Agricultural Innovations for Sustainable Development

Contributions from the Finalists of the African Youth in Science Competition

Volume 1 Issue 1

Technical report of the CTA/ ATPS/ AGRA/ FARA/ NEPAD/ RUFORUM

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We appreciate the young professionals who submitted articles that eventually led to this unique publication. We note that several efforts and inputs have been made to ensure that this publication becomes a reality. To this end, we owe many thanks to the following people:

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Foreword

As part of its contributions towards building stronger institutions through science, technology and innovation policy research for sustainable development across African Continent, the African Technology Policy Studies Network (ATPS) and her partners, the Technical Centre for Agricultural and Rural Co-operation (CTA), the Alliance for a Green Revolution in Africa (AGRA), the Forum for Agricultural Research in Africa (FARA), The New Partnership for Africa's Development (NEPAD), and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), organized the maiden Competition for Young Professionals and Women in Agricultural Science & Technology in 2008. The final competition and award ceremony was hosted during the African Union Fourth conference of Ministers of Agriculture, Lands and Livestock, Addis Ababa, Ethiopia from 20-21 April 2009.

This initiative led to the production of the maiden issue of the book series, Agricultural Innovations for Sustainable Development 1(1), based on the contributions made by African Young Professionals below the age of 35 who have carried out diverse researches in agricultural science, technology and innovations on the continent. Contributions mainly ranged from issues in agricultural production, marketing, value addition, to biotechnology, information communication technology, and climate change. Participation was open to all African Young Professionals but only 18 Young Professionals from 10 African countries emerged as finalists in the competition after a rigorous expert review and assessment processes. Special awards were given to the best two researchers whose research was judged to have contributed most to the improvement in agricultural innovations and sustainable development.

African Young Professionals in Science Competition is hinged on the fact that youths play prominent role in science and technology development of any nation especially in maintaining continuity and sustainability in the system. Youths are endowed with energy, knowledge, mental alertness and wisdom to confront social, economic, political, environmental, cultural, and even religious challenges. Agricultural Innovations for Sustainable Development vol. 1 (1) is therefore a must read. It is a compendium of best agricultural practices and innovations today for sustainable development tomorrow, by African youths.

Dr. Kevin Chika Urama,
Executive Director, ATPS

Table of Contents

Enhancing Agricultural Productivity and Livelihood of Rural Women through Information and Communication Technology

Amongi Mary[1]

Keywords: marketing, sensitization, rehabilitation, farmers, empowerment

Abstract

Uganda is one of the world's least developed countries. Its populationdepends on agriculture as a major source of livelihood; however, agriculturalproduction has been negatively affected by civil war in the north of the country. The impact of this war was severe on women and yet they are the major participants in the agricultural industry. HIV/AIDS and structural adjustment programmes have further increased the poverty level. With over two decades of civil war raging in northern Uganda, and rebels having resorted to abducting children to fight in their battle, girl children became targets of devastating abuse. Girls were often given as 'wives' to rebel soldiers, destining them to a life as a sex slave. Many girls become pregnant and gave birth in the bush to what are called 'bush babies' (babies born as a result of rape by Lord's Resistance Army rebel soldiers). This is a significant percentage of the much needed agricultural labour force. However, some managed to escape and need to be supported during this period of resettlement and rehabilitation. Child mothers are the quiet strength, and desperately need others to join hands and support them towards restoration. An initiative was made by Women Empowerment for Rural Development (WEFORD) to boost agricultural production and marketing opportunities for the rural women, using information and communication technologies (ICTs) as one of the avenues of its contribution to the post-war rehabilitation process. The major objectives of this project are: to build the capacity of rural women to use ICTs for marketing their products, to facilitate value addition on agricultural products for income generation, and to integrate agro forestry with crop production for improved yields and environmental management.

[1] *PO Box 37802, Kampala, Uganda; or PO Box 204, Lira, Uganda.*

INTRODUCTION

Uganda is one of the world's least developed countries. Its population depends on agriculture as a major source of livelihood; however, agricultural production has been negatively affected by civil war in the north of the country. The impact of this war was severe on women and yet they are the major participants in the agricultural industry. HIV/AIDS and structural adjustment programmes have further increased the poverty level. With over two decades of civil war raging in northern Uganda, and rebels having resorted to abducting children to fight in their battle, girl children became targets of devastating abuse. Girls were often given as 'wives' to rebel soldiers, destining them to a life as a sex slave. Many girls become pregnant and gave birth in the bush to what are called 'bush babies' (babies born as a result of rape by Lord's Resistance Army rebel soldiers). This is a significant percentage of the much needed agricultural labour force. However, some managed to escape and need to be supported during this period of resettlement and rehabilitation. Child mothers are the quiet strength, and desperately need others to join hands and support them towards restoration.

The Women Empowerment for Rural Development (WEFORD) project is focusing on enhancing agricultural productivity and livelihoods of rural women's groups through training on and use of appropriate and available information and communication technology (ICT). Prior to designing the project and drafting strategies (highlighted in the following sections), a detailed community information-needs assessment survey was carried out. The project embarked on a campaign to establish a small resource centre at a location deemed to be easily accessible by the majority of the members. The centre would be used to support activities such as research, Internet access, documentation, lobbying and advocacy, training sessions and facilitate knowledge sharing for best production practices among existing member and interested non-member farmers. In turn, it would help them to access quality marketing opportunities locally, regionally and internationally in the near future. The major question arising is: can ICTs really help in improving agricultural productivity, marketing strategies and livelihoods of these identified groups?

