trial using an incomplete block design with three replications, and screened for CBSD resistance under natural spread of CBSV from spreader rows. Each block consisted of nine families. During the clonal trial, 40 progeny from each family (selected on ability to produce at least six cuttings) were evaluated in an incomplete block 9 × 4 alpha design with two replications. Each of 40 progeny was represented by three plants in a replication. Asymptomatic plants were inoculated with CBSV by wedge-grafting infected scions of cv. Guzo during the clonal trial. The incidence (I_{CBSD}) and severity (S_{CBSD}) of CBSD were rated according to methods of Hillocks *et al.* (1996) and Anon. (2003), respectively. The I_{CBSD} and S_{CBSD} were rated at 4 and 5 MAP during the seedling trial and monthly, starting from 5 to 10 MAP, during the clonal trial on the worst affected plant of each progeny. Yield, incidence and severity of root necrosis (I_{RN}, S_{RN}), root yield and root cyanide were assessed at 6 and 12 MAP for the seedling and clonal trials, respectively, while DM% was determined at harvesting during the clonal trial only. A row and column design was

superimposed on the original incomplete block design in order to adjust for the heterogeneity of the plots in two dimensions for both seedling and clonal stages. The data at family level at both seedling and clonal stages were analysed using the REML spatial analysis procedure in GENSTAT version 11.1 for I_{CBSD}, S_{CBSD}, I_{RN} and S_{RN}. The linear trends across rows, columns and families were declared fixed, while the rows, columns, and their interaction were considered random. If there were missing values within families, REML calculated chi-square (χ^2) probability, while the *F*-probability was calculated if there were no missing values. Griffing's (1956) diallel method IV for the fixed model was fitted for the GCA and SCA analyses for the data collected.

Results

Preferred Cassava Characteristics in New CBSD-resistant Varieties

The most important characteristic preferred by farmers in new CBSD varieties across the districts was early maturity, followed by high yield and sweet taste (Table 1). Other characteristics, in decreasing order of importance, were drought resistance, low fibre content, ease of cooking, marketability, and resistance to major pests and diseases.

Table 1. Frequency of farmers' preferences for CBSD-resistant varieties in Kilifi, Kwale and Malindi Districts

	Proportion of farmers (%)			
Characteristic	**Kilifi**	**Kwale**	**Malindi**	**Mean**
Early maturity	10.4	43.6	62.3	38.8
High yield	26.7	23.3	27.5	25.8
Sweet taste (low cyanogenic potential)	16.6	13.4	3.4	11.1
Drought tolerance	13.3	3.3	3.4	6.7
Low fibre content	10.1	0.0	0.0	3.4
Ease of cooking	6.5	3.3	0.0	3.3
Big, long roots	6.5	0.0	0.0	2.2
Marketability	0.0	6.5	0.0	2.2
Resistance to pests and diseases	3.3	3.3	0.0	2.2
Other	6.6	3.3	3.4	4.4

Effective Cassava Brown Streak Inoculation Technique

All the inoculation techniques transmitted CBSV except the control. Plants inoculated with CBSV by wedge-grafting infected scions had significantly the highest incidence of plants with CBSD and the shortest period to appearance of CBSD symptoms.

Genetic Effects Controlling CBSD, Yield and Quality Characteristics

At the seedling stage, family variation was significant ($P \leq 0.05$) only for I_{CBSD}, while at the clonal stage it was highly significant ($P \leq 0.001$) for both I_{CBSD} and S_{CBSD} (Table 2). In addition, the mean I_{CBSD} and S_{CBSD} were higher at the clonal than at the seedling stage. The differences in I_{RN} and S_{RN} between families were highly significant ($P \leq 0.001$) at the clonal stage only (Table 3). Significant GCA and SCA effects were observed for I_{CBSD} and root yield during the seedling and clonal trials (Tables 4 and 5). The GCA and SCA effects for S_{CBSD}, I_{RN}, S_{RN}, DM% and picrate score (for cyanide

level) were significant only during the clonal trial. The GCA effects were more important than the SCA effects for most traits, except for DM%. Kaleso, followed by Gushe, had the most negative and significant GCA effects for CBSD resistance, while Kibiriti-mweusi had the highest and most significant GCA effects for root yield. Thirty progeny with resistance to root necrosis, yields of over 40 t ha^{-1} and acceptable farmer characteristics were identified.

Dissemination of the Research

I trained 36 breeders and technicians from Burundi, Democratic Republic of Congo, Ethiopia, Kenya, Madagascar, Malawi, Mozambique and Tanzania on wedge-grafting of infected scions during two workshops organised by the East African Root Crops Research Network and the National Root Crops Research Programme–Tanzania. The results of these studies have been presented in workshops and conferences.

Table 2. Residual maximum-likelihood Wald test for incidence and severity of above-ground CBSD symptoms of families in the seedling and clonal stages

	df			χ^2				
Variable	**Lin_R**	**Lin_C**	**Families**	**Lin_R**	**Lin_C**	**Families**	**Mean**	**SE**
I_{CBSD} seedling	1	1	35	1.31	0.09	1.96*	39.8	±0.94
I_{CBSD} clonal	1	1	35	1.88**	5.57	22.06***	72.1	±1.50
S_{CBSD} seedling	1	1	35	2.67	0.03	1.45	2.1	±0.39
S_{CBSD} clonal	1	1	35	9.06**	26.48***	55.09***	3.2	±0.01

Lin_R, linear trend across rows; Lin_C, linear trend across columns.

*, **, *** significant at $P < 0.05$, < 0.01 and < 0.001 (χ^2), respectively; SE, standard error of the mean.

Table 3. Residual maximum-likelihood Wald test for incidence and severity of root necrosis of the families at the seedling and clonal stages

	df			χ^2		
Variable	**Lin_R**	**Lin_C**	**Families**	**Lin_R**	**Lin_C**	**Families**
I_{RN} seedling	1	1	35	16.95*	0.00	1.10
I_{RN} clonal	1	1	35	46.24***	1.96	8.29***
S_{RN} seedling	1	1	35	15.15*	0.29	1.30
S_{RN} clonal	1	1	35	8610.13***	1200.30***	405.56***

Notes: see Table 2.

Table 4. Combining ability mean square values for above- and below-ground symptoms of CBSD in seedling and clonal trials

		Seedling trial	Clonal trial			
Source	**df**	I_{CBSD}	I_{CBSD}	S_{CBSD}	I_{RN}	S_{RN}
Family	35	0.014*	306.472*	0.839*	0.141*	0.017*
GCA	8	0.018**	876.746*	2.289**	0.453*	0.055**
SCA	27	0.013**	137.502*	0.202*	0.049*	0.006*

df, degrees of freedom; *, ** significant at $P \leq 0.05$ and ≤ 0.01, respectively.

Table 5. Mean square values of GCA and SCA for root yield and yield components in the seedling (non-bold values) and clonal (bold values) trials

Source	df	Root yield (kg per plant)		DM%	PS
Families	35	0.177*	**0.009***	**1.169***	**0.427***
GCA	8	0.642**	**0.030****	**0.929***	**1.068****
SCA	27	0.039**	**0.002***	**1.240***	**0.237****

*, **, significant at P ≤ 0.05 and ≤ 0.01; df, degrees of freedom; PS, picrate score.

Discussion and conclusions

Farmers preferred a range of characteristics in the CBSD-resistant varieties to be developed. Early maturity was the most important because cassava is produced under continuous cultivation in coastal Kenya, which favours varieties that mature within 12 months. Sweet taste is associated with low levels of cyanide in the root, which reduces the risk of poisoning. Therefore new CBSD-resistant varieties should be early maturing and low in root cyanide to enhance adoption. Grafting was the most effective inoculation technique and should be used in the advanced stages of variety development to enhance efficiency in screening for CBSD resistance. The significant GCA and SCA effects in the inheritance of CBSD, root yield, DM% and root cyanide indicated that both additive and non-additive effects were involved in the inheritance of these traits. In addition, additive effects were more important than non-additive effects for CBSD resistance, root yield and root cyanide. Therefore breeding for resistance to CBSD, high root yield and low root cyanide may be achieved via recurrent selection and gene pyramiding. Varieties with the most negative GCA effects for CBSD resistance (such as Kaleso and Gushe) should be crossed with varieties that have the most positive, highest and significant GCA effects for root yield (such as Kibiriti-mweusi) to breed acceptable varieties. The 30 CBSD-resistant varieties will be evaluated in major cassava-growing areas to select suitable varieties for specific agro-ecological zones and uses. It is expected that these varieties – once released and adopted by farmers – will result in increased productivity for enhanced food security and income generation.

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A Sustainable Approach for Management of the Legume Pod Borer, Maruca vitrata, on Bean in Mauritius

L. Unmole[1]

Keywords: azadirachtin, *Bacillus thuringiensis****, chlorantraniliprole, indoxacarb, spinosad,*** *Trichogramma chilonis*

Abstract

French bean (*Phaseolus vulgaris* L.) is a strategic crop grown on about 360 ha in Mauritius. *Maruca vitrata* (Fabricius), *Etiella zinckenella* (Treitschke) and *Lampides boeticus* (L.) are reported as major pod borers damaging floral parts and pods of bean, but there has been no investigation into their economic importance. Previously, insecticides were screened only at field level to update control recommendations. However, chemical control has not always been effective, and farmers have resorted to indiscriminate use of insecticides. Such practices have raised health, economic and environmental concerns. The aim of this study was to develop an effective and sustainable pod borer management strategy that relies primarily on ecological processes of control. Research on pod borers was conducted in sequential steps: (1) a 10-month survey to identify the key pod borer and determine its abundance on bean and other legumes; (2) development of a cheap technique to rear *M. vitrata*; (3) search for natural enemies of *M. vitrata*; (4) laboratory investigation of the attributes of the identified egg parasitoid, *Trichogramma chilonis* Ishii, for its eventual use in *M. vitrata* management; (5) laboratory and field testing of chlorantraniliprole, spinosad, indoxacarb, *Bacillus thuringiensis*, *Beauveria bassiana* and azadirachtin as alternatives to broad-spectrum insecticides; and (6) testing the attractiveness of four pheromone lures to males of *M. vitrata*, for their eventual use as a monitoring tool in bean fields. *Maruca vitrata* was the only economically important pod borer, causing up to 42% pod damage in untreated bean plots. Three plant species were recorded as *M. vitrata* hosts for the first time in Mauritius: *Phaseolus lunatus* L., *Pueraria phaseoloides* (Roxb.) Benth. and *Macroptilium atropurpureum* (DC.) Urb. High larval survival (87.5%) and high fecundity of female (241.3 ± 54.6 eggs per female) raised on mung bean sprouts indicate the suitability of sprouts as a diet for rearing *M. vitrata* larvae. Three types of biocontrol agent (egg parasitoid, entomopathogenic fungus and nematode) were detected on *M. vitrata* in the field for the first time in Mauritius. *Trichogramma chilonis* and the unidentified entomopathogenic nematode were retrieved by the exposure method, and the pathogenic fungus *Metarhizium* sp. was detected in diseased *M. vitrata* larvae collected from the field. The high rate of egg mortality (>77%) due to feeding and parasitism by a *T. chilonis* female indicate its potential as a biocontrol agent against *M. vitrata*. *Bacillus thuringiensis*, azadirachtin, chlorantraniliprole, indoxacarb and spinosad were found to be effective against *M. vitrata* larvae. Males of *M. vitrata* did not respond to any of the tested lures but were attracted to caged virgin females.

1. Entomology Division, Agricultural Research and Extension Unit, Réduit, Mauritius.

Introduction

French bean (*Phaseolus vulgaris* L.) is a strategic crop cultivated on about 360 ha by about 3,000 farmers in smallholdings (≤0.25 ha) mostly within residential areas in Mauritius (Anon., 2008). As with many other crops, growers of *P. vulgaris* traditionally depend heavily on broad-spectrum insecticides for the control of key pests. *Maruca vitrata* (Fabricius), *Etiella zinckenella* (Treitschke) and *Lampides boeticus* (L.) are reported as major pod borers on *P. vulgaris* in Mauritius (Moutia, 1955). Their economic importance has not been determined, and research has focused only on screening insecticides against them in the field. Chemical control is often ineffective as pod borer larvae (caterpillars) have well protected floral parts and pods, so farmers spray with mixtures of insecticides at high doses and frequencies to achieve effective control (Fagoonee, 1984; Abeeluck *et al.*, 1997). Such practices have raised health, economic and environmental concerns among the public at large, and have even jeopardised existing opportunities to export fine beans to the European market. The Mauritian government has provided incentives to farmers to increase legume production through good agricultural practice, with particular emphasis on integrated pest management (IPM) strategies.

This 4-year study aimed to develop an IPM package for pod borer management through (1) determination of predominant pod borer species on bean; (2) development of a suitable technique to rear pod borers in the laboratory for bioassays and field trials; (3) study of their biology and ecology; and (4) identification of alternatives to broad-spectrum insecticides.

Materials and methods

Pest Status of Pod Borers on Bean

A 10-month survey was conducted in 27 randomly selected fields (<0.25 ha) of farmers who treated their beans with insecticides in the three main bean-growing areas. During each fortnightly site visit, flower buds and flowers (50 of each) were collected from each field. Permanent untreated bean plots (9 m^2) set every 5 weeks at Réduit Crop Research Station of the Agricultural Research and Extension Unit (AREU) were also surveyed. Sampled floral parts and pods were kept in individual plastic containers for 7 days in the laboratory at 27 ± 2°C and relative humidity (RH) 70 ± 10%. Collected larvae were raised on fresh flowers and pods of bean. Emerging moths were identified and sexed.

Laboratory Rearing of *Maruca vitrata* and Study of its Biology

Twenty pairs of moths were reared on 10% sucrose solution in a transparent cylindrical plastic container (15 cm wide × 20 cm long), which had both ends cut and fitted with white muslin cloth as oviposition substrates. These substrates were removed daily and collected in plastic containers. Hatched larvae were regarded as the F_1 generation. A set of 200 newly hatched F_1 larvae was reared on mung bean sprouts. Emerging moths were placed in cages and eggs were collected as described above. Hatched larvae were regarded as F_2 larvae. To study the performance of larvae raised on mung bean sprouts and bean flowers and pods, and the performance of emerging moths, 30 F_1 larvae (1-day old) were set in six cups (five per cup) and fed on bean flowers and pods. Similarly, 30 F_1 and 30 F_2 larvae were set in cups and fed on mung bean sprouts. Larval

and pupal survival and adult emergence were recorded for each diet. Emerging moths from respective diet treatments were sexed and set in individual pairs in small plastic containers (n = 8) and fed on 10% sucrose solution. The life span of moths and the number of eggs laid by a female during her lifetime were recorded. Results were presented as mean ± SE.

Ecology of *Maruca vitrata*

The abundance of *M. vitrata* and its natural enemies was determined on nine legume plots set (within a range of 50 m) at Réduit Crop Research Station. Each week, flowers were randomly collected from untreated plots (40 per crop) of *P. vulgaris*, *Vigna unguiculata*, *Arachis hypogea* and *Pisum sativum* (flowering to fruiting stage), and held in the laboratory for 7 days. At each harvest, 12 plants were randomly selected from each crop (except *A. hypogea*), and damaged and undamaged pods were recorded. Pods with larvae were brought to the laboratory. Flowers and pods (50 each) were randomly collected in individual plastic bags from an untreated pigeon pea (*Cajanus cajan*) plot and examined in the laboratory. Florets from inflorescences (n = 50) were randomly collected from untreated *Pueraria phaseoloides*, *Mucuna pruriens* and *Macroptilium atropurpureum* plots. Pods (n = 50) from each of *P. phaseoloides* and *M. pruriens* plots were collected in individual plastic bags and examined in the laboratory. Fifty pods from each of 39 newly introduced *Phaseolus lunatus* varieties (treated plot) were examined, and damaged ones were brought to the laboratory. Collected larvae were raised on mung bean sprouts to adult moths to confirm species.

Inventory of Natural Enemies of *Maruca vitrata*

Besides the existing larval parasitoids, an investigation was conducted to detect the possible occurrence of other natural enemies of *M. vitrata*.

Egg Parasitoid

The exposure method of Arodokoun (1996) was used. A bean plant with freshly laid eggs was placed in the pigeon pea plot for 48 h. Leaves with eggs were excised, kept in a glass jar and observed daily in the laboratory. Parasitised eggs (n = 32), distinguished by their black coloration, were kept in individual glass vials. Emerging parasitoids were sexed under a binocular microscope. Plant exposure was repeated four times using a fresh bean plant with eggs each time.

Larval Pathogen

Larvae of *M. vitrata* (n = 1906) were collected from *P. vulgaris*, *A. hypogea*, *P. sativum*, *C. cajan*, *V. unguiculata*, *P. lunatus* and *P. phaseoloides*. Collected larvae were raised individually on sprouts in sterile plastic cups and examined daily. Diseased larvae were isolated and the pathogenic organism was identified in collaboration with the Plant Pathology Division of AREU.

Entomopathogenic Nematode

Fifty *M. vitrata* pupae were placed at a depth of 3 cm in soil in a bean field (per Bedding and Akhurst, 1975) and brought to the laboratory after 7 days. They were washed with water to remove soil particles and placed in individual petri dishes with 5 mL of water. Each pupa was macerated and examined under a binocular microscope. When nematodes were detected, the macerated content was filtered through cheesecloth. A stock solution was prepared and used

to conduct pathogenicity test with healthy *M. vitrata* larvae (fifth instar) (per Kaya and Stock, 1997). Larvae were examined daily under a binocular microscope.

Laboratory Bioassays and Field Trials for Testing the Efficacy of Products

Two commercial formulations of microbials (*Bacillus thuringiensis* var. *kurstaki* [Bt, Dipel 16,000 IU mg^{-1}] and *Beauveria bassiana* [Biofix larvo-guard 2×10^9 CFU mL^{-1}]), and one botanical (azadirachtin, Bioking 0.15% EC) and one IPM-compatible (spinosad, Tracer 480 SC) insecticide, were tested at different rates against 4- and 7-day-old larvae of *M. vitrata* in the laboratory. Bt was tested at 1.0, 1.5 and 2.0 g L^{-1} water; *B. bassania* at 2.0, 3.0 and 4.0 g L^{-1} water; and spinosad at 0.25, 0.3 and 0.5 g L^{-1} water. Larval mortality was corrected with mortality in the control using Abbott's (1925) formula. The percentage mortality was arcsine transformed and analysed by one-way analysis of variance (ANOVA) with means separated by Tukey's studentised range test (SAS, 2004).

Field Testing of Azadirachtin, Chlorantraniliprole and Indoxacarb

The field experiments were set in a bean plot in a randomised complete block design with four replicates. The first trial consisted of azadirachtin treatments at three rates (5.0, 7.5 and 10.0 mL L^{-1} water) and a control (untreated). The second trial consisted of chlorantraniliprole treatments at 0.25, 0.30 and 0.34 mL L^{-1} without adjuvant, and at 0.30 mL L^{-1} with the adjuvant Trend 90 (0.75 mL L^{-1}), indoxacarb at 0.25 g L^{-1} with the same adjuvant and a control (untreated). In each trial, flower buds and flowers (10 each) were sampled from five randomly selected plants from each treatment plot. At each harvest, damaged and undamaged pods from five randomly selected plants were recorded. Collected samples were kept in plastic containers in the laboratory for 7 days and hatched larvae were counted. Larval numbers on floral parts were corrected as proportion of larvae after treatment over number of larvae before treatment. Percentage pod damage was arcsine transformed and analysed by one-way ANOVA with means for different treatments separated by Fisher's least significant difference (LSD) test (SPSS, 2002).

Response of Male *Maruca vitrata* to Pheromones

With a view to developing a threshold for control actions based on trap catches, four pheromone blends were procured from the Natural Resources Institute (NRI), UK. They contained 0.1 mg of the pheromone and were impregnated in rubber septa. One of them was effective in Benin and Ghana, and another in Burkina Faso (Downham, 2006). Two types of delta trap (one transparent, from Plant Resource International [PRI], The Netherlands; one yellow, from Pest Control India [PCI], India) and a locally prepared water trap were used for evaluation of pheromone lures. A set of four PRI pheromone-baited traps was placed in each of the three farmers' treated bean fields (each ≤0.1 ha) and in an untreated bean plot (10 × 10 m) at Réduit Crop Research Station. Traps were set on wooden stakes at about 1 m above ground level and at a distance of 5 m from one another. Septa were renewed fortnightly over 5 weeks. A blank PRI trap (without pheromone septa) was set as control in each field. A second trial was run in an untreated bean plot (10 × 10 m) at Réduit Crop Research Station with water traps using same method. In a third trial, PCI traps with septa were placed in an untreated bean plot intercropped with maize and another untreated bean plot following the same method described above. A trap with two caged virgin females (fed on 10% sucrose solution) was also placed in the two plots. Traps were examined daily and caught moths identified to confirm presence of males.

Study on Biology of *Trichogramma chilonis* Ischii

Longevity and Fecundity of Mated Female Trichogramma chilonis

Oviposition substrates were cut in strips, each with 30 eggs of *M. vitrata*. A mated *T. chilonis* female in a vial (5 × 1.8 cm diameter) with a streak of honey on its inner wall was offered one strip per day until death of the female. The removed strip was held in a 30 mL plastic container and observed daily for 5 days. Parasitised and unparasitised eggs were counted. This experiment was replicated 10 times.

Effect of Host Egg Age on Parasitism by Trichogramma chilonis

A mated *T. chilonis* female was placed in a glass vial with a streak of honey on its inner wall with one strip of eggs. After 24 h, the strip was transferred to a 30 mL plastic container. Parasitised, desiccated and hatched eggs were counted daily under a binocular microscope. This experiment was replicated 10 times for each age of egg (1-, 2- and 3-day-old). Data were arcsine transformed and analysed by one-way ANOVA with means separated by the Student–Newman–Keuls test (SAS, 2004). Total egg mortality was calculated as the sum of parasitised and desiccated eggs.

Results

Key Pod Borer in Bean

Maruca vitrata constituted the major proportion (99.6%) of field-collected pod borer larvae, with very low incidence of *L. boeticus* (0.1%) and *Helicoverpa armigera* (0.3%). *Etiella zinckenella* was not recorded. Pod damage in treated and untreated fields was 22 and 42%, respectively. Larvae collected from floral parts and pods were parasitised by two species of parasitoids (*Bracon* sp. and *Eiphosoma annulatum* Cress); parasitism was generally low, but higher in untreated fields (2.4%) than in treated ones (0.7%).

Biology of Maruca vitrata on Bean Flowers and Pods and Mung Bean Sprouts

Larval survival in F_1 and F_2 generations on mung bean sprouts was higher (>87%) than that on bean flowers and pods (52.5%). Moth emergence from pupae on both diets was above 85%. The pupal period for the F_2 generation was shorter (8.5 ± 0.1 days) than for the F_1 (10.2 ± 0.2 days) on mung bean sprouts and on bean flowers and pods (10.1 ± 0.2 days). Male and female moths from the F_2 generation on mung bean sprouts lived longer than those of the F_1 raised on either diet. The F_2 females from mung bean sprouts were more fecund (359.4 ± 51.2 eggs) than F_1 females on the same diet (241.3 ± 54.6 eggs) and F_1 females on bean flower and pods (127.5 ± 30.3 eggs).

Pod Borer Infestation in Nine Legumes

Floral infestation was high (52.5%) in the *P. vulgaris* crop cycle, but low (<9.4%) in *V. unguiculata*, *P. sativum* and *A. hypogea*. More than 99% of the larvae from *P. vulgaris* and *V. unguiculata* flowers were those of *M. vitrata*. Floral infestation in *C. cajan*, *P. phaseoloides* and *M. atropurpureum* was 11.3, 15.2 and 28.4%, respectively. The percentage of *M. vitrata* larvae was high (85.5%) in *P. phaseoloides*, but low in *M. atropurpureum* (16.9%). *Lampides boeticus* larvae made up a high percentage in *M. atropurpureum* (83.1%) and *C. cajan* (54.8%), but low

in *P. phaseoloides* (14.5%). Pod damage in *P. vulgaris*, *P. sativum*, *V. unguiculata* and *P. lunatus* was 36.9, 21.9, 8.6 and 12.8%, respectively. Only *M. vitrata* larvae were recorded in damaged *P. vulgaris* and *V. unguiculata* pods and represented 99.2% of larvae from damaged *P. lunatus* pods. Flowers and pods of *M. pruriens* were not attacked by pod borers.

Inventory of Natural Enemies

Sixty-two per cent of exposed eggs were parasitised. Each parasitised egg gave rise to a single parasitoid, and 69% of the emerged parasitoids were female. The egg parasitoid was identified as *Trichogramma chilonis* and was confirmed by the Natural History Museum, London. Fifty-six per cent of exposed pupae were infected with nematodes. The isolated entomopathogenic nematode was pathogenic to healthy larvae, which then died on the third day after infection. Diseased larvae were recorded on *P. phaseoloides* only: 14.6% of collected larvae (n = 287) were infected with a *Metarhizium* sp., a pathogenic fungus.

Efficacy of Products

Mortality in young and mature larvae reached above 70% after 7 days in the Bt treatment of 2.0 g L^{-1}. Mortality in both stages of larvae fed on mung bean sprouts treated with *B. bassiana* at all three rates was low (<15%) without any significant difference in treated and untreated sprouts. However, mortalities in young and mature larvae fed on sprouts treated with spinosad at the three rates were above 85% at 24 h after treatment and 100% at 48 h. Azadirachtin application (all rates) did not reduce larval counts in floral parts; however, pod damage was significantly reduced compared with control plots in which pod damage was highest ($P < 0.05$, Fisher's LSD test.). Pod damage did not differ significantly among azadirachtin treatments. In plots treated with chlorantraniliprole and indoxacarb, larval numbers on floral parts were significantly lower ($P < 0.05$) than in control (untreated) plots, but the level of larval infestation on floral parts among treated plots (irrespective of insecticide and rate) did not differ significantly. Similarly, the percentage pod damage in plots treated with the two insecticides was significantly lower than in control plots ($P < 0.05$), but without any significant difference among plot treatments.

Response of Males of *Maruca vitrata* to Pheromones

No males of *M. vitrata* were recorded in any of the pheromone-baited traps, but males were captured in traps baited with virgin females.

Biology of *Trichogramma chilonis* on *Maruca vitrata* Eggs

Females lived up to 13 days with an average life span of 8.5 ± 0.7 days. A female laid her full complement of eggs within the first 8 days after emergence, with an average of 42.4 ± 1.3 eggs and with a peak of 16.1 eggs on the first day.

Effect of Host Egg Age on Parasitism by *Trichogramma chilonis*

Parasitism was observed in 1- and 2-day-old eggs only, and was significantly higher (56%) in 1-day-old than in 2-day-old eggs (26.3%; $P < 0.01$, Student–Newman–Keuls test). Egg desiccation due to probing by females was significantly lower (23.2%) in 1-day-old eggs than in older ones (>49%; $P < 0.01$). The combined egg mortality due to egg parasitism and desiccation was high in 1-day-old (79.2%) and 2-day-old (77.1%) eggs, but lower in 3-day-old eggs (49.4%).

Discussion

This study is a pioneer work on *M. vitrata* in Mauritius, and has generated basic information for the eventual development of sustainable pod borer management in bean cultivation. The pod borer complex, known since the 1950s, has now been specifically identified. *Maruca vitrata* is the only major pod borer species causing economic damage to bean pods, and *H. armigera* was recorded on *Phaseolus vulgaris* for the first time. This is also the first record of three plant species (*P. lunatus*, *P. phaseoloides* and *M. atropurpureum*) hosting *M. vitrata* in Mauritius. Mung bean sprouts are a new larval diet, enabling laboratory production of *M. vitrata* at low cost. This diet can be useful for researchers to easily procure test materials for laboratory and field trials. Three IPM-compatible products (chrorantraniliprole, indoxacarb and spinosad) and two biopesticides (Bt and azadirachtin) were suitable alternatives to broad-spectrum insecticides. Their use in farmers' pest-management programmes will mitigate health, environment and social concerns. The ineffectiveness of the lures tested in luring male moths did not permit development of an economic threshold based on trap catches. However, this study has revealed that these blends, which are effective in other countries, require further modification for use in Mauritius. This suggests that the Mauritian population of *M. vitrata* could be a geographically distinct population. Such a phenomenon has been previously reported in Africa and Asia (Hassan, 2007). The list of natural enemies of *M. vitrata* in Mauritius now comprises an egg parasitoid and two larval parasitoids, an entomopathogenic fungus, and an entomopathogenic nematode. The egg parasitoid *T. chilonis*; the entomopathogenic fungus *Metarrhizium* sp.; and the unidentified entomopathogenic nematode are new records on *M. vitrata* in Mauritius. The occurrence of *T. chilonis* on *M. vitrata* is a first record worldwide and is the third egg parasitoid species reported on *M. vitrata*. The use of *Metarrhizium* sp. in the country could be limited because it requires high humidity to be effective. The nematode targets pupae and suppresses the following generation rather than the *M. vitrata* population on a standing bean crop. In contrast, laboratory studies have demonstrated that *T. chilonis* may be a potential biocontrol agent for *M. vitrata*.

Conclusion

The results were considered valuable for the scientific and farming community and were communicated at the International Neem Conference in India (Unmole, 2007) and National Research Week Forum. Research results on management of pod borers on bean, laboratory rearing of *M. vitrata*, response of male *M. vitrata* to pheromone lures, and the biology of *T. chilonis* were published in the peer-reviewed *Journal of the University of Mauritius* (Unmole 2009a, b, c, 2010). Farmers were made aware of the results through a radio talk (2008) and technology review meetings with extension officers of AREU (2009). An updated recommendation sheet for the management of *M. vitrata* was produced (AREU, 2010). A 4-year research programme (2010–13) has been planned on: (1) laboratory rearing of *T. chilonis*; (2) toxicity of tested products on *T. chilonis*; and (3) improvement of the cost effectiveness of laboratory-reared *T. chilonis* through nuclear techniques.

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Economic Evaluation of Sweetpotato Varieties under Different Intercropping Systems in Nigeria

A. Amaefula[1] and G.N. Asumugha[1]

Keywords: profitability, yield, revenue, cost of production, benefit/cost ratio

Abstract

Sweetpotato plays an important role in the diet of many Africans. It is nutritionally rich in calcium, iron, vitamins and minerals. Sweetpotato is tolerant of adverse weather and soil conditions, and gives a high yield in a short growing season. However, high incidence of pests and diseases, inappropriate agronomic practices, degeneration of older varieties, and low output prices (among other factors) limit sweetpotato production in Nigeria. Intercropping ensures a better use of resources, reduces pest and disease load, and insures against crop failure. It is therefore important to evaluate the different sweetpotato intercrops before making recommendations to farmers. The objectives of this study were to compare cost, revenue, yield and profitability of the various sweetpotato production enterprises, and to compare the profitability of sole and mixed cropping systems. The profitability of the different enterprises was determined using benefit/cost ratio (BCR). The maize and sweetpotato enterprise was the only profitable cropping system. Maize and sweetpotato intercrop had a BCR of 1.17, which suggests a profit of ₦17 for every ₦100 invested. Maize and TIS87/0087 was the most profitable sweetpotato intercrop with a BCR of 1.28.

Introduction

Sweetpotato (*Ipomoea batatas*) belongs to the family Convolvulaceae. It plays an important role in the diet of many Africans. It is a good source of energy, calcium and iron. It is nutritionally rich in vitamins and minerals, and has higher carotene content than other root and tuber crops. It is the fourth most important root and tuber crop in Nigeria (Islam *et al.*, 2002).

Sweetpotato is adapted to tropical and sub-tropical climates, tolerates drought, and grows well under marginal soil conditions. It has a high yield potential and a short growing season. Yield from farms can be as low as 7 t ha^{-1} with local varieties, while yields of 30–35 t ha^{-1} are obtained with improved varieties (Larbi *et al.*, 1998).

The major constraints to sweetpotato production are high incidence of pests and diseases, inappropriate agronomic practices, degeneration of older varieties, and low output prices. Intercropping ensures a better use of resources and reduction of the pest and disease load, and provides insurance against crop failure.

1. National Root Crops Research Institute, Umudike, PMB 7006, Umuahia Abia State, Nigeria.

In Nigeria, sweetpotato is predominantly monocropped in the north, but mostly intercropped with other arable crops in the south. Sweetpotato performs well intercropped with maize and sorghum in dryland farming, grown in horticultural gardens under irrigation and in backyard gardens (Madibela *et al.*, 1998). Sweetpotato is intercropped with maize, cassava, sorghum and other crops (Ewell and Mutuura, 1994).

Intercropping sweetpotato would help solve the problem of food scarcity and resource use management. It is necessary to evaluate the different sweetpotato intercrops before making recommendations to farmers.

The objectives of this study were to compare the cost, revenue, yield and profitability of the various sweetpotato production enterprises, and to compare the profitability of sole and mixed cropping systems.

The hypothesis tested was that sweetpotato cropping systems are profitable.

Materials and methods

This research was carried out on Eastern Farm, National Root Crops Research Institute, Umudike, Abia State, Nigeria, within latitude 50°29'N and longitude 70°33'E.

Three sweetpotato varieties – TIS87-0087, TIS 2532.1.OP.13 and TIS 8164 – were each planted in four cropping systems: sweetpotato–castor, sweetpotato–maize, sweetpotato–maize–castor, and sole sweetpotato. The maize variety used for the intercrop was Oba super, while the local variety of castor was used. The crops were planted in a randomised complete block design (RCBD) and replicated three times on a 6 x 5 m plot. Sweetpotato vines with three nodes were planted at a spacing of 0.3 x 1 m. Maize and castor were planted two each per hole at a spacing of 1 x 1 m.

This research was carried out as a 2-year trial. In the first year (2006), sweetpotato, maize and castor were planted on 9–13, 14–19 and 19 June, respectively. The trial plots were weeded three times. Fertiliser (NPK 15:15:15) was applied at the rate of 600 kg ha^{-1}. Maize was harvested on 19 September. Sweetpotato was harvested on 15–17 November. Castor was harvested at intervals from December 2006 to January 2007. The experiment was repeated in 2007 following the same agronomic practices.

Data from the different systems were analysed using benefit/cost ratio (BCR). BCR was derived by dividing the total revenue by the total cost of production. Profitable enterprises have a BCR value greater than 1. Revenue was expressed in Nigerian naira (₦) currency.[2]

Results

Comparative Analysis of Mean Yield and Revenue of Sweetpotato for Different Intercrops

Table 1 shows the mean sweetpotato yield and revenue for the different systems. In monocrop, TIS2532.1.OP.13 had the highest yield (12.95 t ha^{-1}), followed by TIS8164 (9.90 t ha^{-1}) and TIS87/0087 (9.19 t ha^{-1}). Sweetpotato yields in TIS87/0087–maize, TIS2532.1.OP.13–maize and

2. N150 ≈ US$ 1.

TIS8164–maize intercrops were 7.19, 7.62 and 8.92 t ha^{-1}, respectively. Sweetpotato yield in TIS87/0087–castor, TIS2532.1.OP.13–castor and TIS8164–castor intercrops were 7.70, 8.72 and 7.22 t ha^{-1}, respectively. Sweetpotato yield for TIS2532.1.OP.13 intercropped with castor and maize was 7.17 t ha^{-1}; TIS8164 intercropped with castor and maize yielded 5.20 t ha^{-1}. The lowest yield of 4.52 t ha^{-1} was obtained from TIS87/0087 intercropped with castor and maize.

Converting the revenues obtained from the trial plots to per-hectare equivalents, in monocropped sweetpotato, TIS25.32.1.OP.13 gave the highest revenue (₦207,200.00), followed by TIS8164 (₦158,400.00) and then TIS87/0087 (₦147,040.00). In the sweetpotato intercrops with maize, the highest revenue of sweetpotato was obtained by TIS8164 (₦142,720.00), followed by TIS25.32.1.OP.13 (₦121,920.00) and then TIS87/0087 (₦115,040.00). In intercrop with castor, TIS2532.1.OP.13 gave the highest revenue (₦139,520.00), followed by TIS87/0087 (₦123,200.00) and then TIS8164 (₦115,520.00). In the three-crop intercrops, the sweetpotato revenue obtained was highest for TIS2532.1.OP.13 (₦114,720.00), followed by TIS8164 (₦83,200.00) and then TIS87/0087 (₦72,320.00).

Table 1. Mean sweetpotato yield and revenue for the different cultivars and intercrops

Cultivar/intercrop	Yield (t ha^{-1})	Revenue (₦/ha)*
TIS87/0087	9.19	147,040
TIS2532.1.OP.13	12.95	207,200
TIS8164	9.90	158,400
TIS87/0087 and castor	7.70	123,200
TIS2532.1.OP.13 and castor	8.72	139,520
TIS8164 and castor	7.22	115,520
TIS87/0087 and maize	7.19	115,040
TIS2532.1.OP.13 and maize	7.62	121,920
TIS8164 and maize	8.92	142,720
TIS87/0087, castor and maize	4.52	72,320
TIS2532.1.OP.13, castor and maize	7.17	114,720
TIS8164, castor and maize	5.20	83,200

*Based on sale price of sweetpotato of ₦16,000 t^{-1}.

Source: field trial, 2007.

Mean Sweetpotato Yield and Revenue for Sole and Mixed Cropping Systems

Table 2 shows the mean yield and revenue for sweetpotato in sole and mixed cropping systems. The sole sweetpotato enterprise had the highest sweetpotato yield (10.68 t ha^{-1}), followed by sweetpotato–maize (7.91 t ha^{-1}), sweetpotato–castor (7.88 t ha^{-1}) and sweetpotato–castor–maize (5.63 t ha^{-1}).

Table 2. Mean sweetpotato yield and revenue for sole and mixed cropping systems

Intercrop	Yield (t ha^{-1})	Revenue (₦/ha)*
Sweetpotato, castor and maize	5.63	90,080
Sweetpotato alone	10.68	170,880
Sweetpotato and maize	7.91	126,560
Sweetpotato and castor	7.88	126,000

*Based on sale price of sweetpotato of ₦16,000 t^{-1}.

Source: field trial, 2007.

Mean sweetpotato revenues for sole sweetpotato, sweetpotato–maize, sweetpotato–castor and sweetpotato–maize–castor intercrops were ₦170,880.00, ₦126,560.00, ₦126,000.00 and ₦90,080.00, respectively – sole sweetpotato had the highest sweetpotato revenue.

Profitability of the Cropping Systems

Table 3 shows the mean revenue, cost and BCR for the different enterprises. The costs of producing a hectare of TIS87/0087–maize–castor, TIS2532.1.OP.13–maize–castor and TIS8164–maize–castor were ₦281,481.39, ₦287,512.84 and ₦278,895.21, respectively. Costs of TIS87/0087–maize, TIS2532.1.OP.13–maize and TIS8164–maize were ₦191,786.55, ₦183,271.07 and ₦179,091.39, respectively. Costs of sole crops TIS87/0087, TIS2532.1.OP.13, TIS 8164, castor and maize were ₦175,695.99, ₦171,433.60, ₦172,966.10, ₦214,877.10 and ₦131,012.40, respectively. Castor–maize–TIS2532.1.OP.13 had the highest cost of production, while sole maize had the lowest cost.

Table 3. Mean revenue, cost and BCR for the different cultivars and intercrops

Intercrop	Revenue (₦/ha)	Cost (₦/ha)	BCR
TIS87/0087	147,331.00	175,695.99	0.84
TIS2532.1.OP.13	207,208.90	171,433.60	1.21
TIS8164	158,320.00	172,966.10	0.92
Castor	55,127.56	214,877.10	0.26
Maize	128,000.00	131,012.40	0.98
TIS87/0087 and castor	156,841.50	281,083.03	0.56
TIS2532.1.OP.13 and castor	179,841.20	277,660.02	0.65
TIS8164 and castor	156,160.70	274,494.69	0.57
TIS87/0087 and maize	245,953.30	191,786.55	1.28
TIS2532.1.OP.13 and maize	187,010.00	183,271.07	1.02
TIS8164 and maize	215,620.10	179,091.39	1.20
TIS87/0087, castor and maize	217,628.30	281,481.39	0.77
TIS2532.1.OP.13, castor and maize	209,421.40	287,512.84	0.73
TIS8164, castor and maize	221,197.90	278,895.21	0.79

Source: field trial, 2007.

All the sweetpotato–maize intercrops were profitable (Table 3). The most profitable enterprise was TIS87/0087–maize, which had a BCR of 1.28. This suggests that a profit of ₦28 was realised for every ₦100 invested. TIS2532.1.OP.13–maize had a BCR of 1.02 and TIS 8164–maize had a BCR of 1.20. Sole TIS2532.1.OP.13 was the only profitable sole sweetpotato enterprise, with a BCR of 1.21. None of the enterprises involving castor was profitable.

Comparative Economic Analysis of Sole and Mixed Cropping Systems

Overall, and averaged across sweetpotato varieties, the highest revenue was obtained from sweetpotato–maize, while the lowest revenue was obtained from sole castor.

Costs of producing a hectare of sweetpotato–maize–castor, sweetpotato–castor, sweetpotato–maize, sole sweetpotato, sole castor and sole maize were ₦282,629.18, ₦277,745.91, ₦184,716.34, ₦173,365.23, ₦214,877.10 and ₦131,012.40, respectively (Table 4). The highest cost of production was for sweetpotato–castor–maize.

Overall, the sweetpotato–maize enterprise was the only profitable cropping system, with a BCR of 1.17 (Table 4).

Table 4. Mean revenue, cost and BCR for sole and mixed cropping systems

Cropping system	Revenue (₦/ha)	Cost (₦/ha)	BCR
Sweetpotato and castor	164,281.10	277,745.91	0.59
Sweetpotato and maize	216,194.50	184,716.34	1.17
Sweetpotato, castor and maize	216,082.51	282,629.81	0.77
Sweetpotato alone	170,953.30	173,365.23	0.99
Castor alone	55,127.56	214,877.10	0.26
Maize alone	128,000.00	131,012.40	0.98

Source: field trial, 2007.

Discussion and conclusion

Comparing sweetpotato yield and revenues obtained from the cropping systems, it is evident that sole cropping of sweetpotato gave higher sweetpotato yield and revenue than the intercrops – variety TIS2532.1.OP.13 gave the highest yield and revenue. Although cultivar TIS87/0087 gave the lowest yield and revenue in the sole cropping system, its values were still higher than the highest sweetpotato yields and revenues obtained in the intercrops. Sweetpotato yields and revenues obtained in the sweetpotato–maize enterprise were similar to those obtained in the sweetpotato–castor enterprise. Sweetpotato yields and revenues in the sweetpotato–maize–castor enterprise were lowest among the four cropping systems. Although sweetpotato revenue from TIS2532.1.OP.13–maize–castor was highest in this enterprise, it was still less than the lowest revenue in the sweetpotato–maize and sweetpotato–castor enterprises. The highest revenue for all crops was obtained from TIS87/0087–maize, while the lowest was obtained from sole castor. Revenue obtained from sweetpotato increased with a decrease in the number of crops.

TIS2532.1.OP.13–castor–maize had the highest cost of production, while sole maize had the lowest. Costs of production increased with increase in number of crops.

TIS87/0087–maize was the most profitable sweetpotato intercrop. TIS2532.1.OP.13 was the only profitable sole sweetpotato enterprise. The best intercropping system for sweetpotato production was TIS87/0087–maize.