Statement of the Problem

In the few years since those internally displaced by the civil war began returning home, there have been a number of initiatives, some government based and others monitored by non-government organizations. Most of these initiatives have either been dominated by men or men were the beneficiaries. Hence the need for a more gendersensitive approach and intervention to support and enable the local population to generate and exchange reliable information in a relevant setting, thereby enhancing agricultural productivity and livelihoods of rural women through appropriate and readily available ICT facilities.

Literature Review

ICTs have been defined in many ways; Slater and Tacchi (2004), for example, consider ICT as encompassing a full range of media commonly used with reference to communication media, including radio, television, the press, physical notice boards, computers and the Internet. However, this project has opted to use just a few of the highlighted ICTs. Broad-based economic growth also requires information and communication systems that enable two-way information flows (Saith, 2001). However, for the poor, particularly in rural areas and remote villages, accessing information is extremely difficult as economic barriers to equal participation in the markets are common, limiting the degree of mobility that these groups can exercise (Bracking, 2003).

For these groups, the outcome is a dramatic increase in the transaction cost component of any economic activity (Bracking and Hickey, 2005; Bracking and Sachikonye, 2001–2006). Where such barriers exist among groups who have well-developed access to information, it can be argued that information asymmetries may perpetuate poverty and inequality (Stiglitz, 1988, as well as social exclusion. Social exclusion is defined as a process in which certain groups are systematically disadvantaged because of who they are (gender, caste, class, ethnicity and so forth) and where they live (poorer areas in the cities, rural areas) (Beall, 2002a, b, c; DFID, 2005).

For these reasons, this project recognizes that deprivation, whether socioeconomic or digital, is multidisciplinary, typically made up of these dimensions: economic/financial (comprising income and expenditure; communicating in emergencies) and natural/physical (infrastructure, natural resources, biodiversity). ICTs can act as facilitating factors linking social, economic and natural well-being by improving communication and networking (whether social or economic in intention), and by reducing exclusion, reducing transaction costs and building social capital. Through ICTs, the poor are able to learn of new production strategies and technologies, access market information faster and more accurately, and keep in regular contact with peers and other social and economic contacts and associates.

Project Scope

1. Target Group. The target group comprises rural women farmers, young girls who were and were still directly or indirectly affected by the war.
2. Technical Scope. At the time of writing (June 2008), the focus is to use radio shows, telephones and Internet to achieve the project purposes highlighted below.

Purpose of Project

The overall purposes of this project are: to build the capacity of rural women to use ICTs for marketing their products, to facilitate value addition on agricultural products for income generation, and to integrate agroforestry with crop production for improved yields and environmental management. In order to achieve this broad purpose, the project intends to help women's groups market their agricultural products profitably using the appropriate available ICT, and to identify and meet the ICT training needs of the identified groups.

MATERIALS AND METHODS

Materials

The major products that are sold by these women are sesame and groundnuts in various forms (roasted, paste). To market these products profitably, these women add value to them. After harvesting or purchasing, the groundnuts are shelled and roasted; they can then either be ground into paste or packed as seeds ready for consumption. In either form, the product can be consumed as a snack, but the paste can further be used as seasoning in different sauces. Sesame is first washed, dried and roasted, and then either packed as seeds or ground into paste. Other products include packed millet, soya flour and maize flour.

To integrate agroforestry with crop production for improved yields and environmental management, the women farmers' groups have considered planting environmentally friendly pine trees, which allow co-

survival of other seasonal crops. These trees are early maturing and can be harvested at two different stages for construction poles and timber. The trees are intercropped with groundnuts, sesame, beans, maize and millet, which benefit from the tree residues (fallen leaves). The sawdust from the timber will be used as fuel in a locally made energy-saving stove for domestic cooking and for processing the sesame and groundnuts—thereby addressing the issues of environmental management and fuel shortage.

Methodology

Women's groups from Lira district (one of the places that suffered the impact of the war) were identified through local council authorities.

1. Group Categorization. Different group categories (illiterate, literate) were trained on how to use various ICTs at their disposal; for example, Internet/e-mail, mobile phones and radios. This was done in such a way that the literate members were given basic computer training for information generation (e-mail usage) and sharing about their products (including on word processor to design product labels). Members of the groups who either own or have access to mobile phones were trained on how to get market information through available mobile network services. The illiterate are facilitated to participate in radio talk shows that market their products, and occasionally networking sessions and mini workshops are organized to facilitate farmer-to-farmer sessions.

2. Communication Strategy. The information and communication strategy used was community-sensitization meetings, which aimed at tapping ideas on how best rehabilitation can be achieved gradually without destroying the environment. Lessons learnt from the project were also shared with partners through workshops and radio talk shows. The project also meets farmers' needs by creating an 'all-round ICT service' using Internet-based information systems, such as e-mail services combined with a mini call centre and training components. The project uses a participatory strategy to develop its information services and mobilize stakeholders.

RESULTS

ICT Training and Agricultural Productivity

The project activities have yielded the following: of six groups with a total membership of 120, some 21% of members have successfully acquired basic computer skills and are able to use e-mail services, and computer application packages to design labels for their products; 11% use telephone services to access market information; and a third of the remaining members (22.6% and 45.4%, respectively) have participated in radio talk shows and farmer-to-farmer interaction to market their products. Through the talk shows and farmer-to-farmer interactions, five new groups with a total of 61 members have been formed and are undergoing the same training at the resource centre. The training is being conducted by members of the original groups.

A number of ICT-driven solutions have been developed towards the creation of the 'information villages'. Because of the government's tax-free policy on computer equipment, acquisition of training equipment (desktop computers, mobile phone handsets and fixed desk telephone units) intended to increase access to communications was made (to a certain extent) easier for the project. During the training sessions, at least two participants can share a telephone, which provides easy access to the project's mini call centre, making technical consultancy on use of ICTs feasible via telephone and mobile phone. Building on this infrastructure, the project set up a dedicated hotline that provides answers to frequently asked questions

from member or non-member farmers. Income generated from the products has been reinvested in agricultural production (areas of beans, maize, sesame, groundnuts and millet have increased from 1 acre [0.405 ha] to 3 acres [1.214 ha] per farmer), improving food security and income. Nutrition has been improved from both homemade production and food purchased with income from the products. Soil fertility has been improved, leading to improved yields. The project has boosted community cohesion and rehabilitated those who suffered losses as a result of the civil war in this region.

Future Prospects

The project is intended to extend further, including the establishment of a saving scheme that could possibly lead to village banking supported by the various relevant ICTs. This could cater for credit facilities for the members, and perhaps later nonmembers would have access to these services. It is hoped that the gradual savings will enable members to educate their children, most of whom have lagged behind for the many years that the war displaced them from their homes.

1. Partnerships. The project partners with the Ministry of Gender and the Ministry of Health at the district level to address gender- and HIV/AIDS-related issues, respectively. Some of the support is still in the informal negotiation stages and we hope in time the project will not only target women, but also try to get men's participation in order to have a balance in the homes.

2. Project Website. ICT consultancy firm Information Management Consult Incorporated, based in Kampala, has agreed to work with the project to design a website, which the trained members could use to market their products. The firm also intends to train the project facilitators on how to use simple web tools to get massive information shared across the targeted members and/or potential partners.

3. Other Plans for the Future. To improve livelihoods, another long-term plan is to provide better low-cost shelter for those members who are unable to obtain shelter on their own. For most of these people, the only shelter they have known for the past decade (since they were night commuters in search of safety) is shop verandas .

DISCUSSION AND CONCLUSION

Much has been achieved to the best of the team's ability and facilitation; however, the project needs to improve the services in order to establish (beyond reasonable doubt) that impact can be observed in the following areas:

- Improved access to market and other production information through technology, so that better yields and returns can be obtained, as well as information about prices for inputs and outputs—this impact can be measured in terms of improved incomes, profits and sales that can be attributed to ICTs.
- Better understanding of the institutional frameworks that govern members' access to essential services and facilities—this includes knowledge of distribution systems, as well as of rights and how to enforce those rights.
- Being able to reduce the time and cost involved in identifying, obtaining and making use of essential services would form part of this benefit—this impact can be measured in terms of improved access to and use of essential services, as well as improvements in the quality of the services obtained that can be attributed to ICTs.
- Better understanding of the institutional frameworks that govern their social, economic and political environments and hence the ability to assert themselves—this can be measured in terms of

improvements in perceptions of connectedness, reduced isolation and empowerment that can be attributed to ICTs.

In conclusion, ICTs have shown potential to improve agricultural productivity and livelihoods of rural women in particular, and the rural poor in general. They have streamlined the channels of communication for better and more effective ways of information sharing, in order to adopt and apply the appropriate technologies to achieve meaningful results. Through this, rural women have accessed useful information to market their products and have also implemented useful ideas that have improved food security and income.

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VAVAN Information Communication Technology (ICT) Agricultural Sustainable Project (VICTASUP)

Gilbreth Ngando Namuene[1] and Nalova Becky Etinge[2]

Keywords: mobile phones, kiosks, Internet, subsistence, farmers, training

Abstract

VAVAN[3] Information Communication Technology (ICT) AgriculturalSustainable Project (VICTASUP), initiated in 2003 is educating and training rural subsistence farmers on modern land-sustainable mixed organic farming and urban poor farmers on intensive organic market gardening. It uses information and communications technology (ICT) for rural agricultural development (ICT4RAD) to improve productivity, in the rich volcanic region of Mount Cameroon. As the world relies on ICT, ICT skills are essential for education and socio-economic development for individuals and countries. Through computers, the Internet, mobile phones and short message service (SMS), citizens gain access to new markets and services, and students acquire education/skills needed to compete globally. Through the combination of technology and training, ICT centres offer cost-effective means to educate and empower local citizens. They are designed to help local communities improve their digital skills, and increase socio-economic and educational development. By increasing ICT skills and participating in the information-based global economy, the centres help communities globally to bridge digital gaps. But in Cameroon, the digital gap between the privileged and underprivileged is very wide. Even those subsistence farmers and underprivileged people who do have the means to use the digital systems, lack knowledge and training to operate computers. This situation is the result of poverty, ignorance and marginalization of the masses, which hinder underprivileged Cameroonians acquiring ICT knowledge to connect them with their communities and globally for educational and socio-economic benefits. VICTASUP is answering the question: which farming methods and ICT system(s) can sustainable deliver our objectives to targeted population? The sum total of ICT plus Information Dissemination (ID) is equal to Sustainable Development (ICTID4SD). Evidently the ICT equipment with the best chance for effecting change, which is cost-effective, easy to manipulate, transport, maintain and harness, is the mobile phone. VICTASUP is training subsistence farmers on organic mixed farming or intensive market gardening to improve yields, and to use cell phones/SMS and computer/Internet to acquire necessary agricultural and marketing skills and information.