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Young Professionals in Science Competition

Keynote Paper: Understanding Past, Present and Future Climate Changes from East to West Africa

A. Gebrekirstos[1,2], A. Bräuning[3], M. Van Noordwijk[2] and R. Mitlöhner[1]

Keywords: agroforestry, carbon and oxygen isotopes, climate proxies, dendrochronology, Sahel region

Abstract

Tree rings and stable isotopes in tree rings provide evidence of past climate variability. Given the short instrumental climate records that exist in Africa, dendrochronology adds an essential longer-term perspective on climate change and variability and on the adaptation of agroforestry landscapes and forest ecosystems. Tree-ring analyses were conducted as part of three independently established international research collaborations with different partner institutes in Germany and Africa. Stable carbon and oxygen isotopes in tree rings of *Sclerocarya birrea* from the Sahel region (Burkina Faso) showed strong climatic signals. Tree-ring chronologies spanning more than 100 years are under development for Burkina Faso and Tanzania. The ongoing project in Munessa Forest, Ethiopia may result in chronologies of more than 350 years. Finally, the tree-ring series developed in the three projects will be combined to establish large-scale correlation patterns between tree growth and sea-surface temperatures in order to explore continent-wide climate teleconnections. In order to have representative data sets and draw continent-wide recommendations, however, there is a need to extend the study to other parts of Africa.

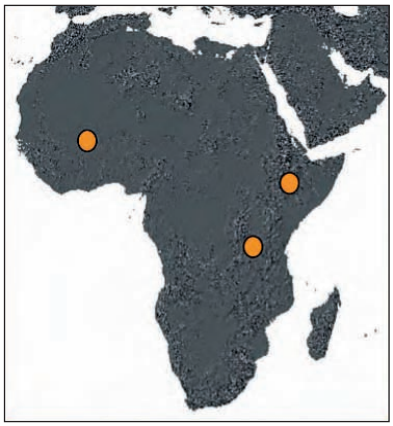
1. Georg-August University of Göttingen, Institute of Silviculture, Sect. II: Tropical Silviculture, Büsgenweg 1, D-37077 Göttingen, Germany.
2. World Agroforestry Center, United Nations Avenue, Gigiri, PO Box 30677-00100, Nairobi, Kenya.
3. Institute of Geography, Friedrich-Alexander University of Erlangen-Nürnberg, Kochstraße 4/4, D-91054 Erlangen, Germany.

Introduction

Climate change affects all sectors of society at local, regional and continental scales, but available evidence is not sufficient to guide policies. Unravelling past climatic events is essential if we are to understand the present and to derive reliable scenarios of future climate change. Thus interdisciplinary and international collaborations are needed to extend research frontiers and to develop regional and sub-regional climate models at a scale relevant for decision-makers (Gebrekirstos, 2009). The pattern in atmospheric circulation, plus the tendency of heavy isotopes to condense first and evaporate last, causes distinct isotope signals (relative to average 0.2% of O that is ^{18}O) in rainfall that reflect the degree of recycling of water vapour by re-evaporation of rainfall over land masses from its oceanic origin (Bowen, 2010). The role of evaporation from terrestrial vegetation in the causation of rainfall patterns is still hotly debated (Worden, 2007; Makarieva *et al.*, 2010) and the isotopic composition of rainfall is the major evidence available (Treble *et al.*, 2005; Noone, 2008). Analysis of isotopes in tree rings to obtain a dated historical indication of past rainfall patterns (Leavitt *et al.*, 2010) can thus contribute to determine an anthropogenic element of past climate change through tele-connections between forest cover and rainfall further inland.

In three current interdisciplinary research projects, analysis of tree rings (dendrochronology) is combined with analysis of current land use and options for adaptation. The project 'Adaptation of Land Use to Climate Change in Sub-Saharan Africa (ALUCCSA)' (www.aluccsa.de) is coordinated by the Centre for Tropical and Subtropical Agriculture and Forestry (Georg-August Universität, Göttingen, Germany) in collaboration with national partner institutes in Burkina Faso and the World Agroforestry Centre. The project aims to develop climate-change scenarios for the next 100 years on a regional/local scale for Sub-Saharan Africa and to achieve ready-to-use scenarios and recommendations for agroforestry and silvopastoral ecosystems. The project, 'Resilient Agro-landscapes to Climate Change in Tanzania' (ReACCT), is coordinated by the Leibniz-Centre of Agricultural Landscape Research, Germany. ReACCT aims to assess the regional impacts of climate change on agriculture and the environment in Tanzania (Morogoro) and to design adaptation strategies and practices for small-scale agriculture and land use (www.reacctanzania.com). Both projects are funded through the Adaptation of African Agriculture to Climate Change funding scheme initiated by BMZ (Ministry of technical cooperation of the federal government of Germany) and GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit, Germany). A separate project, funded by the German Research Foundation (DFG) and entitled 'Climate response of tree growth in Ethiopia along an altitudinal transect and implications on local climate and regional atmospheric circulation dynamics', has been running in Ethiopia since the beginning of 2008. Its goal is to reconstruct climate variability during historical times along an elevation gradient and to unravel large-scale variations of the East African–South Asian Summer Monsoon circulation during El Niños and La Niñas. Apart from

Figure 1. *Location of the study sites (Ethiopia, Tanzania and Burkina Faso)*



other objectives, these projects have the common goal to put the existing short instrumental climate records in Eastern and West Africa (Fig. 1) into a longer perspective, and to investigate the impact of climate variability on the adaptation and water use of important forest and agroforestry tree species in the face of climate changes.

Tree Rings and Stable Isotopes as Climate Proxies

Tree rings are excellent archives, providing information about past climate changes and about the impact of ongoing climate variability on major constituents of forest ecosystems and agroforestry landscapes. Trees grow radially by adding new layers of wood cells on the inside of the cambium. The rings added each year can indicate the environmental conditions the tree experienced during the growing season. As a result, these rings are indicators of climate factors that played a significant role in the growth of that particular tree. In certain cases, trees can live for many hundreds and even thousands of years, like the famous bristlecone pine of the USA.

Dendrochronology is the discipline of dating tree rings to the year of their formation. By applying a wide spectrum of modern analysis techniques, the field has wide applications in environmental research (dendroecology) – in climatology, hydrology, glaciology, tectonics/volcanism, geomorphology and forestry sciences. In order to know more about climate over an even longer period, in some cases thousands of years, it is possible to date dead trees of unknown age and fossil wood that is well preserved. Their rings can be cross-correlated to construct longer records of former climate conditions. Trees forming annual growth rings are found in temperate climates. It has been widely assumed that trees growing in the tropics do not form annual rings. However, many authors have succeeded in using tree rings in tropical trees to determine tree age, understand growth dynamics, and carry out ecological and climate studies (Worbes, 2002). Although dendrochronological work in Africa is still in its infancy, there are successful results reported from different tropical regions. The potential of tree rings as climate proxy in semi-arid Africa has been reported (Fichtler *et al.*, 2004; Trouet *et al.*, 2006; Gebrekirstos *et al.*, 2008, 2010; Wils *et al.*, 2010). In more humid tropical environments with biannual rainfall distribution, annual ring formation is still uncertain. In such cases, high-resolution dendrometers have been successfully applied to document the dynamics of wood formation and to prove the formation of annual rings (Krepkowski *et al.*, 2010).

Since the early 1970s, stable carbon and oxygen isotope signatures in tree rings have been investigated as potential proxy indicators of past climatic conditions, and promising results have been reported (Leavitt and Long, 1991; Robertson *et al.*, 1997; Saurer *et al.*, 1997). Wood is formed on the basis of photosynthesis, which derives carbon from CO_2 and oxygen and hydrogen atoms from water. Once formed, the isotope composition of wood is stable, and still reflects the ease with which CO_2 could be derived from the atmosphere and the type of water available in the leaves. Gebrekirstos *et al.* (2009, 2010) demonstrated the potential of $\delta^{13}C$ in tree rings of *Acacia* species to reflect physiological responses to environmental and climate changes as a tool for palaeoclimatic reconstructions in Ethiopia. High correlations ($r > -0.82$) were found between the $\delta^{13}C$ chronologies and rainfall, demonstrating the potential to reconstruct precipitation in semi-arid tropics. Wils *et al.* (2010) applied $\delta^{13}C$ variations in *Juniperus procera* for reconstructing the flow of the Blue Nile River.

It is in this context that we extended the study to tropical moist forest in Ethiopia, parkland agroforestry systems in Burkina Faso and Miombo woodland in Tanzania. The overall purpose of the study was to establish large-scale correlation patterns between tree growth, precipitation and temperature that are affected by the Indian Summer Monsoon and the West African Monsoon in Eastern and West Africa, respectively. This knowledge will help us to explore local and regional climate processes.

In this paper, we present preliminary results that indicate the potential of stable oxygen and carbon isotopes in tree rings of *Sclerocarya birrea* from the Sahel region in Burkina Faso and Tanzania as a climate proxy. In addition, we briefly outline a research perspective for climate reconstructions from regions in tropical Africa influenced by different climatic regimes.

Methodology

Tree Ring Measurement and Stable Isotopes

Study Sites and Climate

The study sites were in Burkina Faso, Miombo woodlands in Tanzania, and tropical moist forest (Munesa Forest) in Ethiopia (Fig. 1). In this paper, we focus on the results of the Sahel region in Burkina Faso. Burkina Faso has three major climate zones: the Sahel zone in the north, the Sudan–Guinea zone in the south, and the Sudano–Sahel in between. The Sahel zone is influenced by the Sahara Desert and the West African Monsoon. The rainfall distribution of the region is unimodal within a range of 500–600 mm in the north to 1,000 mm in the south. The rainy season starts in May and extends to September, with the wettest month in August. Mean annual temperature is about 37°C, with the hottest season lasting from March to May (about 40°C).

Study Species and Measurement of Stable Isotopes

Sclerocarya birrea (Anacardiaceae) is a common deciduous tree species in Eastern and West Africa, growing up to 20 m in height. For the $\delta^{13}C$ and $\delta^{18}O$ measurements, we selected stem discs of two *S. birrea* collected from the Sahel region in Tugure (13°22′17.5″N 00°28′16.7″W). The discs were dated using standard dendrochronological procedures (Geb rekirstos *et al*., 2008). The $\delta^{13}C$ and $\delta^{18}O$ analyses were performed at annual resolution from 1983 to 2007. Powdered samples of bulk wood were produced from two to three radii of each tree using a drill width of 0.5 mm (Fig. 2b). The powder was pooled into tin capsules and homogenised with a metal stick to represent the whole ring formed in each calendar year. After collecting each sample, the disc was cleaned with compressed air to avoid cross-contamination. From each sample, 1 and 0.2 mg of powdered wood was used for the $\delta^{13}C$ and $\delta^{18}O$ measurements, respectively. This analysis was carried out at the Center for Stable Isotope Research and Analysis, Forest Ecosystem Research, University of Göttingen, Germany.

A long-term trend in $\delta^{13}C$ series, related to the decline in atmospheric $\delta^{13}C$ values, was determined following the method described by McCarroll and Loader (2004). To determine the relationship between the $\delta^{13}C$ and $\delta^{18}O$ values and climate variables, we used precipitation (monthly and annual means), Palmer drought severity index (PDSI), mean relative humidity, sunshine hours, maximum temperature and evapotranspiration. The climatic data were obtained from the

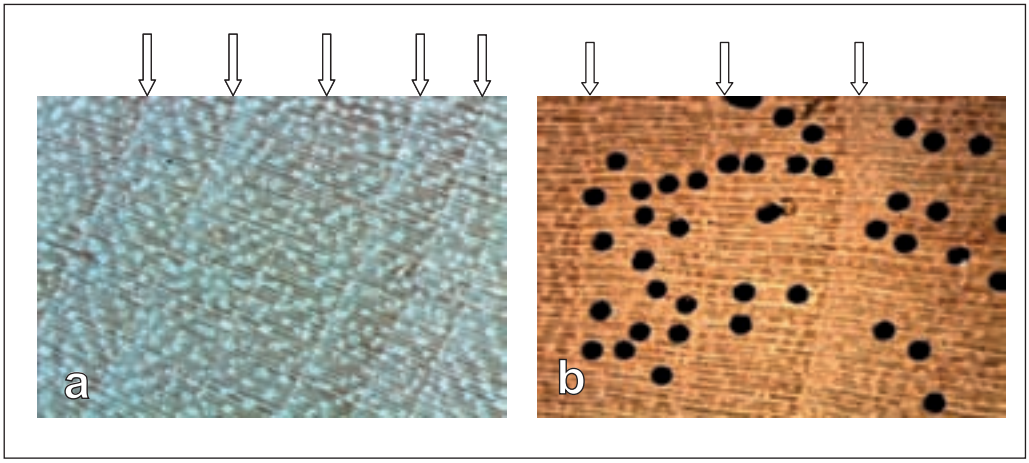


Figure 2. *Cross-sections of S. birrea: (a) arrows indicate annual growth boundaries; (b) method of sample preparation – black dots are holes drilled for obtaining wood material for stable isotope analyses.*

Burkina Faso Meteorological Agency, except for PDSI data, which were obtained from Dai *et al.* (2004). We used data from Dori Meteorological Station, which is the closest available station to our study site. Unless stated otherwise, results are statistically significant at $P < 0.05$.

Results and discussion

Formation of Growth Boundaries

Sclerocarya birrea forms very distinct ring boundaries characterised by marginal parenchyma bands, which run around the entire stem disc (Fig. 2a). This corresponds to the phenology of *S. birrea,* which is a drought-deciduous species shedding its leaves during the dry season, which lasts about 8 months and triggers the formation of annual growth boundaries. Compared with drought-deciduous *Acacia* species in Ethiopia, ring formation in *S. birrea* is very distinct.

Inter-annual $\delta^{13}C$ and $\delta^{18}O$ Variations

First results showed that the inter-annual patterns of $\delta^{13}C$ and $\delta^{18}O$ ratios in tree rings of *S. birrea* were uniform between the two individual trees, indicating that marked fluctuations in stable isotope ratios were synchronous. This is further confirmed by cross-correlation analyses of the species mean $\delta^{13}C$ series ($r = 0.42$) and $\delta^{18}O$ ($r = 0.62$). The $\delta^{13}C$ and $\delta^{18}O$ values ranged from –24.6 to –26.7‰ and 21.24 to 25.45‰, respectively. However, the statistical correlations are still preliminary and might change as sample size increases in the future.

The $\delta^{13}C$ and $\delta^{18}O$ mean values showed similar co-variation patterns with significant positive correlations ($r = 0.53$) (Fig. 3). The similar pattern of within and between $\delta^{13}C$ and $\delta^{18}O$ ratios indicates that external factors affected isotope fractionations in a similar way. Further analysis of the $\delta^{13}C$ and $\delta^{18}O$ ratios suggests that they provide information on the tree growth conditions in early, mid- and latter part of the growing seasons in the respective years.

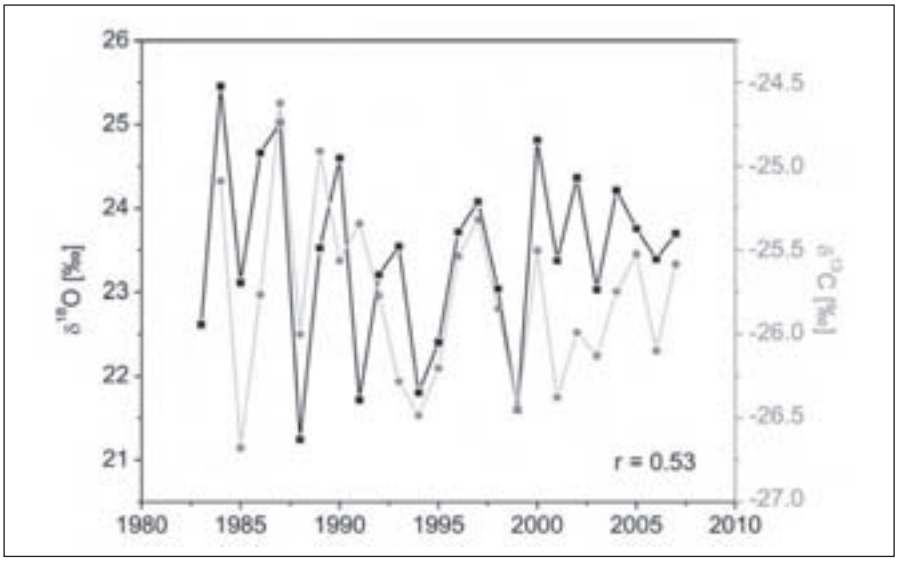


Figure 3. *Sclerocarya birrea* $\delta^{13}C$ *and* $\delta^{18}O$ *patterns and correlations*

$\delta^{13}C$, $\delta^{18}O$ and Climate

Sclerocarya birrea responded to the short rains that normally started in May, and showed significant correlations to the rainy season (July–September). In general, both $\delta^{13}C$ and $\delta^{18}O$ showed negative correlations with rainfall, humidity and PDSI. Conversely, they were positively correlated with sunshine hours, maximum temperature and evaporation (Fig. 4). Furthermore, precipitation in August (the wettest month) proved to have a stronger influence than annual precipitation on the $\delta^{13}C$ and $\delta^{18}O$ isotopic variations. Some of these relationships can be explained by the covariance of climatic factors, for example, high rainfall is accompanied by higher relative humidity and PDSI. Consequently, stomatal conductance is enhanced, resulting in the depletion of $\delta^{13}C$. In dry years, moisture stress will trigger stomatal closure and enrichment of the heavier isotopes (e.g. Gebrekirstos *et al.*, 2009; Wils *et al.*, 2010). Similarly, $\delta^{18}O$ in tree rings of *S. birrea* also records dry and moist years. During drier conditions, heavier water isotopes evaporate more slowly and hence higher concentrations of ^{18}O indicate drought years. In contrast, depletion of the heavier isotope ^{18}O indicates moist years. Treydte *et al.* (2010) report that $\delta^{18}O$ in tree rings primarily record source-water information. Hence the significant correlation of $\delta^{18}O$ with precipitation amount in the rainy season also documents that the main source of water for the growth of *S. birrea* is soil water.

Research Perspectives

Even though the three projects mentioned have been developed with specific objectives and different partner institutes, their results will enable us to draw important general conclusions. First, valuable information can be derived with regard to the adaptation potential of important agroforestry tree species in different climate regimes and agro-ecological zones. Using the stable-isotope technique, the water-use efficiency, growth strategy and adaptability to climate variability and climate change of key agroforestry species can be evaluated.

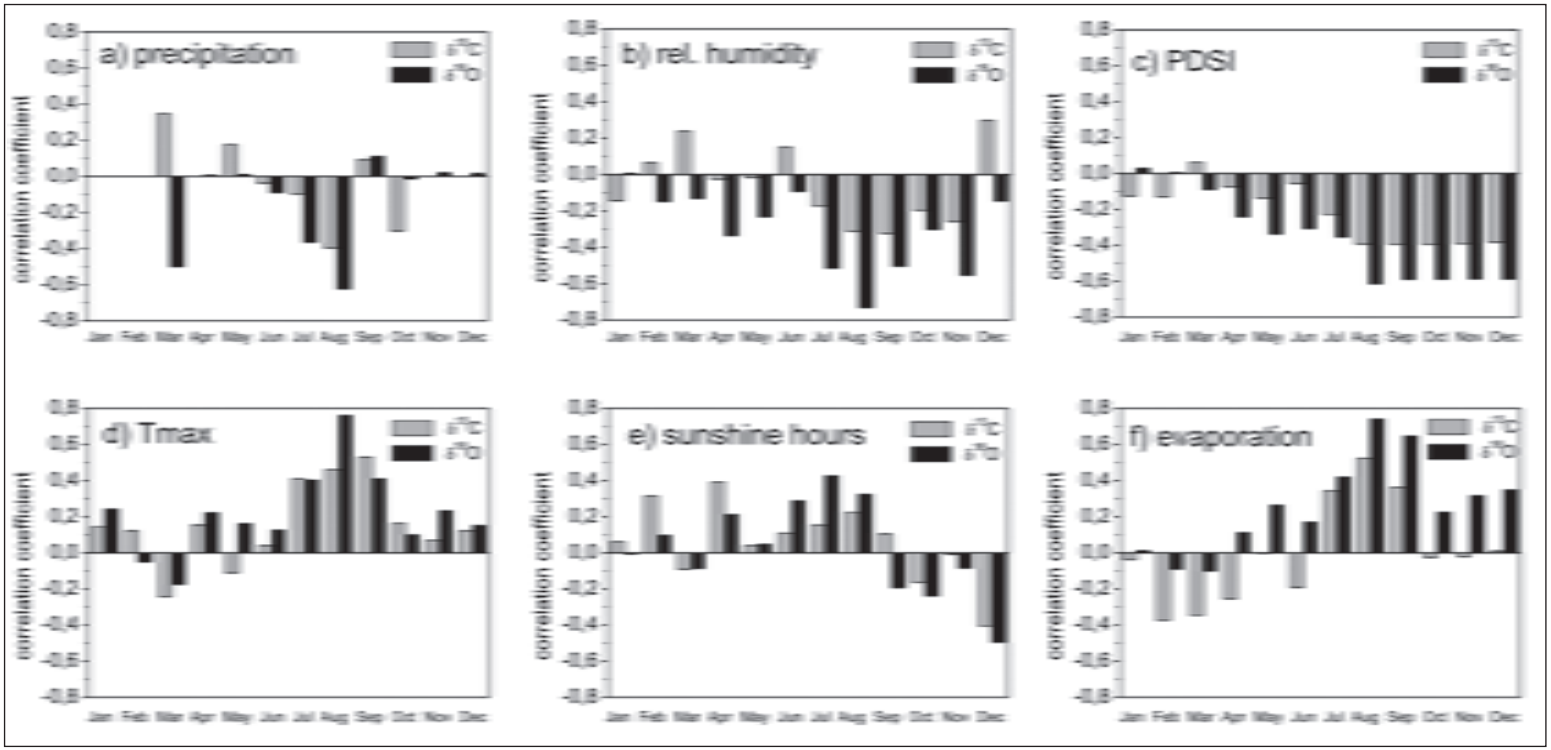


Figure 4. *Correlation between Sclerocarya birrea $\delta^{13}C$ and $\delta^{18}O$ and climate parameters (T_{max} = maximum temperature)*

A second important field of application is the reconstruction of long-term climatic variability and climate trends from tree-ring width and stable-isotope series. Since instrumental climate data are scarce or of short duration for vast areas of Africa, the range of natural climate variability is poorly understood, and thus the range of tree species' tolerance to climatic extremes is not known. Previous results from Ethiopia show strong climatic signals in tree rings and stable carbon isotope series (Gebrekirstos, 2009; Gebrekirstos *et al.*, 2008, 2009, 2010). The ongoing project in Munessa Forest, Ethiopia may result in chronologies of more than 350 years from *Podocarpus procera*. The pilot measurement results from the Sahel region are encouraging. Tree-ring chronologies spanning more than 100 years are under development for Burkina Faso and Tanzania. These findings may help in the identification and interpretation of extreme environmental and climatological events, and may provide information about the ways in which societies and ecosystems respond to them during times when no historical meteorological records are available (Gebrekirstos, 2009). This may form important input to the future Intergovernmental Panel on Climate Change report from Africa as well.

Finally, the tree-ring series developed in the three projects will be combined to establish large-scale correlation patterns between tree growth and sea-surface temperatures in order to explore continent-wide climate teleconnections and variations of atmospheric circulation patterns. In order to do this, there is a need to extend this work to additional important species and other parts of Africa.

Furthermore, these regional chronologies will be combined with tree-ring series surrounding the tropical oceans, established by project partners in other regions – the Middle East: Iran (e.g. Pourtahmasi *et al.*, 2007); and southern Asia: Nepal (e.g. Bräuning, 2004) and the Tibetan plateau (Bräuning and Mantwill, 2004; Bräuning, 2006). Additional tree-ring series from tropical South America (Ecuador) have been established (Bräuning *et al.*, 2009). Altogether, this tree-ring network surrounds the Indian Ocean and the tropical eastern Pacific, and can therefore be used to establish large-scale correlation patterns between tree growth and sea-surface temperatures in order to explore global processes around the tropics.

Acknowledgements

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Effect of Human Urine on Eggplant (Solanum melongena) Production and Salt Accumulation in Soil

Delwendé Innocent Kiba[1], Moussa Bonzi[1], Francois Lompo[1], Noufou Ouandaogo[1] and Papaoba Michel Sedego[1]

Keywords: African smallholders, low-cost fertiliser, optimum dose, soil pH

Abstract

The concept of using human urine as a source of nutrients for crops could be a good approach to supplying low-cost fertiliser to African smallholders. However, human urine could depress growth of plants, especially of salt-sensitive crops such as eggplant (*Solanum melongena* L.). A pot experiment carried out with three doses of human urine in comparison with mineral urea showed that a dose of 540 mL of human urine per plant (supplying nitrogen at half the dose [*Q*] of mineral urea, *Q*/2) improved eggplant growth and flowering as much as mineral urea, while 1.08 and 1.62 L of urine per plant (*Q* and *Q*+*Q*/2, respectively) depressed the yield of eggplant. In an incubation experiment, human urine applied to the soil at the same N dose as in the pot experiment (0.42 N kg^{-1} soil) led within 12 days of incubation to soil pH increase and to nitrification half that of mineral urea. The diluted dose (*Q*/2) of human urine decreased soil pH and increased the nitrification rate 12 times more than the pure urine. We concluded that 540 mL of urine per eggplant is the optimum dose for good production, and suggest that the dilution of human urine would be a suitable way to minimise potential accumulation of salt in the soil and to improve the nitrification process. Dilution techniques for human urine were proposed to farmers.

Introduction

Agriculture contributes greatly to the economy of African countries. In Sub-Saharan Africa, where around 82% of the rural population lives in countries where the economy is largely agriculture-based, agriculture is a strong option to reduce poverty and enhance food security (World Bank, 2008). However, agricultural productivity remains very low, partly due to low inputs of fertilisers, which remain very costly for African smallholders. Stoorvogel and Smaling (1990) estimated yearly soil nutrient depletion in Sub-Saharan Africa at 20, 10 and 20 kg ha^{-1} for nitrogen (N), phosphorus as phosphate (P_2O_5) and potassium as potash (K_2O), respectively.

The ECOSAN (Ecological Sanitation) concept considers human urine and faeces as source of nutrients (Langergraber and Muellegger, 2005), which seems to be a suitable way to supply low-cost fertilisers to farmers and to contribute to environmental sanitation and more productive and sustainable agriculture. Human urine collected via ECOSAN latrines is normally

1. Laboratoire Sol-Eau-Plante, Institut de l'Environnement et de Recherches Agricoles (INERA), BP 476 Ouagadougou 01, Burkina Faso.

free of pathogens and contains important amounts of nutrients, mostly nitrogen, and can be used as fertiliser (Esray *et al.*, 2001). Jönsson and Vinnerås, (2004) estimated the excretion of nitrogen in urine as 2–4 kg per person per year – a huge amount of nitrogen. Previous studies show that human urine used as a source of nitrogen improves crop yields in a similar way to mineral fertilisers. A pilot ECOSAN study in Burkina Faso showed that human urine contains around 2.7 g N L^{-1} and significantly increases maize grain and eggplant yield (Bonzi, 2005; Kiba, 2005). Guzha *et al.* (2005) in Zimbabwe also showed an increase in maize grain yield when human urine was supplied. A positive effect of human urine on beetroot and carrot yields has been shown in South Africa (Mnkeni *et al.*, 2008).

However, human urine contains a large amount of sodium (Na), which may lead to increased soil salinity and thus may affect the nitrification process and inhibit plant growth. In our previous research, we found that human urine supplying the same nitrogen dose as urea led to low survival rate (86%) of eggplant (Kiba, 2005). Adamson (2000) also observed a depressive effect of undiluted human urine on growth of the alga *Scenedesmus acuminatus*. In a study by Mnkeni *et al.* (2008), the application of human urine at 1.20 g N per plant led to high soil electrical conductivity and highest uptake of sodium by maize and tomato (compared with non-fertilised and urea treatments), but did not decrease yields. The depressive effect of human urine on plant yield will depend on the plant's sensitivity to salt. Eggplant is one of the most important vegetable crops and is cultivated in many tropical areas. In a study of the salt tolerance of eggplant, Heuer *et al.* (1986) showed that yields were reduced at the rate of 6.9% per unit (dS m^{-1}) increase in soil salinity. Ünlükara *et al.* (2010) showed that eggplant was moderately sensitive to salinity and that its water consumption and water-use efficiency decreased with increasing salinity. Bresler *et al.* (1982) classified eggplant as a salt-sensitive vegetable crop.

Considering the importance of ECOSAN fertilisers for African smallholders, and the possible depressive effect of human urine on plant production, it is relevant to determine optimum dose of human urine, especially for salt-sensitive crops, in order to propose sustainable use of this low-cost fertiliser. We hypothesised that human urine supplied at the N dose recommended for mineral urea is not the optimum dose for eggplant production. This study aimed to understand the effect of human urine on eggplant production and the evolution of human urine N in soil.

Materials and methods

Soil, Eggplant and Human Urine

The soil used in this study was taken from a farmer's field where a previous ECOSAN experiment had been carried out. All stones and roots were removed and soil was dried at room temperature. Chemical analysis showed that it was a moderately acidic soil (water pH 5.7) with low nutrient content – 0.44 g N, 0.31 g P_2O_5, 0.87 g K_2O and 6.2 g C kg^{-1}.

The human urine used came from ECOSAN latrines installed in a village of the central plateau of Burkina Faso (01°25'W, 12°21'N), located about 30 km from the Institut de l'Environnement et de Recherches Agricoles (INERA) research station at Kamboinsé. Urine was alkaline (pH 8.9) and contained 2.7 g N, 0.85 g P_2O_5 and 0.38 g K_2O L^{-1}.

The eggplant F_1 hybrid 'Kalenda', which is cultivated a lot in Burkina Faso, was used in this study.

Pot Experiment

The pot experiment was carried out in a greenhouse at the research station of INERA Saria (12°16'N, 2°9'E, 300 m altitude). The eggplants were grown first in a nursery for 33 days before being transplanted. No fertilisers were supplied to young plants. Each plant was transplanted into a 5 L plastic pot containing 5 kg of dry soil. The pots were arranged in complete randomised blocks. The following treatments were applied in four replicates:

- AC: absolute control (no fertilisers were applied)
- CMF: complete mineral fertilisation (2.94 g N + 5.9 g P_2O_5 + 6.7 g K_2O).
- U*Q*: urine dose *Q* (1.08 L urine + 4.98 g P_2O_5 + 6.29 g K_2O)
- U*Q*/2: urine dose *Q*/2 (0.54 L urine + 5.44 g P_2O_5 + 6.49 g K_2O)
- U*Q*+*Q*/2: urine dose *Q*+*Q*/2 (1.62 L urine + 4.52 g P_2O_5 + 6.08 g K_2O)
- CMF–N: mineral fertilisation without N (5.9 g P_2O_5 + 6.7 g K_2O).

The doses of fertilisers applied corresponded to those recommended for eggplant production in Burkina Faso (Bélem, 1998). Mineral fertilisers were applied as super-triple phosphate for P, potassium sulphate for K and urea for N.

Phosphorus and potassium were applied once, 2 weeks after transplanting, while urea and urine were fractionated and applied three times at 2, 3 and 4 weeks after transplanting (e.g. 1.02, 1.02 and 0.9 g N per plant, respectively, for CMF). The plants were watered daily in the morning and afternoon according to the farmer's practices. The quantity of water added at each watering was enough to reach the soil water-holding capacity.

Incubation Experiment

The incubation test was carried out at the research station of INERA Kamboinsé (12°28'N, 1°32'W, 296 m altitude). The objective was to study the effects of human urine on nitrogen mineralisation and to better understand the results of the pot experiment. Dry soil (1.5 kg) was introduced in each of four large plastic basins and the following treatments were applied:

- control: soil + 215 mL of distilled water
- urea: soil + 215 mL of distilled water in which 1.86 g of urea (46% N) was dissolved
- urine *Q*: soil + 215 mL of pure urine
- urine *Q*/2: soil + 215 mL of 50% diluted urine.

The amount of 215 mL of solution corresponds approximately to the ratio 4:9 of the soil maximal capacity of water retention required for the incubation (Sedogo, 1981). The amount of N supplied by 215 mL of pure urine and 1.86 g of urea (46%) corresponds to that supplied with the dose *Q* in the pot experiment (0.57 g N kg^{-1} soil). The treated soils were well mixed in the basins and then 50 g of soil was transferred to a small plastic pot and covered with plastic film. For each treatment, 28 small plastic pots were used. The pots were uniformly and gently pierced for airing. The first analyses were done on the first day (D0). The other 96 pots were kept at 28°C, and every 2 days the soil of four pots of each treatment was sampled (destructive sampling) for pH determination and NO_3^- and NH_4^+ extraction.

Parameter Measurements and Soil Analysis

The effects of the treatments on eggplant growth and development were assessed by measuring the height and diameter of the plants at 15, 30, 45, 60 and 90 days after transplanting (DAT) and counting the number of flowers at 70, 80 and 90 DAT.

For the incubation test, the soil pH was determined electrometrically (AFNOR, 1999) in a soil:water ratio of 1:2.5 with a pH meter (WTW InoLab, Weilheim, Germany). A 3 g sample of the incubated moist soil was mixed with 30 mL 1N KCl, shaken for 1 h, and filtered through Whatman no. 40 filters. The concentrations NO_3^- and NH_4^+ in the extracts were measured with a Skalar auto analyser (Skalar SANplus segmented flow analyzer, model 4000-02, Breda, The Netherlands). At each extraction, the soil moisture was determined and then used to calculate the soil nitrogen content on dry matter basis.

Statistical Analysis

Aanalysis of variance (ANOVA) was carried out with the software SAS 9.2. The Newman–Keuls test at 95% of significance level was used to compare the means when the treatment effect was significant.

Results

Effect of Human Urine on Eggplant Growth and Development

Figure 1 shows that eggplant growth in the treatments was not significantly different at 15 and 30 DAT. At 45 DAT, CMF had significantly taller eggplants compared with all the other treatments. At 60 DAT, all urine treatments were similar to CMF, while the treatment without N and the absolute control showed significantly shorter plants. At 90 DAT, treatments U*Q*/2, U*Q* and CMF were similar, with significantly taller eggplants compared with treatments U(*Q*+*Q*/2), AC and CMF–N. Average height at 90 DAT could be classified as U*Q*/2 > CMF > U*Q* > U(*Q*+*Q*/2) > AC > CMF–N.

The diameter growth of eggplant was not significantly different between the treatments at the first measurement (15 DAT). At 30 DAT, the treatment CMF–N induced a significantly smaller diameter stem compared with the treatments CMF and U*Q*, but was similar to U*Q*/2, U(*Q*+*Q*/2) and AC. All the treatments were similar at 45 DAT. At 60 and 90 DAT, all the urine treatments were similar to the CMF treatment and induced a larger eggplant diameter compared with all the other treatments.

At the first counting of flowers (70 DAT), the treatment CMF had more flowers than the other treatments. At the second counting (80 DAT), the number of flowers had increased with the treatment U*Q*, which was statistically similar to CMF. At the last counting (90 DAT), the number of flowers had decreased significantly in U*Q*, while it had increased in U*Q*/2, which was statistically similar to CMF.

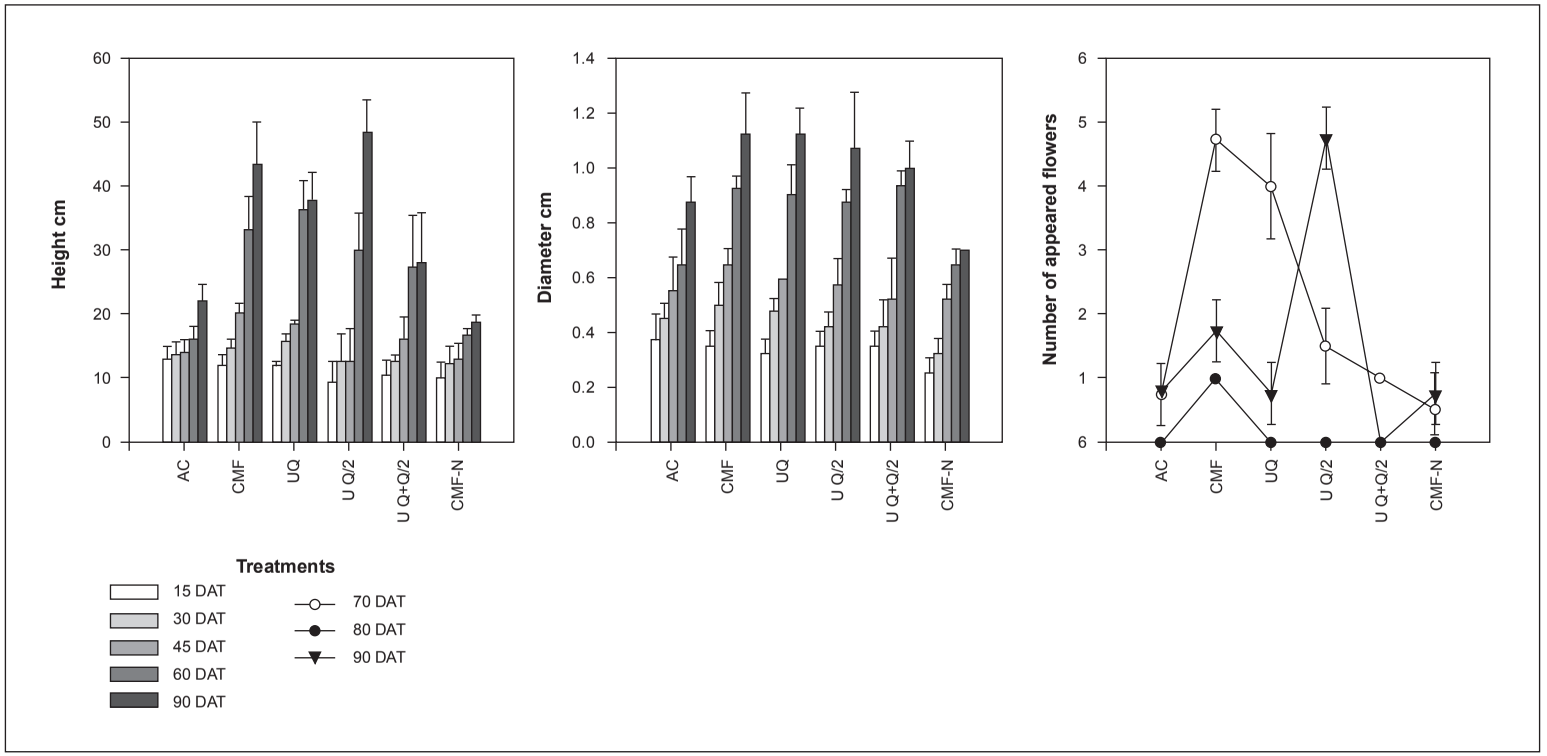

Figure 1. *Height and diameter of eggplants measured at 15, 30, 45, 60 and 90 DAT and number of flowers counted at 70, 80 and 90 DAT*

Evolution of Human Urine N in Soil

Figure 2 shows that the content of NH_4^+ was significantly higher immediately after the addition of diluted (U*Q*/2) and pure urine (U*Q*) than in the control, while those with urea remained at the same level as the control. After 2 days of incubation, the urea treatment induced an increase in NH_4^+ content and reached the level of diluted urine, but was statistically lower than that of pure urine. During 12 days of incubation, NH_4^+ content in the pure urine treatment decreased significantly and reached the same level as the urea treatment; both treatments remained higher than the diluted urine and the control.

Pure and diluted urine induced a significant decrease of NO_3^- content in the first 2 days of incubation compared with the control and urea treatment. After 2 days, NO_3^- content increased with the diluted urine and reached the highest level at the end of incubation, while pure urine induced lower NO_3^- throughout the incubation period compared with all other treatments. The control showed a greater increase in NO_3^- content than the urea treatment.

Soil pH evolution was similar to the evolution of NH_4^+ during incubation (Fig. 2). The addition of urine induced an immediate and significant increase in soil pH.

Discussion

Human urine is a source of nitrogen and can improve eggplant growth and development as well as mineral urea. However, the doses *Q* and *Q*+*Q*/2 had a depressive effect on eggplant growth and flowering. That probably confirms the low survival rate of eggplant that we observed on farm with the dose *Q* in our previous study (Kiba, 2005). We also observed that eggplants were suffering after application of the dose *Q* and *Q*+*Q*/2 during the pot experiment: plants were losing leaves and were stunted – more so with the dose *Q*+*Q*/2. These doses probably induced salt accumulation in the soil, which inhibits plant growth (Adamson, 2000; Simons and Clemens, 2004). We observed that in spite of proper watering, eggplants seemed to manifest water stress with the dose *Q*+*Q*/2, suggesting that high doses of urine probably increased soil osmotic conditions, which may affect water use. Indeed, Ünlükara *et al.* (2010) showed that the water consumption and water-use efficiency of eggplant decrease with increasing soil salinity. The increase of soil pH immediately after the application of the dose *Q* in the incubation experiment confirms the effect of human urine on soil salinity. Human urine applied at 0.42 g N kg^{-1} soil (dose *Q*) affected the nitrification process. Alenka *et al.* (1998) showed that high pH due to ammonium accumulation leads to a decrease in the ammonia-oxidising bacteria community, which probably explains the negative effect of pure urine on nitrification. Feng *et al.* (2006) showed that the dilution of human urine avoids the inhibition of nitrification by high NH_4-N concentration, minimises N loss and leads to high-quality biomass of *Arthrospira platensis*. Considering the quantity of N added with the treatments U*Q* and urea (0.42 g N kg^{-1} soil) and U*Q*/2 (0.21 g N kg^{-1} soil) in the incubation experiment, it appears that the recovery of mineral N is higher with the diluted urine (*Q*/2) than with pure urine and urea. The high soil pH induced by pure urine and urea (after 2 days of incubation) probably led to N losses. Indeed, N losses appear during nitrification through NH_3 evaporation, which is negatively correlated with NH_4-N concentration (Feng *et al.*, 2006). The decrease in pH during the incubation is probably due to the release of H^+ ions during the nitrification of NH_4^+, as shown by Mnkeni *et al.* (2008).