[1–2] *Practical Association (PRACASS), PO Box 402 Buea, Cameroon.*

[3] *VAVAN means children of farmers.*

INTRODUCTION

Subsistence farmers who work the rich volcanic soil of Mount Cameroon complain about poor yields, congested distant markets, bad roads, transportation costs, uncertain fluctuating market prices, poor storage facilities and poor communication. This challenged us, in 2002, to investigate the causes of poor yields and how we can improve marketing conditions and communication.

Literature Review

In the past, the rich Mount Cameroon volcanic region was known for its production of abundant crops and animals, without using chemical fertilizers, but farmers are now using chemical fertilizers in farming.

Historically, the population was small and markets were few and nearer to the farmers, enabling consumers to get there and buy their needs. Farmers did not advertise, since people were close to them and knew their produce. But, as a result of population increase, and growth of villages and towns, new markets have emerged far from farming communities. So, farmers are forced to advertise their produce and travel on bad roads to distant markets with uncertain prices, to market their products.

The problems of advertising and communication, poor yields and market conditions are aggravated by massive demands for food and pressure of increasing farming activities in the limited soil, which is forcing farmers to use bush fires and chemicals to improve crop yields, while they are ignorant of the long-term effects of these practices on the soil.

Problem Statement

As a result of illiteracy and lack of ICT knowledge and equipment (caused by poverty, poor exposure and poor sensitization/awareness), the farmers adopt primitive methods, lack education/training and have inadequate communication with customers and consumers. Consequently, they are depleting the volcanic soil and frustrating themselves, as insufficient income is generated to meet their basic requirements.

Scope and Purpose of Research

The scope of the research reported here was to investigate the causes of poor farming methods, market conditions, education/training and communications among farming communities, with the purpose of obtaining solutions and educating farmers on sustainable organic farming methods and communication skills to promote/sustain their socio-economic activities to alleviate poverty, improve their community and protect their environment.
Through research in collaboration with technicians from the ministry of agriculture and forestry, Institute of Agricultural Research (IRA) Ekona Research Center and Limbe Botanic Garden, we discovered that poor yields are caused by burning of vegetation prior to planting. This may produce abundant yields in early seasons, but later produces poor yields, because soil saprophytes, earthworms, crickets, etc., and colloidal properties that replenish, aerate and enrich the soil are destroyed by fire.

For marketing, we discovered that if the farmers sell their produce on site, it solves the problems of distance, transportation and storage. However, there were still questions of market prices, advertising, weather and

pest control. ICT was introduced to answer these questions. The major problems were: which farming method should we introduce to farmers? Which ICT system(s) would be costeffective to buy, harness, maintain and run? What is the literacy level and ICT knowledge of farmers?

During the research, we discovered the most succinct statement about ICT for socio-economic development in The Economist (Anon., 2005): "the debate over the digital divide is founded on a myth—that plugging poor countries into the internet will help them to become rich rapidly … even if it were possible to wave a magic wand and cause a computer to appear in every house hold on earth, it would not achieve very much: a computer is not useful if you have no food or electricity and cannot read … Plenty of evidence suggests that the mobile phone is the technology with the greatest impact on development". This statement motivated us and we believe that this is the first documented experiment on using mobile phones and computer/Internet for agricultural/socio-economic development.

Evidently the sum total of ICT plus Information Dissemination (ID) is equal to Sustainable Development (ICTID4SD).

MATERIALS AND METHODS

Specific materials and ICT equipment are used, alongside costs-effective simple and friendly methodologies to accomplish the projects objectives.

Materials

The project used: demonstration farm land (10 hectares provided by Bokoko village authorities); agroforestry plants (for composting and fencing to protect the land from stray animals, intruders and to replenish the soil); and farming equipment. Computers connected to the Internet, smart camera–mobile phones for kiosks and 'dumb' mobile phones (capabilities limited to voice and SMS text messaging) for farmers.

Research Methodology

The research occurred in two stages. First, an ethnographic approach was taken to understand the farmers' level of education (i.e. reading and writing), and their knowledge of mixed (crop and livestock) organic farming, phone/SMS and computer/Internet use— we viewed agriculture not just as a process of production, but as a social practice involving interactions among farmers, administrators, extension officers and ICT operators.

This phase aimed to answer two questions: (1) how can we improve farming quality through mixed organic farming, computer/Internet and phone/SMS use? (2) What is the relative value of phones/SMS and computers/Internet compared to various other alternatives to improve agriculture?

Sample questionnaires were used to interview farmers and their families directly, to find out their level of education and communication skills—concerning reading and writing, understanding of organic farming methods, use of mobile phones and computers, and Internet access.

After a cost–benefit analysis, the second stage of the research proposed and implemented mobile phones and computers/Internet as the best combination of ICT systems to benefit farmers, villagers and communities.

Methodologies of Implementation

Farmers were trained in farm partitioning, mixed organic farming, intensive market gardening, and computer/Internet and phone/SMS use.

Project Layout

The demonstration farm was cleared and partitioned into four parts: 5 ha for the planting of perennial and biennial crops (maize, beans, etc.), 1 ha for the construction of poultry- and pig-raising facilities, 3 ha for growing cover crops, potatoes and other crops for animal feed and composting, and 1 ha for growing mushrooms and vegetables. Cleared vegetation from the land was used for composting.

Along the agroforestry and compost fences, the climber eru (Gnetum sp.) was planted, which is nutritious, medicinal, lucrative, economical, in great demand for consumption (nationally, regionally and internationally), endangered, protected and overexploited.

We used an existing SMS toolkit gateway solution, available via free download. It provides a simple PC-based programming interface (consisting of send/receive and process messages) to SMS, connected to an SMS sending/receiving port. We were able to develop a software solution for the project on top of the toolkit, written with only a few hundred lines of C# code. Technically, we used a PC connected to a server, one Windows Mobile Smartphone to provide our SMS sending/receiving port (called the server phone), the SMS toolkit software, our customized software, a number of kiosk Smartphones and farmers' 'dumb' phones for our operations. A General Service Mobile (GSM) card built into the PC could achieve the same functionality.

1. Agricultural Training. Agricultural technicians and forestry engineers from the agriculture and forestry ministries were responsible for training farmers, through demonstrations at the demonstration farm and practically on their farms, on the following: farm partitioning, mushroom cultivation, vegetables, perennials/biennials, eru, animals, construction and use of compost, shifting cultivation, bush fallowing, mulching, crop rotation, local production of animal feed from harvested plants, use of animal waste as manure, planting agroforestry plants along boundaries to protect the farm, replenishing the soil with their fallen leaves and to support the eru climber. The technicians and engineers followed up on the farmers' farms and evaluated them after every harvest.

2. Phone/SMS and Computer/Internet Training. Training is guaranteed and provided by partner organization PRACASS Information Technology Communication Empowerment Center (PICTEC) and other professional ICT volunteers.

Phone and SMS Training. The one-day training workshop always took place at PICTEC and the farmers and their children were trained on: making and receiving phone calls, sending, receiving and replying to SMS, and phone charging.

Computer and Internet Training. Taking into consideration farmers' and their children's level of education, training lasted for up to 6 months and concentrated on: Windows XP Professional, Microsoft Word, Microsoft Excel, Internet fundamentals, and importance of ICT in agricultural and community development.

Communication Strategy

Communication was achieved by the use of mobile phones/SMS linked to computers connected to Internet, e-mail, and radio and TV programmes. Farmers receive SMS messages daily direct from PICTEC (for those who have phones and via mobile kiosks for those without) on: market prices, crops and animals in high demand, weather conditions and pest control. The farmers are encouraged to always use SMS, since it is very cheap and often without charge.

The kiosks' camera–phones are used by farmers and communities to make and receive calls, send and receive SMS messages, and to photograph their produce (they send the images to customers/consumers as advertisements); and the kiosks' computers will in the future be used for a website and database. These services are paid for by farmers and community individuals to sustain the kiosks and project operations.

RESULTS

Sample Survey

Of the 180 families interviewed, 75% knew nothing about organic farming, 80% knew nothing about computers/Internet, 35% could use mobile (cell) phones (at least receive and make calls) and 25% had mobile phones. Some 90% of their children could use mobile phones and 35% access the Internet. So we settled on an SMS text-messagebased system and piloted it in seven villages and three urban poor communities in Fako Division.

Pilot Project

The pilot project is yielding impressive results, within just 2 years of operation (June 2006 to date). Of the 180 farmers (and five kiosks) we started with, 155 farmers are practising organic farming and growing mushrooms, eru, vegetables, perennials and biannuals, and animals on same piece of land, and are recording good yields and sales (bush fires are now very rare). Ninety-seven of the farmers can read and write, use computers and browse the Internet; 98 are using personal cell phones and 175 use mobile phones (personal phones or in kiosks). By 2008, there were 15 kiosks.

With simple coded SMS massages/beeps or per-second calls, farmers invite customers and report farm thieves on sight. With the customers/consumers buying at the farms, the problems of transportation, bad roads, perishability, market prices, congestion/frustration, unpredicted weather and consumers' demands are solved. Theft of farmers' produce has greatly reduced.
Villages are booming, as private phone booths, computer and Internet training centres have emerged; trucks come daily to transport produce and so create temporal employment, and there are job opportunities from phone kiosks, computer/Internet centres and farm labour, as farmers can now afford to pay for labour from their benefits.

Communication Strategy

Most of the farmers use the kiosks to make calls, since it's cheaper, and their cell phones to send and receive SMS to and from customers/consumers and PICTEC exchange centre. The kiosks are used as information centres (both by phone owners and those without phones), they hire smart phone services, photograph their produce and send the images to wherever required. Farmers also communicate easily with agricultural and forestry technicians through SMS for advice and to solve their problems.

DISCUSSION AND CONCLUSION

The project uses organic mixed farming and intensive market gardening, because they do not require a lot of land, are less polluting of the soil and environment, and do not destroy soil organisms and colloidal properties. Moreover, they replenish the soil naturally. They are easy to use, less expensive (than monocropping) and require little effort as the vegetation exists around the farms.

Cell phones are the best ICT instrument because they are portable, cost-effective, easy to use, and easy to charge/maintain. Computers/Internet is the media of choice (over radio/TV), because it is easy and access is free, there is an information database, no censorship, global connectivity, educational/socio-economic value, job opportunities, and it is cheap and fast for advertising and sending of messages.

From our results, it is evident that organic farming is highly productive, lucrative and environmentally friendly, as it does not pollute the environment, but replenishes and enriches the soil. Also the growth of the project (due to the communication strategy and the global use of mobile phone technology for agriculture/socio-economic development) is a clear indication of its successes. The popularity and successes of eChoupals in rural Madivya Pradesh (Kumar, 2004), Warana Unwired in India (Veerararaghavan et al., 2007) and other similar experiences, is thanks to mobile-phone technology linked to computers connected to the Internet. The impact of this project to farmers and the community can be judged from the result indicators.