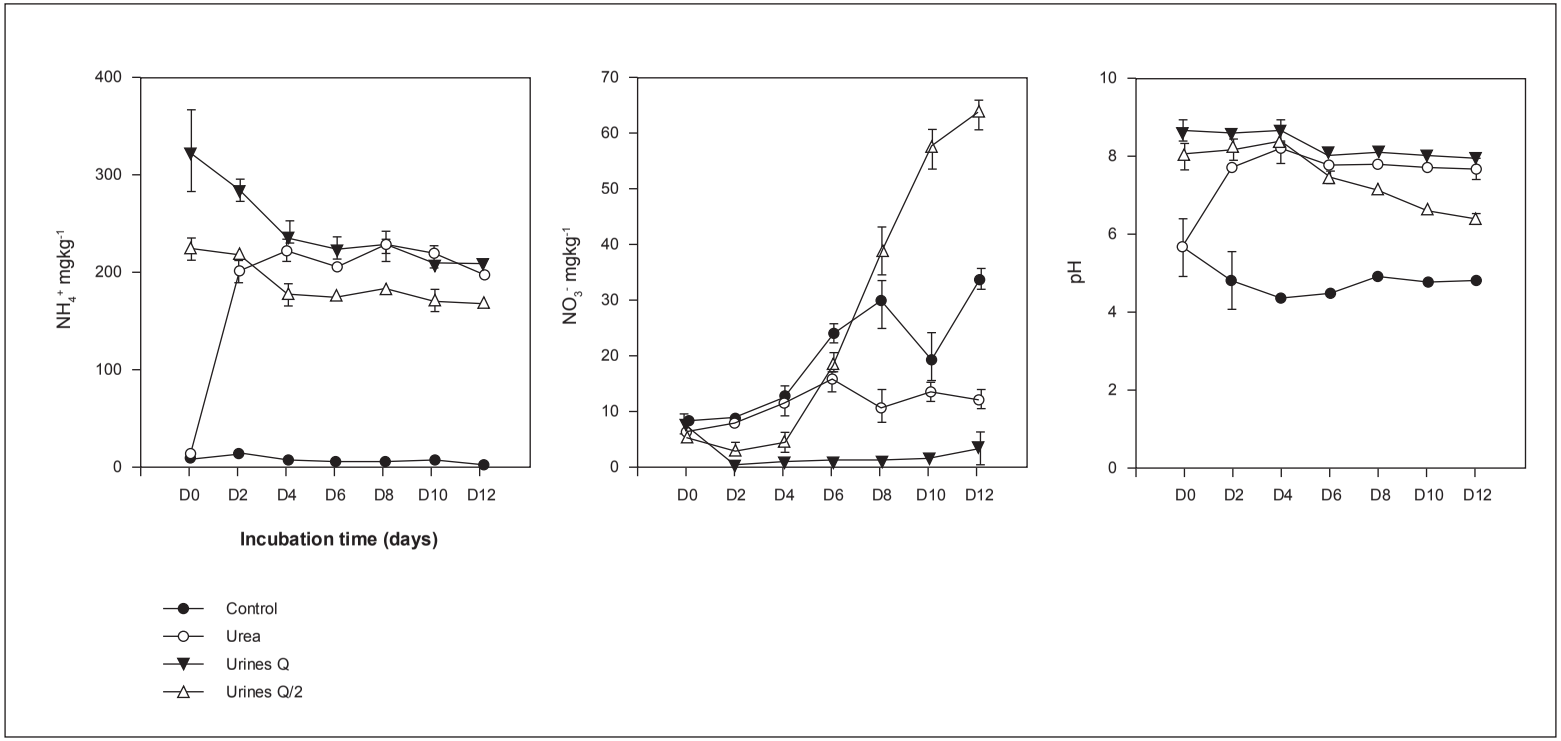

Figure 2. *Ammonium and nitrate content and soil pH measured during 12 days of incubation*

Conclusion

Combining the results of the pot and incubation experiments, it appears that the dose *Q*/2 (540 mL of pure human urine per plant) is optimum for eggplant production. The dilution of human urine with water is required to allow good nitrification and to avoid N losses. This dilution could be done during urine collection via ECOSAN latrines by using cans half full with water. It could be also done during pure urine application by immediately applying a volume of water equal to the volume of pure urine applied to the soil. It would be worthwhile to conduct a long-term experiment on the effect of human urine on the potential accumulation of salt in the soils.

Acknowledgments

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Territories, Flock and Biomass: Management Challenges for Sustainable Use of Resources in Northern Cameroon

Aimé Landry Dongmo[1]

Keywords: biomass, farming system, livestock system, north Cameroon, Sudano-Sahelian Africa, sustainable management, territory

Abstract

Since the late 1970s, the southern part of the Sudano-Sahelian Africa has simultaneously hosted a large population of farmers and of Fulani herders in search of arable land and pasture, respectively. The farmers have developed agricultural practices that maintain soil fertility through long fallow periods. The pastoralists have developed practices in order to exploit both natural forage and crop residues during the year. In this context, where the population tends to double every 20 years while agricultural production is still based on an extensive system, the high human pressure on resources has disturbed the balance of nature. The natural grazing land is cultivated by farmers in order to extend crop production, while the historically free grazing right of pastoralists 'herds on farmers' crop residues is now challenged. Competition, tensions and conflicts have become common over the use of crop residues as forage, as organic manure or for mulch-based cropping. Participatory analyses of practices, experiments and discussions with stakeholders have been carried out in three territories of northern Cameroon. Results show that the use of organic manure is more common and associated with higher dosages on the farms of livestock owners than on those of crop farmers. As a consequence, the livestock farmers obtain much higher biomass yields on much smaller land areas that they cultivate. In the dry season, their cattle freely graze the crop residues produced by farmers. During the rest of the year, part of their herd goes on transhumance towards favourable areas, while the rest is maintained inside the village to satisfy the needs of the family. The yields of biomass depend on both mineral fertilisation and the rates and ways in which biomass and organic matter are transferred between different plots and farms. Systems to enhance the management of the biomass and organic matter are suggested to improve the level of soil fertility and the production/sharing of crop residues in the short term (organic matter produced near the farm, manure produced in stables, penning of livestock), and in the medium term (developing mulch-based cropping systems). Conceptual models for sustainable management of biomass are then presented at different levels: plot, farm and village.

1. Institute of Agricultural Research for Development, PO Box 415, Garoua, Cameroon.

Introduction

Since the late 1970s, the most saturated and well watered lands in the Sudano-Sahelian zones have hosted sizeable populations of migrant farmers and herders in search of lands suitable for cultivation and grazing lands (Duras, 2006; Dongmo *et al.*, 2007; Adriansen, 2008; Dongmo, 2009; Basset, 2009). The extension of farmed land has created difficulties for herders in terms of movement and feeding of the cattle. The disappearance of fallow lands and the continuous export of biomass (through harvests or grazing on crop residues) have hastened the decline of arable farmlands used by farmers (Piéri, 1989; Ganry and Feller, 1998). Tensions and conflicts are rampant among the various stakeholders. To address the issue, techniques for the restoration and maintenance of soil fertility and to increase forage availability (pure forage culture or mixed culture) were designed in a farming environment (Landais and Lhoste, 1990; Berger, 1996). However, their adoption was limited as a result of socio-economic and organisational bottlenecks in the innovation trail and the use of these technologies for other purposes (Landais and Lhoste, 1990). The stakeholders have not succeeded in intensifying production to meet the needs of a population that increases twofold every 20 years. This failure is even more pronounced in northern Cameroon, where the small size of farms does not provide sufficient income to purchase livestock (Djamen *et al.*, 2003; Vall *et al.*, 2003).

To meet this challenge, research was carried out to determine the development conditions for better integration of farming and cattle-rearing. The work aimed to:

- determine the linkages and interactions (modalities and features) between agriculture and cattle-rearing in the farmlands which they share and work on during the year;
- quantify the inter-relationships between farming and cattle-rearing in terms of production/management of crop residues and organic materials in the farm holdings;
- propose innovative models and an approach towards the integration of farming and cattle-rearing.

Methodology

Since the 1980s, the emergence of research–development in farming communities has helped to take local conditions into consideration (Lefort, 1988). To promote innovation, efforts have emerged towards action-research in partnership (Liu, 1992), or intervention research (David, 2002), which takes due cognisance of all stakeholders in the formulation of programmes and in the search for solutions. This approach enables both researchers and stakeholders to adapt and change as the process progresses.

An initial agro-pastoral diagnosis was carried out on three farms in northern Cameroon by a multi-disciplinary team (Fig. 1). This was complemented by a comprehensive diagnosis undertaken by means of surveys on 45 farms per village. Then the farming and cattle-rearing systems of one-third of the farms surveyed were monitored for 2 full years. The involvement and awareness of the stakeholders were sustained throughout the process through a trial of cereal–forage intercrop, and involvement of stakeholders in the conception of a platform of negotiation for individual and collective management of biomass, soils and herds.

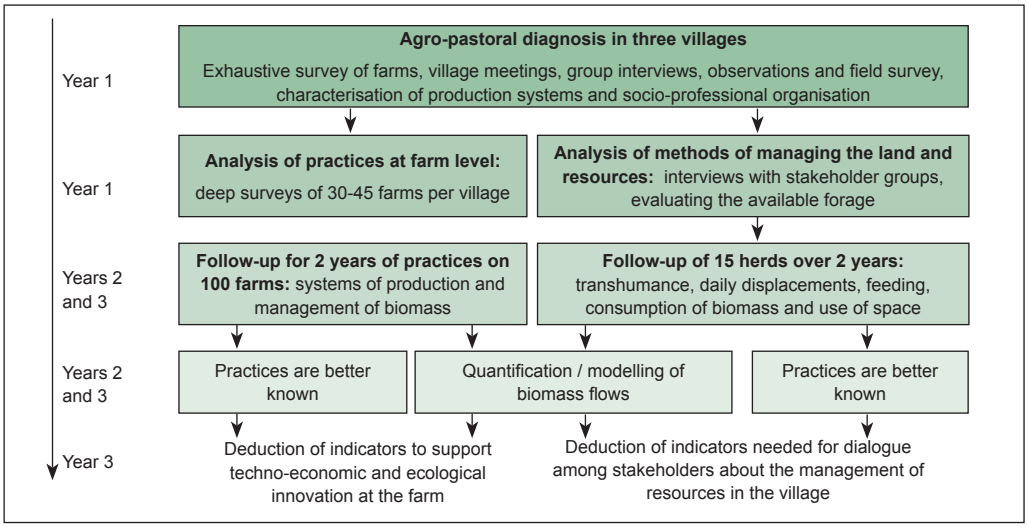


Figure 1. *Methodology for agro-pastoral diagnosis*

The method of collection and analysis of data in different steps of the action-research are presented in detail by Dongmo (2009). The method and results for mixed cereal and forage farming experiments and a framework for dialogue on the management of biomass and cattle are also described elsewhere (Dongmo *et al.*, 2010; Nchoutnji *et al.*, in press).

Results

Links and Interactions between Farming and Cattle-rearing on the Territory

Three Types of Stakeholders are in Charge of Managing the Biomass on the Lands

These are crop farmers, agro-pastoralists and pastoralists (Table 1). There are many farm holdings that have just a few cattle, with the farmer cultivating small areas. The farms of agro-pastoralists may be those of former farmers whose cattle have increased in number (>10 cattle), or those of former pastoralists who have lost part of their livestock and have adopted farming as an intensive occupation.

Agro-pastoralists had fewer farms in northern Cameroon than in the west of Burkina Faso or southern Mali (Table 1), where intermingling/assimilation of ethnic groups of herdsmen and farmers and large-scale farm holdings have promoted the combination of farming and cattle-rearing.

Strategic Herding of Livestock Helps Reduce Forage Pressure on Family Residence Land

The pastoralists who had more than 50 heads of cattle possessed two herds. The first herd ('home-grown' cattle, called *souredji*) brought together the milking cattle and the males intended for sale or draught use. These lived and fed permanently on the land adopted for sedentary life and provided domestic needs (milk, manure, energy), as well as cash. The second herd, numerically greater (bush livestock or *horedji*) was permanently on the transhumance trail throughout the year. This herd came back to the residence land mainly to consume the crop residues and fertilise the land with faeces.

Table 1. Farms in northern Cameroon and West Africa in 2006

	Crop farmers			Agro-pastoralists			Pastoralists		
Region	**SM**	**WB**	**NC**	**SM**	**WB**	**NC**	**SM**	**WB**	**NC**
Farms/type (%)	68	79	85	30	13	2	2	8	13
Working population	7	7	5.5	15	20	4	8	8	4
Area cotton (ha)	2	4.5	1.8	5.2	13	1.5	0.8	0.5	0
Area maize, sorghum + millet (ha)	4.3	3.7	2.2	7.9	10.2	2.1	1.0	2.2	2.1
Area other food crops (ha)*	1.6	0.3	3	4	0.4	3	0.5	0	0.3
Draught cattle† per farm owner	2	3	2	7	8	2	4	2	1
Breeding cattle† per farm owner	2	2.6	3	26	33	15	17	49	44

SM, southern Mali; WB, western Burkina Faso; NC, northern Cameroon.

*Groundnut dominated over rice and cowpea.

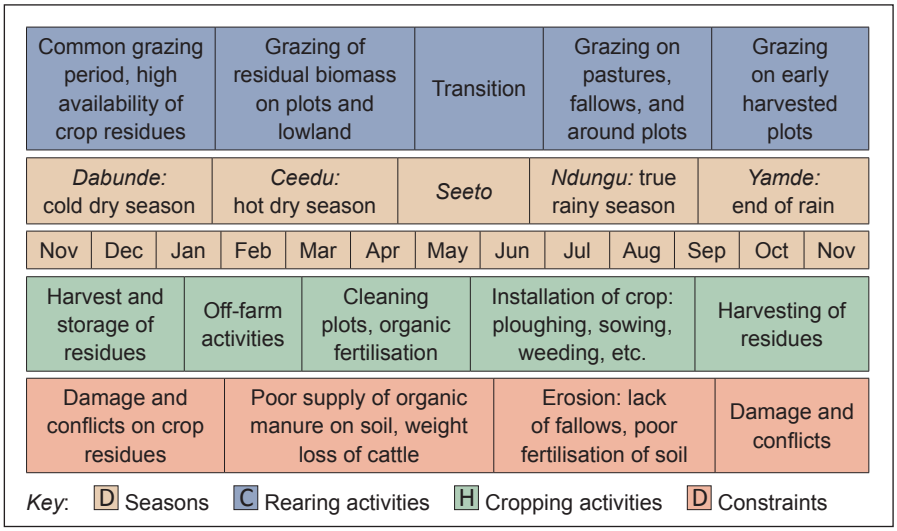
†Average number of cattle in farms that owned at least one breeding cow (25% of farms in NC, 60% in SM, 80% in WB).

Source: Duras, 2006.

Agro-pastoral Timetable Helps Rationalise Operations

The year was subdivided into five distinct seasons by stock breeders and farmers (Fig. 2). During *dabunde,* the transhumant livestock returned to the residence land. The farming residues were grazed directly on the plots, and small amounts of faeces were returned directly *in situ* by the animals. However, most faeces were deposited during the night on stockyards situated on plots near the house. During *ceedu*, the residues became exhausted, but some pastoralists were able to negotiate access to the dry-season farming residues. During *seeto* or *gataaje*, some home-grown cattle left the residence land and returned only when the grass grew. *Ndungu* is not an excellent season, as is commonly supposed. Emerging grazing lands were used much less because of their bad quality, and the grazing inland valleys were flooded. The hills, spaces with herbs between cultivated plots, fallow lands and cattle ranges were used much more by the cattle in *ndungu*. During *yamde*, the cattle used the inland valleys and the residues of the initial harvested lands. Tensions regarding access to the farm residues were high among farmers and pastoralists.

Figure 2. *Timetable for agro-pastoral activities on the land during the year.*



Production, Management and Distribution of Biomass According to Needs

Potential of Farming Residue on the Plots is Known

Sorghum leaves are very palatable for cattle, as is the straw (stem + leaves) of maize (Table 2). However, the partially consumed stalks are used for domestic construction. The empty groundnut shells, cereal cobs and rachis are generally thrown away, as are cotton tree stalks and sorghum canes. These are often burnt during the clearing of the plots instead of being transformed to produce manure or used to develop a mulch-based cropping system.

Table 2. Average yields (t ha^{-1}) of biomass in northern Cameroon (2006/07 and 2007/08)

	Farmers + agro-pastoralists + pastoralists					Farmers		Pastoralists	
Plant part	**Gnut**	**Maize**	**Sorg**	**Cott**	**Rice**	**Maize**	**Sorg**	**Maize**	**Sorg**
Grains	1.68	2.99	1.41	NC	3.49	2.79	1.07	3.76	2.39
Haulm	2.91	–	–	–	–	–	–	–	–
Shells	0.72	–	–	–	–	–	–	–	–
Straw	–	2.93	–	–	3.92	2.66	–	3.83	–
Cobs	–	0.63	0.24	–	–	0.58	0.21	0.76	0.41
Stalks	–	–	2.05	1.08	–	–	1.52	–	3.39
Leaves	–	–	1.02	0.97	–	–	0.89	–	1.89

G'nut, groundnut; Sorg, sorghum; Cott, cotton; –, not part of the plant; NC, not collected.

Farms are Theoretically Self-sufficient in Biomass

The recycling of farming residue into organic manure (OM) is characterised by about 25% shrinkage of initial dry matter (Berger, 1996). Based on the supply of the recommended 2.5 t ha^{-1} per year (Berger, 1996), the theoretical potential of OM (calculated from Tables 1 and 2) could – in a closed system (without range pasture) – ensure the appropriate maintenance of soil fertility in all types of farms. In practice, however, only 37% of farmers have access to OM, and they use it on less than 5% of their crop production area, at a rate of 1 t of dry matter OM per hectare in this part of the treated land. The priority is given to the most demanding areas in terms of fertility. Other farmers (63%) lack cattle, cart or labour force and cannot collect, transport and recycle the biomass during the dry season.

Similarly, based on a forage intake of 7 kg dry matter per tropical livestock unit (TLU)[2] per day, the forage potential should enable all the cattle to be fed for at least 470, 163 and 33 days in the farming areas belonging to farmers, agro-pastoralists and pastoralists, respectively. In practice, this residue is meant for feeding cattle over a period of 7 months during the dry season. To close the system (elimination of range pasture) requires an increase in the availability of biomass for use as forage. Thus biomass farming partnerships were tested with producers without compromising food crop yields.

Current Biomass Distribution is Carried Out to the Detriment of Farmers' Lands

The stocks of farming residue produced by farmers are low (Table 3). Before cleaning the land, biomass debris that has not been consumed by the cattle remains on the land. During the dry season, the cattle cover a distance of 8.5 km in 8–9 h on their residence land (Table 4). Grazing

2. TLU (tropical livestock unit) is a standard tropical cow weighing 250 kg.

takes place on farmers' lands, but defecation takes place at night on plots belonging to the pastoralists, at the rate of 1.65 kg TLU^{-1} day^{-1}. There were 19 TLU available per ha of crop lands, allowing for an average supply of 7 t of dung per ha on their land during the 7 months of the dry season. This quantity can be doubled or tripled with the arrival of the bush cattle.

Table 3. Production and supply of plant residues on crop production areas

Residue	Production (kg ha^{-1})	Proportion stored on farm (%)	Remainder on land after harvest (of crop residues) (kg ha^{-1}) [1]	Remainder before new crop season in May (kg ha^{-1}) [2]	Amount consumed by cattle in dry season (kg ha^{-1}) = [1] – [2]
Groundnut haulm	2,903	2	2,845	1,043	1,734
Stems + cotton plant leaves	2,047	0	2,047	1,314	665
Maize straw	2,930	2	2,872	1,335	1,469
Cowpea haulm	1,142	30	799	625	106
Rice straw	3,486	24	2,649	586	1,995
Sorghum stalks	2,051	11	1,825	1,939	723
Sorghum leaves	1,028	12	905		

Table 4. Proportion of activities (% time) of daily movement (*dabunde*)

Area	Grazing	Movement	Movement + grazing	Livestock watering	Total
Harvested lands	53	11	12	0	76
Grazing lands	1	5	1	0	7
Cattle paths	0	4	0	0	4
Water points	0	0	0	1	1
Road	0	1	0	0	1
Inland valleys	7	1	2	0	10
Total	62	23	14	1	100

Proposal for a Farming–Livestock Integration Model on the Land

Innovation at the Level of Farmland

Among farmers, the supply of 2 t OM ha^{-1} year^{-1} to the land (recycling of biomass pit into a cowshed manure pit) or the creation of mulch-based cropping system with 7 t of mulch ha^{-1}, is possible. In this case, if the right of range pasture is maintained, bush straw may have to be imported to supplement the residual biomass of the plots. But, if the right to graze crop residues is modified in favour of farmers, they can then formalise by contract the grazing of their farming residue in exchange for penning cattle on the fields to restore soil fertility. Among the pastoralists, increase in biomass production on the plots as well as on the collective rangeland is necessary.

Innovation at the Level of Land by Developing Rules and Practices

The commitments made by the various stakeholders at the end of the discussions touched on the choice of the level of partial restriction of the free range grazing of farmers' crop residues by pastoralists, and the equivalent biomass in forage units to be produced to make up for the

difference. At the end of an agreed deadline, an evaluation of the rate of acceptance of the OM- or mulch-based cropping system, and of the level of improvement of biomass yields, will help make the adjustment in commitments (Fig. 3).

Conclusion

Improvements in the management of plant biomass, soil fertility and cattle management can promote the intensification of farming and livestock systems. To achieve this, it is necessary to arouse the interest of farmers in innovative techniques and bring about changes in the mode of cattle management and production/management of forage resources. Assistance is necessary to strengthen the technical and organisational capacities of stakeholders on the farms, and to strengthen the negotiation and contract formalisation skills among the strategic groups or resource-users of the lands. The models of current practices and the prospects for the development of farming–livestock integration, co-designed with all stakeholders concerned, must be formulated to that effect. To succeed in these innovative projects, it is necessary that public authorities provide technical and organisational support, as well as strong logistical support (inputs, equipment, etc.), in order to get the process started.

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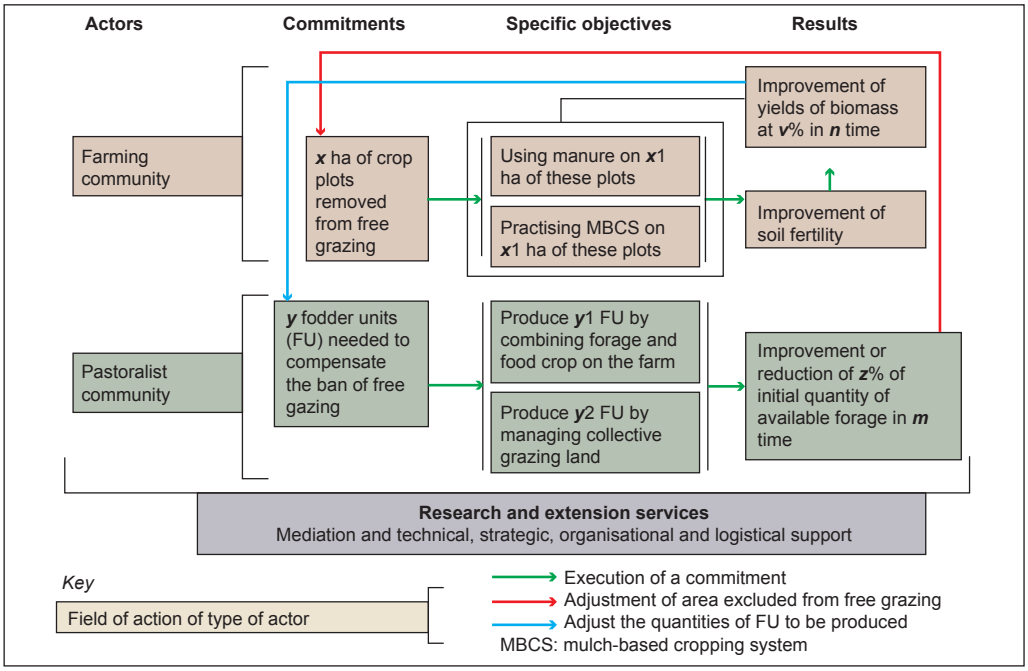
Figure 3. *Conceptual model for concerted management of biomass on the land.*



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Impact of Mosaic Disease on Varieties of Sweetpotato in Rural Sud-Kivu, Democratic Republic of Congo

J.A.K. Rubabura[1] and M.A. Bisusa[1]

Keywords: DR Congo, mosaic disease, *Sweet potato chlorotic stunt virus,* *Sweet potato feathery mottle virus,* *Sweet potato mild mottle virus,* ***Sud-Kivu, sweetpotato***

Abstract

Mosaic virus disease – caused by *Sweet potato chlorotic stunt virus* (SPCSV) – is a major problem on sweetpotato and is often associated with co-infection by *Sweet potato feathery* mottle *virus* (SPFMV) and/or *Sweet potato mild mottle virus* (SPMMV). These viruses may be vector-borne or come from non-healthy planting material. Control of virus diseases of sweetpotato depends primarily on the use of clean planting material, certified if possible. This study concerns the agro-pisciculture project of Centre Scientifique et Médical de l'Université Libre de Bruxelles pour ses Activités de Coopération (CEMUBAC), which aimed to determine the impact of mosaic disease on five varieties of sweetpotato in the rural area on the west coast of Lake Kivu in Sud-Kivu, Democratic Republic of Congo. Analysis of variance and direct observation were used. Variety Elengi showed the best performance, with high yield, large tubers and good weight despite infection by SPCSV. This explains why Elengi is the most cultivated variety by the rural population of Sud-Kivu. We asked the peasant farmers to inspect their fields regularly and remove any diseased-looking plants immediately after they are detected.

Introduction

In Central Africa and eastern Democratic Republic of Congo in general, and Sud-Kivu in particular, sweetpotato (*Ipomoea batatas* [L.] Lam.) is the main calorie-containing food after cassava and plantain; it is consumed daily by the majority of the local population, especially during the 'lean season'. The tubers provide large quantities of carbohydrates.

However, sweetpotato production is severely limited by pests and diseases. For example, *Sweet potato feathery mottle virus* (SPFMV), *Sweet potato mild mottle virus* (SPMMV) and alternaria disease are the most widespread diseases in sweetpotato in almost 68% of farmlands in Rwanda (Ndamage and Alvarez, 1987; Simbashi and Perreaux, 1987). Invasion by the pests *Cylas formicarius* and *Acraea acerata* can lead to decreases in yields of 60–90% (Appert and Deuse, 1988; Munyuli, 2000).

1. Department of Biology, Centre for Natural Science Research (CRSN), Lwiro, Sud-Kivu, Democratic Republic of Congo.

SPFMV can be found in any area where sweetpotato is grown (Karyeija *et al.*, 1998). This virus is transmitted by greenflies, which multiply very rapidly. Cotton greenfly (*Aphis gossypii*), groundnut greenfly (*A. craccivora*) and *Myzus persicae* have experimentally been proven to be carriers of SPFMV, as have the flies *Bemisia tabaci* (whitefly) and *Trialeurodes abutilonea* (Shaefers and Terry, 1976a, 1976b; Talekar, 1987; Raemackers, 2001).

A major disease problem in DR Congo is mosaic disease, caused by *Sweet potato chlorotic stunt virus* (SPCSV) and spread by whitefly (Wisler *et al.*, 1998) or via diseased planting material. Mosaic disease is aggravated by co-infection of the sweetpotato with SPFMV and/or SPMMV, expressed as an increase in the severity of symptoms, virus accumulation and viral movement in plants, and reduced yield.

Despite these disease and pest problems, the crop output obtained in rural areas of Rwanda is between 6 and 21 t ha^{-1} depending on soil fertility, variety and ecological zone (Ndamage and Alvarez, 1987). Moreover, in Sud-Kivu Province, the Bugorhe co-operative (one of 13 co-operatives in Kabare territory) is beset with malnutrition: vitamin A deficiency is affecting children and making them very weak (Bisusa, 2005).

The preferred option in the fight against the various diseases affecting sweetpotato and the elimination of malnutrition is the development of cloning or improved resistant strains that are accessible to farmers (Rakipov, 1995; Bisusa, 2006).

Comparative studies on virus infection of varieties Elenyi, Mugande, Karebe II, Japan and Tainung in the rural area to the west of Lake Kivu had not been carried out previously. The objective of this work was to evaluate the impact of mosaic disease on the yield of these varieties.

Materials and methods

Description of the Test Site

The experiment was carried out under a fish-farming project of the Centre Scientifique et Médical de l'Université Libre de Bruxelles pour ses Activités de Coopération / Biruga et Kalengu (CEMUBAC/BIKA) at the Lwiro Natural Sciences Research Centre (CRSN-Lwiro), which is in one of the villages of the Bugorhe community, Kabare, Sud-Kivu Province, DR Congo (2°14'01.6"S, 28°48'45"E). It was carried out from November 2006 to April 2007, in a climate belonging to the AW_3 type under Kôppen's classification (Leonard and Pecrot, 1960). CRSN-Lwiro is situated at an altitude of 1,647 m, with a sub-equatorial low-altitude tropical climate or damp tropical climate characterised by a short dry season of about 3 months. The annual rainfall varies between 1,200 and 1,700 mm and is spread unevenly over the year (Hecq, 1958). Generally, the climatic conditions for sweetpotato cultivation are good, the rainfall and temperatures are within acceptable limits for cultivation (Woolfe, 1992), and sweetpotato adapts to different types of agro-ecological environment (Leonard and Pecrot, 1960).

The test site had been fallowed for a period of 6 months after cultivation of soya bean (*Glycina max* L.) and therefore colonised by various plant species, dominated by *Galinsoga* sp., *Comelina* sp., *Bidens pilosa* and *Imperata* sp.

Varieties

Six varieties of sweetpotato were used:

- Japan: early maturing (2–3 months), pennate leaves, red petals, bulging potato with orange flesh, erect stem;
- Tainung: early maturing (2–3 months), coliform leaves, climbing stem, thick potato with orange flesh;
- Cancaolado: early maturing (3–4 months) with potato-like leaves, blackish stem, three-layered potato (violet, deep yellowish-blue) (these sweetpotatoes were stolen when they matured!);
- Karebe II: early maturing (3–4 months), lobed leaves, white potato with a sugary taste, strong green stem;
- Elengi: early maturing (3–4 months), lobed leaves, short ramification, early flowering, strong green stem, with several violet spots and a violet spot at the leafstalk insertion at the lower portion, potato with yellow flesh and a sugary flavour;
- Mugande: early maturing (3–4 months), lobed leaves, strong green stem, potato with white flesh and a sugary flavour.

These varieties were selected because they are the most widely cultivated and their yields are high in rural areas. Furthermore, the organoleptic features are highly appreciated by consumers. The yellow flesh is referred to in Bugorhe as '*namale*' or 'the potato with a yellow colour like palm oil' – it is more nutritious than white-fleshed sweetpotato, however, white-fleshed varieties are more commonly cultivated. The orange flesh is the most nutritious in terms of vitamins and mineral salts. Table 1 shows sweetpotato mineral and nutrient composition compared with other crops available in the area (Rakipov, 1995; Bisusa, 2006).

Table 1. Mineral and nutrient composition of sweetpotato compared with some other crops available in the area

Crop	Ca (mg)	P (mg)	Fe (mg)	Vit. A (IU)	Thiamin (mg)	Riboflavin (mg)	Aluminium nicotinate (mg)	Ascorbic acid (mg)
Boiled yellow sweetpotato	66	58	0.8	1,025	0.09	0.04	0.6	31
Boiled white sweetpotato	72	51	0.7	10	0.06	0.03	0.5	47
Plantain	23	36	0.9	340	0.06	0.04	0.6	32
Mango	8	17	0.5	2,580	0.09	0.05	0.7	47
Orange	41	20	0.4	200	0.10	0.04	0.4	50
Pawpaw	23	10	0.7	425	0.03	0.03	0.4	87
Pineapple	19	9	0.2	15	0.08	0.04	0.2	21
Tomato	18	18	0.8	735	0.06	0.04	0.6	29

Method

The work was carried out according to the direct observation method: observing the plant environment and taking note of the differences between infected plants and perfectly healthy plants at the same stage of growth by following them diagonally (Dupriez and Simbizi, 1996). Observation focused on 10 plants – five infected and five healthy – for each variety, once a week.

A completely randomised block design was used. Each plot was 2 x 2 m, with 1 m between plots in both directions (i.e. a 5 x 5 plot square). Key observations were made on parameters known to influence tuber yield: number of tubers, weight and diameters of tubers – the tubers were graded, separated (the infected ones and the good ones), weighed and grouped according to variety.

Harvest took place 4.5 months after commencement. An analysis of variance using one criterion for classification (ANOVA 1) was carried out, including the comparison of the averages two by two with values calculated from the least significant difference (*PPDS*) using the following formula:

$$PPDS = t_{1-\alpha/2} \times 2CMR/n$$

where *t* is the value from Student's *t*-test, *CMR* is the residual mean square, and *n* is the total.

Results and discussion

Elengi produced the most tubers, followed by Mugande, Karebe II and Tainung (Table 2). Japan had fewest tubers, but large ones (weight and diameter); the other varieties had tubers graded as large and small.

Table 2. Average number of sweetpotato tubers harvested per five sample plants

	Elengi	Mugande	Karebe II	Japan	Tainung
Healthy	35	20	20	18	20
Infected	23	20	20	18	20

Weight of Healthy Tubers

ANOVA showed highly significant differences between the weights of tubers of sweetpotato varieties – the weight of healthy tubers depended on genotype (variety) (Table 3). The least significant difference was 0.105.

Variety Japan had the heaviest tubers, followed by Mugande, Elengi, Tainung and Karebe II (Table 4). From the tuber weights, we were able to calculate the average yields of healthy tubers: Japan 300.55, Elengi 254.14, Mugande 202.10, Tainung 183.54 and Karebe II 181.52 kg ha^{-1}.

Table 3. Summary of comparisons of average weight of healthy tubers

	Karebe II	Tainung	Elengi	Mugande
Tainung	NS			
Elengi	S	S		
Mugande	S	S	S	
Japan	S	S	S	S

NS, not significantly different; S, significantly different.

Table 4. Weight (kg per tuber) of healthy tubers and differences between varieties

	Karebe II	Tainung	Elengi	Mugande	Japan
Tuber weight	1.8	1.82	2.004	2.52	2.98
Tainung	0.02				
Elengi	0.204	0.184			
Mugande	0.72	0.7	0.516		
Japan	1.18	1.16	0.976	0.46	

Weight of Diseased Tubers

ANOVA showed highly significant differences between the weight of diseased tubers of varieties (Tables 5 and 6), and the calculated least significant difference was 0.097.

Table 5. Summary of comparisons of average weight of infected tubers

Variety	Tainung	Elengi	Karebe II	Mugande
Elangi	S			
Karebe II	S	S		
Mugande	S	S	S	
Japan	S	S	S	S

NS, not significantly different; S, significantly different.

Table 6. Weight (kg per tuber) of infected tubers and differences between varieties

	Tainung	Elengi	Karebe II	Mugande	Japan
Tuber weight	0.832	1.016	1.42	1.52	2.518
Elengi	0.184				
Karebe II	0.588	0.40			
Mugande	0.688	0.5040	0.1		
Japan	1.186	1.002	0.598	0.46	

Variety Japan was most infected, followed by Mugande, Kabarebe II, Elenga and Tainung (data not shown). The average yields of diseased tubers were: Japan 203.51, Mugande 153.30, Karebe II 143.19, Elengi 102.44 and Tainung 83.89 kg ha^{-1} (derived from data in Table 6).

Thus co-infection by mosaic with SPFMV and/or SPMMV had an impact on tuber yield, which also depends on the use of diseased (pre-infected) planting materials, local eco-climatic conditions more or less favourable to outbreaks of vectors, and the health status of sweetpotato crops nearby.

Diameter of Tubers

Variety Japan had the largest tubers, followed by Mugande, Karebe II, Elenga and Tainung (Table 7). The varietal differences between the diameters of healthy tubers were highly significant (Table 8). The calculated least significant difference was 0.366.

Table 7. Diameters (cm) of healthy tubers and differences between varieties

Variety	Tainung	Elengi	Karebe II	Mugande	Japan
Diameter of healthy tuber	3.5	5.06	6.5	7.04	8.2
Elengi	1.56				
Karebe II	3	1.44			
Mugande	3.54	1.98	0.54		
Japan	4.7	3.14	1.7	1.16	

Table 8. Summary of comparisons of average diameters of healthy tubers

Variety	Tainung	Elengi	Karebe II	Mugande
Elengi	S			
Karebe II	S	S		
Mugande	S	S	S	
Japan	S	S	S	S

S, significantly different.

ANOVA showed highly significant differences between the diameters of diseased tubers. The diameters of diseased tubers were variety-dependent, and the least significant difference was 0.19 (Tables 9 and 10).

Table 9. Diameters (cm) of infected tubers and differences between varieties

Variety	Elengi	Tainung	Mugande	Karebe II	Japan
Diameter of tuber	3.06	3.2	6.08	6.1	7.8
Tainung	0.14				
Mugande	3.32	2.88			
Karebe II	3.04	2.9	0.02		
Japan	4.74	4.6	1	7.2	

Table 10. Summary of comparisons of average diameters of infected tubers

Variety	Elengi	Tainung	Mugande	Karebe II
Tainung	NS			
Mugande	S	S		
Karebe II	S	S	S	
Japan	S	S	S	S

NS, not significantly different; S, significantly different.

The viral infection had greatest impact on the diameter of the tubers of Elengi, followed by Japan, Mugande, Karebe II and Tainung.

Overall, however, Elengi gives high yield, large tubers and good weight despite viral infection, compared with the other varieties. Hence the rural population of Sud-Kivu on the western coast of Lake Kivu cultivates this variety the most. Tainung performs second best, but is less appreciated as it does not have a good flavour and is less consistent. Thus the public prefer Mugande (over Tainung) for its large tubers, robust and sweet flavour, despite its sensitivity to mosaic.

Conclusion

Elengi produced more tubers and gave good yield compared with other varieties, despite viral infection. This explains why this variety is liked by communities living in rural Sud-Kivu and why it is the most commonly cultivated. Tainung was second best, but less liked as its taste is not so appealing and it is less nourishing. These deficiencies explain why the rural populations like Mugande, which has big tubers in large quantities and has a sugary taste, in spite of its sensitivity to mosaic disease.

Mosaic is a destructive disease that affects sweetpotato. It most often occurs as co-infection with SPFMV and/or SPMMV. The control of viral infections of sweetpotato depends primarily on the use of healthy planting materials – if possible, certified materials. The infection rate of this material will vary depending on the local eco-climatic conditions that more or less promote the proliferation of carriers and the health condition of nearby sweetpotato crops. For this reason, we are requesting that farmlands be subjected to regular inspections and plants exhibiting any disease symptoms be destroyed immediately after they are detected.

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Integration of Farmers in Technology Developments as a Basis for Enhancing Sweetpotato Productivity in Kenya

J.K. Mwololo[1,2], P.W. Muturi[1,2], M.W.K. Mburu[2], R.W. Njeru[2], N. Kiarie[2], J.K. Munyua[2], E.M. Ateka[3], R.W. Muinga[4], R.E. Kapinga[5] and B. Lemaga[6]

Keywords: biotic stress, dissemination, focus group discussion, food security, participatory, sweetpotato virus disease, technologies

Abstract

Sweetpotato is a food security crop for smallholder farmers in Eastern Africa. Pest and disease constraints are the most important biotic stresses, with viral diseases being the most devastating. Through a focus-group discussion, it was established that lack of clean sweetpotato planting vines is a major constraint in production. Consequently, most farmers establish a new crop from virus-infected volunteer plants or an old sweetpotato crop. The objectives of the study were to identify farmer-friendly technologies for conservation and maintenance of healthy planting vines; disseminate the best appropriate technology for farmers and varieties tolerant to sweetpotato virus diseases (SPVD); and expose farmers to sound sweetpotato production and value-addition practices for increased income generation. The experiments evaluated spraying with dimethoate, physical barriers to virus vectors (insect-proof net and polythene), maize plants as a physical barrier surrounding plots, and roguing. Parameters monitored were SPVD incidence, whitefly and aphid populations. High numbers of whiteflies were recorded on the control and none on the plots protected by net or polythene barriers. Disease control through roguing was effective, and netting and polythene covers can be of value for rapid multiplication and maintenance of sweetpotato planting materials. Through a participatory approach, the roguing, net and polythene-cover technologies were demonstrated to farmers in coastal Kenya alongside farm trials to evaluate 17 sweetpotato genotypes for resistance and/or tolerance to the SPVD. By the end of the project, more than 100 farmers had adopted roguing on their farms. Disease-tolerant varieties were also disseminated to the farmers after the end of the evaluation period. The on-farm evaluation trials formed a basis for training farmers. Some farmers from the two key groups had an opportunity to attend a farmer-exchange visit in Uganda by courtesy of the Regional Universities Forum for Capacity Building in Agriculture. Integration of farmers in research, coupled with capacity-building, can enhance the adoption of new technologies, thereby enhancing sustainability.

1. Faculty of Agriculture, Makerere University, PO Box 7062, Kampala, Uganda.
2. College of Agricultural and Veterinary Sciences, University of Nairobi, PO Box 29053, Nairobi, Kenya.
3. Department of Horticulture, Jomo Kenyatta University, PO Box 62000, Nairobi, Kenya.
4. Kenya Agricultural Research Institute, PO Box 16, Mtwapa, Kenya.
5. International Potato Centre, PO Box 22274, Kampala, Uganda.
6. Regional Network for Improvement of Potato and Sweetpotato in Eastern and Central Africa (PRAPACE), PO Box 22274, Kampala, Uganda.

Introduction

Sweetpotato is an important food, feed and cash crop, especially for smallholder farmers in Eastern Africa, yet its productivity is greatly reduced by sweetpotato virus diseases (Mukasa *et al.*, 2003; Njeru *et al.*, 2004). The main sweetpotato-producing regions of Kenya are western, eastern, central and coastal areas (MoA, 2005). The most devastating virus disease affecting sweetpotato encountered in Africa and elsewhere is sweetpotato virus disease (SPVD) (Geddes, 1990). The disease is complex caused by dual infection by and synergistic interaction of the aphid-borne *Sweet potato feathery mottle virus* (SPFMV) and the whitefly-borne *Sweet potato chlorotic stunt virus* (SPCSV) (Gibson *et al.*, 1998). Virus diseases alone can cause yield reductions ranging from 56 to 98% (Mukasa *et al.,* 2003). The disease is perpetuated through planting diseased sweetpotato vines and this has led to its persistence in the farmers' fields (Ateka, 2004).

From a survey conducted in Kenya, it was observed that farmers seldom remove infected material from mature crops, destroy the infected haulms of harvested crops, or purposely isolate new plantings from affected crops – due to lack of information on the cause and spread of viruses. However, improved phytosanitation offers unknown but potentially considerable benefits for SPVD control (Ateka, 2004). Variety-based tolerance to SPVD has been identified (Byamukama *et al.*, 2002) and provides a cheap and sustainable way of increasing productivity. Farmers' awareness and knowledge of how to manage the disease, identification of tolerant varieties with traits desired by farmers and markets, and methods of maintaining clean planting materials in farmers' fields are vital for maintaining high productivity. Therefore this study aimed at identifying a farmer-friendly agro-technological package for conservation and maintenance of healthy sweetpotato planting vines prior to planting, and evaluation and dissemination to farmers of disease-tolerant varieties.

Materials and methods

Participatory Rural Appraisal

Focus-group discussions were conducted in Lukore of Kwale district in 2006. Farmers (from Lukore and Mwaluvanga), scientists from the University of Nairobi and Kenya Agricultural Research Institute (KARI) Mtwapa and extension staff from the Ministry of Agriculture (MoA) jointly conducted the activity. The approach provided an interactive forum for farmers, extension and research staff to share views and jointly plan ways of addressing the issues identified. Information was collected on resource availability, crop production patterns, role of sweetpotato in agricultural systems and marketing. There was a general group discussion, and later gender-based discussions were held (men and women separately). A structured questionnaire was used to guide the discussion. Fifty farmers (30 women and 20 men) participated and flip charts were used to capture pertinent issues.

Evaluation of Technologies for Multiplication of Clean Planting Materials

Clean sweetpotato vines of a moderately susceptible variety (SPK004) were obtained from the International Potato Centre (CIP) in 2006. Planting beds measuring 2 × 3 m were prepared. The experimental design was a randomised complete block design (RCBD) and treatments were

replicated three times. Sweetpotato cuttings with three or four nodes were planted on the beds at a spacing of 20 × 10 cm, with two-thirds of the cutting being buried in the soil. The treatments were: spraying with dimethoate once every 2 weeks after planting; physical barriers to virus vectors (insect-proof net and polythene); maize plants as a physical barrier surrounding plots; and the control. The polythene and net barriers were supported by wooden frames, which were about 1 m above the ground. During irrigation, the net and polythene covers were removed then replaced immediately after water application. The crop was irrigated weekly and weeded whenever weeds grew. Calcium ammonium nitrate fertiliser (30 kg ha^{-1}) was applied at 3 and 8 weeks after planting. The gross margin per unit area of spray, net, polythene, maize and roguing was analysed with labour costs excluded.

Sampling was done fortnightly, starting 1 month after planting, to monitor disease incidence and severity, and whitefly and aphid populations. To obtain disease incidence, the number of plants per plot showing SPVD symptoms (stunting, distorted leaves with a chlorotic mottle or vein clearing) was determined and expressed as a percentage of the total number of plants assessed. Severity was rated on a scale of 1 to 5, with 1 = no disease symptoms, 2 = mild disease symptoms, 3 = moderate disease symptoms, 4 = severe symptoms, and 5 = very severe symptoms (Hahn *et al.*, 1981).

Assessment of vector populations (whiteflies and aphids) was done early in the morning when the insects were less active. The number of adult whiteflies underneath the leaves was counted to obtain the whitefly population, whereas the number of aphids on the same plants gave the aphid population. Data were subjected to analysis of variance (ANOVA) using Genstat software, and least significant difference (LSD) was used to separate means.

Sweetpotato Variety Evaluation for Tolerance/Resistance to Virus Disease

Seventeen sweetpotato genotypes were tested at three sites for two seasons – short (May to September 2006) and long (October 2006 to February 2007) rainy seasons. The 17 genotypes were either improved or local landraces. The three sites were KARI-Mtwapa farm in Kilifi District, which is located at an altitude of 30 m above sea level, and Lukore and Mwaluvanga in Shimba hills, Kwale District, both located at an altitude of 46 m above sea level. The soils are sandy and sandy loams in Kilifi and Kwale, respectively (Michieka *et al.*, 1978). The mean annual rainfall is 1,200 mm in Mtwapa and 1,400 mm in Kwale, with a mean monthly maximum temperature of 33°C in Mtwapa and 27°C in Kwale, and minima of 22 and 16°C, respectively (Jaetzold and Schmidt, 1983).

Apparently clean planting materials were obtained from CIP and KARI-Embu, and multiplied at KARI-Mtwapa under a stringent spraying regime to control vectors. The vines were distributed to farmers, who planted in May 2006. At the beginning of the short rainy season (October 2006), vines were obtained from the previous season's crop and planted in new fields approximately 200 m away at all sites. The experimental design was RCBD replicated three times. The land was ploughed, harrowed and ridged at the three sites before planting. The sweetpotato clones were planted at a spacing of 0.8 × 0.3 m on plots measuring 4 × 3 m. Weeding was done twice a month in the first 2 months and the plots were rogued once thereafter. The parameters monitored were disease incidence, whitefly and aphid populations, assessed as in the previous experiment (above). Yield of varieties was also determined.

Results and discussion

Lack of market, lack of quality planting materials, insect pests, drought and scarcity of land were the key factors that constrained sweetpotato production. High transport costs, price fluctuations and lack of quality standards in markets were also mentioned. None of the farmers was aware that SPVD limits sweetpotato production and is spread by insect vectors. Rather, they attributed low productivity and SPVD symptoms to soil infertility. There was therefore a need to make farmers in the area aware of SPVD, train them in methods to produce disease-free/clean vines, and evaluate and disseminate disease-tolerant varieties with consumer-acceptable traits. Field sanitation, selection of clean planting vines and isolation of new crops from the old ones were not practised.

There was no disease incidence observed in any of the treatments throughout the growing season at the two sites. The absence of SPVD incidence in all the treatments can be attributed to low disease inoculum level at the sites of experimentation, rather than the treatments. High incidence of SPVD is attributed to year-round cultivation of sweetpotato, which provides ready sources of disease inoculum (Alicai *et al.*, 1999); the current study concurs with this as sweetpotato is not widely grown at Kabete field station and Juja farm. Aphids were absent from all the treatments and whiteflies were in low numbers, thus the absence of SPVD can also be attributed to the low numbers of the insect vectors responsible for the transmission of the component viruses (Aritua *et al.*, 1998).

There were significant differences in the number of whiteflies among the treatments (Fig. 1). Whitefly population increased with time, then decreased. The whitefly population decreased greatly in the 19th week after planting, probably due to the onset of heavy rains. Whitefly population was highest in the control and lowest in the net and polythene cover treatments. The populations were high in sweetpotato surrounded by a maize barrier at the end of the season. Whiteflies were absent in the net- and polythene-covered plots, as the structures formed a physical barrier to insect vector entry. Whitefly populations in the other treatments differed significantly only at 16 weeks after planting (Fig. 1). The maize barrier seemed to harbour a high population of whiteflies, possibly because maize has wide leaves, which provide a sheltered micro-climate. The wide maize leaf offers conducive conditions for whitefly multiplication and oviposition (Legg, 1994). The low population in the maize-protected plots in weeks 12–14 could be attributed to oviposition and multiplication within the maize barrier itself. Where a maize barrier is used, it would be prudent to spray the maize, and the maize would act as a trap and reduce the spray area since it would not be necessary to spray the sweetpotato crop.

Chemical spray would lead to a reduction in the number of whiteflies only for a short period, then the population would build up steadily, concurring with reports by Aritua *et al.* (1998) that spraying does not always keep away disease vectors. It was also observed that, immediately after irrigation, the whitefly population was greatly reduced, possibly due to physical damage caused by the impact of water drops (Legg and Ogwal, 1998) or reduced oviposition (Fishpool and Burban, 1994). These results are consistent with earlier reports by Aritua *et al.* (1998), Alicai *et al.* (1999) and Otim *et al.* (2001) that climatic conditions have a strong influence on the population dynamics of insect vectors.

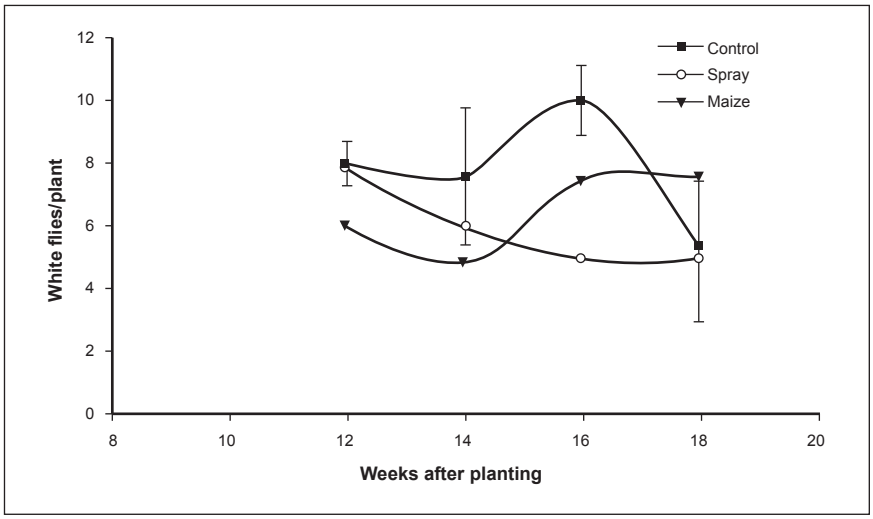

Figure 1. *Whitefly population among treatments over time*

Note: The polythene and net covers had no whitefly infestation, so are not presented in the graph. Error bars (standard difference) are given only for the control as it acted as the check against the other treatments.

The unit cost of polythene, spraying and netting was 0.5, 0.5 and 1.2 Kenyan shillings[7] (Ksh), respectively. Thus the use of polythene covers is cheaper for farmers and farmer groups for fast multiplication of sweetpotato without a delay in transferring the vines to the field.

Disseminating the Technology to Farmers

Dissemination of the technology was enhanced through a participatory research approach whereby farmers were involved in the on-farm sweetpotato evaluation for tolerance to SPVD. The farmers were from two major sweetpotato-growing groups in Shimba Hills, Kwale District. Variety-based tolerance was found in Jonathan, Japonese and Zapallo. Evaluation of sweetpotato quality was done at the end of the long rainy season. More than 50 farmers took vines of the different varieties. The farmers preferred Jonathan, SPK004, Zapallo, Japonese, Ejumula, Kemb10 and Ex-shimba, because they had consumer- and farmer-preferred traits and had reasonable tolerance to SPVD. This indicated that these varieties possess the best farmer-preferred traits, and they can be used in breeding as a source of those traits. Although variety Jonathan was ranked among the best field performers coupled with high yields, farmers ranked it as intermediate on general acceptability. Thus its adoption could be slow compared with other farmer-preferred varieties. Consequently, it would be of great value if the desirable traits were incorporated in this variety through breeding. Ranking of varieties by children might well influence selection of the best varieties, so this should be included in the future – children are also key consumers of sweetpotato as food.

Maintenance of disease-free planting vines over the dry season was identified as a pivotal requirement for sustainable supply of planting materials. Consequently, an on-farm demonstration of maintenance and multiplication of healthy planting materials was conducted.

7. Exchange rate: €1 ≈ Ksh 120.

The farmers established a communally owned nursery near a river. They practised roguing to keep the vines of different varieties free from disease. The varieties multiplied were Jonathan, SPK004, Ejumula, Kemb10 and Jubilee. This was expected to supply clean planting vines and save farmers the cost of accessing them from research stations (Kapinga *et al.*, 2005). Extension staff from MoA and scientists from KARI were also trained so that they can continue promoting the appropriate technologies and practices among farmers.

The farmers who were involved in the participatory research had a chance to visit fellow farmers in Uganda as a capacity-building strategy. This was facilitated by the Regional Universities Forum for Capacity building in Agriculture (RUFORUM). The farmers visited national agricultural research stations, food processing industries and farmers' groups in Uganda, where they learned good methods of crop production (particularly sweetpotato, among others) and on-farm value addition to generate more income. For instance, they were trained in how to make juice from orange-fleshed sweetpotato and how to process fruits into juice by a fellow farmers' group. This again contributed to technology transfer, and the Forum enlightened the farmers on how they can use locally available farm produce to empower themselves economically.

Conclusion

The key outcomes were that farmers and extension staff jointly identified production problems and solutions; awareness was created; 20 farmers were trained in maintaining clean germplasm; and disease-tolerant varieties were disseminated to the farmers. The netting and polythene covers can be recommended for maintenance and multiplication of quality sweetpotato planting materials due to their ability to exclude disease vectors. Commercial farmers and farmers' groups can adopt net structures if they grow vines for seed as a business. Farmers can also adopt roguing of infected plants as a way of managing the disease in both nursery and field. The identification of tolerant varieties with consumer-preferred traits together with the farmers was a major boost to sweetpotato production in the region.

Acknowledgement

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Impacts of Proposed Large-scale Monoculture Development Projects on Wetlands and Wetland-dependent Communities, Tana Delta Coast Province, Kenya

Joan Aum Otengo[1]

Introduction

Tana Delta is a place of spectacular panoramic views, composed of scrubland teeming with game and birds. The Tana Delta is best accessed by road (3 h drive) from Malindi. The Tana River is Kenya's largest river at nearly 1,014 km long. The headsprings for the Tana are found on the slopes of Mount Kenya and the Aberdare Range. These tumbling streams converge into a wide and powerful torrent to the east of the mountains before changing nature yet again into a slow, meandering river for the lower half of its course to the Indian Ocean. The river is filled with hippopotami and crocodiles.

The lower part of the Tana River dissects a wild and vast area of Kenya, where the riverine strip makes a vivid contrast to the parched bush stretching for miles on either side. The Tana River is the only supply of water for a wide area of dry bush, rocky soil and little rainfall. It is not until the river passes Hola and approaches the coastline that the surrounding countryside becomes greener and less stark. The delta area is a low, flat area of savannah grassland, stands of doum palm trees (*Hyhaene thebaica*) and swamps, criss-crossed with tide channels. Small, narrow channels, the colour of milky coffee, meander through thick green jungle which opens into small villages, where herd boys bring their cattle to drink and women wash clothes in the river despite the ever-constant threat of crocodiles. Hippos wallow in shallow pools; reedbuck, topi, buffalo, bushbuck and elephants roam the grassy clearings. The Tana Delta is most famous, however, for its prolific birdlife, featuring huge flocks of egrets, pelicans, ibis and storks.

Finally, the river pours its silt-rich, chocolate-coloured waters into the Indian Ocean at Ungwana Bay, a huge sweep of deserted beach, which stretches to the horizon on both sides of the delta. The Tana Delta wetlands are located in the new Tana Delta District, which was separated from the larger Tana River District. Tana Delta District covers Garsen and Kipini Divisions, both in Garsen Constituency. The Tana Delta is one of the six deltaic areas of Eastern Africa and is Kenya's largest deltaic zone. It is estimated to cover about 130,000 ha, of which 69,000 ha are regularly inundated. The Tana Delta is arguably one of Kenya's most pristine natural environments; it is located in a semi-arid area in Garsen, Tana Delta District, Coast Province.

A striking feature of the delta is the prodigious variety of its wetland inhabitants and the richness of its biodiversity. The area supports a wide gallery of forest, floodplain and swamp. The freshwater floodplain creates rich grassland, ringed by stands of doum palm. Permanent oxbow lakes and ponds are also abundant in this wetlands ecosystem. The delta supports uncounted

1. Kenya Wetlands Forum Secretariat, c/o East African Wild Life Society, PO Box 20110-00200, Nairobi, Kenya.

plant and animal species, some of them endangered on a global scale. The Tana Delta coastline is a stronghold for endangered marine turtles. The delta wetlands contain high concentrations of fish and wildfowl, both migratory and resident. The forest areas are largely indigenous. They are home to two endangered primates – Tana River Colobus and Crested Mangabey monkeys.

The Tana Delta is immensely valuable to the local people, especially minority groups who have built an intricate connection with it. The production systems and livelihoods of the majority of the delta's communities are linked to the dynamics and functioning of the river–wetlands ecosystem. These communities include the Watta (who gather wild flora and fauna), Wagoshi, Wasanya, Malakote, Boni, Bajuni and Wakone. The delta is used extensively by pastoralists, who graze their cattle in the areas around the floodplains. It is a dry-season grazing fallback area for many pastoral communities, some of which come from neighbouring districts, such as Ijara, Lamu, Garissa and Wajir. The regular inundation of the delta also supports crop farming and fishing. The near-permanently available grassland gives the Pokomo farmers favourable conditions for engaging in farming and fishing activities in the hostile semi-arid environment.

Study Problem

The Tana Delta is under threat, jeopardising its environmental value and functions, and livelihood support to the local minority communities dependent on the wetlands. Some of the projects and activities either proposed or implemented in the area include: the Global Environment Facility's Tana River Primate Reserve Project; the Tana Delta (Rice) Irrigation project; industrial prawn farming; the Lower Tana Village irrigation scheme; the Bura irrigation scheme; titanium mining; oil and gas exploration. At stake is a proposal from Mumias Sugar Company, together with the Tana and Athi River Development Authority, to convert 20,000 ha of the wetland into a monoculture sugar plantation. In addition, there is a pending proposal by Mat International to convert a further 60,000 ha into sugarcane, the Kenyan government plans to lease 40,000 ha to the Qatar government for horticulture, and Canadian biofuel company Bedford has a proposal to establish a *Jatropha* plantation in the delta to be used in production of ethanol and biodiesel.

The proposed sugarcane plantations would be sited at the very heart of the delta, where the people live and where fauna and flora are at their most diverse. This would displace a number of people, and there is no relocation plan. The depletion of grazing resources following the implementation of the proposed scheme would increase the grazing pressure on the remaining portion of the delta and the arid and semi-arid environment surrounding the delta. The scheme would cause physical depletion of the grazing resources, particularly the dry, seasonal fallback areas. Further grazing may also be lost due to the general drying up of the delta. Tana Delta wetlands, which support numerous lives, are now becoming seasonal at an alarming rate, while others have dried out completely. This has affected local livelihoods, especially those of pastoralists, who have lost almost all their flocks to the continued dry spell in the area. Climate change has not spared fauna and flora either. Its impacts can be perceived from the increasing cases of human–wildlife conflict in the area. With wild animals (herbivores and carnivores) entering villages as they hunt for water and food, the farming and pastoralist communities are joining the Watta minority groups whose occupation is hunting and gathering in the wild. At stake are the wild fauna and flora, which currently face too much pressure.

Salt is now infiltrating into farms. This has never been recorded in these areas before and is perceived to be due to the rising of the sea level and to the fact that the mangrove vegetation along the coast has been degraded through deforestation.

Ironically, the livelihood of minority indigenous groups in Tana Delta is threatened by the opportunity brought about by the Kyoto Protocol of carbon trading and carbon sequestration plans. Due to their insecure land tenure system, these groups are facing displacement as the government and its development partners are taking advantage of the situation to bring in tourist projects. The critical ecosystems, used as fallback areas for pastoralists during the dry season, will be affected by these projects. The schemes will cause physical destruction of the floodplain habitat upon which livestock herding is dependent.

Both projects are proposing to use irrigation technology, which not only will lead to depletion of valuable water resources for human and wildlife use, but also will alter the hydrological systems and characteristics of the area. The proponents of the projects believe that the Tana River region lags behind in development and records high levels of poverty, despite the resource base it is endowed with. Emphasis is placed on development and economic growth with an agenda of alleviating poverty, providing alternative livelihoods, improving quality of life and raising material standards of living. There is no clear resource or land-use plan that recognises the rights of indigenous people to live and depend on the wetland or its environmental significance.

The expected negative and positive impacts of the sugarcane projects on the wetlands and wetland-dependent people are as follows.

- The hypothesis is that the projects will have a negative impact on biodiversity, wetland integrity, and consequently wetland functions and local (wetland-dependent) people. These projects will displace thousands of indigenous minority groups and erode their tradition (which is a pillar of community unity and togetherness), destroying their customary practices and beliefs, which act as a source of hope and inspiration in difficult times. In addition, these plantations might result in loss of property and possessions, and prevent future efforts by these indigenous groups to develop the land for their own needs.
- The local community will be marginalised by denying them access to natural resources such as fishing.
- The food security of thousands of people will be affected, as will health and wellbeing, particularly of indigenous marginalised groups.
- The plantations will have a direct bearing on the wellbeing of the majority of the local population – vulnerable groups affected by poverty.

Objectives of the Study

The objectives of the study were to identify Tana Delta resources and design suitable and sustainable alternative use techniques for those resources with the aim of improving the socio-economic benefits to the local communities.

Method

A field visit (focus-group discussion) was organised to gather the information.

Tana Delta Present Situation

The Tana Delta is communal land used by the local people, the sole right of the land lies in the hands of the local community, thus the land's resources lie in the custody of the local community. The Tana Delta ecosystem has been the lifeline for the local community from time immemorial.

Value of Wetlands

The Tana Delta wetlands support:

- water filtration;
- fisheries;
- flood regression agriculture;
- subsistence irrigations;
- livestock herding;
- hunters and gatherers, including collecting honey;
- transport (water-borne);
- livelihoods of wetlands-dependent peoples.

Objectives for the Area

- To develop a clear, sustainable development and conservation strategy for the delta ecosystem to guide and inform future development and/or conservation activities with the aim of maintaining the ecological and economic integrity of the Tana Delta ecosystem.
- To protect the rights of local communities and the livelihoods and role of community members – their rights to make decisions, and to access and benefit equally from the development activities that target the delta's natural resources. To protect and conserve the ecological and socio-economic value and integrity of the Tana Delta by emphasising sustainable and wise use of the delta's wetlands resource, as stated in Kenya's wetlands strategy documents.
- To stop large-scale monopolistic schemes and advocate for development that takes into account the multiple uses of the Tana Delta, such as proposals to convert more than 100 ha of the delta into large-scale sugar production and large-scale *Jatropha* plantations to be used in production of ethanol and biodiesel. The local communities may not receive any of the profits from these plantations, as they have been left out of all decisions pertaining to their environment. In addition, these plantations might prevent future efforts by these indigenous groups to develop the land for their own needs. Rather, we would aim to maximise socio-economic benefits through conservation development.

Health and nutrition are other factors that have contributed to the high level of vulnerability. With the acute food shortage in this area, high levels of malnutrition and a variety of health problems continue to occur. The communities have little access to prevention mechanisms and health services beyond traditional healers, who are challenged by changing diseases. The infrastructure (e.g. roads) in Tana Delta is in poor condition, which further aggravates living conditions and limits community aid networks. The indigenous groups in the Tana Delta have relied on their traditional knowledge to overcome catastrophes in their surroundings, but due

to the unpredictability of the local climatic conditions (such as planting and flooding seasons), coupled with a lack of scientific knowledge, traditional knowledge seems inadequate, although it is crucial to their psychological, socio-economic and ecological survival.

Conclusion

If the Tana Delta wetlands are important – not wastelands to be converted into monoculture, but recognised for their multiple use potentials – a comprehensive wetland and river-basin management plan needs to be designed, developed and implemented to safeguard the interests of all, particularly rural livelihoods. The rich and diverse resources of the Tana Delta currently support over 52,000 indigenous people through fishing, livestock herding, small-scale subsistence farming, and gathering of wild flora and fauna, among many other uses. The proposal to convert Tana Delta wetlands into large-scale sugarcane and *Jatropha* plantations by the Government of Kenya in collaboration with private investors is at an advanced stage. In the absence of an agreed development and conservation plan for the area, the policy- and decision-makers and private developers show little respect for the marginalised indigenous people who live in and depend on the delta.

The issues of land tenure and access rights should be addressed. They are not legally recognised, leading to potential exploitation and encroachment. Further, these minority communities would benefit greatly if facilitated with access to scientific information and technology on global climate trends, and provided with subsidised, improved and climate-adapted propagation materials. Early warning systems and information should be considered for these groups so they can protect their crops and flocks. Modern, small-scale, irrigated agriculture should be encouraged, as opposed to large-scale monoculture. Moreover, improved education, healthcare and general infrastructure, as well as diversification of their resource base, including diversifying sources of food and income, could enhance the resilience of indigenous minority groups to climate change effects.

I suggest that indigenous groups should be consulted before any negotiations on carbon sequestration projects and biofuel projects are established where they reside. I further submit that climate-change coping interventions, and particularly the application of the Kyoto Protocol, should be guided by ethical thinking and respect for the civil and democratic rights of the disadvantaged and marginalised.

The government should adhere to the obligations of the Ramsar Convention on Wetlands and the UN Convention of Biological Diversity and to principles of sustainable development, and demonstrate its commitment to UN Millennium Development Goal (MDG) Number 7 ('Ensure environmental sustainability') – this will contribute to the realisation of other MDGs, particularly 1 ('Eradicate extreme poverty and hunger') and 8 ('Develop partnership for development').

A lot needs to be done to ensure that the country's vision for 2030 and the MDGs are seen to be achievable. This initiative and all the lessons learned should form a basis for developing a more viable approach in realising socio-economic development and sustainable environmental considerations.

Design, Construction and Testing of a Low-cost Maize Thresher

J.N. Nwakaire[1] and M. Mkpado[2]

Keywords: construction, low-cost, maize thresher, efficiency, rural farmers

Abstract

The processing of agricultural product into quality forms not only prolongs the useful life of these products, but also increases the net profit farmers make from them. In this work, emphasis was placed on demand-led design, which involved understanding farmers' needs and designing appropriate systems to meet those needs. The objectives of the work were to design, construct and evaluate a low-cost maize sheller for rural farmers in Nigeria. The methods used involved the collection of farmers' opinions on their sheller needs, selecting appropriate materials, and using 'appropriate design equations' that enable the determination of allowable shear stress on the bearing supports. The communication methods used were interactive sessions with farmers, especially women and children, in order to determine their shelling problems. Comparisons were made between the human performance index for shelling and the machine performance index. The human mechanical efficiency, throughput capacity and grain-handling capacity were 45%, 26.67 kg/h and 21.1 kg/h, respectively, at a biomaterial test weight of 20 kg with actual shelled weight of 15.8 kg in a shelling time 45 min. The efficiency, throughput capacity and grain-handling capacity of the sheller were 86%, 119.76 kg/h and 109.99 kg/h, respectively. The price difference shows a drastic discount in the purchase price of a maize thresher, compared with those available commercially, of ₦32,500.00 (€175.66; US$216.67) – a 56.52% saving. Market days were also used as an opportunity to show farmers and agro-processors the advantages of using the maize sheller.

Introduction

'Maize', derived from a Native American word for corn, means literally 'that which sustains life'. It is, after wheat and rice, the most important cereal grain in the world, providing nutrients for humans and animals, and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and, more recently, fuel (FAO, 1992). In Africa, maize has become a staple food crop that is known to the poorest families. It is used in various forms to alleviate hunger, including pap or *ogi*, and maize flour. It is because of the importance of maize that its processing and preservation must be optimal. The major steps involved in the processing of maize are harvesting, drying, de-husking, shelling, storing and milling. For rural farmers to maximise profit from their maize, appropriate technology that suits their needs

1. Department of Agriculture & Bioresources Engineering, University of Nigeria, Nsukka, Nigeria.
2. Department of Agriculture, Ngor-Okpoala LGA, Imo State, Nigeria.

must be used. The processing of agricultural products such as maize into quality forms not only prolongs the useful life of these products, but also increases the net profit farmers make from them. One of the most important processing operations carried out to enhance the quality of maize is shelling or threshing.

Background

Traditional shelling methods do not support large-scale shelling of maize, especially for commercial purposes. Locally in northern Nigeria (the region that produces the largest amount of maize in the country), it was observed that most shelling of maize was done by hand. Hand-shelling takes a lot of time, even with some simple hand-operated tools. It was also observed in the study area, Nasarawa State, that most mechanical shellers were designed for multi-grain threshing or shelling, which causes great damage to the maize grains and breaks the cob into pieces. The shellers available locally were equipped with a rotating threshing drum with beaters or teeth, which damage the grain. Moreover, the cost of purchasing such shellers was high for poor rural farmers. There was a need for an affordable, low-cost system to increase threshing efficiency and reduce damage to the grain.

Objectives

The specific objectives of the work were to:

- design, construct, and test a low-cost maize sheller;
- evaluate the efficiency of the maize sheller;
- use the maize sheller in establishing an agro-processing centre for rural farmers.

Design Considerations

Maize shelling is the removal of maize grains from the cob. This operation can be carried out in the field or storage environment. Maize shelling is an important step towards processing maize into its various finished products, such as flour. The different methods of maize shelling can be categorised on the basis of the mechanisation technology used, including hand-tool, animal, and engine-powered technologies (Onwualu *et al*., 2006). Hand tools are used in shelling, and we also observed animals used in threshing in the field – trampling the maize. Engine-powered technology involves the use of mechanical assistance in threshing or shelling the maize. Some examples were seen of a maize sheller that was designed and constructed in Nigeria by Abdulkadir *et al.* (2009). To facilitate speedy shelling of maize in order to reduce post-harvest deterioration, mechanical shellers are recommended.

Fashina and Abdulahi (1994) report an average moisture content of 15–18% for maize that is to be threshed or shelled. Moisture content seriously affects the threshability of maize. Another factor that affects the threshability of maize in a mechanised system is the size of the maize cob, and mechanical shellers need to be adjusted to the various sizes of cobs. According to Joshi (1981), maize cobs range from 50 to 85 mm in diameter, depending on variety. There are also engineering design factors that affect the design of mechanical shellers. These factors are the design of the power-transmission shaft, selection of the prime mover, type of pulley, appropriate belt design, key and selection of appropriate bearing support.

According to Shigley (1986), the power delivered by a shaft is given by

$$P = F \times V$$

where P = power (Nm/s), F = force of threshing, and V = velocity.

The force required to thresh the maize (f) is

$$f = mw^2r,$$

where m is the mass of threshing bars, w is the angular velocity of the shaft, and r is the radius of the shaft. The angular velocity (w) is determined by the equation

$$w = 2\pi N/60$$

where N is the speed of threshing in revolutions per minute.

The power delivered by the shaft (P) is

$$P = fwr$$

The appropriate electric motor is selected when the total power requirement for threshing is determined at an appropriate threshing speed. According to Fashina and Abdulahi (1994), the threshing speed that will give very low mechanical damage but high threshing output is within the range 300–650 rpm. William (1953) gives the relationship between the driven pulley speed and the speed of the prime mover as

$$N_1D_1 = N_2D_2$$

where N_1 is the speed of the driver, N_2 is the speed of the driven, D_1 is the diameter of the driver pulley, and D_2 is the diameter of the driven pulley. The weight of the pulley on the shaft is given as

$$m = \rho v$$

where m is the mass of the pulley, ρ is the density of the pulley, and v is the volume of the pulley. Weight is mass multiplied by acceleration due to gravity (g):

$$W_p = \rho \times (\pi d^2/4) \times lp \times g$$

where W_p is the weight of pulley, d is the diameter of pulley, and lp is the length of pulley.

Appropriate belt selection will assist in effective power transmission. A belt provides a convenient means of transferring power from one shaft to another. The effective pull on a belt is given by

$$T = T_1 - T_2$$

where T_1 is tension on the tight side, and T_2 is tension on the slack slide.

$$T_s = F \times r$$

where T_s is the torque on the shaft and F is the total force of threshing, which is equal to the total torque requirement of the system; therefore,

$$T_s = T \times r$$

T_m (motor torque) = $T \times r$

where $T_s = T_m$. Note that

P_m (power of motor) = wT_m ,

thus

T (effective pull) = $P_m/(wr)$

and

M_T (torsional moment) = $(T_1 - T_2)\, r_1$

According to Hannah and Stephens (1970), the power transmitted by a belt is given by

$P = (T_1 - T_2)V$

but

$V = (\pi DN)/60$.

Also

$T_1/T_2 = \exp(\mu\theta\text{cosec}\beta)$

where β is the grove semi-angle, θ is the angle of lap (angle between the belt and the pulley), and μ is the coefficient of friction. According to Ogunwede (2003), μ = 0.3 for a rubber belt on cast iron or steel operating on a dry surface. The angle of lap for an open V-belt drive is given as

$\theta = (180 - 2\alpha) \times \pi/180$ rad

Also

$\sin \alpha\ (r_2 - r_1) / x$

where x is the distance between pulleys, r_1 is the radius of the bigger pulley, and r_2 is the radius of the smaller pulley. The length of the pulley is given as

$L = 2x + (\pi/2XD + d) + (D - d)^2/4x$

The minimum shaft diameter is determined using the ASME (1995) code equation, which states that

$d^3 = [16/(\pi S_s)] \times [(k_b M_b)^2 + (k_t M_t)^2]^{1/2}$

where d is the diameter of shaft, M_t is the overall torsional moment, M_b is the bending moment, K_b is the combined shock and fatigue factor applied to the bending moment, K_t is the combined shock and fatigue factor applied to the torsional moment, and S_s is the allowable shear stress. According to ASME (1995), the K_b and K_t factors when shock is applied suddenly to a rotating shaft are 1.5–2.0 and 1.0–1.5, respectively. For shafts without key-way and with key-way, the allowable stress (S_s) is 55 and 40 MN/m^2, respectively. The bearing is selected on the basis of load-carrying capacity, life expectancy and reliability in line with PSG Tech (1989, in Abdulkadir *et al.*, 2009). The threshing force is either by impact loading as seen in cylindrical beaters, or shearing force as seen in hand threshing.

The shelling machine was tested to determine its effectiveness. Agricultural machines are evaluated on the basis of their throughput capacity, effective throughput capacity and mechanical efficiency (Onwualu *et al.*, 2006). The throughput capacity (T_p), in kg/h, is given as

$$T_p = W_t/t_t$$

where W_t is the total weight of material processed (threshed and unthreshed), and t_t is the total time taken to handle the materials. The effective throughput capacity is the actual weight of grains processed that was not damaged (per hour). The efficiency is the total weight of grain actually processed (output) expressed as a percentage of the total weight of grain to be processed (input).

Materials and methods

The methods used were in three phases. The first phase involved finding out rural farmers' sheller needs and other problems associated with agricultural operation. The second stage was the design of an appropriate system to meet their needs; and the third was to communicate the results to farmers and determine whether their problem had been addressed. Farmers' shelling capacity was determined in the field. A comparison was made between the time it took a farmer to shell the quantity of maize harvested and the time before deterioration set in. We also observed that appropriate technology was not available for storage, including pesticides to manage weevil attack. Pesticides were purchased with the help of local administrators, who were told of the need in the community.

Design Calculations

The average threshing plate speed is 450–700 rpm. This maize sheller comprises a hopper designed to take three maize cobs lying on its vertical axis (*ZY* plane), a threshing plate with spikes that simulates the tangential force applied to the surface of the maize, a supporting framework, a threshing wall that has grooves where the falling maize rotates, and an adjustable spring that allows adjustment of the threshing wall to the different sizes of maize. It also had a container for storage beside the threshing cylinder and hopper. The shaft length was 590 mm and the shaft diameter 60 mm. The angular velocity (w) was 73 rad/s, with a maximum available threshing force of 501.2 N at the tip of spikes. The torque developed at the top of the spike was 36.45 Nm. The power delivered at the threshing spikes was 2.92 kw, which means that a prime-mover power of 4 or 5 hp was used. The prime mover was a 4 hp Yamaha combustion engine. Figure 1 shows the completed maize thresher and views of the thresher parts.

Performance Analysis

The throughput capacity, actual throughput capacity and mechanical efficiency were determined. Unthreshed maize (200 kg) was measured using a weighing scale. A local farmer loaded the cobs three at a time into the hopper. The time taken to load and finish threshing 200 kg of cobs was recorded. The total weight of threshed grains was determined. The total weight of broken or damaged grains was also determined, and the cob was weighed. The percentage mechanical damage was determined. A comparison was made between human performance index and machine performance index.

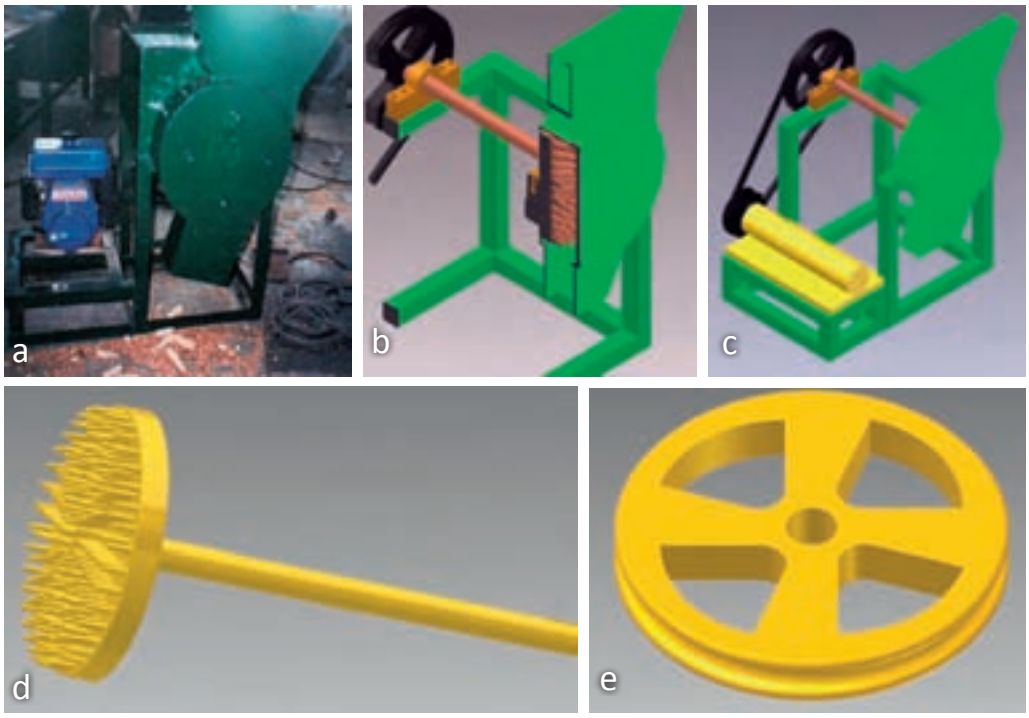

Figure 1. *The maize thresher: (a) finished machine; (b) cross-sectional view; (c–e) orthographic views of (c) machine; (d) power shaft; (e) pulley*

Information Communication Strategy

Experts from the federal Polytechnic Nasarawa Nigeria were invited to assess the performance of the machine and communication to the rural community. The machine was taken to nearby farms with large area of maize, in order to thresh their maize. The thresher was also taken to markets during market days for people to see it in operation. Meetings were arranged with politicians to discuss options for financing the building of up to five agricultural processing centres in the nearby farm settlements. Agricultural extension workers were contacted to facilitate information dissemination. The existence of the maize thresher and its pricing was announced on local radio, and state television showed pictures of the maize sheller.

Results

The human mechanical efficiency was 45% at the biomaterial test weight of 20 kg, with an actual shelled grain weight of 15.8 kg. The human throughput capacity was 26.67 kg/h, with actual grain-handling capacity of 21.1 kg/h for a shelling time of 45 min (0.75 h). This result is based on the spot assessment of shelling done by five selected farmers from farm settlements, although this efficiency will drop over time due to an increase in drudgery. The machine efficiency and throughput capacities were 86% and 119.76 kg/h, respectively. When further evaluation was carried out to determine the actual grain-throughput capacity based on actual weight of grain threshed but not broken, the capacity was 109.99 kg/h. The result showed that the sheller was effective.

Effective communication tools resulted in people bringing maize for threshing, and farmers organising themselves into groups to purchase the machine built locally at a cost of ₦25,000 (US$166.66 or €135.14). The five farm settlements identified were given five shellers each, plus other machines for cassava grating, and milling. These were donated by the local government council and a senator. More shellers have been constructed and distributed. Other states are making requests for the thresher. At the 2009 Polytechnics Fair held in Kano, Nigeria, the sheller took second position in the category of processing machinery.

Discussion and conclusion

From the results, it is clear that the machine was designed successfully. The actual throughput capacity of 109.99 kg/h was far better than the human actual throughput capacity (21.1 kg/h). The net present value of the thresher was attractive to farmers, who said that available threshers in the market were about ₦55,000–60,000 ($367–400 or €297–324). The price difference shows a drastic reduction in the purchase price of a maize thresher by ₦32,500 ($217 or €176) – a 56.52% saving. The number of replaceable parts was low compared with most threshers available in the market. The machine has an estimated useful life of 10 years. The threshing capacity of the maize sheller was such that it handled the threshing needs of farmers within the required time and with zero drudgery. Thus farmers had more time and energy for other activities. Both the farmers and the agro-processing centres not only reduced their cost of threshing maize per bag, but also created more wealth for themselves.

The agro-processing centres established helped many farmers to process their agricultural products in a market-acceptable form, which added to the market prices at which the farmers sold them. More research should be done to identify the many needs of these rural farmers, so that experts can design systems and proffer solutions that meet their needs.

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Resource Use Optimisation in Main Food and Cash Crops Production – A Route to Food Security and Poverty Alleviation in Sudan

Elgilany Abdelhafeez Ahmed[1]

Keywords: environmental conservation, yield improvement, increasing farm income

Abstract

Resource-use efficiency is critical for Sudanese agriculture. Since resources are economic inputs, the aim should be to obtain maximum production per unit. In Sudan, land tenants use numerous crops to intensify production in an attempt to improve home food security and income. Field crops such as pulses, food legumes and vegetables are regarded as essential food and cash crops within the prevailing crop combination in Sudan. The research looked at River Nile State (Nahr Elneel State) as a case study due to its high potential to grow food and cash crops. The crops are commonly produced under pump irrigation from the River Nile. Production of these crops in the state faces numerous constraints, including inefficiency of resource use, low levels of productivity and high costs of production. The research aimed to optimise the use of available resources in food and cash crops. Primary data were collected from 70 randomly selected respondents through structured questionnaires. A linear programming technique was used to assess the optimal combination of resources in the crops under study. The model revealed that tenants would obtain higher returns by optimising resource use in food and cash crop production. Producers should therefore be guided on how to use their resources optimally and encouraged to grow cash and food crops as a significant contribution to farm sustainability and malnutrition alleviation in the state.

Introduction

Sudan is rich in agricultural resources that, if properly managed, can generate sufficient food for the country with surplus for export to neighbouring countries. Water from the River Nile and its tributaries, underground sources and impressive rainfall in the centre and south enable cropping and herding at various intensities. Of a total arable area of about 85 million ha, only 20% is currently under cultivation, but with inter-seasonal variation (MAF, 2006). Given the country's high dependence on crops and livestock for livelihoods, the availability of and access to natural resources are paramount (De Pauw, 2009). In River Nile State, high competition for land and water, resulting from high population pressure and chronic low and unstable crop yields (emanating from environmental stresses and poor use of improved technology) poses

1. Ministry of Science and Technology, Agricultural Research Corporation, Agricultural Economics Research and Policy Center, Sudan.

challenges for resource management. Farmers are faced with the double scenario of low food availability and low incomes. According to Elsir *et al.* (2004), it has long been recognised that high production costs, low productivity and lack of a cheap source of power for water pumping hinder realisation of the full agricultural potential in River Nile State. Being limited to narrow land strips at river fringes, crop production needs to be intensified via removal of seasonal water-supply constraints and through balancing the demand and supply of water. This calls for resource-use optimisation. This paper is based on research on the Elzeidab public pump-irrigated scheme, where tenants are fully responsible for the management of their farms, with the government selling water and setting policies. Although significant biological research has been conducted there, research on resource allocation has been limited. The study looked into options to maximise tenants' returns from food and cash crops under optimal and sustainable combinations of the scarce resources of water, land, labour and capital. Thus it addressed the issues of food security, poverty alleviation and farmers' livelihoods.

Materials and methods

The study was carried in the Elzeidab public irrigation scheme of River Nile State, where annual cereals, legumes and perennial crops are grown, and animal production and oil crops have recently expanded. The study used mainly primary data collected in 2006 from 70 randomly selected tenants via probability proportional sampling and a structured questionnaire. Analytical techniques comprised linear programming and water-use efficiency models, as well as simple statistical methods using General Algebraic Modeling System (GAMS), CropWat4, Excel and SPSS software. Data were collected on the crop mix and existing resource allocation.