Result Indicators

Result indicators are measured from the number of trucks or tonnes of produce they carry during harvesting seasons, number of farmers having phones, number of phone booths and Internet training centres locally, frequency of buying phone credits by farmers and kiosks, references to the project being successful (on radio and TV stations), growth of other economic activities in the community—all of these are positive. There are numbers of school dropouts going back to general education and technical school or to vocational institutions, increase in students, kiosk benefits, job opportunities, invitations from other farming communities to introduce the project to them, numbers of youths undertaking online education in various disciplines, and pressure from the community to develop a website and database for the project, create its own sustainable cyber café, and increase the services provided by the kiosks.

Conclusively, the advantages of organic farming are that it is non-pollutant, environmentally friendly, and soil-replenishing. And of mobile phones: durability of battery power and easy to charge, mobility, fast and easy to access at any time, cheap to buy and cost-effective to use, and global connectively of the Internet with its easy to access information.

Discussion and Future Work

VICTASUP successes demonstrate how organic farming and mobile-phone technology can sustain lasting socio-economic development. Considering domestic/global demands for safe energy and continuous involvement of ICT in daily activities, the future of safe energy and involvement of ICT in education and socio-economic development in Cameroon and Africa shall be initiated by VICTASUP.

1. Safe Energy. The numerous composts owned by farmers will be used in future to generate energy, from

gases coming from rotting vegetation, trapped and tapped by pipes connected beneath the composts, to a processing plant.

2. Expansion of ICT in VICTASUP. The mobile phone/computer and Internet connectivity with it's local, national and global demand and influence, will be used in future to develop a cyber café for the project with additional services like: voice-activated helplines, webcam, to be used for sustainable education, advertisement and marketing of produce, keeping farmers sales/income records, creating a co-operative to serve and loan scheme for farmers/community, website and database for the project.

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Waste and Environmental Management through Geospatial Information Technology for Agricultural Productivity

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Key words: dryland farming, maize, variable rate technology, waste management, environmental quality

Abstract

Recycling animal manure for crop production is a sustainable practice and has potential to enhance grain yield while improving soil quality. The objectives of this study were (i) to evaluate the influence of variable-rate manure applications on continuous maize fields under dryland cropping systems, and (ii) to further transfer the science to the society for public-health protection. This study was conducted on a dryland field on a fine-loamy, mixed, mesic Aridic Haplustalfs soil. Treatments included variable yield goal (VYG) manure application and VYG commercial N application across management zones. Experimental strips were 4.5 m wide and 540 m long spanned across all management zones, with treatments nested within management zones. VYG manure application based on soil productivity management zones has the potential to positively influence maize grain yield in low-productivity areas of fields over time. On historically low-producing areas of the field, manure application was able to produce higher grain yield than VYG N fertilizer application. The study suggests that VYG application of animal manure using geospatial information technology has a potential to improve soilfertility status and can be used in conjunction with synthetic N fertilizer for improving grain yield.

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INTRODUCTION

Historical Background and Situational Analysis

The world's population is growing by nearly 80 million people per year (United Nations Population Fund, 1999). At the start of the third millennium, there were almost three times as many people in Africa as there were in 1960 (Cohen, 2003), when Africa had less than half the population of Europe. In 2050, Africa may be approaching three times as many people again (United Nations Population Fund, 1999). Africa's share of global population is projected to rise to 20% in 2050 from only 9% in 1960. As the population increases, the demand for food correlates positively with population (Dyson, 1996). This growing population and demands for food products are chief driving forces for farmers to increase the scope of their farming (Lafferty, 2007). This population growth has seen most farmers completely disconnecting from organic farming in favor of conventional farming (Paull, 2006). The growth of human population and resultant increase in demands for animal products has led to an increase in concentrated animal feeding operations (CAFOs).

The costs to the environment associated with these operations are the chemicals contained within manure loads from these CAFOs. There is a large body of literature indicating that the chemicals and gases in manure can be noxious, not only to plants and animal life, but also to entire ecosystem. The byproducts of anaerobic degradation of the manure include gaseous compounds such as hydrogen sulfide, methane, ammonia, methyl mercaptan, as well as carbon dioxide. These gases pollute the air and can be a nuisance to those living nearby. These gases also have a detrimental effect on the atmospheric chemistry, ranging from nuisance brown clouds to global warming.

Livestock raising is an important contributor to the agricultural economy in most parts of the world. However, the impact of animal farms on the environment has come under close scrutiny (Giasson et al., 2002). The challenge is that most of these livestock farms are close to water bodies and pose a high risk of contaminating the environment through manure. The livestock farming industry has been facing a serious predicament of too much phosphorus (P) from excreted manure (Lory, 1999). The threat with manure P is that when P is eroded into water bodies it causes eutrophication in aquatic ecosystems (Sims et al., 1998). The water bodies become anaerobic, killing off aerobic organisms such as fish. Aerobic organisms are replaced by anaerobic organisms such as sulfur- and ammonia-producing microorganisms because of the development of algae (Amora- Lazcano and Azcon, 1997).

Current Dilemma

High transportation costs have led most animal operations to recycle animal manure on the same land or close to where manure was originally produced in order to meet nitrogen (N) requirements of the crops (Janzen et al., 1999; Kellogg et al., 2000). The challenge with manure applied to meet N requirements is that over time P may accumulate beyond crop requirements because the N:P ratio in manure does not correlate with the N:P requirements of the crops—there is always more P than crops can consume. When manure is applied uniformly or at excessive rates to soil, it may potentially degrade surface- and ground-water quality (Burkart and James, 1999; Smith et al., 2001a, b), and large piles of stored manure may result in related problems of environmental contamination. There is a need to identify alternative and perhaps more appropriate use(s) for manure.