Results

Production of Food and Cash Crops

Although most of the crops grown in the state are highly profitable, limitations on land, water, labour and capital hinder the attainment of adequate benefits. The largest area of the land (48%) is allocated to cereals, followed by legumes (22%). A diversity of vegetables, spices and fodder crops occupies small areas. Crop yields were much lower than research yields. Yield gaps of 47 and 81% were derived for dry beans and vegetables, respectively, indicating high potential to boost yields. According to Peter (2001), every 10% increase in crop yield reduces the number of income-poor by an average 7.2% in Sub-Saharan Africa. Variable costs of production play a unique role in producing annual crops where material-input costs largely influence earned profits (Doll and Orzem, 1984). The survey revealed that about 15 components constitute most of the production cost. Most respondents complained about the high cost of production inputs. Irrigation water is considered the single most expensive resource due to the high cost of water pumping from the River Nile. However, sampled farmers invariably over-irrigated their annual crops (Fig. 1), with crop water requirements exceeded annually by 60%. This suggests high potential for water use (e.g. for additional crops) once water-use efficiency is improved. Labour is also an important resource, but tenants tended to avoid using hired labour to reduce production costs. On average, tenants employed two family members; however (for example), 10 and 34 work-days of hired labours are recruited for chickpea and potato production,

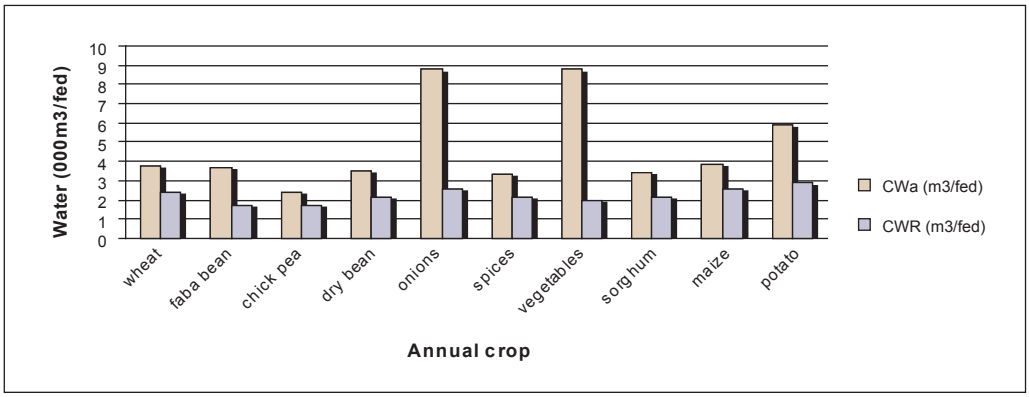

Figure 1. *Physical gaps between crop water requirements (CWR) and applied crop water (CWA) for the crops under study*

respectively. After land, water and labour, the fourth pillar of production is capital. The formal financial system provides only a small part of the credit used by farmers, and 93% of the tenants surveyed depended on their own resources, while informal sources such as village merchants contributed only 2.8%.

Crops' Contribution to Household Food Security and Poverty Reduction

Annual crops – especially wheat, sorghum, food legumes, vegetables and forage crops – are generally considered the main food and cash crops. Moreover, they play an important role in sustaining the production of the farming systems. Decisions on marketable surplus quantities and the timing of their sale depend on the type of crop. Given limited infrastructure, this leads to high levels of sales immediately after harvest; however, some is withheld for disposal over the rest of the year: 88% of the produce was sold (77% immediately after harvest and 11% kept for future sale), with the remaining 12% going into storage. About 32% of the stored quantities were for next season's seeds and 68% for household consumption. Of individual crops, grains and legumes are partly sold after harvest and partly stored, while vegetables, spices and potatoes are sold immediately due to lack of appropriate storage infrastructure and inadequate markets. Most studies have confirmed that diversified income sources might enhance farm sustainability. Beetz (2002) reports that integrating trees and shrubs with the other enterprises on a farm can create additional sources of income, spread farm labour throughout the year, and increase the productivity of other enterprises, while protecting soil, water and wildlife.

The main off-farm sources of income in the area are remittances and contributions of family members, formal employment, trade, and other off-farm private activities (Table 1).

About 37% of the tenants earned off-farm income beside their farm income, while 63% relied solely on farm returns. Most of the farm income accrued from perennial crops (78%). The majority of tenants (63%) diversified by growing several crops at one time, having both livestock and annual crops, and sometimes value-adding enterprises. Enterprise diversification makes it easier for households to be more self-sufficient in terms of nutrition, livestock feed, soil organic matter and energy.

Table 1. Household income sources

Source of income	Value (SD)[1]	Farm income (%)	Of total (%)	Of tenants (%)
Perennial crop returns	1,870,280	78	–	–
Annual crop returns	396,533	17	–	–
Livestock returns	107,059	5	–	–
Total average of farm income	2,373,872	100	82	32
Total average of off-farm income	522,700	–	18	68
Total average income of tenants	2,896,572	–	100	100

(Source: Field survey, 2006.)
1. Sudanese Dinar = US$0.50.

Optimal Annual Production Obtained by River Nile State Model

The integrated modelling approach is useful for linking biophysical and socio-economic factors influencing decision-making on smallholder farms and evaluating trade-offs for resource use in terms of nutrient balances, labour use, food sufficiency and cash balance (Fischer, 2001). The agricultural background of River Nile State tenants is growing annual and perennial crops. Animal breeding offers a promising option for improving the farm system and livelihood of people in both rural and peri-urban areas. The output from the model run is the objective function value (returns), the optimal crop combination, and utilised resources accompanied by their respective marginal value productivities. The model suggested the optimal land use is chickpea and dry bean only (on 8.62 and 1.38 feddans [3.62 and 0.58 ha], respectively), due to these crops' high returns when compared with other annual crops in the area of study. Actual returns from crop production were SD 399,487, while the optimal returns are SD 811,597 (a 103% increase on current levels).

The average tenant had up to 10 feddans (4.2 ha) of land, 28,573 m^3 water, 191 work-days of labour and SD 179,532 (about US$ 870) as capital available for the cropping season. Resources were allocated to food legume crops as per the model. The model indicated that all other crops were unfeasible unless improvements were made. However, these crops are regarded as strategic (important for food security and household income), so incentives should be provided to make them more profitable. The research designed a scenario based on model solution to confirm the importance of crops that did not appear in the optimal plan. The model assumed a decline in prices for both chickpea and dry bean as a dominant phenomenon in the state markets. Seasonal price variation is a normal feature of agricultural products in River Nile State: the prices of food crops in general follow a common seasonal pattern. The model predicted that the decline of prices for chickpea and dry bean would lead to a fall in gross margins, but the margin would remain positive. Table 2 shows the results of the new model solution. The scenario analysis provides the changes of chickpea and dry bean prices in the optimal solution. The optimal return was SD 845,496, 112% more than the current return. The optimal levels of the resources used were 10 feddans (4.2 ha, all the available land), 17,645 m^3 water, 133 work-days of labour and SD 202,608 of cash capital – less than the actual quantities available. The distribution of the cultivated area per feddan was diverse, including all crops except maize and faba bean (Table 2).

Table 2. Impacts of low prices of chickpea and dry beans

Item	Actual	Optimal	Units
Resource use:			
Total land	10	10	feddan[1]
Total irrigation water	28,573	17,644.94	cubic meter (m^3)
Total labour	191	133	work-day
Total capital	267,118	202,608.4	SD
Returns: objfn[2] value (Z)	399,487.28	845,495.61	SD
Crop:			
Wheat	1.1	1.0	feddan
Faba bean	1.1	0.0	feddan
Chickpea	0.3	1.0	feddan
Dry bean	0.6	1.0	feddan
Onion	0.6	1.0	feddan
Spices	0.9	0.5	feddan
Vegetables	0.8	1.5	feddan
Sorghum	1.7	1.7	feddan
Maize	0.7	–	feddan
Potato	0.4	1.3	feddan
Fodder	1.8	1.0	feddan

(Source: model results, 2008.)

[1]Feddan = 4200 m^2.

[2]objfn = objective function.

The results indicated that crucial manipulation is needed to stabilise resource sub-sectors to achieve food security and poverty alleviation, and improve the livelihoods of farmers in the state. Staple food systems will remain dominant sources of food supply, and optimised farm activities are more dependable sources of income. Crop diversification offers higher returns from resource investments and hence needs to be guided.

Discussion and conclusion

The research demonstrates that River Nile State has the opportunity to take a lead in annual crop production due to its stable and high-quality natural resources. This paper explores some of the findings of the field survey, and describes the resources use for agricultural production in term of food security and poverty alleviation. We are able to draw the following conclusions.

- The farming system is dominated by cereals production, which occupies 48% of the farm land.
- The study reveals the low productivity of the annual food and cash crops that are promising strategic crops.
- Surface irrigation – the dominant system in the state – is regarded as inefficient and expensive.

- Agricultural production in the state is characterised as challenging. This might be attributed to the high cost of numerous production inputs, but irrigation water is considered the most expensive resource.
- The irrigation cost item of field crop production was 19% of the total cost of production – the largest of the variable cost items.
- Overall lack of awareness about resource-use optimisation among the tenants surveyed might be due to the limitations of the extension services.
- Annual crops in the state are well established, diversified and economically important products.
- The tenants of the scheme were not optimally allocating the available resources and they devoted only small portions of their farmland to the most profitable crops, especially food legumes.

Based on the foregoing conclusions and the results obtained, the study indicated the following.

- The potential for food and cash crop production in the area is quite promising on account of the vast natural resources. The policy-makers of the state should consider the economic use of the scarce resources to increase farm gross margins, conserve soil fertility and increase farm sustainability.
- While the expected contribution of annual crops to household nutrient intake can be promoted by diversifying and optimising farm productivity, reducing the need for purchased inputs and (eventually) developing households' market orientation for earning additional income will be conducive to resource-use optimisation, thereby contributing to hunger and poverty alleviation. This could be achieved by state intervention and application of participatory approaches.
- Because basic services are regarded as a chronic constraint facing agricultural production in the state, intervention is needed to establish infrastructure (roads, stores, processing stations).
- The study detected that the tenants considered the misuse of resources as a cost issue, while they ignored the dimension of negative environmental consequences. So it is very important to raise tenants' awareness of environmental issues through an efficient mechanism that can be applied by the extension system.
- Most of the annual crops under study were considered low-value crops. Incentives should be provided to make these crops more profitable due to their importance for food security. Relevant policies may include reducing production costs or interventions to purchase them at reasonable prices.
- Appropriate combination of land, water, labour and capital resources for producing food and cash annual crops in the area of the study is very important and should be well designed and applied.

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Development of Appropriate Surveillance Systems for Honeybee Pests and Diseases for Improved Production of Honey and Other Bee Products in Uganda

Robert Kajobe[1]

Keywords: agro-ecological zones, BQCV, honeybee pests, honeybee pest control, distribution, PCR, Uganda, viral pathogens

Abstract

Beekeeping in Uganda is vital as a source of food, employment, poverty alleviation, diversification of the export base and environmental conservation. In 2005, the European Union licensed Uganda to export honey to its market, thus creating an opportunity. However, efforts to increase production are curtailed by constraints related to production, processing, packaging, storage and marketing. There is inadequate information on bee pests and diseases. The objective of this study was to develop an appropriate surveillance system for honeybee pests and diseases to improve the quality of honey and other bee products in Uganda. Data collection was carried out in the different agro-ecological zones of Uganda. Within each zone, indigenous knowledge was gathered about honeybee pests and their prevalence using participatory rural appraisal tools such as pairwise ranking. Samples of bees were preserved in 70% ethanol for examination. Some samples were dissected and examined under a microscope to detect parasites and pests. A simple feasibility trial of local materials and techniques for pest control methods was carried out. For the molecular analysis of honeybee diseases, samples were screened for the presence of seven honeybee viruses: *Black queen cell virus* (BQCV), *Chronic bee paralysis virus* (CBPV), *Sacbrood virus* (SBV), *Deformed wing virus* (DWV), *Acute bee paralysis virus* (ABPV), *Invertebrate iridescent virus 24* (Apis iridescent virus, AIV) and *Israeli acute paralysis virus* (IAPV). Results showed that 12 honeybee pests and predators were found. The important pests were black ants, red ants, small hive beetles and wax moths. Honey production with traditional hives was most affected by pests, followed by the top-bar hive. Langstroth hives were the least affected by pests. Effective methods for pest control included keeping the apiary tidy and clean, and avoiding throwing combs around the apiary. Many beekeepers made biopesticides to control the pests. In the molecular screening of bees, no samples tested positive for DWV, SBV, CBPV, ABPV, IAPV or AIV. However, BQCV was found in 32 of the 90 samples tested, in adult and larval samples, but not in any of the pupae, even those from BQCV-positive colonies. The virus was detected far more often in adults (88% of samples) than in immature bees (13%). Cycle threshold values for BQCV were between 21 and 35, and no differences between levels of infection were detected between adult and larval bees.

1. Head of Apiculture Research Programme, National Agricultural Research Organisation (NARO), National Livestock Resources Research Institute (NaLIRRI), PO Box 96, Tororo, Uganda.

Introduction

Beekeeping in Uganda is important as a source of food, employment, rural poverty alleviation, diversification of the export base and environmental conservation (MAAIF and MFPED, 2000). Compared with other agricultural projects, such as fish farming (aquaculture), poultry and livestock, beekeeping is a relatively low-investment venture that can be undertaken by most people, especially the vulnerable (women, youths, disabled and elderly). Pharmaceutical and cosmetic industries use bee products such as honey, propolis, royal jelly, bee venom and beeswax (UEPB, 2005). Honey and bee broods are sources of carbohydrate and protein food that rural people can obtain at minimal cost (FAO, 1990).

The most important service that honeybees render to humankind is pollination of agricultural and forestry crops. However, farmers have little knowledge about the importance of pollinators. According to the Commonwealth Secretariat (2002), honeybees are used in Uganda for pollination of coffee, tea, cotton, pulses, oil seeds, maize, sorghum, mango, orange, peas, beans and spices.

There are local and international markets for bee products. However, the expanding international market for specially flavoured and organic honey is unexploited in Uganda. In 2005, the European Union licensed Uganda to export honey to its market, creating an immense opportunity. Efforts to increase production are, however, curtailed by various constraints related to production, processing, packaging, storage and marketing (UEPB, 2005). In order to produce and export honey, Uganda must maintain a large, healthy bee population. However, there is inadequate information on bee pests and diseases in the country. It is suspected that colony populations in the country are declining due to pests and diseases, with a negative effect on productivity.

There is a need to manage the major pests and pathogens that affect honeybees and thus the quality of their products. There is no national honeybee pest and disease surveillance system tailored for their eradication and for the creation of pest- and disease-free export zones. Effective eradication programmes require an efficient honeybee pest and disease control system to be in place, but this has yet to be established in Uganda.

Overall Objective

The overall objective of the study was to develop an appropriate surveillance system for honeybee pests and diseases to improve the quality of honey and other bee products in Uganda.

Specific Objectives

- To document the pests and diseases of honeybees in the different agro-ecological zones of Uganda.
- To assess the prevalence of pests and diseases affecting honeybee colonies and thus their production.
- To examine and document organic (bee-safe) methods of control of honeybee pests and diseases.
- To engage beekeepers and other stakeholders in dialogue for sharing experiences in honeybee pest and disease control methods.

Materials and methods

Study Area

Data collection was carried out in the different agro-ecological zones of Uganda. These are classified on the basis of distinct vegetation type, elevation and climatic conditions.

Sampling Honeybee Pests

Data collection for honeybee pests was carried out from February 2007 to June 2009 in five of the 10 agro-ecological zones of the country. One district was selected from each zone (Kampala in Lake Victoria Crescent; Mbale in Eastern; Hoima in Lake Albert Crescent; Lira in Mid Northern; and Kabarole in Western Highlands). The selection of the agro-ecological zones was guided by the number of active bee farmers' groups and honey productivity in the zones. The study took the form of participatory action research. Data collection within each zone involved gathering indigenous knowledge from farmers about the different honeybee pests and their prevalence using participatory rural appraisal (PRA) tools such as pairwise preference ranking. Within each zone, the intensity of sampling reflected the extent to which apiculture is practised. Samples of bees collected from beehives in different zones were preserved in 70% ethanol for morphological examination. Some samples were dissected and examined under a microscope to detect parasites and pests. Samples of infected combs and other bee products were also collected for laboratory analysis. A simple feasibility trial was carried out to test local materials and techniques for pest control. Farmers and researchers worked as partners in the technology development process. The participatory trials also helped in ascertaining farmers' assessments of practice and their ideas on how it may be modified, and in observing their innovations.

Molecular Screening of Honeybees

In the first study of its kind in Uganda, larval, pupal and adult *Apis mellifera* were collected (between February 2007 and May 2008) from beekeeping sites in nine of Uganda's 10 agro-ecological zones – Eastern, Lake Albert Crescent, Lake Victoria Crescent, Mid Northern, South East, Southern Drylands, Southern Highlands, West Nile and Western Highlands. Within each zone, the intensity of sampling reflected floral diversity and the extent to which apiculture is practised there. In total, 138 colonies were sampled from 63 sites. Since viruses infect all developmental stages of bees (Chen *et al.*, 2006), larvae, pupae and adult specimens were taken from each site. All samples were stored in 70% alcohol prior to RNA extraction.

All molecular diagnoses were carried out using real-time PCR (TaqMan) in the Molecular Technology Unit of the Food and Environment Research Agency, York, UK. Samples were screened for the presence of seven honeybee viruses: *Black queen cell virus* (BQCV), *Chronic bee paralysis virus* (CBPV), *Sacbrood virus* (SBV), *Deformed wing virus* (DWV), *Acute bee paralysis virus* (ABPV), *Invertebrate iridescent virus 24* (Apis iridescent virus, AIV) and *Israeli acute paralysis virus* (IAPV). An internal control, designed to detect *Apis mellifera* 18S rRNA, was included in the study to compare extraction efficiencies between samples and to allow interpretation of negative results (Ward *et al.*, 2007).

The C_T (cycle threshold) value, which is the number of cycles required for the fluorescent signal to cross the threshold, was assessed using Sequence Detection Software v.2.2.2 (Applied Biosystems). Samples giving the lowest C_T values were selected for confirmatory testing using direct sequencing. This selection of candidate viruses was chosen because of their known associations with honeybee colonies, the damage they can cause, and their high or potentially high economic significance in international beekeeping outside Africa.

Results

Honeybee Pests

At least 12 honeybee pests and predators that affect beekeeping production were recorded (Table 1). According to pairwise ranking, the most important pests causing economic losses to beekeepers were (in order of importance): black ants, red ants, small hive beetles and wax moths. Birds, snakes, spiders and rats were the least important pests. Termites destroyed bee hives that were not well managed. At least 41% of farmers reported that pests and diseases led to the absconding of their colonies. Honey production with traditional hives was most affected by pests, with a 35% loss in yield; followed by the top-bar hive with a 21% loss. Langstroth hives were the least affected by pests, with a 15% loss.

Symptoms that beekeepers used to diagnose the presence of pests in their hives included very frequent in-and-out flights without any visible loads, presence of pests in the hives, reduction in hive occupancy, and absconding. Effective methods for pest control included keeping the apiary tidy and clean; avoiding throwing combs around the apiary; and frequent smoking of hives (to drive out small hive beetles). Many of the beekeepers made biopesticides to control most of the pests. The major ingredients in the manufacturing of these pesticides included red pepper, neem tree (*Azaradichta indica*) and *Tephrosia* sp. Keeping the apiary tidy and clean was the most effective way to control pests. Application of ash near the hive stands in the apiary and fencing off the apiary were effective methods of organic pest control (Table 2). Most of the biopesticides were mixed with ash and urine, then sprinkled directly on the pests or in their path.

Table 1. Prevalence of honeybee pests and predators affecting colonies

Pest	Most common (very frequent)	Common (frequent)	Not common (rare)
Small hive beetles		×	
Birds		×	
Honey badgers, foxes, chimpanzee			×
Lizards		×	
Human	×		
Rats			×
Red ants	×		
Small black ants	×		
Snakes			×
Spiders			×
Wax moths		×	

Table 2. Traditional/local organic (bee-safe) methods for honeybee pest control

Method	Most effective	Effective	Less effective
Ash application at the apiary		×	
Avoiding throwing/scattering combs and honey around the apiary	×		
Fencing of the apiary			×
Frequent smoking of hives (many pests)	×		
Keeping the apiary tidy and clean	×		
Siting hives on wires		×	
Use of hive stands placed in used engine oil		×	
Use of biopesticides	×		

Honeybee Diseases

No samples tested positive for DWV, SBV, CBPV, ABPV, IAPV or AIV. However, BQCV was found in 32 of the 90 samples that were tested (36% occurrence); all blank extraction controls tested negative for all seven honeybee viruses. BQCV was found in adult and larval samples, but not in any of the pupae that were screened during this study, even those from BQCV-positive colonies. The virus was detected far more often in adults (88% of samples) than in immature bees (13%).

Cycle threshold (C_T) values for BQCV were between 21 and 35, and no differences between levels of infection were detected between adult and larval bees. BQCV-infected material came from seven of the agro-ecological zones that were sampled, the two exceptions being South East and Southern Highlands. BQCV was most prevalent in samples from Western Highlands, where it was found in seven sites (accounting for over 40% of positive results for BQCV nationally). It was comparatively less widespread in the Eastern zone (found at three sites), and present only in single sites elsewhere.

Discussion

Honeybee Pests

A wide variety of pests and predators are known to attack adult honeybees, bee brood stages, materials stored in the hive, and even the hive itself (Caron, 1999). Some of these organisms may simply use the hive as a place to live or as a shelter for their own young/nest, but some may cause harm by feeding on honey, pollen, brood remains or beeswax. Black ants suck out honey and kill pupae and eggs. They are too small to be stopped by beehive guards, and in many cases make the bees leave the hive. Wax moths are opportunistic pests and quickly lay eggs on older, abandoned honeycombs where a weak colony is in residence. Birds feed on bees, especially those that forage for nectar. FAO (1990) notes that termites are only after the wood and may not be classified as a pest. Lizards were reported by respondents to eat bees and honey. The beekeepers demonstrated local pest control methods, especially for pests such as black ants, red ants and termites. Most of the pests, especially the crawling ones, were controlled by siting the hives on wires, and this was considered an effective method in controlling crawling pests. Nsubuga (2000) reports that beekeepers in Luweero district control ants by siting the hives on

wires that are greased. Hive stands were also used in the control of crawling pests: hive legs were placed in a used engine oil container or a grease ring between the hive and the ground. The hive stands were alternatively treated with used engine oil, which is quite effective (FAO, 1990). Metal plates can also be placed on the stands to prevent lizards from reaching the hives. Nsubuga (2000) also suggests that a combination of ash and grease can be used to control ants. Most of the biopesticides are mixed with ash and urine then sprinkled directly on the pests or in their path. Most of the biopesticides are not harmful to bees, compared with inorganic pesticides. Most of the ingredients used in the control of pests and diseases were available locally and affordable to farmers. The beekeepers also reported that good hive management can be an effective method of controlling pests and diseases in the bee colonies.

Honeybee Diseases

Only BQCV was found to be present in the bee colonies. This is the first molecular detection of BQCV in any Eastern African honeybee stocks. BQCV was initially isolated in the 1970s, from the remains of developing queens found decomposing within blackened cells (Bailey and Woods, 1977). BQCV affects all life stages of *A. mellifera*, but is more often detected in adult bees than in larvae or pupae (Tentcheva *et al*., 2004); this was also found to be the case in Ugandan samples testing positive for BQCV. The annual incidence cycle of BQCV is closely associated with that of a microsporidian gut parasite of bees, *Nosema apis*, and the presence of the virus has been shown to increase the pathogenicity of *N. apis* (Bailey *et al.*, 1981, 1983). The incidence of *N. apis* in Uganda is currently unknown. Regarding the implications of BQCV infection for Ugandan apiculture, with one exception, samples collected for the purposes of this study came from asymptomatic colonies, so it is likely that the presence of virus within a colony does not necessarily result in overt disease. It has been observed elsewhere that various types of virus can be found in apparently healthy adult bees and pupae (Hung *et al*., 1996), and only when they occur in colonies co-infested with the parasitic mite *Varroa destructor* will virus-induced mortality follow (Hung *et al.*, 1996).

Although there are no available data for the incidence of *Varroa* in Uganda, the mite is believed to be absent from this country (personal observation), and current evidence suggests that *Varroa* is also absent from the neighbouring countries of Kenya, Tanzania, Sudan and DR Congo (Griffiths and Bowman, 1981; Kigatiira, 1984). The mite is prevalent throughout much of the rest of the world, having spread rapidly from outside its natural range in Asia to all continents except Australia. *Varroa* has been confirmed as present and spreading in Sub-Saharan Africa (Allsop, 1999), including a recent report in Nigeria (Ukattah, 2008). This means that while the current impact of BQCV in Uganda may be minimal, should *Varroa* mites reach districts where BQCV is endemic, then the combination of the mite and the virus could have a much greater negative effect on beekeeping. Data from the current study clearly demonstrate the presence of at least one virus in Ugandan honeybee stocks. Screening for additional potentially damaging viruses, e.g. *Cloudy wing virus*, and the further characterisation of BQCV from Uganda could provide useful information on virus provenance.

Information and Communication Tools and Strategy Used

The research findings were disseminated to beekeeping stakeholders to inform them about the important honeybee pests and diseases in Uganda. The following information and

communication tools and strategies were used for technology transfer: farmer training workshops, which benefited the beekeepers; production and distribution to beekeepers of information materials (leaflets, brochures and posters); use of communication media to reach a wider farming community (FM radio and local newspapers); farm (apiary) visits organised to enable beekeepers to share knowledge, skills and experiences; demonstrations at the apiary of the National Livestock Resources Research Institute; participation in agricultural shows and publishing in scientific journals targeting the scientific community.

Table 3. Incidence of BQCV in different bee development stages from nine agro-ecological zones of Uganda

Agro-ecological zone	District	Site no.	Bee life stage	Mean C_T value (±SD)	
				BQCV-positive	Internal control 18S rRNA
Eastern	Mbale	1	Adult	38.48 (±2.143)	15.05 (±0.102)
	Mbale		Adult	30.91 (±0.044)	15.17 (±0.020)
	Mbale		Adult	29.97 (±0.125)	16.98 (±0.128)
	Mbale	2	Adult	34.77 (±0.071)	15.71 (±0.124)
	Mbale		Larva	32.16 (±0.320)	13.97 (±0.038)
	Mbale	3	Larva	21.56 (±0.312)	14.60 (±0.053)
	Mbale		Larva	28.12 (±0.007)	13.87 (±0.082)
Lake Albert Crescent	Hoima	1	Adult	33.59 (±0.342)	16.05 (±0.007)
	Hoima		Adult	32.10 (±0.195)	15.32 (±0.227)
	Hoima		Adult	33.71 (±0.575)	15.56 (±0.034)
Lake Victoria Crescent	Mubende	1	Adult	31.52 (±0.583)	22.70 (±0.367)
	Mubende		Adult	33.70 (±0.068)	28.77 (±0.115)
Mid Northern	Lira	1	Adult	38.27 (±0.395)	18.45 (±0.072)
South East	No samples tested positive for BQCV				
Southern Drylands	Mbarara	1	Adult	27.47 (±0.428)	16.96 (±0.060)
Southern Highlands	No samples tested positive for BQCV				
West Nile	Yumbe	1	Adult	30.22 (±0.468)	14.31 (±0.071)
	Yumbe		Adult	32.17 (±1.316)	14.37 (±0.062)
	Yumbe		Adult	30.54 (±0.171)	14.38 (±0.105)
	Yumbe		Adult	32.75 (±0.222)	15.20 (±0.132)
	Yumbe		Larva	36.97 (±4.279)	14.31 (±0.225)
Western Highlands	Kabarole	1	Adult	35.84 (±0.122)	22.76 (±0.079)
	Kabarole	2	Adult	33.17 (±0.948)	17.45 (±0.364)
	Kabarole		Adult	30.34 (±0.027)	15.96 (±0.042)
	Kabarole		Adult	28.74 (±0.566)	16.75 (±0.020)
	Kabarole	3	Adult	35.72 (±2.277)	18.10 (±0.005)
	Kabarole	4	Adult	35.62 (±0.676)	16.90 (±0.365)
	Kabarole	5	Adult	32.83 (±0.500)	20.13 (±0.198)
	Kabarole		Adult	29.82 (±0.046)	16.04 (±0.030)
	Kabarole		Adult	30.00 (±0.075)	18.16 (±0.050)
	Kabarole		Adult	28.76 (±2.083)	17.02 (±0.027)
	Kabarole	6	Adult	38.36 (±2.326)	16.00 (±0.036)
	Kabarole		Adult	34.32 (±0.246)	16.87 (±0.167)
	Kyenjojo	7	Adult	32.03 (±0.199)	16.16 (±0.186)

Impact on Agriculture and Rural Livelihoods

The impact on agriculture and rural livelihoods includes the fact that major pests and diseases affecting honeybee colonies in Uganda have been identified; prevalence and distribution of diseases affecting honeybee colonies were determined; and effects of honeybee pests and diseases on the production of honey and other hive products determined. The results of this study were used to develop a national surveillance system for honeybee pests and diseases for improved production of honey and other bee products.

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Variation of Biological Activity on Plots with Stone Lines in Kouritenga Province, Burkina Faso

Sabine Marie Flore Doamba[1] and Hassan Bismarck Nacro[1]

Keywords: Kouritenga, macro-fauna, soil degradation, stone lines

Abstract

Burkina Faso is a country located in the Sudano-Sahelian zone of West Africa. For many decades, it has been facing serious problems of degradation of its natural resources. The development of agro-sylvopastoral production is limited to degraded lands. To solve these problems, measures have been taken by the local population for the restoration and conservation of their space with stone lines. This study consisted of monitoring biological activity through an inventory of soil macro-fauna and of the characterisation of soil physicochemical parameters. This was done using two kinds of plots (a plot with stone lines and a control plot). There was an increase in the size and diversity of the macro-fauna in the plot with stone lines, while values were low in the control plot. There was also an increase in the proportion of fine particles, and improved levels of total carbon, in the plot with stone lines. These results attest to the ecological impact of stone lines in improving soil fertility in the Sahel.

Introduction

Burkina Faso is a landlocked country, the economy of which is based on the primary sector. Agriculture is the main economic activity, accounting for 38–40% of the gross domestic product (GDP) and more than 65% of export earnings to the country (Adda, 1999). However, for several decades the country has faced problems of soil degradation and a decline in soil productivity. Furthermore, a study conducted by INERA (2000) showed that about 24% of arable lands are highly degraded and 31% of the annual rainfall is lost through run-off. There is continuous land degradation as a result of over-exploitation of the soil and the gradual disappearance of the vegetation cover, leading to the formation of stripped and degraded aprons, referred to as *zipellés* in the Moré language (Roose *et al.*, 1993).

In the face of this heavy soil degradation, the population has taken measures aimed at soil protection and restoration, including water and soil conservation measures through the construction of anti-erosion structures such as filtering dykes, demi-lunes, dikelets, hedges, mulching, *zaï* and stone lines.[2] Producers combine these technologies in order to take advantage of their synergistic effects (Kaboré and Reij, 2003). This is characteristic of the *zaï*, which is associated with stone lines, or stone lines linked by grassed strips. These traditional soil

1. Rural Development Institute, Université Polytechnique de Bobo-Dioulasso, 01 BP 1091, Bobo-Dioulasso, Burkina Faso.

2. 'Stone lines' (French, *cordon pierreux*): erosion-control structure consisting of double rows of stones following the contour lines of a plot or field.

conservation techniques, in particular stone lines, together help to restore natural landscapes (Sangaré, 2002; Doamba, 2007), soil fertility and, as an indirect result, increase the quantity and enhance the quality of production (Kambou and Zougmoré, 1995).

Although a lot of research has been carried out on the physicochemical characteristics of degraded soil, only a few studies have shown interest in the quantification of biological activity of the soil. Physical and chemical degradation are by far the most serious in the Sahel. However, biological degradation is also a form of land degradation. This degradation is the result of a decline in biological activity of the soil; soil biological activity is sustained by organic matter and by the presence of various living organisms (fauna, micro-organisms, plant roots, etc.). As a result, biological activity is an important component of soil fertility. Consequently, we undertook this study of soil fauna (respiratory potential, abundance and diversity) in two environments (plot with stone lines and plot without stone lines). The objective was to evaluate the impact of developments in the plot with stone lines on soil fertility.

Materials and methods

Study Location

The study was located in Kouritenga province (Koupéla) about 140 km east of Ouagadougou (Fig. 1). Kouritenga province is part of the North-Sahelian phyto-geographical area (Guinko, 1984). Its characteristic feature is the alternation of two highly contrasting seasons: a rainy season, from May to October, and a dry season, from November to April. The work started specifically from Kampelzougou, a village situated 50 km from Koupéla town.

Two types of plot were involved in the study: a plot with stone lines and a plot without stone lines (the control plot). The plot with stone lines was subdivided into three strips depending on the slope (Fig. 2). Soil samples were taken from each strip and the soil macro-fauna identified.

Search and Inventory of Soil Macro-fauna

The evaluation of soil macro-fauna was carried out using the quadrat technique, with the soil search done by manual sorting according to the method of the Tropical Soil Biology and Fertility Institute (TSBF) (Anderson and Ingram, 1989). The soil search was done with a hoe after marking out a square measuring 25 × 25 cm (Fig. 3). Operators simultaneously dug a 30-cm-deep trial pit around the square to limit (as much as possible) animals from escaping. The land block marked out was then divided up and crumbled by hand. Sorting was done using a pair of pliers. Macro-fauna specimens were kept in pill boxes filled with 70% alcohol. The carefully gathered soil macro-fauna were examined and identified in the laboratory. Several keys were used for the identification of macro-fauna: Bland and Jacques (1978); Villiers (1997); CIRAD and CNEARC (1998); Delvare and Aberlenc (1999).

Measurement of Physicochemical Properties of Soil

In total, 30 soil samples were taken and analysed, representing nine samples for each stone lines strip. They were taken from the 0–20 cm horizon. Total carbon and nitrogen assays of soil samples were carried out using the Walkley and Black (1934) method. Then the organic

Figure 1. *Study site (Kouritenga, Burkina Faso)*

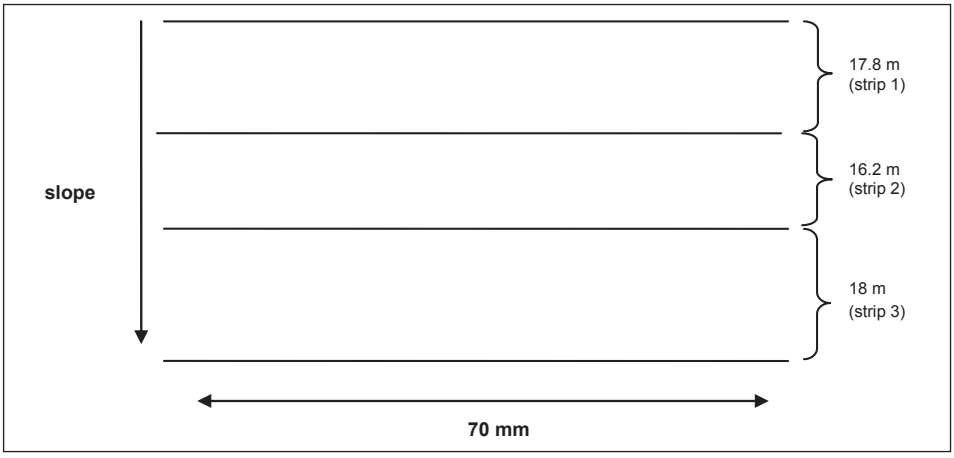

Figure 2. *Plot with stone lines*

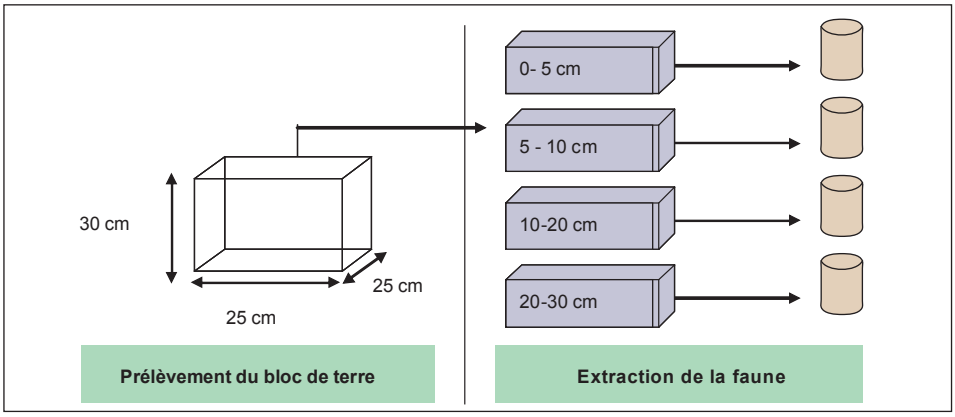

Figure 3. *Sampling device for soil macro-fauna (TSBF method)*

material was subjected to a granulometric fractionation on a 2-mm sifted soil according to the method described by Feller (1979).

Data Analyses

The data from the study were processed with XLSTAT 7.5 software. They were then subjected to analysis of variance (ANOVA) at a 5% threshold according to the Newman–Keuls test. For the inventory of the soil macro-fauna, the data were obtained after calculation of the Shannon–Weaver index (H') and the equitability index (E):

$$H' = \sum P_i \log 2\ P_i$$

where P_i is the probability of finding a taxon i in a plot;

$E = H'/\log(S)$

where S is the total number of taxa found in the plot.

Results

Impact of Stone Lines Technique on Soil Micro-fauna

Some 289 specimens representing 13 families were collected from the stone lines plot – double the number of families encountered in the control field (Table 1). The results show that stone lines have a positive effect on populations of soil macro-fauna. This is confirmed by the Shannon–Weaver diversity index, which reflects the change in the relative abundance of species (Table 2). The diversity index calculated for the stone lines field was three times that of the control field: 0.54 cf. 1.25–1.76.

Impact of Stone Lines Technique on Soil Physicochemical and Biological Parameters

Table 3 summarises the physical and chemical composition of the soils at the study location.

Fine elements (0–50 µm) made up 29% of the control soil and 67% of the soil with stone lines (Table 3). The development of stone lines in fields also caused an improvement in the content of soil organic carbon (4.9 to 7.5 g/kg soil) and total nitrogen (0.48 to 0.69 g/kg soil; Table 3).

The microbial mineralisation of carbon is shown in Figure 4. The lowest daily releases of CO_2 were from the control. The biological activity was more intense in high (361 mg CO_2/kg soil) and mid-slope (255 mg CO_2/kg soil) sections of the stone lines plots.

Discussion

A large number of specimens of a wide diversity of soil fauna were observed in the plot with stone lines. Conversely, the control plot had fewer specimens and less diversity. This can be explained by the fact that the stone lines are a filtering mechanism, as they slow down the water run-off and therefore lead to an increase in the level of soil moisture content (Serpantié

Table 1. Distribution of specimens by order and family

Order	Family	Stone lines plot	Control plot
Aranea	Araneidae	1	0
	Various Aranea	3	0
Hymenoptera	Formicidae	110	21
	Gryllidae	5	0
Haplotaxida	Lumbricidae	6	1
Hemiptera	Lygaeidae	0	0
	Pentatomidae	0	0
	Various Hymenoptera	0	0
	Coreidae	0	0
Geophilomorpha	Geaophilidae	3	5
Scutigeromorpha	Scutigeridae	1	1
Scorpions	Scorponidae	1	0
Beetles	Staphylinidae	1	0
	Tenebrionidae	1	1
	Scarabaeidae	1	0
Isoptera	Termitidae	74	3
Mites	Various mites	1	0

Table 2. Diversity indices of soil macro-fauna

Type of plot	Location in relation to slope	Shannon–Weaver index	Equitability index
Stone lines plot	Band 1	1.76	0.3
	Band 2	1.34	0.22
	Band 3	1.25	0.21
Control plot		0.54	0.09

Table 3. Physicochemical characteristics of soil

Type of plot	Location in relation to slope	Fine element (% clay + % silt)	Total C (g/kg soil)	Total N (g/kg soil)	pH (H_2O)	pH (KCl)
Stone lines plot	Band 1	5.49 a	7.5 a	0.69a	6.4 a	5.02 a
	Band 2	67.38 a	7.3 a	0.64a	6.35 a	4.74 b
	Band 3	63.13 a	5.4 a	0.52a	6.27 a	4.56 b
Control plot	Control	28.82 b	4.9 a	0.48a	6.23 a	4.68 b
	P> F	0.0001	0.08	0.483	0.467	0.001
	Significance	HS	NS	NS	NS	S

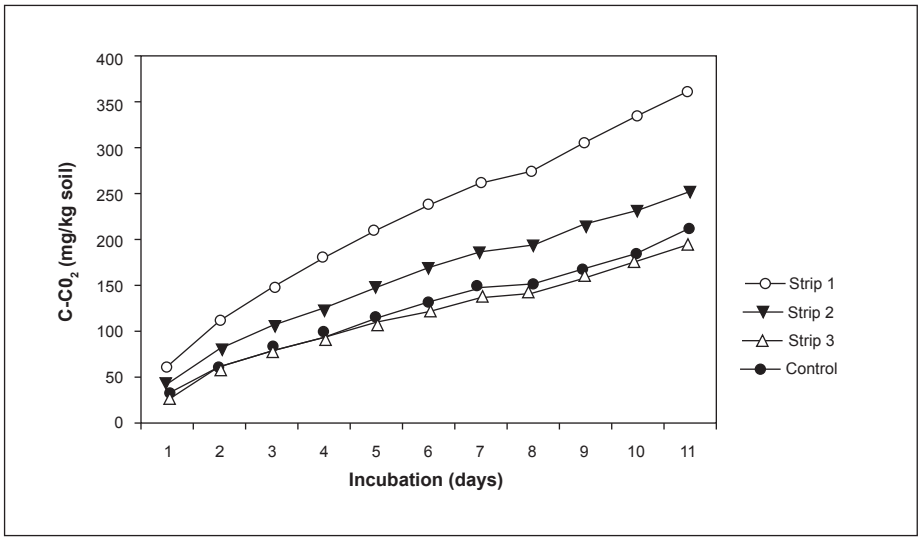

Figure 4. *Evolution of cumulative C-CO2 (mg/kg soil) reached for each treatment (stone lines and control)*

and Lamachère, 1988). Furthermore, the stone lines promote sedimentation of particles (sand, fine earth, organic material) in upstream locations of the dikelets (Hien, 1995; David, 2003). This environment becomes favourable for other soil organisms, such as termites, earthworms and ants, not found in the control plot. These organisms – particularly the termites and earthworms – are often called 'engineers of the ecosystem': in addition to their important role in improving the soil's physical properties (porosity and water drainage), they fragment litter and consequently induce carbon mineralisation (Lepage, 1981; Lavelle, 1997). This explains the very high levels of total carbon in the plot with stone lines. The outcome of all these factors is an increase in agricultural yields (Ouédraogo, 2005). We deduce that the importance of biological activity is in the maintenance of soil equilibrium and its physical and chemical characteristics.

Thus, this technology (plot with stone lines) ensures the rehabilitation of degraded soils and, as a result, improves agricultural production in the Sahel. Furthermore, in the context of climate change, loss of biodiversity and soil degradation, water and soil conservation techniques in general assist in maintaining soil fertility, thereby sustaining agricultural production. In general, soil conservation ensures sustainable management of natural ecosystems.

Conclusion

The study identified the beneficial effects of stone lines on:

- infiltration of rainwater;
- trapping of solid particles upstream of stone lines;
- colonisation by diverse wildlife.

These results could explain the good yields obtained in plots with stone lines, which are evidenced by many studies. Moreover, this technique is known to farmers and could be easily

adopted by the population. However, the constraint on the use of this technique remains the availability and transportation of stones to the site. Also, its effectiveness is enhanced when combined with other techniques, such as use of compost/manure or *zaï*. In conclusion, this technology can reduce the need for mineral fertilisers and can be considered eco-friendly. Finally, in the context of climate change, it is a method of adaptation.