Toward Sustainability

The successful development of sustainable and innovative agricultural techniques and methodologies are as much reliant on farmers' involvement as on scientific research. While researchers continuously seek innovative techniques for crop production, farmers provide views that are indispensable to the process of technology innovation and development. Geospatial information technology, which involves the use of remotesensing techniques, global positioning systems and geographic information systems, has been endorsed as a viable method for the management of waste and natural resources, and protection of the environment. The US Environmental Protection Agency (EPA) regulations under the Clean Water Act and concentrated animal feeding operations (CAFOs) are driving the need for improved record keeping and accountability of manure applications.

The objectives of this study were (i) to evaluate the influence of variable-rate manure applications on continuous maize fields under dryland cropping systems, and (ii) to further transfer the science to the society for public-health protection.

MATERIALS AND METHODS

The study was conducted on a farmer's dryland fields. Maize fields were mapped with Trimble Ag114 (Trimble Navigation Ltd, Sunnyvale, CA) differentially corrected Global Positioning System (DGPS). The gray-scale bare-soil satellite imagery of the fields was acquired. Using farmer's management experience and satellite imagery, site-specific management zones based on soil color were delineated using commercially available AgriTrak Professional software (Fleming et al., 2000). Management zones of high, medium and low productivity potential were delineated.

Before planting, soil samples were collected with a JMC Backsaver probe using systematic unaligned sampling design, and navigation to sapling points was done with GGPS and FarmGPS Software (Red Hen Systems Inc., CO). Manure was sampled at time of application. Animal manure was incorporated on the same day immediately after application. Soil and manure samples were analyzed for pH, electrical conductivity (EC), organic matter, total N, nitrates-N, and phosphorus. In addition, particle-size distribution of soils was analyzed.

Experimental strips spanned across all zones, with treatments nested within zones. The treatments for the study included variable-rate manure treatments using variable yield goal (VYG) manure management strategy of 22–67 t/ha of animal manure across management zones, and VYG commercial N fertilizer application based on soil analysis results. VYG nutrient application strategy is based on applying lower rates of nutrients on low-producing areas of the field and higher rates on highly productive areas of the field. The theory behind VYG is that lower yields are expected on low-producing areas and higher yields on historically high-producing areas.

RESULTS

Variable Yield Goal Manure Applications

In the first year of study, maize grain yields of 3.1, 2.9 and 5.1 t/ha were recorded on low, medium and high

management zones, respectively, with yield on high management zones being significantly ($P \leq 0.05$)higher than that on low and medium management zones. In the second year of study on the same field, grain yields of 5.4, 4.9, and 4.1 t/ha were harvested on low, medium and high management zones, respectively. Grain yield on low management zones in the second year of study was significantly higher than that of the high management zone.

Variable Yield Goal N Application

In the first year of study, grain yields of 3.3, 4.3 and 3.6 t/ha were harvested on low, medium and high management zones, respectively (no significant differences). In the second year of study, yields of 4.3 and 4.9 t/ha were harvested on low and medium management zones (no significant difference). Nothing was recorded on high management zone because maize was infected by corn smut.

DISCUSSION AND SCIENTIFIC CONCLUSIONS

The results of the study showed that VYG manure application based on soil productivity management zones has the potential to positively influence maize grain yield of low productivity areas of a field over time. On historically low-producing areas of the field, manure was able to produce maize grain yield of 3.1 and 5.4 t/ha in the first and second year of study, respectively. This increase in grain yield can be attributed to increased N, P and organic matter that manure supplies when applied to agricultural fields. In this study, manure was able to produce higher grain yield than commercial N fertilizer on the historically low-producing areas of the field. The study suggests that variable rate application of animal manure using global positioning systems has a potential to improve soil fertility status and can be used as an alternative to or in conjunction with synthetic N fertilizer for improving or maintaining grain yield. The good thing about applying manure on dryland fields in semi-arid areas is that there are few environmental concerns related to leaching and erosion.

Practical Conclusions and Transferring Science to Society

Animal-manure stocks are a growing concern to both the farming and non-farming public, because of the risk of eventual contamination of surface and ground water, nutrient and mineral toxicity of soil, and excessive odors from polluted air. In Africa, there is a gap between scientific research and transfer of knowledge to farming communities (Moshia, 2006). These scenarios demand that the scientific world take action. Environmental scientists have proposed easy steps for solving environmental problems: assessment or scientific analysis, risk assessment, public education, political action, and follow-through have been identified as such steps for solving environmental problems. Animal manure should be moved away from residential areas and water bodies, and taken to areas where it will not serve as a waste but as a resource. If taken to the field, animal manure may potentially supply crops with necessary nutrients and organic matter, thus improving soil health. The study suggests that use of geospatial information technology in applying animal manure is worth implementing. The key to this study project is to find the balance between agronomically and environmentally sound manure application.

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Differential Impact of Microfinance Participation on Smallholder Behavior and Livelihood in Rural Ethiopia

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Keywords: poverty reduction, technology use, asset poverty, Sub-Saharan Africa

Abstract

This paper argues that the impacts of microfinance on use of improved technology and on consumption vary across subpopulations differentiated by their asset holdings and structural transitions (or lack thereof). Correcting for sample selection bias and controlling for other household characteristics with data from rural Ethiopia, the analysis finds no relationship between household participation in microfinance programs and the use of modern technologies or consumption growth for the poorest households. In contrast, microfinance has a positive direct effect on consumption growth and an indirect effect through modern technology use for less poor households. The findings highlight the need to more carefully assess the diverse nature of constraints faced by different classes of poor agricultural households and show that recognizing target-group differences using asset-based poverty classifications can contribute to the development and evaluation of sustainable poverty-reduction programs.