However, it must be noted that problems relating to soil degradation and the environment are always related to how society plans and uses its environment. As a result of this, the solution to these problems cannot be solved simply by a technical component.

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Prices of Raw Materials, Budgetary Earnings and Economic Growth: A Case Study of Côte d'Ivoire

Nguiakam Sandrine[1] and Kabore Augustin[1]

Keywords: GDP, cocoa, coffee, exports, impact, oil, trade shock

Abstract

The objective of this study was to evaluate the impact of the fluctuation of international prices of raw materials on the variability of the gross domestic product (GDP) in Côte d'Ivoire. The study used the vector autoregressive model on an international data set of primary products and export earnings; inflation and GDP were selected variables analysed in relation to this variability. From 1960 to 2005, fluctuations of coffee prices explained about 15% of the variability of the GDP, while export earnings in total explained approximately 20% of this variability. The exchange rate of the dollar and fluctuation of the petroleum price, which are external factors, also had a significant impact on the dynamics of the growth of Côte d'Ivoire. These results confirm the dependence of the Ivorian economy on raw materials. They illustrate the need for the continuation of efforts aimed at diversifying the economy, in particular of the agricultural sector, and encouraging the setting up of an observatory for a better interpretation of the world economic environment, in order to predict and weather the various shocks.

Introduction

Côte d'Ivoire contributes to global trade through a limited range of products including cocoa, coffee, timber and oil. According to statistics (National Statistical Institute of Côte d'Ivoire) on Côte d'Ivoire's external trade, these few products have accounted for more than half of the value of exports since the attainment of independence. Like the majority of Sub-Saharan African countries, Côte d'Ivoire is a 'price taker'. For this reason, it does not wield any control over the level of prices of its exports or imports. Furthermore, its exports are quoted in foreign currency and it has no control over the exchange rate, which affects the export earnings quoted in national currency. It therefore seems that Côte d'Ivoire's dependence on raw materials makes the country vulnerable. As an illustration, between 1980 and 2002, annual world prices dropped by 58% in nominal value. In real value (that is, when inflation for the entire period is taken into account), the effect was a gradual decrease in the purchasing power of farmers – the decline in prices observed was 80.8%.

1. Ecole Nationale Supérieure de Statistique et d'Economie Appliquée (ENSEA), 08 BP 3, Abidjan 08, Côte d'Ivoire.

Issue

Côte d'Ivoire relies on the prices of raw materials, like most other Sub-Saharan African countries, but what is the effect of the instability of these prices on budgetary earnings, and what is the indirect effect on the economic growth of Côte d'Ivoire? Is it possible to evaluate the magnitude of the effect? Finally, how can the effects (since we can't do away with them) of this instability on our economies be cushioned?

Objectives

General objective

The purpose of this study was to demonstrate that there is a high correlation between international prices of raw materials (coffee, cocoa, oil, etc.), the budgetary earnings from entry-point taxation and economic growth.

Specific objectives

To analyse Côte d'Ivoire's export structure in order to highlight the importance of raw materials in export earnings; to analyse the coffee–cocoa sector, the oil sector and stakeholders; to evaluate the influence of price fluctuations on revenue from entry-point taxation; to highlight the impact of the variations of this revenue on the economic growth of Côte d'Ivoire.

Literature Review

There is a great deal of literature relating to variability (instability) of prices of raw materials. Kose and Reizman (2001) demonstrated that in Sub-Saharan Africa, trade shocks linked to fluctuations of international prices accounted for almost 45% of GDP fluctuations, 87% of investment variations and 80% fluctuation of labour supply. A study carried out by the Central Bank of West African States (BCEAO, 2007) with the Projection Macro-Econométrique et de Simulation (PROMES) model on regional economic prospects, proved that, in general, oil shocks contributed to the worsening of financial stability of the electricity sector in most of the countries of the West African Economic and Monetary Union (WAEMU) in view of the fact that a greater part of the electrical energy being produced is from thermal sources. Harvard economist David Dawe (1996) carried out an econometric audit on the assumption that fluctuation in export earnings leads to instability in household incomes. Chambas (CERDI, nd) notes that, in the 1970s, mismanagement of the rise in international prices of phosphate led to the appearance of the 'Dutch syndrome' in Senegal.[2] However, these studies are general and conceal the specificities particular to each country.

Materials and method

To attain the objectives of this study, the following tools were used: documentary research and economic analysis, descriptive statistics and econometric analysis.

- Documentary research helped with a theoretical analysis of the economic repercussions of a shock on the raw materials.

2. 'Dutch syndrome' is a paradoxical phenomenon: a boom in a sector that produces a natural resource would spontaneously tend to compromise any effort of industrialisation or diversification of exports, so aggravating the vulnerability of the economy.

- Graphical analysis and descriptive statistics helped in the presentation and description of the macro-economic magnitudes used in the study.
- Econometric analysis, particularly the vector autoregressive/vector error correction model (VAR/VECM) modelling, helped in analysing the impact of an increase in prices of raw materials on Ivorian macro-economic variables. This econometric analysis was subdivided into three parts.
    - Causality, which helps in the correct formulation of economic policy and decision-making. In this study, Granger's (1969) notion of causality was used. According to Granger, an effect of *X* magnitude causes a response of *Y* magnitude, if the knowledge of *X* improves the prediction of *Y*. This definition established the anteriority of events.
    - The functions of impulse responses, which measure the consequences of a shock on the variables.
    - Analysis of the decomposition of the variance of error prediction, the objective of which is to elicit information on the relative importance of innovation in the variations of each of the model variables.

Results

Economic Analysis

The effect of international prices on the GDP is not a direct one, but comes by way of intervening variables. One can distinguish between the following channels: taxation, distribution of national revenue, consumption and investment behaviours.

These shocks on the prices of raw materials can trace their source to the supply and demand sides, or result from a variation in the exchange rate (for countries in the CFA franc zone, it will be the difference between euro and dollar). On the supply side, it could be the result of an overproduction crisis, a domestic supply shock (e.g. increase in the cost of inputs); whereas on the demand side, the shocks emanate from a decline in global demand, which is generally external.

A negative price shock of raw materials meant for export would result in a decline in export revenue. This decrease in revenue has an effect on all economic operators. Households, particularly those of farmers, experience a decline in their incomes and therefore also adjust their consumption patterns.

Graphical Analysis and Descriptive Statistics

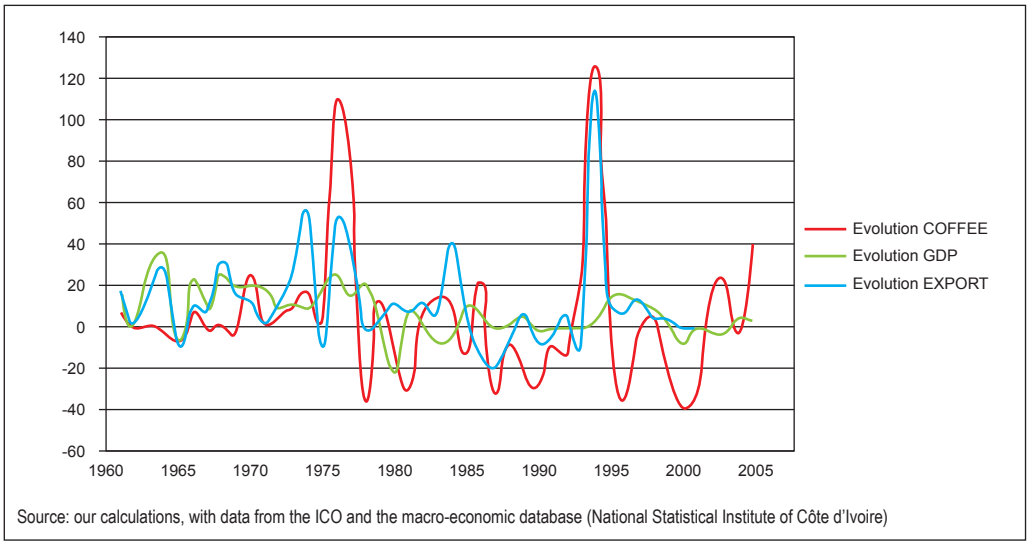
Importance of Raw Materials in Exports

The engine of growth of Ivorian exports is coffee and cocoa, which contribute greatly in terms of exports. In 1960, exports of these two products accounted for more than 80% of total exports and remained above 55% of total exports until 1979. In 1999, the share of cocoa among the export crops was still 43.8% (Table 1, which gives an idea about the concentration of Ivorian exports on cocoa).

Table 1. Distribution of major export crops, 1991 and 1999

No. products exported		Share of total exports (%)			
		Product most exported (cocoa)		Three major products exported (cocoa, coffee, oil)	
1991	1999	1991	1999	1991	1999
23	20	33.1	43.8	48.5	55

Source: Gros *et al*. (2002).



Source: our calculations, with data from the ICO and the macro-economic database (National Statistical Institute of Côte d'Ivoire)

Figure 1. *Developments in terms of GDP, exports and coffee price*

Developments in the Prices of Coffee and Cocoa

On the whole, the prices of the two products witnessed similar developments from 1960 to 2002. Two periods can be identified in terms of developments in prices of these two products at the world level. The first is from 1960 to 1977, characterised by an upward trend with an all-time record of 1977, corresponding to a positive shock in prices of these two products. In fact, the prices of cocoa and coffee increased from US$56.49/pound and $61.05/pound in 1975 to $17.96/pound and $233.75/pound in 1977. In 3 years, prices tripled for cocoa and quadrupled for coffee. The second period, from 1977 to 2002, was characterised by a very serious downward trend. During that period, a very wide price variability and two negative shocks (in 1982 and 1993) were observed, and prices returned to the 1960 level (International Cocoa Organization, ICCO, www.icco.org; International Coffee Organization, ICO, www.ico.org).

In terms of the comparative developments of entry-point taxation revenue, Ivorian GDP and world coffee prices, it appears that variations in the price of coffee correspond with variations in revenue and, in a similar vein, with GDP (Fig. 1). One can therefore surmise that there is a close link between instability of prices of raw materials and an increase in GDP.

Econometric Analysis

Definition of Variables of the Study

The variables used in this study are as follows:

- DOLLAR = international price of US dollar;
- COFFEE = international price of coffee (annual average calculated from monthly averages);
- OIL = international price of oil (annual average calculated from monthly averages);
- EXPORT = export earnings (per year);
- INFL1 = rate of inflation (annual average calculated from monthly averages);
- GDP = gross domestic product.

In application of the VAR model, all variables are considered in logarithms. Thus, the 'L' before the rating variables is the logarithm. The logarithmic form can easily derive the elasticity and function of growth rate. The difference in log Y_t and log $Y_{(t-1)}$ corresponds to the growth rate of Y. Therefore the first log difference of each function gives an approximation of the growth rate of the function.

One step in the VAR model is the stationarity test. We used the Dickey–Fuller and Phillips–Perron tests. (The use of these two tests is motivated by the fact that the first takes into account the existence of a possible correlation of residuals, while the second takes into account the existence of possible heterocedasticity.) The results of these tests show that only the variable 'inflation' is stationary at a probability level of 5%. So we differentiated all the variables to make them stationary. Differentiated series are denoted by 'DL'.

Causality

As the developments in the prices of coffee and cocoa were similar over the period under review, we use only coffee prices in this modelling (to do away with the risk of multi-collinearity). After carrying out the different tests, the VAR model obtained was:

$$Y_t = A_0 + \sum A_j Y_{t-j} + \varepsilon_t$$

where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}, \varepsilon_{4t}, \varepsilon_{5t}, \varepsilon_{6t})$ (the vector of stochastic error terms is called impulses or innovations or shocks in the VAR language); Y_t is the stationary process; A_j is the matrix coefficient; and t stands for any given year. The order of our model is 1, and in matrix form, we used the following equation:

$$\begin{pmatrix} DLCDOLLAR_t \\ DLCPETROLE_t \\ DLCCAFE_t \\ DLEXPORT_t \\ LINFL1_t \\ DLPIB_t \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \\ c_6 \end{pmatrix} + \begin{pmatrix} a_{11} & a_{12} & \dots & a_{16} \\ a_{21} & a_{22} & \dots & a_{26} \\ a_{31} & a_{32} & \dots & a_{36} \\ a_{41} & a_{42} & \dots & a_{46} \\ a_{51} & a_{52} & \dots & a_{56} \\ a_{61} & a_{62} & \dots & a_{66} \end{pmatrix} \begin{pmatrix} DLCDOLLAR_{t-1} \\ DLCPETROLE_{t-1} \\ DLCCAFE_{t-1} \\ DLEXPORT_{t-1} \\ LINFL1_{t-1} \\ DLPIB_{t-1} \end{pmatrix}$$

where:

$$Y_t = \begin{pmatrix} DLDOLLAR_t \\ DLOIL_t \\ DLCOFFEE_t \\ DLEXPORT_t \\ LINFL1_t \\ DLGDP_t \end{pmatrix}; \quad A_0 = \begin{pmatrix} a_{01} \\ a_{02} \\ a_{03} \\ a_{04} \\ a_{05} \\ a_{06} \end{pmatrix}; \quad A_j = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{16} \\ a_{21} & a_{22} & \dots & a_{26} \\ a_{31} & a_{32} & \dots & a_{36} \\ a_{41} & a_{42} & \dots & a_{46} \\ a_{51} & a_{52} & \dots & a_{56} \\ a_{61} & a_{62} & \dots & a_{66} \end{pmatrix}; \quad \varepsilon_t = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{pmatrix}$$

Figure 2 provides a summary of the causality between the variables obtained from the estimates of the selected model: the Ivorian GDP growth rate is jointly influenced by the variation in the price of oil, coffee and Côte d'Ivoire's export earnings.

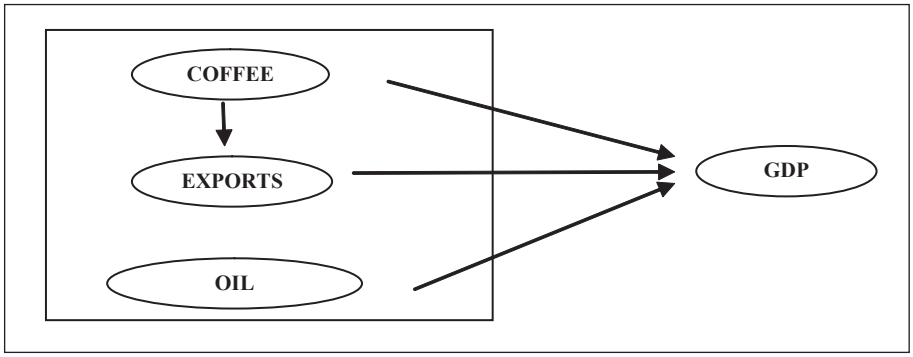


Figure 2. *Causality between the variables*

Impulse Analysis

The impulsive answer measures the consequence of a shock on variables. The graphs (Fig. 3) present some of the essential impulse functions obtained. We are interested in the effect of a shock over 10 years. Generally, the shocks are transitional since their effects disappear at the end of ten (10) years.

This horizon represents the necessary maximal timeframe for the variables to regain their long-term level. The shocks were simulated on the basis of coffee prices.

The effect of a positive shock on coffee price translates into an increase in the GDP. Following this shock, the GDP increases in the first year, then decreases from the second year before gradually finding its long-term level after a period of 6 years. These results once again confirm the coffee price and growth dynamics in Côte d'Ivoire. It must also be noted that the effect of coffee price shock on GDP goes beyond 4 years.

The effect of a positive shock on coffee price is translated instantly into an upward adjustment in export revenue. In the aftermath of this shock, export revenue regains its long-term level at the end of 3 years.

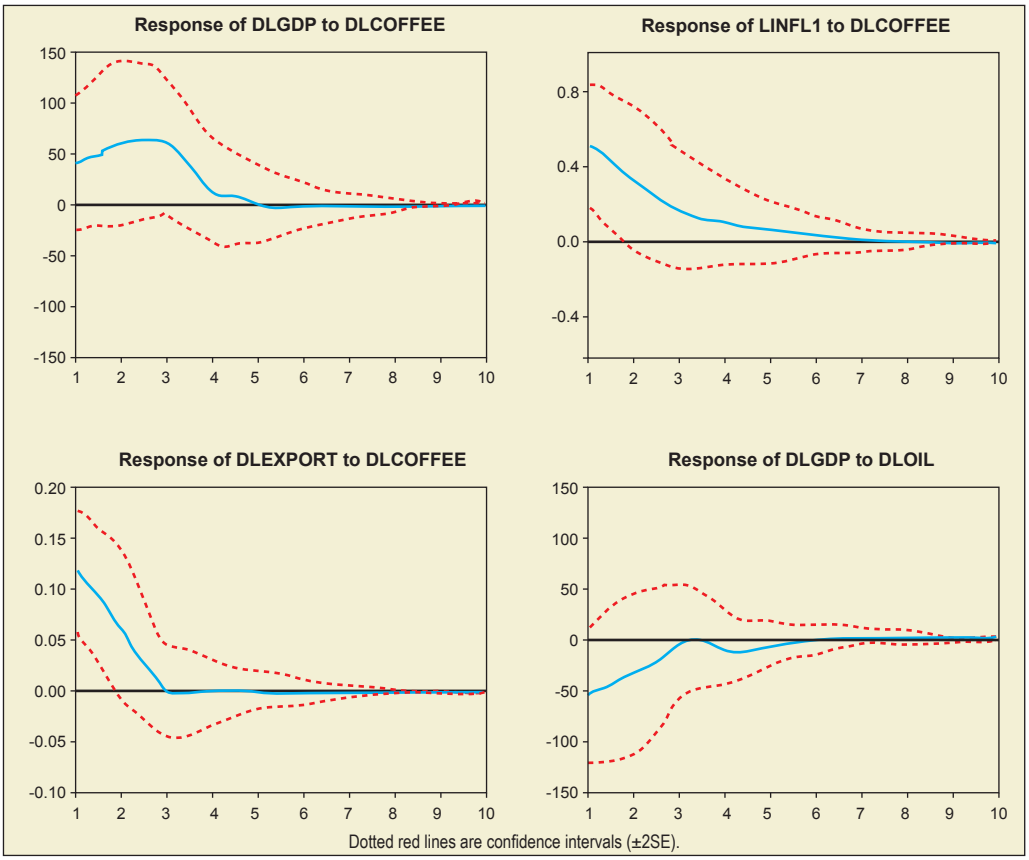


Figure 3. *Impulse response*

Variance Decomposition

The objective is to determine the relative importance of the innovations in the variations of each of the variables of the model. Concretely, we write the variance of the error of forecast on a horizon, *h* (in our case *h* goes from 1 to 5) according to the variance of the error attributed to each of the variables. When an innovation explains a significant proportion of the variance of the forecast error, we deduce that the economy is sensitive to shocks affecting this series. In this section, we analyse the decomposition of the variance of DLGDP and DLEXPORT.

Table 2. Variance decomposition of GDP

Period	SE	DLCOFFEE	DLOIL (%)	DLEXPORT (%)	DLGDP (%)	DLINFL1 (%)
1	1.016124	13.5	7.7	17.7	61.1	0
2	1.124223	17.1	7.5	24.0	51.3	0.1
3	1.145297	20.4	6.9	22.3	49.9	0.5
4	1.153545	20.5	7.1	22.3	49.5	0.6
5	1.156771	20.5	7.2	22.3	49.4	0.6

The variance of error prediction of the GDP in the first year is 61% due to its own changes, 13% to coffee price changes, and 17% to export changes. In other words, the variations of the GDP

depend (on the horizon of 1 year) by 13% on the dynamics of the coffee prices and by 61% on its own innovations (or variations). It can therefore be said that these variables influence GDP fluctuations in Côte d'Ivoire. These results once again reflect Côte d'Ivoire's dependence on this raw material.

Table 3. Variance decomposition of export earnings.

Period	SE	DLCOFFEE	DLDOLLAR	DLOIL (%)	DLEXPORT (%)	DLGDP (%)	DLINFL1 (%)
1	0.203407	33.8	36.0	4.6	25.7	0.0	0.0
2	0.226766	35.8	29.1	3.8	28.6	1.2	1.5
3	0.234586	34.5	28.0	7.3	27.1	1.1	2.2
4	0.238643	33.5	27.8	7.3	26.8	1.2	3.5
5	0.239793	33.2	27.5	7.7	26.9	1.2	3.5

The variance of error prediction of export earnings is attributable by 26% to its own changes, and 10.8% to coffee price changes during the first year. In other words, Table 3 shows that the dynamics of the export earnings in Côte d'Ivoire are due to the variations of the coffee prices (by 34%), variations of the exchange rate of the dollar (33%), and its own variations (26%) on the horizon of 1 year. It therefore seems that the shocks on these variables are dominant in all aspects over the fluctuations in export earnings. It can be concluded that, in Côte d'Ivoire, the coffee price and changes in export revenues have a very great impact on export revenue.

Discussion and conclusion

The objective of this study was to evaluate how world prices of raw materials contribute to the explanation of Ivorian GDP growth. In terms of impact of the simulated shock, the study revealed that, following a positive shock of coffee prices, there would be a positive growth reaction of the Ivorian GDP. Furthermore, the GDP would regain its long-term stability within a period of 4 and 5 years for a positive shock of the dollar and coffee, respectively. On the other hand, following a coffee price shock, GDP and inflation take more time to regain their long-run equilibrium than in the aftermath of any other shock (oil, dollar).

With regard to the contribution of world prices in explaining fluctuations of growth in Côte d'Ivoire, it seems that there, too, export revenue has a role to play in the explanation of the GDP representing over 17.68%. Thereafter, the price of coffee accounts for at least 13.5% in the explanation of GDP fluctuations.

This study helps to confirm the dominant role of coffee and exports in the Ivorian economy, including oil, the development of which is very important to the growth of the country. Diversification of the Ivorian economy appears to be crucial in order to release the country from its dependence on coffee and other export crops such as cocoa by creating processing industries at local level.

Also, as the need for diversification is a long-term policy, in the short term it would be necessary to ensure a prudent budgetary management policy and a good understanding of the international economic environment, for example through the establishment of an observatory.

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Morphological Characterisation of African Eggplant (Solanum spp.) Germplasm in some African Countries

M.K. Osei,[1] M.O. Oluoch,[2] C.K. Osei[3] and B. Banful[3]

Keywords: landraces, traits, variation, breeders, vegetative, selection, characters

Abstract

The high nutritive value of African eggplant leaves and the high leaf and fruit yield, along with its fairly high resistance to pests and diseases, make the crop interesting for development. A long period of selection by peasant farmers has resulted in a number of landraces. The selected landraces are scattered across the major agro-ecologies of Africa, making it difficult to concentrate on the desirable traits required for genetic improvement of the crop. Systematic characterisation of available crop varieties using morphological traits is needed to fuel breeders' efforts in these species. Consequently, this work was designed to characterise African eggplant germplasm collected from Cameroon, Côte d'Ivoire, Ghana, Sudan, Tanzania and Uganda. Twenty-eight accessions of African eggplant – *Solanum aethiopicum* (15), *S. macrocarpon* (9) and *S. anguivi* (4) – were characterised for morphological characters. The results indicated distinct and wide variations between the three *Solanum species*. Distinct variation was noticeable in fruit characteristics, both between and within species. Lines of *S. anguivi* had small, round fruits, while *S. aethiopicum* had medium-sized to large, oval fruits. There were, however, a lot of similarities between the *S. aethiopicum* and *S. anguivi lines*. This suggests the two materials are closer to each other than they are to *S. macrocarpon*.

Introduction

Solanum aethiopicum L. ('the' African eggplant) is one of the most commonly consumed fruit-vegetables in tropical Africa. The high nutritive value of the leaves and the high leaf and fruit yield of *S. macrocarpon* L. (Gboma eggplant), combined with its fairly high resistance to pests and diseases, make this species interesting for development (Bonsu *et al.,* 1998). *Solanum anguivi* Lam. (putative ancestor of *S. aethiopicum*) also has the potential to become a cultivated market vegetable. It is also of potential use as a male parent in breeding programmes to improve *S. aethiopicum* for disease resistance and to increase the number of fruits per inflorescence (Bukenya-Ziraba, 2004). Consumer preference for a variety of African eggplant is based on characteristics such as size, form, colour and taste (sweet or bitter) (Bukenya-Ziraba and Bonsu, 2004).

1. CSIR (Crops Research Institute), Horticulture Division, PO Box 3785, Kumasi, Ghana.
2. AVRDC – The World Vegetable Center, PO Box 10, Duluti, Arusha, Tanzania.
3. KNUST, Agric Faculty/CDL, Univ. Post Office, Kumasi, Ghana.

Although little (formal) breeding of African eggplant has been undertaken, germplasm collections exist and a long period of selection by small-scale farmers has resulted in a number of landraces. Much diversity is exhibited by these materials, including level of sweetness, colour, disease resistance and earliness. Landraces reflect the farmers' preferences, such as larger fruit, colour, taste, early maturity and higher yield. Even though *S. macrocarpon* has a slightly bitter taste, it is considered a minor crop in most African countries except Nigeria, so research to enhance the germplasm potential is scarce. African eggplant has long been neglected by formal crop improvement programmes, except where it is used as a source of specific traits to develop disease resistance in *S. melongena* L. ('the' eggplant). More recently, a few workers have directed research attention into improvement of the agronomic characteristics of the farmers' selections (Lester and Seck, 2004). However, the selected landraces are well scattered across the major agro-ecologies of Africa, making it difficult to focus on the desirable traits required for genetic improvement of the crop. Systematic characterisation of African eggplant varieties or lines using morphological traits is needed to fuel breeders' efforts on the species (AVRDC, 2003).

There was thus a clear need to characterise collected germplasm that could be used in the development of new varieties. The objective of this study was to characterise lines of African eggplant species collected from various African countries. This was to help generate information necessary to rationalise the conservation of the species and to help with selection of core collections and accessions that can be used for breeding.

Materials and method

The experiment was carried out at AVRDC–The World Vegetable Center's Regional Center for Africa in Arusha, Tanzania, during the cool season from July to November 2005. The area has mean annual rainfall of 1,085 mm. The soils are clay loam with a pH of 6.0–7.0. The area lies at an altitude of 1,290 m above sea level, latitude 4.8° S and longitude 37° E. The experiment was laid out in a randomised complete block design (RCBD) with three replications. In all, 28 accessions (from various African countries; Table 1) were sown in seedbeds and transplanted out in the field 6 weeks later. The seedlings were transplanted in two rows for each accession at spacing of 50 × 75 cm in plot sizes measuring 6 m long.

The plants were fertilised with NPK at the rate of 450 kg/ha (90 kg N, 45 kg P_2O_5/ha, 45 kg K_2O). Additional supply of N was provided by urea at the rate of 120 kg N/ha. All the NPK and 60 kg N/ha of urea were applied together 1 week after transplanting. The second urea application (also 60 kg N/ha) was applied when fruit formation began. All weights were measured with an electronic scale (ADP 1200L, Wagtech International Ltd, UK). Furrow irrigation was carried out twice a week during the first few weeks after transplanting and once a week thereafter. Hand weeding was carried out as needed. Pesticide Ridomil (copper + metalaxyl-M, Syngenta Crop Protection, Basle, Switzerland) was sprayed against damping off at the rate of 20 mL/15 litres of water 12 days after transplanting (30 L per plot). This was closely followed by spraying Selecron (profenofos, Sygenta Crop Protection, Basle, Switzerland) at a rate of 20 mL/15 litres of water (30 L per plot), in the second week to control cutworms. Characterisation of these accessions was conducted from seedling to fruiting stage. The morphological characteristics were scored using the descriptor list for eggplant and African eggplant developed by AVRDC (M.L. Chadha, L.M. Engle and M.O. Oluoch, unpublished data). Characterisation consisted of recording those traits that were highly heritable or could easily be seen and expressed in all

environments. Distinct variants within an accession were identified and harvested separately to form sub-accessions. Both the qualitative and quantitative characters were subjected to analysis (NTSYS version 2.11s) (Rohlf, 2004) to generate a dendrogram.

Results

Vegetative Characters

Accessions N14, 11-05 and Ex-Yambio had the widest branching spread, while CR007, No. 9, Ex-Sironkwo and Small oval were short. The lines of *S. aethiopicum* and *S. anguivi* showed wide variation in their plant branching (Table 2). Plant height at maturity varied from 22.9 to 94.6 cm among the *S. aethiopicum* and *S. anguivi* lines, but only 19–68.2 cm among the *S. macrocarpon* lines (Table 2). The petiole of *S. macrocarpon* lines (CR007, CR005, CR001 and CR006) was green and mostly very short (Table 2). Leaf blade length and width of *S. macrocarpon* were mainly intermediate with few or no hairs on the leaves. However, the leaves and stems of *S. macrocarpon* were glabrous and spineless. Lines belonging to *S. aethiopicum* and *S. anguivi* had few leaf hairs.

Table 1. Origin of African eggplant accessions

Accession	Species	Country of origin
Tengeru white	*Solanum aethiopicum*	Tanzania
Ex-Sironkwo	*Solanum aethiopicum*	Uganda
Manyire green	*Solanum aethiopicum*	Tanzania
No.1	*Solanum aethiopicum*	Tanzania
No.9	*Solanum aethiopicum*	Tanzania
N.12	*Solanum aethiopicum*	Tanzania
Small oval	*Solanum aethiopicum*	Tanzania
N13	*Solanum aethiopicum*	Tanzania
N20	*Solanum aethiopicum*	Tanzania
Ex-IVC	*Solanum aethiopicum*	Côte d'Ivoire
N24	*Solanum aethiopicum*	Cameroon
N11	*Solanum aethiopicum*	Tanzania
N14	*Solanum aethiopicum*	Tanzania
DB3	*Solanum aethiopicum*	Ghana
AB-2	*Solanum aethiopicum*	Ghana
CR006	*Solanum macrocarpon*	Cameroon
CN012	*Solanum macrocarpon*	Cameroon
CR007	*Solanum macrocarpon*	Cameroon
N1	*Solanum macrocarpon*	Cameroon
CN009	*Solanum macrocarpon*	Cameroon
CR001	*Solanum macrocarpon*	Cameroon
EX-DSM	*Solanum macrocarpon*	Cameroon
CR.005	*Solanum macrocarpon*	Cameroon
UVPP	*Solanum macrocarpon*	Cameroon
Fovembot	*Solanum anguivi*	Cameroon
Toumbot	*Solanum anguivi*	Cameroon
11-05	*Solanum anguivi*	Cameroon
Ex-Yambio	*Solanum anguivi*	Sudan

Fruit Characters

Distinct variation was noticeable in fruit characteristics, both between and within species. *Solanum anguivi* accessions had small, round fruits, while *S. aethiopicum* had medium-sized to large, oval fruits (Fig. 1). Nevertheless, the majority of the accessions had round fruits, with only two being oblate and cylindrical. The fruits of *S. macrocarpon* were mostly dark green at harvesting. Accessions belonging to *S. aethiopicum* had a mixture of fruit colours involving cream–white to light yellow and green with dark green stripes. *Solanum anguivi* lines had fruits dark green and green with dark green stripes. Distinct variations existed between and within species regarding fruit position. Manyire green and Tengeru white (*S. aethiopicum*) had different fruit positions (Table 2). *Solanum macrocarpon* lines CR006, CR007 and UVPP showed pendant, semi-pendant and horizontal fruit positions, respectively. Fovembot and Ex-Yambio (*S. anguivi*) also showed different fruit positions, i.e. pendant and semi-pendant (Table 2).

Table 2. Phenotypic characteristics of vegetative and some fruit characters

Accession	Plant height (cm)	Petiole colour	Petiole length	Leaf blade length	Leaf blade width	Leaf hair	Fruit position
Tengeru white	68.2	Green	–	Interm.	Mixture	Absent	Pendant
Ex-Sironkwo	45.5	Dark brown	V. long	Long	Wide	V. few	Pendant
Manyire green	86.6	Mixture	Short	Mixture	Mixture	Absent	S.pendant
No.1	76.0	Green	Long	Interm.	Interm.	Absent	Pendant
No.9	22.9	Green	V. long	Interm.	Interm.	Few	S.pendant
N.12	79.0	Green	–	Interm.	Wide	Interm.	Pendant
Small oval	30.2	Green	–	–	Wide	Few	Pendant
N13	46.8	Green	Long	Short	Mixture	V. few	Pendant
N20	71.4	Green	Long	Interm.	Mixture	Few	Pendant
Ex-IVC	81.2	Green	Interm.	Long	Wide	V. few	S.pendant
N24	–	–	–	–	–	–	–
N11	65.4	Mixture	–	Interm.	Wide	Absent	Pendant
N14	81.6	Green	Interm.	Interm.	Wide	Absent	Pendant
DB3	55.0	Green	Long	Interm.	Mixture	Interm.	Pendant
AB-2	69.4	Green	Long	Interm.	Mixture	Mixture	Pendant
CR006	14.4	Green	V. short	Interm.	Interm.	Absent	Pendant
CN012	35.4	Green	Interm.	Interm.	Interm.	Absent	–
CR007	19.0	Green	Interm.	Interm.	Narrow	Absent	S.pendant
N1	68.2	Green	–	Interm.	Mixture	Absent	Pendant
CN009	26.9	Green	Interm.	Short	Interm.	Absent	–
CR001	19.7	Green	V. short	Short	Interm.	Absent	S.pendant-
EX-DSM	53.4	Green	V. short	Interm.	Mixture	Few	–
CR.005	26.9	Green	–	Mixture	Interm.	Mixture	Pendant
UVPP	41.5	Mixture	Short	Interm.	Interm.	Absent	Horizontal
Fovembot	42.2	Violet	Long	Short	Narrow	Absent	Pendant
Toumbot	77.9	Mixture	Long	Interm.	Absent	Absent	Pendant
11-05	79.6	Mixture	Long	Interm.	Mixture	Absent	Pendant
Ex-Yambio	94.6	–	–	–	–	–	S.pendant

Interm.=intermediate; V.=very; S.=semi-; – missing data.

Figure 1. *Morphological characteristics of three species of African eggplant: S. aethiopicum (top, left and right); S. macrocarpon (bottom left); S. anguivi (bottom right)*

Diversity of African Eggplant Accessions

The dendrogram (Fig. 2) groups the accessions into three clusters. Though there were a few mixtures, the first cluster indicated mainly *S. macrocarpon*, with the second and third clusters showing mainly *S. anguivi* and *S. aethiopicum* accessions, respectively. Cluster 1 (mainly *S. macrocarpon*) had a few *S. aethiopicum* accessions (Small oval and Ex-IVC). Similarly, cluster 2 also had a few *S. aethiopicum* accessions. Cluster 3 (mainly *S. aethiopicum*) had a few *S. macrocarpon* accessions.

Discussion and conclusion

Vegetative Characters

Wide branching spread is a very good trait for high yield (AVRDC, 2003). Breeders usually select for this trait to increase the number of fruits per plant and hence yield. African eggplant displays much genetic diversity in plant branching, giving breeders diverse characters for improvement. Most *S. macrocarpon* accessions did not have leaf hairs. Leaf hairs serve as an external mechanism for withstanding certain pests and diseases (AVRDC, 2003).

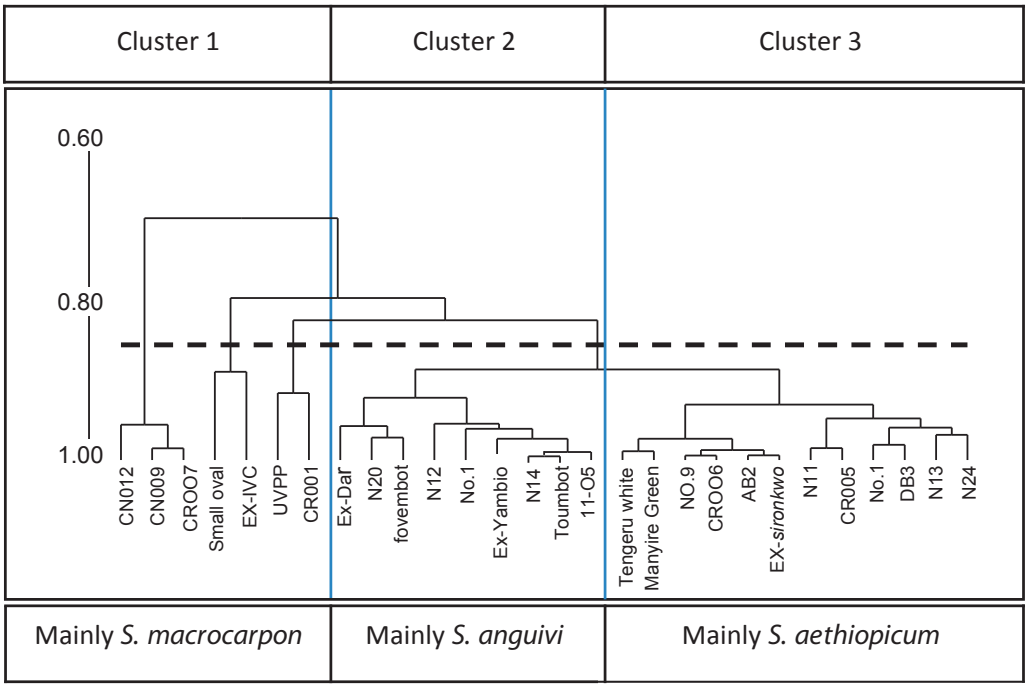

Figure 2. *Dendrogram showing diversity in African eggplant accessions*

Fruit Characters

Variation in fruit shape is also a valuable trait for breeders to select in their breeding programmes. Our results confirmed earlier reports (AVRDC, 2003) that showed similar shapes between and within species. Cylindrical and oblate shapes are preferred in most markets in Ghana and Tanzania. Breeders can therefore incorporate these shapes into other African eggplant lines that have other desirable traits. Wide variation existed in *S. aethiopicum* in terms of fruit colour and shape. This means there is wide genetic diversity available to breeders. Mixtures obtained in the accessions in terms of fruit shapes could be attributed to the fact that some mixture of seeds and seedlings occurred during sowing and transplanting, respectively.

Diversity of African Eggplants

Even though the first cluster indicated mainly *S. macrocarpon*, other accessions belonging to *S. aethiopicum* were also found in cluster 1 – those accessions have something in common. For example, some flowers of *S. macrocarpon* and *S. aethiopicum* are cream coloured. In cluster 2, the accessions were mainly *S. anguivi* with a few *S. aethiopicum*. Again this shows that the two species share common characters. A number of characters – fruit position, flower colour, fruit shape, petiole colour, petiole length and leaf hair – were common between *S. anguivi* and *S. aethiopicum.* Similarly, in cluster 3, where the accessions were mainly *S. aethiopicum*, there were also a few accessions belonging to *S. macrocarpon*, indicating that some common characters are shared among them. One flower colour (cream) and fruit position at maturity were typical of cluster 3.

Overall, there was a considerable variation within the vegetative and fruit characters observed, both within and between the *Solanum* species. Wide variation, however, existed in characters such as diameter of corolla, petiole length, leaf blade width, plant branching, fruit shape, and fruit colour at harvesting. With this information, breeders will now be in a better position to improve and develop new varieties of African eggplant for farmers who will then increase their income and improve their standard of living.

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Grass Reseeding Technology as a Means of Rehabilitating Degraded Lands and Improving Livelihoods of Agro-pastoral Communities in Semi-arid Kenya

K.Z. Mganga,[1] N.K.R. Musimba,[1] M.M. Nyangito,[1] D.M. Nyariki,[1] A.W. Mwangombe,[2] W.N. Ekaya,[3] W.M. Muiru,[2] D. Clavel,[4] J. Francis,[5] R. von Kaufmann[6] and J. Verhagen[7]

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Abstract

Land degradation is a major problem in the semi-arid environments of Sub-Saharan Africa. Fighting land degradation is essential to ensure the sustainable and long-term productivity of the inhabited semi-arid lands. *Cenchrus ciliaris* (African foxtail grass), *Enteropogon macrostachyus* (bush rye) and *Eragrostis superba* (Maasai love grass) are important perennial grasses in the Eastern African semi-arid lands. A study was conducted to establish the contribution of these indigenous grasses in improving soil hydrological properties, rehabilitation, food security and the livelihoods of agro-pastoral communities in semi-arid districts of Kenya. Soil hydrological properties were tested using a Kamphorst simulator at different stubble heights to represent three different grazing intensities (low, medium, high). Ground cover was estimated using the step-point method. A survey was also conducted across 50 agro-pastoral households to establish the multidimensional benefits of the grasses. Sediment production (as a function of run-off and infiltration capacity) was significantly different ($P<0.05$) at different stubble heights. Ground cover estimates of the grasses were also significantly different ($P<0.05$). *Cenchrus ciliaris* had the greatest influence in improving soil hydrological properties. *Enteropogon macrostachyus* and *E. superba* were ranked second and third, respectively. *Enteropogon macrostachyus* had the greatest ground cover. *Cenchrus ciliaris* and *E. superba* were ranked second and third, respectively. These results were attributed to the growth and morphological characteristics of the grasses. Generally, an increase in stubble height increased infiltration capacity and reduced run-off and sediment production. Results from the household survey showed that the grasses provide a source of income through the sale of hay, grass seeds and milk, which also achieve a balanced diet. The grasses also provide a cheap source of thatching materials and livestock feed.

1. Department of Land Resource Management and Agricultural Technology, University of Nairobi, PO Box 29053-00625, Nairobi, Kenya.
2. Department of Plant Science and Crop Protection, University of Nairobi.
3. RUFORUM, Uganda.
4. CIRAD, France.
5. CTA, The Netherlands.
6. FARA.
7. Wagengen University, The Netherlands.

Introduction

Land degradation – a reduction of resource potential by one or a combination of processes acting on the land, such as water and wind erosion – is a major problem in the semi-arid lands of Sub-Saharan Africa. Degraded land can be defined as land that, due to natural processes or human activity, is no longer able to sustain an economic function and/or its original ecological function. Processes that lead to land degradation involve complex interactions between societal and natural climatic factors. The most frequently recognised causes of land degradation are overgrazing, over-cultivation of croplands, waterlogging and salinisation of irrigated lands, deforestation, pollution and industrial causes (Mganga, 2009).

The land degradation issue assumes major significance for world food security and quality of the environment when one considers that only 11% of global land can be considered prime land, and this must feed around 6.3 billion people today plus the 8.2 billion expected by the year 2020 (WMO, 2005). Food security is defined as when all people at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Ericksen, 2008). Grass reseeding, which involves introducing new seed to replenish a depleted soil seed bank, has been used to rehabilitate degraded lands to improve their potential for both livestock and crop production. Rehabilitation can be described as a re-engineering process that attempts to restore an area of land back to its natural state after it has been damaged as a result of some sort of disruption.

The objectives of this study were: (1) to determine the contribution of three perennial grasses – *Cenchrus ciliaris*, *Enteropogon macrostachyus* and *Eragrostis superba* – in rehabilitating degraded semi-arid lands and improving soil hydrological properties; and (2) to determine the contribution of these three grasses in improving the livelihoods of agro-pastoral communities living in a semi-arid district in Kenya.

Materials and methods

Study Area

This study was conducted in Kibwezi division, Kibwezi district, Kenya. The district lies between latitudes 2°6′ and 3° S, and longitude 37°36′ and 38°30′ E, and has a total area of 3,400 km^2 (Mganga *et al.*, 2010a,b). The Kamba agro-pastoralists are the main ethnic inhabitants and their mainstream economic activity is raising livestock and cultivating grains and pulses (Nyangito *et al.*, 2010). The soils are mainly ferralsols, cambisols and luvisols. These soils are generally highly vulnerable to physical erosion and chemical and biological degradation (UNESCO, 2003). The climate is typical semi-arid and the district is characterised by low and unreliable supply of enough moisture for plant growth. The average annual rainfall, evaporation and temperature are 600 mm, 2,000 mm and 23°C, respectively. The natural vegetation is woodland and savannah. Kibwezi district is a typical semi-arid district dominated by *Commiphora*, *Acacia* and allied genera, mainly of shrubby habitat. Shrubs include *Acacia mellifera*, *A. senegal* and *Grewia* spp. (Nyangito *et al.*, 2009). The main perennial grasses include *Cenchrus ciliaris*, *Enteropogon macrostachyus*, *Chloris roxburghiana*, *Panicum maximum* and *Eragrostis superba* (Nyangito *et al.*, 2010).

Site Preparation and Experimental Design of Reseeded Plots

The experimental site preparation involved seed bed preparation, creation of micro-catchments using an ox-driven plough, and fencing. The experimental design was split into three plots each with an area of 150 m^2 (15 × 10 m). Each plot was further divided into six sub-plots of 25 m^2 (5 × 5 m). The three plots were horizontally arranged next to each other separated by 5-m fire-breaks. The seeds of the grasses were sown along the created micro-catchments as pure stands: *C. ciliaris*, *E. macrostachyus* and *E. superba*; and as mixtures: *C. ciliaris–E. macrostachyus*, *C. ciliaris–E. superba* and *E. macrostachyus–E. superba.* The reseeded plots were fenced and put under simulated rainfall to ensure sufficient moisture for germination and subsequent establishment.

Soil Hydrological Responses and Sediment Production Measurements

Simulated rainfall (Young and Burwell, 1972) was used to study soil hydrological responses (infiltration capacity; run-off and sediment production) in all sub-plots. Infiltration capacity in all the sub-plots at different grass stubble heights was measured using the Kamphorst rainfall simulator (Kamphorst, 1987). Each simulation consisted of a rain shower of 5 min with intensity of 375 mL/min (6 mm/min) (Rietkerk *et al.*, 2000). Infiltration capacity was calculated by subtracting the run-off from the amount of rainfall applied:

$$\text{infiltration capacity } (cm^3) = \text{simulated rainfall} - \text{total run-off collected}$$

The sediment produced was washed into storage bottles and later filtered off and dried at 105°C for 24 h. The amount of sediment produced was converted into kg/ha. This was used as an index of sheet erosion as given in the equation of Nyangito *et al.* (2009):

$$\text{sediment production (kg/ha)} = \frac{(\text{sediment produced} \times \text{area})}{\text{plot area}}$$

Sediment production and infiltration rates were estimated at different grass stubble heights of 0 cm (bare ground), 20 and 40 cm to represent three grazing intensities (low, medium and high). The percentage basal cover was estimated using the step-point method of vegetation sampling (Evans and Love, 1957).

Household Survey and Statistical Analyses

Survey data were collected from a total of 50 agro-pastoralists using semi-structured questionnaires. Soil hydrological responses of the three grasses at the different grass stubble heights were compared using one-way analysis of variance and means were separated using Tukey's *b*. Mean comparison was done at $P<0.05$. Descriptive statistics were used to analyse survey data. The Statistical Package for Social Scientists (SPSS) computer program (Einstein and Abernethy, 2000) was used to analyse data.

Results

Soil Hydrological Responses and Sediment Production Measurements

There was a significance difference ($P<0.05$) in the infiltration capacity, run-off and sediment production with an increase in grass height in all the grass species (Tables 1–3). However, there

was no significant difference (P>0.05) in infiltration capacity for *E. superba* at 0 and 20 cm stubble heights.

Basal Cover Estimates

The results of basal cover as an indicator of rehabilitation success showed significance differences (P<0.05) among the sub-plots both as pure stands and two-grass mixtures (Table 4).

Table 1. Effect of different grass stubble heights on infiltration capacity

	Infiltration capacity (cm^3)		
Height (cm)	**CC**	**EM**	**ES**
0	$1,047^{a} \pm 0$	$1,047^{a} \pm 0$	$1,047^{a} \pm 0$
20	$1,530^{b} \pm 65.57$	$1,413^{b} \pm 32.15$	$1,067^{a} \pm 30.55$
40	$1,883^{c} \pm 25.17$	$1,760^{c} \pm 55.68$	$1,513^{b} \pm 70.95$

CC, *Cenchrus ciliaris*; EM, *Enteropogon macrostachyus*; ES, *Eragrostis superba*.

Column means with different superscripts are significantly different at $P < 0.05$.

Table 2. Effect of different grass stubble heights on volume of run-off

	Run-off (cm^3)		
Height (cm)	**CC**	**EM**	**ES**
0	$953^{a} \pm 0$	$953^{a} \pm 0$	$953^{a} \pm 0$
20	$470^{b} \pm 65.57$	$587^{b} \pm 32.15$	$933^{a} \pm 30.55$
40	$117^{c} \pm 25.17$	$240^{c} \pm 55.68$	$487^{b} \pm 70.95$

For notes see Table 1.

Table 3. Effect of different grass stubble heights on sediment production

Grass stubble height (cm)	Sediment production (kg/ha)
0	$3476^{a} \pm 1996$
20	$1178^{b} \pm 1010$
40	$652^{b} \pm 957$

For notes see Table 1.

Table 4. Basal cover

Plot	Basal cover (%)
CC	$30^{c} \pm 26.4$
EM	$54^{ab} \pm 19.3$
ES	$23^{c} \pm 15.4$
CC–EM	$34^{bc} \pm 22.8$
CC–ES	$33^{bc} \pm 16.0$
EM–ES	$58^{a} \pm 20.0$

For notes see Table 1.

Household Survey

Results from the survey study showed that the three grasses used for rehabilitating degraded semi-arid drylands had additional benefits to the agro-pastoral Kamba community. These included: source of good-quality feed for livestock; source of income through the sale of grass seeds, hay and milk; readily available source of thatching materials; and source of a balanced diet from milk.

Communication Strategy

To communicate the findings of this study to both the local and international communities, two journal articles have been accepted and are awaiting publication (Mganga *et al.*, 2010a,b). The MSc thesis is also available in the University of Nairobi library. In addition, a demonstration site has been set out in the study area to communicate and demonstrate issues to do with reseeding and rehabilitation on site. Finally, the first author has been able to attend numerous farmers' *barazas* (informal gatherings) in the study area to share the research findings.

Discussion

Observed differences in infiltration capacity and subsequent run-off could be attributed to the growth and morphological characteristics of the grasses. *Cenchrus ciliaris* is densely leaved with branching culms arranged in a funnel shape. The grass is also relatively broad leaved. These characteristics present a greater surface area for collecting water and rain drops that are concentrated more into its rhizosphere. *Enteropogon macrostachyus*, though narrow leafed, tends to be more leaf than stem, especially at its base, and therefore closely compares with *C. ciliaris* in trapping rain water. In contrast, *E. superba* has more stem and thus is less effective in concentrating rainwater into its rhizosphere. As a result, *E. superba* showed no significant difference in infiltration capacity at 0 and 20 cm stubble heights, since the grass at 20 cm height had a low leaf count, which reduced its ability to trap enough water droplets and channel water near the rhizosphere.

There was a general decline in sediment production with an increase in grass stubble height. This can be attributed to the reduction of the force of water drops hitting and destablising the soil structure. Generally, vegetation cover intercepts rainfall kinetic energy and thereby decreases the mobilisation of soil particles. Taller grass traps more water drops and funnels them down its crown, thus concentrating more water around the rhizosphere compared with shorter grass. Larger leaf blades also reduce the force of the water drops directly hitting the ground. This improves infiltration capacity, reduces run-off and thus reduces sediment production.

Higher percentage basal cover of *E. macrostachyus* can be explained by the faster germination of this species, giving it a head start in normal plant competition. Lower basal covers of *C. ciliaris* and *E. superba* can be explained by their delay in germination. Higher percentage basal cover in the plots with the *E. macrostachyus–E. superba* mixture can also be attributed to the faster germination of *E. macrostachyus* in the mixture, whereas the lower percentage basal cover in plots under *C. ciliaris–E. macrostachyus* and *C. ciliaris–E. superba* can be explained by the allelopathic nature of *C. ciliaris* in the mixture, which suppresses the growth and establishment of the other grass species in the mixture.

Results from the survey showed *E. superba* to be the most popular among the agro-pastoral farmers (97%). Higher preference of *E. superba* was primarily attributed to its role in milk production and fattening in cattle (Wasonga *et al.*, 2003). *Cenchrus ciliaris* and *E. macrostachyus* were ranked second and fourth, with 63 and 37% of the farmers planting them, respectively. Surplus milk is sold at Ksh 30[8] per litre. Sale of grass seeds (Ksh 600–1000 per kg) and hay (Ksh 150 per 13 kg bale) also improved the livelihoods of farmers. Money generated from these sales was channelled to other social amenities such as health, education and entertainment. Moreover, these grasses provide a ready source of thatching materials for houses and granaries. This boosts the longevity of the harvested crops and therefore improves food security.

Conclusion

The hydrological responses of the perennial grasses in this study suggest that grazing could negatively affect the soil's physical properties, leading to increased run-off, sediment loss and decreased infiltration capacity, and subsequent soil erosion in free-grazing semi-arid environments. Rehabilitation using grass-reseeding technology improves the hydrological properties of the soil in semi-arid environments, particularly by reducing high run-off that is common in bare degraded grazing areas.

The grasses predominantly used in rehabilitating degraded semi-arid areas – notably *C. ciliaris*, *E. macrostachyus* and *E. superba* – are not only beneficial in improving the soil's hydrological properties, but also improve the livelihoods of agro-pastoral farmers through sales of milk, hay and seed, and as a source of livestock feed and thatching material, thus contributing to food security.

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Effects of Moisture Stress at Flowering on Phenotypic Characters of Selected Local Landraces of Maize in Kenya[1]

S.W. Munyiri,[2] R.S. Pathak,[2] I.M. Tabu[2] and D.C. Gemenet[2]

Keywords: anthesis–silking interval, drought, leaf rolling, tassel size, silking, grain yield

Abstract

Arid and semi-arid areas constitute about 82% of the total land area of Kenya and support about 20% of the country's human population. Local maize landraces are an important livelihood resource in these areas. The objective of the study was to characterise selected Kenyan local maize landraces for drought tolerance. Secondary traits exhibiting high heritability for drought tolerance were evaluated, including grain yield, anthesis–silking interval (ASI), tassel size, ears per plant, and leaf rolling. In the first season, 25 genotypes were grown under optimum conditions under normal rainfall supplemented with irrigation for the determination of ASI, ears/plant, tassel size and grain yield. In the second season, the genotypes were planted in an alpha lattice design (based on the ASI) with two treatments: optimum and water-stressed conditions, each replicated three times. In the drought-stressed plots, irrigation was withheld 1 week before tassel anthesis and resumed after male flowering had been achieved. Among the characters evaluated, a low ASI (1–6 days) was associated with a high level of drought tolerance and small yield losses. Drought stress resulted in 17–81% relative grain yield loss. Landraces GBK-032419 and GBK-034659 exhibited lowest grain yield losses of 28 and 17%, respectively, while two dryland composites used as controls exhibited higher grain yield losses of 62 and 68%. In general, more ears per plant, reduced leaf rolling and low ASI were associated with better yield under moisture stress. Local landraces that exhibited drought-tolerance characteristics were identified. These could be recommended for production in marginal areas of Kenya inhabited by resource-poor farmers. Research approaches aimed at stabilising yields in these landraces could play a key role in mitigating hunger, as they are already adapted to the diverse environments in Kenya. Further, the drought-tolerant traits identified could be introgressed into recommended composites for the marginal areas.

Introduction

Only about 18% of Kenya is classified as medium- to high-potential agricultural land; the remaining 82% that is arid to semi-arid has to play a major role in providing for livelihoods of many Kenyans (GoK, 2004). Maize is the most important staple food crop grown on about

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2. Egerton University, PO Box 536, Njoro, Kenya.

1.6 million ha of land (FAO, 2007). The average maize yields of highland farmers in Kenya range from 2.8 to 3.5 t ha^{-1}, though some achieve 7 t ha^{-1}, while that for low-altitude farmers is only 1.0 t ha^{-1} (FAO, 2007). The challenge to crop production in dryland areas is compounded by the fact that the occurrence, timing and severity of drought fluctuate from year to year (Ribaut *et al.*, 2002). Overcoming the drought problem is a challenge that can be solved by provision of irrigation water or technologies packaged as drought-tolerant cultivars with characteristics likely to withstand drought conditions. However, irrigation is becoming a less realistic solution as global water demand increases (Boyer and Westgate, 2004). In many marginal areas, farmers use local landraces because they are perceived to perform better under low moisture or zero input use (Bellon *et al*., 2006). Some local maize landraces exhibit desirable attributes like resistance or tolerance to major diseases and pests, tolerance to drought, and productivity under low soil fertility. The existence of these highly valuable maize landraces represents a potential wealth of genetic material already adapted to diverse environments.

Secondary traits are a few plant characteristics that are highly heritable, and variations in which result in proven genotype × environment interactions for grain yield. They are important in maize characterisation for drought tolerance as they improve the precision with which drought-tolerant germplasm can be identified (Banziger *et al.*, 2000). Furthermore, secondary traits are correlated with yield and demonstrate segregation with high heritability under water-limited conditions (Ribaut *et al.*, 2002). Though several maize hybrids have been developed, they have failed to produce satisfactorily in dry areas. Many farmers therefore continue to grow locally adapted landraces. While the existence of local maize landraces is recognised, their characteristics and performance under drought have not been documented. The objective of this study was to evaluate the effect of drought at flowering on selected maize landraces using secondary traits.

Materials and methods

Site

The experiments were carried out at the Kenya Agricultural Research Institute (KARI) Masongaleni farm, Kenya. The farm is located at 2°21.6′ S, 38°7.3′ E, at an elevation of about 650 m above sea level. The farm is within a semi-arid area of Kenya, agro-ecological zone VI; it receives approximately 400 mm of rainfall per year, with an annual evapo-transpiration potential of 1,650–2,300 mm per year. The soils are rhodic and orthic ferralsols (Jaetzold and Schmidt, 1983).

Germplasm

The experimental materials consisted of 25 genotypes, 15 of which were maize local landraces from the Gene Bank of Kenya (GBK). Ten inbred lines were included for comparison purposes. These included five lines from KARI-Kitale, three from KARI-Katumani and two from CIMMYT-Nairobi (International Maize and Wheat Improvement Center). Katumani Composite B (KCB) and Makueni Dry Land Composite (DLC) – which are recommended for the marginal areas – were used as checks. The germplasm was grown under optimum conditions for one season under normal rain supplemented with irrigation to determine their anthesis–silking interval

(ASI), ears per plant, tassel size and grain yield. The crop was protected from pests and weeds so that characters could be expressed well. Diammonium phosphate fertiliser at the rate of 40 kg N/ha and 102 kg P_2O_5/ha was applied at planting (Ministry of Agriculture, National Agriculture Laboratories, 1987). Each experimental plot consisted of 10 plants spaced at 0.75 × 0.3 m. Data were collected from the eight middle plants of each plot.

In the second season, on the basis of their ASIs, the 25 lines were planted in an alpha lattice design with two treatments – optimum and water-stressed conditions, each replicated three times. Each experimental plot was 2.25 × 2.7 m. Husbandry practices were performed as described for the first season (above). In drought-stressed plots, irrigation was withdrawn about a week before tassel anthesis. Irrigation was resumed later when male flowering had occurred. The well watered plots had sufficient water throughout the growing season to ensure normal growth.

Data recorded included days from sowing to 50% tassel anthesis (AD), days from sowing to 50% silking (SD), ASI, leaf rolling (measured on a scale of 1–5 after irrigation withdrawal and before flowering), tassel size (measured on a scale of 1–5), and grain yield (t ha^{-1}; all harvested ears were hand shelled and grain weight determined at 13% moisture content). Data were tested for normality using $\log_e\sqrt{(ASI + 10)}$ and subjected to analysis of variance (ANOVA) using the general linear model (SAS version 7). Treatments found to be statistically significant ($P \leq 0.05$), according to the *F*-test were subjected to mean separation.

Results, discussion and conclusions

Germplasm differed significantly in variables evaluated for drought tolerance (Table 1). Under water-stressed (WS) conditions, days to tassel anthesis, days to silking, leaf rolling intensity and ASI increased, while tassel size, number of ears per plant, plant height, 100-grain weight and grain yield decreased significantly.

Table 1. Variability of characters in local maize landraces under two watering regimes

	Water stressed (WS)		Well watered (WW)	
Trait	**Mean**	**Range**	**Mean**	**Range**
Days to tasselling	63.6	43.0–78.0	62.9	40.0–74.0
Days to silking	71.7	53.3–85.0	69.1	48.7–80.7
ASI (days)	7.9	–1.3–12.3	6.3	–1.0–12.3
Leaf rolling (1–5)	3.0	1.7–4.3	1.0	1.0–1.0
Tassel size (1–5)	2.9	1–5	3.3	1–5
Shelling (%)	68.4	50–83	75.0	56.7–81.7
Grain yield (t ha^{-1})	1.7	0.4–3.7	3.6	1.8–5.9
Ears/plant	0.9	0.5–1.1	1.1	0.7–1.7
100-seed weight (g)	27.2	15.7–42.1	31.1	19.7–44.6
Plant height (m)	1.7	1.3–2.3	2.1	1.6–2.5

Days to Tassel Anthesis

In 65% of the germplasm, water stress delayed tassel anthesis by 1–5 days. Monneveux *et al*. (2005) report that severe stress prior to flowering induces leaf rolling and reduces stomatal conductance, which affects photosynthates partitioning to the male inflorescence (tassel) and

hence promotes delayed tassel anthesis. In the composite controls, KCB and DLC, water stress delayed tassel anthesis by 3 and 4 days, respectively. Water stress did not affect timing of tassel anthesis in KTL N 70188-2 or GBK-044593. The control genotypes, KCB and DLC, exhibited earliest tassel anthesis (40–45 days) under both moisture regimes. This indicated that these checks had the ability to escape drought. Time to tassel anthesis in the germplasm expected to be drought tolerant on the basis of ASI duration ranged from 57 days in GBK-044593 to 71 days in CML-492, implying that the composites escaped drought better than other germplasm tested.

Days to Silking

Water stress increased the mean time to silking from 69 to 72 days, thus stress caused a delay in silking by 3 days. Richards (2006) similarly found that drought that occurs from the mid- to late vegetative stage onwards in maize delays the process of ear silking. Time to silking in the composite controls ranged from 52 to 54 days in KCB and from 49 to 53 in DLC. Inbred lines KTL N 10162-1, KTL N 70133-3, KTL N 10168-2, KTL N 70188-2, KTL N 70140-4 (all from Kitale) and CML-265 (from CIMMYT) had latest silking (76–82 days). Mugo *et al*. (1998) reported that delayed silking was associated with barrenness, and reflected on reduced partitioning of assimilates to the developing ear at flowering, thus reducing yields. In Richards' (2006) experiments, the reason for silk delay was that the drought-susceptible genotypes allocate less assimilates to ear growth when the ears are quite small. Under water stress during flowering, changes such as accelerated leaf senescence, leaf rolling and reduced stomatal conductance result in reduced flow of photosynthates to the ear.

Anthesis–Silking Interval (ASI)

Under moisture stress, ASI increased by 2 days. A long ASI duration was an important cause of yield loss and was highly correlated with grain yield and number of ears per plant (data not shown). ASI is one of the most important traits that can be used to indicate a maize genotype's tolerance to stress (Mugo *et al*., 1998; Richards, 2006). Under such conditions of delayed silking, pollen can arrive after it has desiccated, when silks have withered or senesced, or after ovaries have exhausted their starch reserves. Richards (2006) reports that under moisture stress the ASI period was negatively correlated with grain yield. Bolanos and Edmeades (1996) link high grain yield under stress with short ASI. Mugo *et al*. (1998) and Frova *et al*. (1999) similarly found that when drought stress occurs just before or during the flowering period in maize, a delay in silk emergence is observed, resulting in an increase in the length of the ASI. Inbred lines DT/BT/1917.DT and DG/BT/2443.DT exhibited shortest ASI duration of –1 day under both moisture regimes, that is, silking before tasselling.

Leaf Rolling

Leaf rolling under moisture stress was highest in control DLC, KTL N 70133-3, KTL N 10162-1, GBK-027054 and KTL N 70140-4 with a score of 4, and lowest in DG/BT/2443.DT, DT/BT/1470.DT, CML-492 and CML-265 with a score of 2. Monneveux *et al*. (2005) associate leaf rolling with a reduction in photosynthesis due to decreased radiation interception. Bolanos and Edmeades (1993) attribute the reduction in photosynthesis to a decrease in radiation interception

associated with leaf rolling and reduced leaf expansion. Bolanos and Edmeades (1996) found that leaf rolling is a drought-adaptive trait, while Sambatti and Caylor (2007) note ecological, morphological and physiological trade-offs associated with drought-adaptation traits. For example, in selection for reduced stomatal conductance, plants will avoid drought by saving water when it is scarce; however, when water is available, growth will be limited by the same mechanism, by limiting carbon dioxide intake.

Tassel Size

Water stress significantly reduced tassel size score from 3.2 to 2.9. The smallest tassels (score 1) were recorded in inbred lines KTL N701104, DG/BT/2443.DT and DT/BT/1917.DT. Landraces GBK-043227, GBK-27054 and GBK-034659 exhibited largest tassels (score 5). Both KCB and DLC controls exhibited medium-sized tassels. Selection for a small tassel is often associated with improved partitioning to the ear. Inbred lines DG/BT/2443.DT and DT/BT/1917.DT exhibited small tassels and also a low ASI, and thus better tolerance to drought than those exhibiting large tassels. Monneveux *et al*. (2005) report that recurrent selection for small tassels resulted in substantial increase in partitioning to early ear growth, increased ear and husk weight, and successful grain set, and thus improved grain yield. According to Banziger *et al*. (2000), such genotypes demand less allocation of the available assimilates during times of drought, thus more can be channelled to the developing ear for grain production. Selection for reduced tassel size may also increase canopy photosynthesis through reduced shading. The composite controls flowered and also reached physiological maturity earlier than other germplasm evaluated, indicating that they escaped drought better than the landraces.

Grain Yield

The grain yield of the genotypes varied significantly. A large fraction of the yield potential was thus not realised in many genotypes under moisture stress (Table 2). Genotypes GBK-032419, DT/BT/1470.DT and GBK-034659 had the lowest grain yield losses under moisture stress of 28, 22 and 17%, respectively. DT/BT/2443.DT (from Katumani), KTL N 10150-1 and KTL N 701104 (from Kitale) were the highest-yielding inbred lines under well watered (WW) conditions, at 4.6, 4.2 and 4.1 t ha^{-1}, respectively. The KCB and DLC controls yielded 3.7 and 3.6 t ha^{-1} under WW conditions, and recorded yield losses of 62 and 68%, respectively, under moisture stress (Table 2). According to Banziger *et al*. (2000), drought-tolerant genotypes should perform well under both well-watered and water-stress conditions. Eighteen genotypes had lower yield losses under moisture stress than the composite controls, thus better tolerance to drought than the recommended composites. Ouk *et al*. (2006) note that the practical approach for selection of a drought-tolerant parent is to use a measure or an index of the grain yield of genotypes under stress relative to that under well watered conditions as an integrative measure of the complex of traits that provide drought tolerance.

The germplasm most tolerant to drought stress in terms of low ASI and lower grain yield losses in this study included GBK-034659, DT/BT/1470.DT, GBK-032419, CML-265, DG/BT/2443.DT, DT/BT/1917.DT, KTL N 701104, CML-492 and GBK-044593. Notable in this category was a highland germplasm, Kitale inbred KTL N 701104. The most drought-susceptible germplasms were KTL N 70140-4, GBK-044611, GBK-043731, KTL N 70133-3 and DLC.

Table 2. Relative yield loss in maize germplasm under moisture-stress conditions

Genotype	Yield (t ha^{-1}) WW		Yield (t ha^{-1}) WS		Yield loss (%)
DT/BT/2443.DT	4.6	(±0.28)	2.2	(±0.95)	52
DT/BT/1917.DT	3.7	(±0.46)	1.7	(±0.43)	54
GBK-032419	5.1	(±2.21)	3.7	(±0.54)	28
DT/BT/1470.DT	3.9	(±2.20)	3.1	(±0.68)	21
GBK-032357	4.7	(±0.69)	1.8	(±0.26)	62
GBK-032423	2.9	(±0.26)	1.6	(±0.49)	45
GBK-027017	3.7	(±0.91)	1.7	(±1.40)	54
GBK-034659	2.9	(±1.15)	2.4	(±0.39)	17
CML-492	2.5	(±0.47)	1.3	(±0.40)	49
KTL N 701104	4.1	(±0.67)	2.0	(±0.55)	51
GBK-044593	3.0	(±0.78)	1.8	(±0.66)	40
KTL N 70188-2	1.8	(±0.75)	1.0	(±0.16)	44
KTL N 70140-4	2.2	(±0.37)	0.4	(±0.36)	81
GBK-045385	4.0	(±0.92)	1.6	(±0.50)	60
GBK-043731	5.9	(±1.70)	1.8	(±0.74)	70
GBK-044611	4.5	(±0.99)	1.0	(±0.53)	77
GBK-034711	3.3	(±0.53)	1.5	(±0.62)	55
GBK-027054	2.0	(±0.64)	1.0	(±0.40)	50
Katumani Composite B (KCB)	3.7	(±1)	1.4	(±0.43)	62
Dry Land Composite (DLC)	3.6	(±0.22)	1.1	(±0.97)	68
CML-265	2.2	(±0.29)	1.4	(±0.30)	36
KTL N 10168-2	3.1	(±0.62)	1.3	(±0.70)	54
GBK-043227	4.3	(±0.91)	2.1	(±0.14)	51
KTL N 10150-1	4.2	(±0.90)	1.7	(±0.97)	60
KTL N 70133-3	3.9	(±1)	1.2	(±0.35)	69

WW, well watered; WS, water stressed.

Numbers in brackets represent the standard error of the mean.

Since phenotypic characterisation of this germplasm has been done, molecular characterisation of local landraces identified as drought tolerant should be carried out for the development of improved maize varieties for dry areas. Local landraces exhibiting superior drought-tolerance traits may be evaluated for performance at farmers' level in the marginal areas, so that the best landraces could be recommended for use. Some of these landraces were made available to neighbouring farmers by the researcher following expressed need.

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Looking at Wastes as Valuable Resources – An Example from the Sugarcane Industry in Mauritius

A. Soobadar[1]

Keywords: vinasse, ash, sewage sludge, nutrients, fertilisation

Abstract

The combustion of coal and bagasse for co-generation of electricity by the sugarcane industry in Mauritius generates annually some 40,000 tonnes of ash as waste that need to be disposed of in an environmentally sound manner. From the same perspective, the production of 30 million litres of ethanol will generate 400,000 t of vinasse. With the rising standard of living, some 35,000 t sewage sludge will be produced, to become a burden on the community at large. All these wastes can serve a useful purpose and can be turned into resources. Mauritius imports annually 9,000 t nitrogen (N), 3,000 t phosphorus (P) and 9,000 t potassium (K) to fertilise its sugarcane fields, and there should be no reason why re-use of wastes could not be a substitute for mineral NPK. Applying wastes to crops, however, requires careful consideration on account of undesirable organic contaminants and heavy metals, which may pose a hazard to the natural ecosystem and human health. A study initiated in Mauritius under four agro-climatic conditions showed that coal ash, vinasse and sewage sludge did not affect soil pH, soil salinity or soil exchangeable bases, even when applied at 100 t ha^{-1}. With vinasse, sewage sludge and ash, when used judiciously, no significant difference in the cane or sugar yield was encountered compared with mineral fertilisers. Leaching of heavy metals and organic micro-pollutants down the soil profile to ground water sources is very unlikely and should not be an impediment to the disposal of sewage sludge, vinasse or ash in sugarcane fields. As adequate fertilisation is the key to crop production, the present study provides a fresh outlook on how crop nutritional requirements can be met to provide enough food to feed the poor, particularly in rural areas.

Introduction

As the standard of living improves, the amount of waste generated – be it municipal waste or industrial waste – also rises and the demand for non-renewable resources is accentuated. For instance, the intensive cultivation of sugarcane on some 69,000 ha in Mauritius requires that some 9,000 t of N, 3,000 t of P and 9,000 t of K be imported annually for application to sugarcane fields. Five million tonnes of sugar cane are produced and are processed by seven sugar mills to yield, on average, 500,000 t sugar and 1.5 million t bagasse (fibrous waste left after the crushing of cane stalks and extraction of juice).

1. Agricultural Chemistry Department, Mauritius Sugar Industry Research Institute, Réduit, Mauritius.

The sugarcane industry in Mauritius will also be producing ethanol from molasses (residue obtained after repeated crystallisation of sugar) and will be optimising energy production from bagasse during the harvest season and from coal during the intercrop season. Through the combustion of bagasse during the crop season, and of 440,000 t coal during the intercrop season, the sugarcane industry supplies some 1,300 GWh of electricity to the national grid, representing around 60% of the country's needs. In so doing, however, the Mauritian sugar industry will be generating considerable waste – 400,000 t of vinasse during ethanol production and 40,000 t of coal and bagasse ash during the generation of electricity per year. How can these waste products be disposed of or, better still, how can they be made useful?

It is reasoned that, with an average composition of vinasse of 1.22 kg N/t, 0.11 kg P/t and 9.37 kg K/t, and of coal/bagasse ash of 1.20 kg N/t, 8.58 kg P/t and 20.91 kg K/t, the 400,000 t vinasse per year can contribute 488 t N, 44 t P and 3748 t K to Mauritian agriculture, and the 40,000 t of coal/bagasse ash can provide another 48 t N, 343 t P and 836 t K to crops. Apart from the coal/bagasse ash and vinasse obtained from the sugar industry, the improvement in the standard of living in Mauritius generates 35,000 t of sewage sludge for disposal annually. With an average composition of 34.6 kg N/t, 10.5 kg P/t and 0.75 kg K/t, sewage sludge is able to contribute a further 1,211 t N, 368 t P and 26 t K to crop production in Mauritius. In all, the amounts of NPK in the vinasse, sewage sludge and coal/bagasse ash can meet 20% of the N, 25% of the P and 50% of the K needed by the sugarcane industry in Mauritius. The agronomic benefits of sewage sludge application to crops are well documented and are the basis for its successful utilisation elsewhere in the developed world (Lindsay and Logan, 1998).

Applying wastes to crops to take advantage of the nutrients they contain, however, needs careful consideration because of undesirable chemicals such as organic contaminants and heavy metals which they may harbour, and which may be potentially harmful to natural ecosystems and to human health. Repeated addition of the wastes may enhance the levels of heavy metals such as mercury, cadmium and lead to an extent that they become toxic to plants and cause contamination of the human food chain (Bevacqua and Mellano, 1994).

Methodology

In the study of wastes as alternatives to mineral NPK fertilisers, an integrated approach that considers not only the nutrient value of the wastes to crops, but also the environmental and health hazards associated with their use, was adopted. This integrated approach is summarised in Fig. 1.

To attain the objectives of soil, plant and water quality assessments, field trials were laid down in the different agro-climatic conditions of Mauritius. Different rates of the wastes (sewage sludge, coal/bagasse ash and vinasse) were compared against a control treatment of NPK fertilisers at rates recommended for sugarcane. All the treatments were replicated four times in a randomised complete block design at each experimental site. Soil was sampled at regular intervals to monitor the impact of the wastes on the major soil characteristics (pH, electrical conductivity) after application of the waste products. At harvest, the uptake of NPK and heavy metals (Cu, Zn, Ni, Mn, Pb, Cd and Hg) in the different parts of the sugarcane plant (cane top, stalk and dead leaves) was measured over three consecutive years. The sugarcane yield was also monitored for the plant cane and first two ratoons.

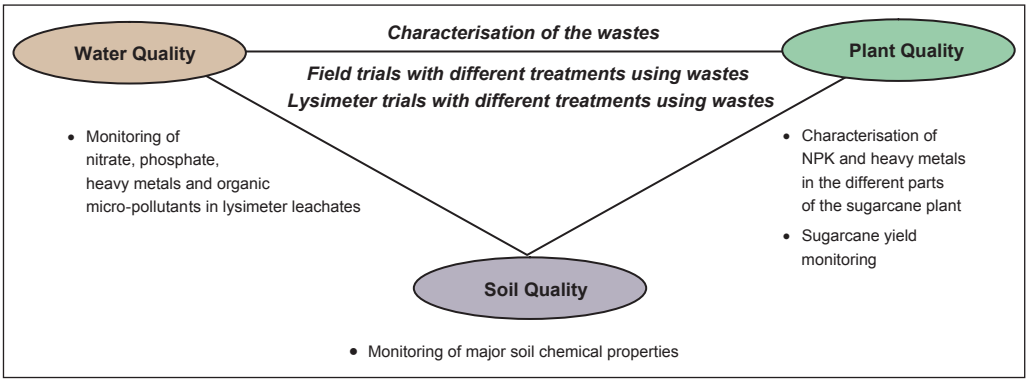


Figure 1. *The main themes of the study carried out*

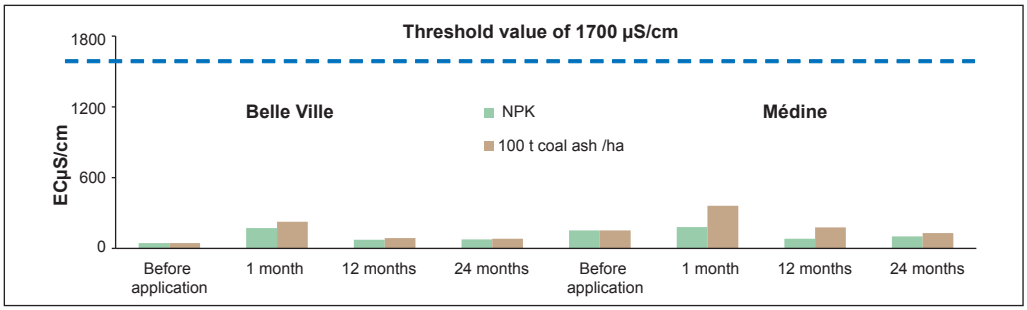
To determine the effects of the wastes on groundwater quality, lysimeter studies were conducted at two sites (Belle Rive and Réduit) differing in rainfall regimes (3,500 and 1,500 mm/year, respectively). Drainage water percolating at 1 m depth was collected after each heavy rainfall event and analysed for nitrate, phosphate, heavy metals and organic micro-pollutants.

Results

Analyses of the soils at the study sites showed that the application of vinasse lowered soil pH from an average of 5.9 to 5.4, but this decrease was only temporary and was not significant enough to affect sugarcane growth – the soil pH returned to its original value less than 1 month after vinasse application. On the other hand, coal ash and sewage sludge raised soil pH (e.g. from 5.1 to 5.7 for coal ash at one location), but this rise in pH likewise did not significantly affect crop growth. Vinasse and coal ash applied at the high rates of 100 m^3/ha and 100 t ha^{-1}, respectively, raised the electrical conductivity of the soil, but in spite of this increase, the electrical conductivity remained well below the threshold value of 1,700 µS/cm recommended for sugarcane (Fig. 2). Both vinasse and coal ash improved the level of exchangeable calcium and magnesium in the soils.

The field trials provided evidence that increasing application rates of vinasse and sewage sludge did not reduce cane or sugar yield (Fig. 3). On the contrary (and as an example), vinasse at 100

Figure 2. *Impact of 100 t coal ash/ha on the soil electrical conductivity 1 and 24 months after application at two sites (Belle Rive and Médine)*



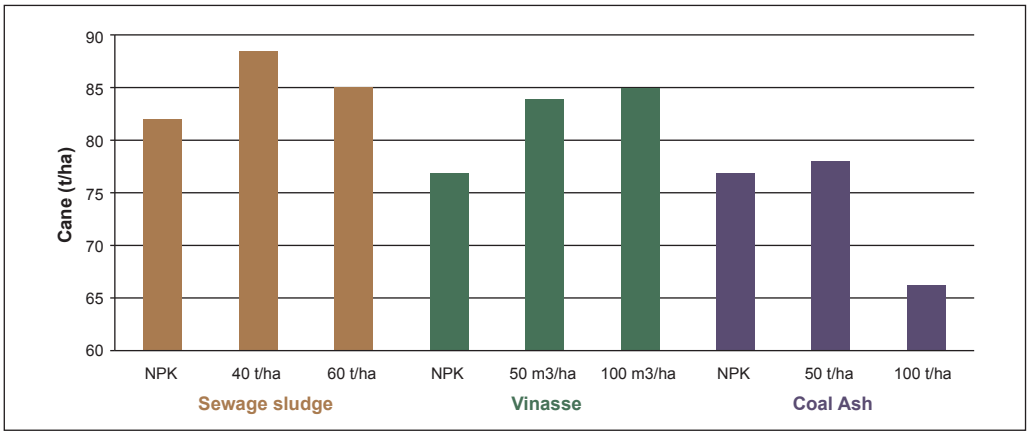


Figure 3. *Effects of sewage sludge, vinasse and coal ash on sugarcane yield in Mauritius (mean of 3 years' data for four sites)*

m^3/ha gave a higher cane yield (an average of 84.9 t ha^{-1} per year) than NPK fertilisers alone (an average of 77.3 t ha^{-1} per year). This increase in yield was probably due to better K nutrition and an improvement in soil organic matter status brought about by the vinasse (Parnaudeau *et al.*, 2008).

In the present study, however, although the coal ash contained appreciable amounts of plant nutrients (in particular P), it had a negative impact on sugarcane yield when applied at 100 t ha^{-1}. The detrimental effects of high rates of coal ash observed on plant growth could be attributed to a shift in the chemical conditions of the soil due to the highly alkaline pH and the high levels of soluble elements released from the coal ash (Singh and Yunus, 2000).

Additionally, because of their low heavy metal concentrations, vinasse, coal ash and sewage sludge did not increase the heavy metal content in the sugarcane plant. In fact, the concentrations of heavy metals (Cu, Zn, Ni, Mn, Pb and Hg) in the above-ground parts of the cane crop (stalk, top and dead leaves) 12 months after the application of coal ash at 50 and 100 t ha^{-1} remained low and were not significantly different from the concentrations found in the sugarcane plants that received only mineral fertiliser.

Lysimeter studies conducted at the two sites with different rainfall regimes showed that high rates of vinasse and sewage sludge did not enhance loss of N in the form of nitrate. If, as expected, the heavy metals known to be mobile (Cu, Ni and Zn) had been detected in drainage water, their concentrations remained well below the drinking water limits proposed by the World Health Organization (USEPA, 1992). High rates of bagasse ash (e.g. 100 t ha^{-1}) would, however, move significantly more nitrate into the groundwater compared with mineral fertiliser, vinasse and sewage sludge. The limit of 10 mg/L N-NO_3^-, recommended by the World Health Organization for drinking water, was exceeded on many occasions (Fig. 4).

Discussion and conclusions

The role of agriculture in alleviating hunger and poverty is well documented. Most of the world's poor people live in rural areas. As summarised by Roberts (2009), meaningful estimates have

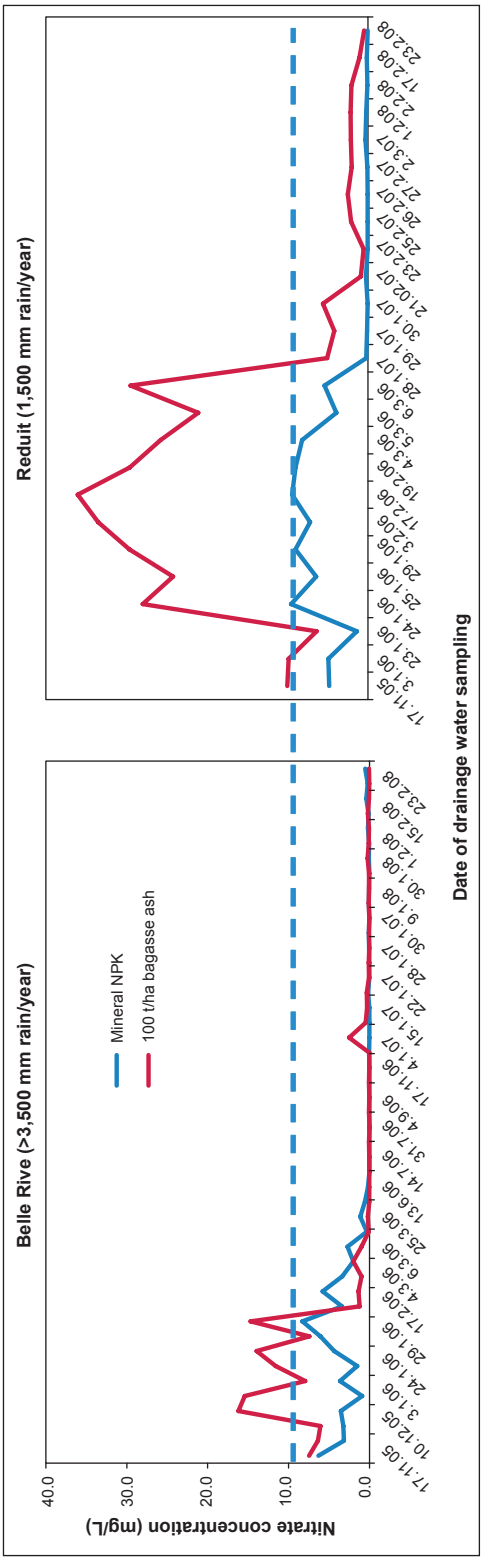


Figure 4. *Impact of applying 100 t bagasse ash/ha on nitrate level in drainage water percolating at 1 m depth in lysimeters at Belle Rive and Réduit, Mauritius*

shown that 40–60% of crop yield in temperate regions can be attributed to commercial fertiliser inputs, the figures being higher in the tropics. Fertilisers are thus necessary to maintain global crop productivity at current levels and will be even more crucial if yields are to be increased. Food security is one of the greatest challenges currently facing humanity. With the current world population of 6.7 billion expected to reach 9.2 billion by 2050, food production will have to double in 30 years to meet the growing demand (Glenn *et al.*, 2008). Producing higher yields will never be achieved without good plant nutrition.

Yet commercial fertilisers are finite resources and their prices are subject to fluctuations in petroleum costs, and their availability – or rather their scarcity – in rural areas of the developing world has been well documented. In the developing world, crop yields are most often well below the potential of the crops grown on account of inadequate or unbalanced fertilisation.

The research reported in this paper has shown how that unbalanced/inadequate fertilisation can be mitigated (but not necessarily overcome) with existing waste products to help avoid reccurrence of the global food crisis encountered in 2008. The study has shown that waste products can be used as alternatives to mineral fertilisers. While the use of vinasse or sewage sludge on agricultural land under sugarcane can certainly be recommended, some caution needs to be exercised in the case of coal/bagasse ash, as high rates of application would represent a threat to ground-water quality. High application rates of coal ash to sugarcane fields in Mauritius may also cause a decrease in sugarcane productivity (Soobadar *et al.,* 2010).

ICT Tools and Strategy Used to Disseminate Research Findings

The findings of the research conducted would have been meaningless if they were

not made known to and adopted by the agricultural community. The Mauritius Sugar Industry Research Institute (MSIRI) promotes awareness of sound agronomic practices and encourages their adoption to enable the sugarcane-planting community to achieve competiveness and sustainability. Targeted interventions towards the different planter categories are conducted through:

- provision of information and advice during scheduled field visits;
- establishment of large-scale trials and observation plots;
- organisation of small-scale planters' days and tours conducted for planters;
- group discussions, seminars and brainstorming sessions on selected themes;
- use of information technology and development of decision-support tools;
- targeted training to meet specific needs of the planting community.

Electronic tools have come to the fore, providing a fast and accessible means of enhancing the flow of knowledge between researchers and growers. Electronic resources such as decision-support tools (software for rapid access to scientific data and technical information, interactive DVDs) have been developed for Mauritian sugarcane growers to promote efficient production of sugarcane.

Dissemination of knowledge to the planting community is often not enough. Studies have previously shown that the occurrence of numerous improper practices at field level could be traced back to social and organisational constraints at the local community level, rather than to lack of scientific knowledge. Factors such as trust, communication and co-ordination between growers and service providers are equally important. In this study, transport of wastes to the fields, for instance, is an important prerequisite to the success of the technology proposed. Efforts in technology transfer are therefore also directed towards facilitating the necessary negotiations and communications between the growers and the transport providers and other stakeholders involved, such as the managers of sugar mills and sewage-treatment plants.

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Rural Livelihoods and Agricultural Policy Changes in Malawi

Mariam A.T.J. Mapila[1]

Keywords: propensity score matching, simulation analysis, partial equilibrium modelling, impact assessment, enabling rural innovation, fertiliser subsidies

Abstract

A study was conducted in Malawi to assess the impact on rural livelihoods of the use of agricultural innovation systems concepts in implementing agricultural research interventions and the potential impact on future household incomes of linking households to the macro-economy, given fertiliser policy distortions. Using propensity score matching to establish a counterfactual and single differencing to measure impact showed that livelihood outcomes were significantly affected by agricultural innovation system interventions: participating households had more robust livelihoods and higher production outcomes. However, phasing out of the agricultural research programme led to erosion of the improved livelihood outcomes. This was evident in the dwindling of livelihood outcomes of participating households with each new cropping season. The study further found that fertiliser subsidy policy distortions have the potential to lead to small but significant negative changes in future rural household incomes. Recommendations are that the establishment of a national innovation forum would go far as a communication tool to ensure greater capacity building of local extension agents, and increased budgetary support to ensure understanding and application of agricultural innovation systems concepts in public agricultural extension programmes. In addition, such a forum would ensure the mainstreaming of innovation system concepts in all public agricultural research and extension policy documents, and work towards demystifying the concepts of innovation systems for rural communities, whose participation is crucial.

Introduction

To overcome poverty and low productivity in Malawi, the government put in place complementary strategies for ensuring food security in the short term and increasing staple food crop productivity in the long term. This has been done through the creation of an enabling environment for the work of agricultural research and development agencies, and through the reinstatement of a fertiliser subsidy programme. The reintroduction of the fertiliser subsidy programme led to numerous debates, as its proponents state that increased staple food production has led to improved rural livelihoods (Dorward, 2007). Sceptics, however, argue that the macro-economic fallout and the budgetary implications of the subsidy programme far outweigh any livelihood improvements (Morris *et al.*, 2007). But all these arguments are unsubstantiated due to the lack of contemporary empirical evidence. In addition, although numerous studies remove any

1. Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, South Africa.

doubts about the effectiveness of agricultural research in enhancing rural livelihoods in Africa (Meinzen-Dick *et al.*, 2003; Alene and Coulibaly, 2009), there are no robust quantitative studies for Malawi that have attempted to ascertain the impact of changing fertiliser policies, given agricultural research interventions that are driven by innovation systems concepts. Hence the scope of this work was to assess the extent to which agricultural research interventions that are driven by agricultural innovation systems (AIS) concepts have an impact on the livelihood outcomes of rural smallholder farmers, and to determine the extent to which these households are affected by macro-level fertiliser policy distortions, in order to provide credible evidence upon which effective policies and agricultural research programmes can be based.

Materials and methods

The study was conducted in the villages of Katundulu, Kango and Mphamba in Lilongwe district of Malawi. Katundulu and Mphamba villages are the intervention communities in which the Enabling Rural Innovation (ERI) approach, which is driven by AIS concepts, was used to implement research interventions. Kango village is the counterfactual community in which such interventions had not been implemented. Purposive and simple random sampling were used to select a total of 303 study participants from the intervention and counterfactual, respectively. A quasi-experimental design with propensity score matching (PSM) using single differencing was used to assess differences in livelihood outcomes. Single differencing with PSM does not require randomisation and was therefore appropriate for creating the counterfactual in this study, as it produces better results in comparison with other methods (Ravallion, 2005). Logistic regression modelling was used to generate the propensity scores. Counterfactual households whose propensity scores for participation were outside the range of scores for the intervention households were dropped from the analysis. Thus differences in outcome variables were compared only between households that had almost identical characteristics prior to the intervention and those that had an equal chance of participating in the intervention, to overcome selectivity bias and the problem of attribution. Secondary time-series data were used to estimate single-equation models for the Malawi maize commodity market. Parameter estimates from these equations were used to build a partial equilibrium model in which a price-linkage equation of the maize commodity market was used to link rural households in the study to the macro-economy.

Results

Impact of ERI on Livelihood Outcomes

The results indicate that the ERI intervention impacted differently upon different aspects of livelihoods. The ERI intervention impacted household production with statistically significant differences being observed for the outcomes pertaining to livestock and upland crop production, value of maize production and assets ownership. Differences in maize yields were, however, not affected by the ERI intervention. The value of all upland crops for intervention households was higher by US$812.34 and $627.10 for the 2007/08 and 2008/09 cropping seasons, respectively (Table 1).

The value of maize production in the 2008/09 season was higher for the intervention than for the counterfactual by US$287 (Table 1). The study further found that ERI was significant in increasing the value of participating households' total assets and livestock ownership by US$391.00 and

US$300.12, respectively (Table 1). The ERI intervention positively impacted upon incomes in both the 2007/08 and 2008/09 cropping seasons with participating households having on average US$280.21 and 340.54 more income than their counterparts in the counterfactual, respectively (Table 1).

An assessment of the ERI initiative's impact on membership of farmer groups and the number of training activities attended by a household was also carried out. The ERI initiative had a positive impact as it increased the number of training activities that a household attended. When ERI was being implemented, households in the intervention attended on average 1.62 more training sessions than households in the counterfactual (Table 2). But after the initiative scaled down in 2007/08, the number of training sessions for households in the intervention and counterfactual communities were not statistically different. The ERI initiative did not have a statistically significant impact on households' membership of farmer groups (Table 2).

Table 1. Impact of ERI on production and income

	Intervention		Counterfactual		
Production outcomes	**Mean**	**SD**	**Mean**	**SD**	**Effect**[1]
Total value (US$)					
Livestock value	445.03	1620.99	144.82	926.47	300.12*
Upland crops 2007/08	1349.48	0.016	537.14	0.0114	812.34***
Upland crops 2008/09	992.24	0.0179	365.14	0.0084	627.10**
Maize harvest 2007/08	259.35	308.77	180.01	340.24	79.33
Maize harvest 2008/09	506.76	0.013	219.66	490.80	287.09*
Total value of assets	550.74	3008.51	159.65	581.58	391.00*
Maize yield 2007/08 (t ha^{-1})	0.84	1.00	0.85	1.47	0.0055
Maize yield 2008/09 (t ha^{-1})	1.17	2.61	0.88	1.33	0.287
Total household cash incomes (US$)					
Cash income 2007/08	511.49	0.0072	231.28	465.61	280.21**
Cash income 2008/09	636.21	0.0088	299.56	655.75	340.54**
Livestock income 2008/09	51.34	138.48	23.60	186.08	27.78

1. Significant at *, 10%; **, 5%; ***, 1% level.

Table 2. Impact of ERI on training, group membership and fertiliser use patterns

	Intervention		Counterfactual		
	Mean	**SD**	**Mean**	**SD**	**Effect**[1]
Training and group membership					
Total farmer groups per household	0.35	0.865	0.49	0.0743	–0.139
Training activities in 2002/03	2.64	5.67	1.02	3.86	1.62*
Training activities in 2007/08	1.92	5.29	1.26	3.66	0.66
Training activities in 2008/09	1.14	4.43	1.22	3.55	–0.08
Fertiliser use patterns (no. 50 kg bags)					
2004/05	1.24	1.85	0.567	1.55	0.679***
2005/06	1.38	1.87	0.624	1.12	0.761**
2006/07	1.50	1.88	0.858	1.38	0.644*
2007/08	1.68	1.97	1.38	3.39	0.297
2008/09	1.95	2.49	1.77	6.18	0.171

1. Significant at *, 10%; **, 5%; ***, 1% level.

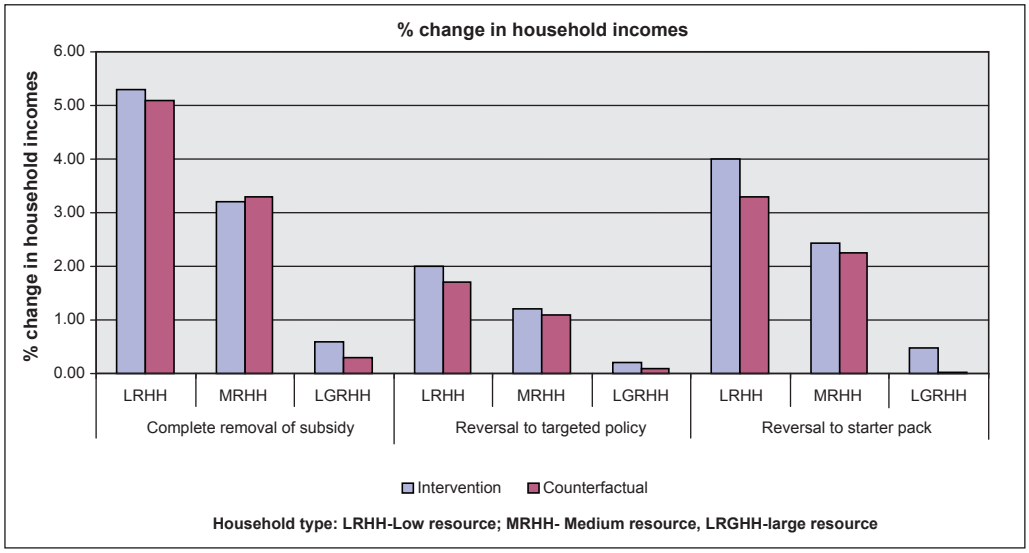
The impact of the ERI intervention on fertiliser use patterns in the intervention was also assessed by analysing the differences in the number of 50 kg bags of inorganic fertiliser that farmers used per hectare of farmland. Inorganic fertilisers, in combination with hybrid seeds and good rainfall, play a crucial role in ensuring maize production and food security in Malawi.

There were statistically significant differences between the amounts of inorganic fertiliser applied between the intervention and counterfactual households in the 2004/05, 2005/06 and 2006/07 agricultural seasons, with intervention households applying relatively more inorganic fertiliser than counterfactual households in each season (Table 2).

Fertiliser Subsidy Distortions and Future Household Incomes

Results of a simulation analysis to determine the impact of fertiliser policy distortions given the work of AIS research interventions showed that all households in both the intervention and the counterfactual were negatively affected. The differences in future income losses for all households in both communities did not vary widely under the exit strategy that completely removed the subsidy and the one that targeted only a few productive members of the rural community (Fig. 1). However, a strategy that entails distributing to all rural farmers a starter pack of inorganic fertiliser in combination with hybrid maize seed shows that households in the intervention stand to lose relatively more income than those in the counterfactual. Losses in income were higher in the short term, but stabilised in the medium term, which implies that in the medium term, intervention households that were linked to the market economy were able to benefit from higher prices that may arise as the result of the removal of input subsidies. This can be attributed to the fact that households in the intervention are more integrated into the market economy (through the ERI intervention) and so rely more on the market for their cash incomes. Because of this, they are more vulnerable to fertiliser policy distortions than their counterparts in the counterfactual, who are not linked to the market.

Figure 1. *Percentage change in household incomes as result of fertiliser policy distortions*



Discussion

The results indicated that intervention households had higher production outcomes than counterfactual households in terms of livestock and asset ownership, incomes, and the number of agriculture-related training activities.

Given that there were no statistically significant differences in the prices of crop and livestock products in the two communities, the higher outcome variables in the intervention can be attributed to the fact that households invested more in their farm and agro-enterprises. In addition, the higher incomes seen in the intervention emanated from greater access to markets, as ERI focused on assisting farmers to develop feasible agro-enterprises in order to meet existing market opportunities as opposed to marketing any surplus that they kept from their subsistence. The ERI initiative also provided communities with significantly more training and networking opportunities than are provided by the local agricultural extension officers. This led to changes in households' thought processes and decision-making, as it also built the capacity of households to better understand their faming system as well as the opportunities and threats to their livelihoods. Further observations were that a phasing out of the ERI led to a gradual reversal and erosion of the positive outcomes in the intervention households. This is demonstrated by fewer and smaller differences in outcomes, such as training and fertiliser use between the intervention and counterfactual communities. This can be attributed to the fact that local agricultural extension agents are unable to maintain the innovative strategies and contact levels used during the ERI, most likely because of a lack of financial capacity to do so.

Conclusion

This study found that agricultural research interventions that are driven by AIS concepts have a positive and significant impact on the livelihood outcomes of rural smallholder farmers in Malawi. However, long-term sustainability of the positive outcomes is eroded by phasing out of the interventions. In order to ensure sustainability, there is the need for capacity-building of grassroots-level agricultural extension staff to enable greater understanding and application of AIS concepts.

In addition, there is a need to mainstream AIS concepts in all public agricultural research and development initiatives. This will, however, require deliberate and greater budgetary support for AIS mainstreaming and implementation in all public agricultural extension and research programmes, and the realignment of public agricultural extension and research policy documents. These should be done concurrently in order to ensure effective mainstreaming, otherwise it runs the risk of becoming synonymous with changing the rhetoric and policy documents, but with no real implementation.

Finally, the study finds that alternative exit strategies of the fertiliser input subsidy programme in Malawi have the potential to lead to small but significant negative changes in future rural household incomes. Policy-makers need to consider carefully any exit strategy from the input fertiliser subsidy programme before implementing it, and to consider putting in place complementary strategies for maintaining not only crop productivity, but also robust rural livelihoods.

The establishment of a national innovation forum would best suit the interests of all stakeholders in the country, as it would ensure that the use of AIS concepts is mainstreamed and that common ground is set for greater understanding of the concepts. Through this platform, policy-makers would interact and work with tools developed to carry out scenario analysis of future policy changes on the micro level, given an integrated agricultural research programme that uses AIS concepts. This can then be a springboard to link quantitative trade policy models for Malawi to other existing regional initiatives to improve forecasting and policy formulation. Additionally, this platform would work to engage with rural end-users in order to demystify the concepts of innovation systems, as communities understand very little of innovation processes and the role they must play if such programmes are to be effective. This would improve not only communities' understanding and participation in development initiatives, but also the success of agricultural research initiatives and communities' capacity to lobby for changes in policies that affect them.

Acknowledgements

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Impact Assessment of Post-harvest Repayment Deductions on Sugarcane Out-growers' Profitability: A Case Study of Ruembe Cane Growers Association

Lutengano Mwinuka[1]

Keywords: profit, out-growers' scheme, gross, unnecessary deductions, Tanzania

Abstract

This study was conducted at the Kilombero sugarcane out-growers' scheme under the Ruembe Cane Growers Association (RCGA). It investigated the impact of post-harvest repayment deductions on sugarcane out-growers' profitability through identifying benefits to farmers participating in the scheme, assessing their profitability, and analysing costs to sugarcane out-growers. A structured questionnaire was used for data collection. Profitability analysis was done by calculating the farmers' gross revenues, gross cost and profit (both with and without 'unnecessary deductions'). There were significant differences in farmers' profitability, between all deductions included and 'unnecessary deductions' excluded. The analysis shows enough evidence that the 'unnecessary deductions' identified (Tanzania Sugarcane Growers Association, TASGA and government 'CESS' levy) had a significant impact on farmers' final profits. In addition, farmers have been subject to many deductions and higher costs regarding their general involvement in cane production, compared with other crops, and with less help from the association management. Farmers participating in the sugarcane out-growers' scheme benefited through a guaranteed market for their canes (the factory), price determination and negotiation by the Association, the possibility of getting loans and other credit facilities, and a guarantee of infrastructure services during the rainy season. However, double payments, duplicate roles of some deductions, and high transport costs because of inaccurate farm registration are some of the problems that need to be evaluated and addressed for Tanzanian sugarcane out-growers.

Introduction

Problems encountered by sugarcane out-growers and the sugar industry in Tanzania have been reported in several ways. Sserunkuma and Kimera (2003) made a general study of the impact of European Union (EU) sugar trade on developing countries. They recommend vigorous expansion of the sugar industry in East Africa to meet the under-supplied domestic and sub-regional markets, and possibly the demand of the EU under the Preferential Trade Area (PTA) agreement. This would therefore help to reduce expensive sugar importation into Tanzania.

1. Sokoine University of Agriculture, Department of Agricultural Economics and Agribusiness, PO Box 3007, Morogoro, Tanzania.

Farmers in the Kilombero out-growers' scheme have been subject to various deductions. For example, for production in the 2005/06 season: CESS levy (government levy for development purposes paid to district council) of TZS[2] 120/tonne of sugarcane; Kilombero Cane Growers Association/Ruembe Cane Growers Association (KCGA/RCGA) levy of TZS 100/t; cane group[3] TZS 100/t; Tanzania Sugarcane Growers Association (TASGA) fee of TZS 50/t; cutting, TZS 1,000/t; loading, TZS 700/t; and transport, TZS 3,000/t. Problems arose when the processing factory started scaling down services to out-growers, who largely depended upon its formerly organised services such as cane cutting, loading and transporting using company facilities.

Deductions to sugarcane out-growers resulted in some losses and became a significant burden to some of farmers in the industry. For example, Mtibwa Out-growers Association successfully reclaimed payments unjustly deducted by the miller ranging from TZS 81 million to 300 million for the eight seasons to 2005/06. However, some out-growers' claims against reductions for reduced cane quality (sucrose content) have not been settled (Matango, 2006). Delayed payments for sugarcane sales make it impossible for out-growers to have enough capital during the weeding period, which is very important in sugarcane farming (Rwalins, 1989).

According to FAO (2001), there are several ways in which prices can be calculated. Under the fixed price scheme typical in the Tanzanian sugarcane industry, farmers are offered a set price at the beginning of each season. In most cases, fixed prices are related to grade specifications. For example, Kilombero Sugar Company offered TZS 39,500/t on the basis of 10% sucrose content for the 2008/09 season (Illovo Sugar Limited, 2008).

The application of deductions and transparent pricing formulae is crucial, and the drafting of a clear structure and the organisation of a practical method of payment encourage confidence and goodwill (FAO, 2001). In Kilombero, a division of proceeds system is used whereby the farmer receives 55% and the miller 45% of the ex-factory price. From this, other deductions are made so as to reach the actual amount obtained by the farmer (net pay) (ADF, 2005).

However, the relationship between sugarcane out-growers' associations and sugar millers (factory) has been characterised by mistrust. The out-growers feel that cane is not graded honestly, that the weighbridge is tampered with, and that millers often delay payments. For example, from 1999 onwards, the millers frequently delayed payments in violation of their contracts with the associations. The situation was particularly critical in Mtibwa, where some farmers had to wait 6 months or longer before they were paid (Matango, 2006).

Generally, out-grower farmers in Tanzania have been facing a number of constraints, including poor physical, technological and financial infrastructure, inadequate extension services and inadequate raw materials such as pesticides, fertilisers and herbicides (Mbilinyi and Semakafu, 1995; Tarimo and Takamura, 1998).

Objectives

The general objective of this study was to assess the impact of post-harvest repayment deductions on sugarcane out-growers' profits in Kilombero out-growers' scheme. To that

2. TZS = Tanzanian shilling; €1 ≈ TZS 1620.

3. The 'cane group' is a group of sugarcane farmers, a farmers' association for group action, so this deduction aims to facilitate particular group-related activities.

end, the study had three specific objectives: (1) identify benefits to farmers participating in the sugarcane out-growers' scheme; (2) assess profitability to farmers participating in the out-growers' scheme; and (3) analyse costs to sugarcane out-growers.

Methodology

The research was conducted in Kilombero in 2008/09. Ruembe Cane Growers Association (RCGA) was used as a case study, in which the impact of post-harvest repayments deductions on sugarcane out-growers' profitability was assessed. Both purposive and simple random sampling techniques were used. Purposive techniques were used to select the target population (Kilombero out-growers) working for the RCGA. Simple random sampling using random numbers was used to select 60 sugarcane farmers, since each farmer is subject to the same post-harvest deductions.

Some data were collected using open questions (in a questionnaire); these were supplemented by secondary data obtained from the RCGA office to identify the benefits to farmers of participating in the scheme.

An Excel spreadsheet was used to facilitate calculation of total cost (TC), total deductions, 'unnecessary deductions' identified by farmers, and profit.

$$\text{Profit } (\pi) = TR - TC$$

where TR represents total revenue from sale of cane obtained by multiplying sugarcane sold (tonnes) by price per tonne, and TC represents total expenses incurred by the farmer in production (soiling, weeding, herbicides, etc.), obtained by multiplying production cost per unit area (in this case, acres) by farm size (in acres) plus total deductions per tonne multiplied by cane sold (tonnes).

After obtaining out-growers' profit with deductions and with 'unnecessary deductions', a *t*-test was used to determine whether means were equal for profit with and without 'unnecessary deductions' ($\mu_1 = \mu_2$), thus determining the impact of deductions on the profit of sugarcane out-growers.

Results and discussion

'Unnecessary Deductions' from Sugarcane Sales

To assess the impact to out-growers' profitability, 'unnecessary deductions' were identified. Fifty-one (out of 60) farmers identified the CESS levy as an 'unnecessary deduction'; 48 farmers identified the TASGA fee, imposed on farmers as a contribution to Tanzania Sugarcane Growers Association; 42 farmers identified both. The CESS levy was TZS 120/t and TASGA fee TZS 100/t in 2008/09. The out-grower farmers indicated that these deductions had no direct benefits to them. They said that they already paid for development support through deductions such as infrastructure development fees and secondary school contributions, hence they considered the CESS levy unnecessary. TASGA had no direct input to the out-grower farmers, who are members of and derive benefit from RCGA.

Analysis of Costs to Sugarcane Out-growers

Sugarcane out-growers in Kilombero were subjected to different costs in supporting cane production. Preparation costs varied between farmers, and also differed with respect to the stage of ratoon – high production costs at the beginning of cultivation compared with those at the second or next stage of ratoon (some costs already covered from the first ratoon).

However, there were several deductions which were compulsory on farmers for different services offered. These deductions ranged between TZS 4,249.58 and 8,438.00/t, and cover cutting, loading and transporting service costs which are paid direct to contractors, while most other deductions (i.e., association fee, operations service fee, infrastructure fee, secondary school contribution, group fee, TASGA fee and CESS levy) range between TAS 50 to 624/t, and they are paid direct to the association (RCGA).

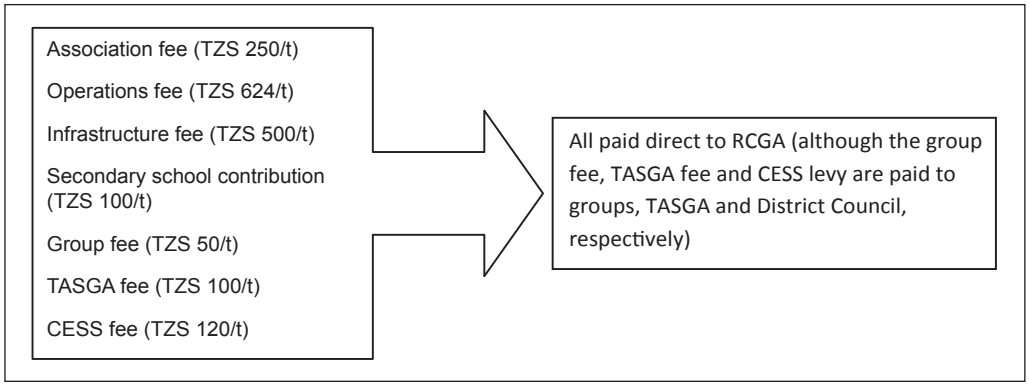

Figure 1. *Post-harvest deductions for RCGA and rates per tonne*

Cane-loading fees of TZS 2,500 (including Value Added Tax) per tonne were paid directly to the contractors. Table 1 shows transport service cost rates.

Table 1. Cane transport costs (TZS/t)

Distance range (km)	Cost (excluding VAT)
0–10	4,249.58
11–20	5,926.00
21–30	8,438.75
31–40	10,894.60

If farmers decide not to use transport contractors, the next available option to them is Unitrans services – the company used most by the Kilombero Sugar Company. Their transport service cost as agreed by the association (RCGA) in 2008/09 were:

- loading: TZS 2,374 per tonne (including VAT);
- transport cost: 0–10 km TZS4,880.71, and 11–20 km TZS7,615.27 (including VAT).

Other deductions are as shown in Table 2.

Table 2. Additional deductions

Deduction	Rate/tonne (TZS)	Payment instruction
Association fee	250	Paid to RCGA General
Operations service fee	624	Paid to RCGA Operation
Infrastructure fee	500	Paid to RCGA Infrastructure
Secondary school contribution	100	Paid to RCGA General
Group fee	50	Paid to respective groups
TASGA fee	100	Paid direct to TASGA
CESS levy	120	Paid direct to District Council

Profitability Analysis for Sugarcane Out-growers

Profitability analysis was done by calculating the farmers' gross revenues, gross costs and profit obtained (after subtraction of all deductions). Sugarcane cultivation incurs costs for farm preparation, inputs used, making furrows and fire breaks, and harvesting. The study treated all post-harvest repayment deductions as costs to farmers and included them in the total cost, and then calculated profit. There were significant differences in farmers' profitability ($P \leq 0.05$), with a mean difference of TZS 30,628.4 profit.

The study shows that 'unnecessary deductions' identified by respondents (such as the TASGA fee and CESS levy) had a significant impact on their profit. The critical two-tailed *t*-test score was 1.67, which indicates that the 'unnecessary deductions' identified by farmers (CESS levy and TASGA fee) had a significant impact on profit. Thus the mean difference between profit with all deductions and profit without 'unnecessary deductions' was not equal ($\mu_1 \neq \mu_2$).

Conclusion and recommendations

Conclusion

There were significance differences in farmers' profitability. 'Unnecessary deductions' that were identified by respondents included the TASGA fee and CESS levy. The analysis showed that these had a significant impact on farmers' final profit.

In addition, farmers have been subjected to many deductions and higher costs regarding their general involvement in cane production compared with other crops grown with less help from the association management. Farmers participating in the sugarcane out-growers' scheme benefited through having a guaranteed market for their canes (the factory), price determination and negotiation by the Association, the possibility of getting loans and other credit facilities, and a guarantee of infrastructure services during the rainy season.

On the basis of these results, this study rejects the hypothesis that 'unnecessary deductions' have no significant impact on the profit of sugarcane out-growers.

Recommendations

The results of this study indicate that there are still a number of things to be done. Cane growers' associations need to ensure higher benefits for farmers involved in sugarcane production at Kilombero. These include the following:

- critical analysis of existing deductions should be carried out to identify 'unnecessary deductions' and build a case for either reducing their rates or eliminating them;
- the paucity of benefits identified by respondents who participate in the sugarcane out-growers' scheme should be considered, and problems such as high transport costs through inaccurate farm registration and complicated loan procedures should be assessed further to determine their impact on farmers;
- double payment of some deductions, such as secondary school contributions, should be further assessed and resolved so as minimise the cost burden on farmers.
- the contradiction of deductions with duplicate roles should be resolved, such as the presence of both the infrastructure fee and CESS levy, which both aim to deal with development activities.

Acknowledgements

I am particularly indebted to my supervisor, Dr Evelyne A. Lazaro of the Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, for her excellent and untiring guidance from the initial planning stage onwards, and for her valuable criticisms during the whole period of the study.

I wish to express my sincere gratitude to staff and all members of Ruembe Cane Growers Association for their assistance during data collection, and I would like to thank RCGA Chairperson Mr Nyembe for his tireless efforts during the data collection process.

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Annex 1: Programme Overview

2009/2010 Women and Young Professionals in Science Competitions

18–23 July 2010,
Plenary Hall, Main Conference Hall, Ouaga 2000 International Convention Centre, Ouagadougou, Burkina Faso

Day 1: Sunday 18 July

Morning Session

10:00–12.30 Expert Panel Meeting (Closed)

Afternoon Session

15:00–16:00 Joint Meeting of Expert Panel and Judges (Closed)

16:00–18:00 Registration

18:30–19:30 Welcome Cocktail Reception

Day 2: Monday 19 July

Morning Session

Opening of the finals competition

Chairperson: *Myra Wopereis-Pura, Director Access to Knowledge and Technologies, FARA*

08:30–08:45 Welcome Remarks, *Dr Monty Jones, Executive Director, FARA*

08:45–09:00 Opening Remarks, *Mr Michael Hailu, Director, CTA*

09:00–09:30 Overview of the Competitions: Engaging More Women Scientists and Young **Professionals:** Lessons from the 2008/10 Science Competitions, *Judith Ann Francis, Senior Programme Coordinator, Science &Technology Strategies, CTA*

09:30–10:00 Keynote Address: Strategic Repositioning of Agrobiodiversity in the Horticulture Sector for Sustainable Development in Africa, *Professor Abukutsa Mary Oyiela Onyango, Jomo Kenyatta University of Agriculture and Technology, Kenya* [2008/09 first place winner, Women in Science]

Women in Science Competition

Chairperson: *Dr Hanna Andrea Rother, Programme Leader – Health Risk Management, University of Cape Town, South Africa* [2008/09 winner, Women in Science]

11:00–11:20 Technological and Institutional Innovations Triggered by a Farmer-to-Farmer Rice Parboiling Video in Central Benin, *Enangnon Espérance Zossou, Benin*

11:20–11:40 Entomofaune de Légumineuses en Jachère, *Nathalie Judith Kouakam Melele, Cameroon*

11.40–12:00 Genetic Diversity of Gum Arabic-producing *Acacia senegal* Varieties in Kenya using Inter-Simple Sequence Repeat (ISSR) and Chloroplast Simple Sequence Repeat (cpSSR) Markers, *Eunice Wamuyu Githae, Kenya*

12.00–12:20 Cassava: Adding Value for Africa – Gender and Diversity as a Driving Force, *Petra Bola Abdulsalam-Saghir, Nigeria*

12:20–12:40 Development of Endiisa Decision Support Tool for Improved Feeding of Dairy Cattle in Uganda, *Sarah Lubanga Mubiru, Uganda*

12:40–13:00 Contribution des chaines de valeur a base de riz et de culture maraîchères dans les bas-fonds au sud du Benin et Mali : perceptions paysannes sur les contraintes et opportunités et analyse de la rentabilité financier des systèmes de cultures, *Sounkoura Adetonah, Benin*

Afternoon Session

14:30–14.50 Breeding for Cassava Brown Streak Disease Resistance in Coastal Kenya, *Theresia Luvuno Munga, Kenya*

14:50–15.10 A Sustainable Approach for the Management of the Legume Pod Borer, *Maruca vitrata*, on Bean in Mauritus, *Lalini Unmole, Mauritius*

15:10–15.30 Economic Evaluation of Sweetpotato Varieties under Different Intercropping Systems in Nigeria, *Adanma Amaefula, Nigeria*

16:30–18:30 Judges' Deliberations (Closed)

Day 3: Tuesday 20 July

Morning Session

Young Professionals in Science Competition

Chairperson: *Dr Fetien Abey Abera, Mekelle University, Ethiopia* [2008/09 winner, Women in Science]

08:30–09:00 Keynote Presentation: Dendrochronology in Africa: Current Activities and its Potential in Climate Change Studies, *Dr Aster Gebrekirstos Afwork Research Fellow, World Agroforestry Centre, Kenya* (2008/09 winner)

09:00–09:20 Effect of Human Urine on Eggplant (*Solanum melongena*) Production and Salt Accumulation in Soil, *Delwendé Innocent Kiba, Burkina Faso*

09:20–09:40 Territoires, troupeaux et biomasses : enjeux de gestion pour un usage durable des ressources au Nord-Cameroun, *Aimé Landry Dongmo Ngoutsop, Cameroon*

09:40–10:00 Evaluation de l' impact de la mosaique sur les varietes de patate douce, Elenyi, Mugande, Karebe II, Japan, Tainung en milieu rural du sud-Kivu sur la cote occidentale du Lac Kivu, *Jean Augustin Kituta Rubabura, Democratic Republic of Congo*

10:30–10:50 Integration of Farmers in Technology Development as a Basis for Enhancing Sweetpotato Productivity in Kenya, *James Kyalo Mwololo, Kenya*

10:50–11:10 Impacts of Proposed Large-scale Monoculture Developing Projects on Wetlands and Wetland-dependant Communities, *Joan Auma Otengo, Kenya*

11:10–11:30 Using ICT to Improve Farming Activities, *Andrianjafy Rasoanindrainy, Madagascar*

11:30–11:50 Design, Construction and Testing of a Low-Cost Maize Thresher, *Joel Nwaeze Nwakaire, Nigeria*

11:50–12:10 Resource Use Optimisation in Main Food and Cash Crops Production – A Route to Food Security and Poverty Alleviation in Sudan, *Algaylani Abdalhafez Ahmed, Sudan*

Afternoon Session

14:00–14:20 Development of Appropriate Surveillance Systems for Honeybee Pests and Diseases for Improved Production of Honey and other Bee Products in Uganda, *Robert Ada Kajobe, Uganda*

14:20–14:40 Variation de l'activité biologique dans les parcelles aménagées en cordons pierreux de la province du Kouritenga au Burkina Faso, *Wendkouni Sabine Marie Flore Doamba, Burkina Faso*

14:40–15:00 Cours des matières premières, recettes budgétaires et croissance économique : cas de la Côte d'Ivoire, *Sandrine Nguiakam, Cameroon*

15:30–15:50 Morphological Characterisation of African Eggplant (*Solanum* spp.) in some African Countries, *Michael Kwabena Osei, Ghana*

15:50–16:10 Reseeding – A Gateway to Rehabilitation Success, Food Security and Sustainable Rural Livelihoods in Drylands Africa, *Kevin Zowe Mganga, Kenya*

16:10–16:30 Effects of Moisture Stress at Flowering on Phenotypic Characters of Selected Maize Local Landraces in Kenya, *Shelmith Wanja Munyiri, Kenya*

16:30–16:50 Looking at Wastes as Valuable Resources – An Example from the Sugarcane Industry in Mauritius, *Aneeza Soobadar, Mauritius*

16:50–17:10 Assessment of the Macro-Micro Linkages between Rural Livelihoods, Agricultural Research Innovation Systems and Agricultural Policy Changes in Malawi, *Mariam Amale Tanjani Mapila, South Africa*

17:10–17:30 Impact Assessment of Post-harvest Repayment Deductions on Sugarcane Out-growers' Profitability: A Case Study of Ruembe Cane Growers Association, Lutengano, *Edward Mwinuka, Tanzania*

17:30–18:00 Judges and Expert Panel Meeting (Closed)

Announcement of winners by Chief Judge

Day 4: Wednesday 21 July

Burkina Faso Day

Day 5: Thursday 22 July

Opening of FARA General Assembly

FARA Gala: Science Competition Awards

Day 6: Friday 23 July

FARA Plenary Session

About the Collaborating Partners

AGRA: The Alliance for a Green Revolution in Africa provides a platform for the partnerships and programmes needed to catalyse an African Green Revolution that puts smallholder farmers first, increasing their productivity and profits and creating a vibrant food production system that reaches from farmers' fields to regional markets. **www.agra-alliance.org**

ANAFE: The African Network for Agriculture, Agroforestry and Natural Resources Education is a network of 131 educational institutions in 35 African countries whose objective is to strengthen the teaching of multi-disciplinary approaches to land management. The goal is to improve in a sustainable manner the contribution of agricultural education to social and economic development of the African peoples. **www.anafeafrica.org**

CTA: The Technical Centre for Agricultural and Rural Cooperation ACP–EU is a joint institution operating under the framework of the Cotonou Agreement between the ACP Group of States (Africa, the Caribbean and the Pacific) and the European Union (EU) Member States. CTA's mission is to advance food security, increase prosperity and support sound natural resource management through information, communication and knowledge management, facilitation, capacity-building and empowerment of agricultural and rural development organisations and networks in ACP countries. **www.cta.int**

FARA: The Forum for Research in Africa is the apex organisation for African agricultural research, and is a coalition of all stakeholders involved in African agricultural research and development. FARA's primary roles are to advocate for investment in agricultural research for Africa's development; to promote value-adding partnerships; and to enhance the exchange of agricultural information and learning. **www.fara-africa.org**

NPCA: The New Partnership for Africa's Development (NEPAD) Planning and Coordinating Agency is a vision and strategic framework designed to address the current challenges facing the African continent. Issues such as the escalating poverty levels, underdevelopment and continued marginalisation of Africa need a new radical intervention, spearheaded by African leaders, to develop a new vision that will guarantee Africa's renewal. **www.nepad.org**

RUFORUM: The Regional Universities Forum for Capacity Building in Agriculture is an umbrella organisation of 25 universities in East and Southern Africa. It serves to promote integration of university research, training and outreach into national and regional research for development. This task is addressed not only through better trained graduates entering the rural development workforce, but also by conducting more relevant and development-oriented research that is directly linked to participatory outreach programmes. **www.ruforum.org**

Acronyms

AGRA	Alliance for a Green Revolution in Africa
AIDA	Agricultural Innovations for Drylands Africa
AIS	agricultural innovation systems
AIVs	African indigenous vegetables
ALUCCSA	Adaptation of Land Use to Climate Change in Sub-Saharan Africa project
AMOVA	analysis of molecular variance
ANAFE	African Network for Agriculture, Agroforestry & Natural Resources Education
ANOVA	analysis of variance
AREU	Agricultural Research and Extension Unit (Mauritius)
ASI	anthesis–silking interval
BCR	benefit/cost ratio
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, Federal Ministry for Economic Cooperation and Development (Germany)
C:AVA	Cassava: Adding Value for Africa Project (Gates Foundation)
CBSD	cassava brown streak disease
CBSV	*Cassava brown streak virus*
CEMUBAC	Centre Scientifique et Médical de l'Université Libre de Bruxelles pour ses Activités de Coopération
CIP	Centro Internacional *de la Papa*/International Potato Centre
COPR	Centre for Overseas Pest Research
CP	crude protein
cpSSR	chloroplast simple sequence repeat
CREPA	Centre Régionale pour l'Eau Potable et l'Assainissement à faible coût (Burkina Faso)
CRSN-Lwiro	Lwiro Natural Sciences Research Centre (DR Congo)
CTAB	cetyltrimethylammonium bromide
cv.	cultivar
DAT	days after transplanting
DFG	Deutsche Forschungsgemeinschaft/German Research Foundation
DM	dry matter
DST	decision-support tool
EDTA	ethylenediaminetetraacetic acid
ERI	Enabling Rural Innovation approach (Malawi)

FARA	Forum for Agricultural Research in Africa
GCA	general combining ability
GDP	gross domestic product
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
HQCF	high-quality cassava flour
ICCO	International Cocoa Organization
ICO	International Coffee Organization
ICT	information and communications technology
IITA	International Institute of Tropical Agriculture
INERA	Institut de l'Environnement et de Recherches Agricoles (Burkina Faso)
IPM	integrated pest management
ISSR	inter-simple sequence repeat
IUCN	*International Union for Conservation of Nature*
KARI	Kenya Agricultural Research Institute
MAP	months after planting
MDGs	Millennium Development Goals
ME	metabolisable energy
MSIRI	Mauritius Sugar Industry Research Institute
MuZARDI	Mukono Zonal Agricultural Research and Development Centre (Uganda)
NAADS	National Agricultural Advisory Services (Uganda)
NaLIRRI	National Livestock Resources Research Institute, Makerere University (Uganda)
NARO	National Agricultural Research Organisation
NEPAD	New Partnership for Africa's Development
NGO	non-governmental organisation
OM	organic manure
PROMES	Projection Macro-Econométrique et de Simulation model
PSM	propensity score matching
PTA	Preferential Trade Area
RCBD	randomised complete block design
RCGA	Ruembe Cane Growers Association (Tanzania)
ReACCT	Resilient Agro-landscapes to Climate Change in Tanzania project
RH	relative humidity
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
SCA	specific combining ability
SILEM	Sahelian Integrated Lowland Ecosystem Management Project (IUCN)

SME	small and medium-sized enterprise
SMS	short messaging service
SPCSV	*Sweet potato chlorotic stunt virus*
SPFMV	*Sweet potato feathery mottle virus*
SPMMV	*Sweet potato mild mottle virus* .
SPSS	Statistical Package for Social Scientists
SPVD	sweetpotato virus diseases
T&V	training and visit system
TASGA	Tanzania Sugarcane Growers Association
TLU	tropical livestock unit
TSBF	Tropical Soil Biology and Fertility Institute (CIAT)
UPGMA	unweighted pair group method with arithmetic mean
VAR/VECM	vector autoregressive/vector error correction model
VPU	village processing unit
WAEMU	West African Economic and Monetary Union
ZIZO	zooming-in, zooming-out approach to video-making

About FARA

FARA is the Forum for Agricultural Research in Africa, an apex organisation that brings together and forms coalitions of major stakeholders in agricultural research and development in Africa. Its mission is to create broad-based improvements in agricultural productivity, competitiveness and markets by supporting Africa's sub-regional organisations (SROs) in strengthening capacity for agricultural innovation. FARA is funded by the African Development Bank (AfDB), the Canadian International Development Agency (CIDA), Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), the Danish International Development Agency (DANIDA), the UK's Department for International Development (DFID), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), the European Commission (EC), the International Development Research Centre (IDRC), the Global Fund for Agricultural Research (GFAR), the Swiss Agency for Development and Cooperation (SDC), the Syngenta Foundation for Sustainable Agriculture, the World Bank and the Governments of Italy and the Netherlands.

About CTA

The Technical Centre for Agricultural and Rural Cooperation (CTA) is a joint international institution of the African, Caribbean and Pacific (ACP) Group of States and the European Union (EU). Its mission is to advance food and nutritional security, increase prosperity and encourage sound natural resource management in ACP countries. It provides access to information and knowledge, facilitates policy dialogue and strengthens the capacity of agricultural and rural development institutions and communities. CTA operates under the framework of the Cotonou Agreement and is funded by the EU.

Forum for Agricultural Research in Africa
12 Anmeda Street, Roman Ridge,
PMB CT 173, Accra, Ghana
Telephone: +233 302 772823 / 302 779421
Fax: +233 302 773676 / Email: info@fara-africa.org
Website: www.fara-africa.org

CTA
Postbus 380
6700 AJ Wageningen, The Netherlands
Telephone: +31 (0) 317 467100
Fax: +31 (0) 317 460067 / E-mail: cta@cta.int
Website: www.cta.int