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INTRODUCTION

Since the 1990s, Ethiopia has experienced economic growth and declining poverty rates. Nonetheless, the prevalence of poverty remains staggeringly high (Dercon, 2006). Faced with persistent rural poverty, the Government of Ethiopia, donor communities and nongovernmental organizations (NGOs) have increasingly sought to enhance farmers' productivity by increasing their access to and use of improved agricultural technology and non-farm enterprises. In addition to the actual development of agricultural technology, it is also important to have a clear understanding of the dissemination process of the new information and/or technology, as well as its adoption and use. Despite numerous interventions to promote innovation in Ethiopia, technology-adoption rates remain low (Spielman, 2007). Moreover, the impact of many technologies and interventions among the poorest households has not been assessed.

Innovation may be inhibited by lack of sufficient credit to acquire inputs and make necessary investments. Furthermore, underdeveloped financial markets that are not sufficient to allow consumption smoothing stifle the adoption of profitable innovations that could raise income variability. With direct gender implications, limited access to input and output markets and inadequate information on market prices or on the practice of new techniques can also constrain the adoption. By combining credit with training, microfinance institutions (MFIs) might provide households with access to new technologies and pathways out of poverty. While MFIs have spread rapidly in Ethiopia since the mid-1990s, little has been done to formally explore the mechanisms through which MFIs serve their beneficiaries, what types of poor households use their services, or how their impacts on technology use and consumption vary among poor households.

The terms and conditions of microfinance contracts are likely to imply differential access to their services across households with different poverty profiles. For example, joint-liability systems common in microfinance are likely to discourage participation by households that control very limited resources and whose income streams are more variable and therefore pose a risk for co-signers. Moreover, poor households with different asset bases could experience different returns from participation. Those with complementary assets or more capacity to absorb risk could find microfinance and new technologies allow a broader range of farm and non-farm opportunities than do other households. Thus, both access to microfinance and the payoff from investments could differ across households with different poverty profiles.

This research examines the differential impact of credit provision among farm households experiencing different degrees of poverty in rural Ethiopia. It considers the effects of farmer participation in microfinance programs on the use of new technologies and the impact of these technologies and finance on consumption growth. The paper considers three farm technologies (fertilizer use, chemical use and irrigation) and participation in non-farm enterprises, all of which could affect household income and be affected by microfinance. Because MFIs might enhance income directly by delivering other useful services, we consider the direct impact of microfinance participation on consumption growth, as well as its impact through technology adoption. Given that most MFI providers in Ethiopia highlight a focus on encouraging female participation, we also test for any gender bias in the use of MFI services. The analysis relies on an assetdynamics model to distinguish the poverty status of households[3]. Households were stratified on the basis of the persistence of their asset-poverty status over a 10-year period (1994–2004). Households were classified as 'always asset poor' if their estimated consumption based on their assets was below the

expenditure-poverty line in each survey year. Households whose asset base would predict consumption above this threshold each year were labeled 'never asset poor,' and those whose status varied from year to year were classified as 'transitory asset poor.' The always asset poor households are considered to have effectively been trapped in poverty from the initial period.

METHODOLOGY

Technology choice can be modeled as a constrained utility maximization problem for a household as characterized in Singh et al. (1986). As described by Sadoulet and de Janvry (1995), the solution to this problem yields reduced form specifications of demand for inputs and technologies and supply of outputs. Based on these reduced form specifications, this paper models participation in microfinance and its impact on household livelihood in a two-part procedure. The first step analyzes the impact of microfinance participation on use of technology and non-farm enterprises within each of the poverty classes considered. The second step estimates the impact of technology use and microfinance on consumption growth among households in each poverty class. 2 The asset-based measure used in this research was developed by a nonlinear regression of household consumption on its physical and human assets. This measure was constructed by the authors and has been compared (using various methods) to the traditional income measure used in the development literature. This measure was found to be more consistent in predicting the medium- and long-term poverty status of households. Following Zeller et al. (1997) and Vidovic and Khanna (2007), we control for potential endogeneity due to unobserved characteristics that could affect participation in MFI programs as well as technology choice, by estimating a variant of the standard sample selection model. Our technology use equation can be expressed as:

$$Pr(T U_{ikt}=1)_x = F((\alpha_A)_x + (\beta_A K_{it})_x + (\Delta_A Z_{it})_x + (\delta_A I_{it})_x + (\Delta_A T)_x + (\Delta_A V_t)_x + (E_{it})_x) \quad (1)$$

Where TU_{ikt} refers to the use of technology k by household i in period t and $Pr(T U_{ikt}=1)$ is the probability that household i uses technology k in period t; K is a vector of explanatory variables that determine a household's use of a technology such as market opportunities; Z is a vector of household demographic characteristics, I_{it} refers to household i'σ participation in a microfinance arrangement in time t, while T and V are time and village dummies to account for time- and village-specific characteristics that could affect a household's decision to use a particular technology. F is a nonlinear function of the explanatory variables assumed to be symmetric around zero and the Greek letters $\alpha A, \beta A, \Delta A, \delta A, \Delta A$ and ΔA are the coefficients associated with the previously defined explanatory variables. However, to address potential endogeneity, prior to modeling the use of modern technologies, we first estimated the following:

$$Pr(I_{it}=1)_x = F((\alpha_i)_x + (\beta IS_{it})_x + (_{\Delta}T)_x + (_{\Delta I} V_t)_x + (E2_{it})_x) \; i=(1,...,N) \; ; \; t=(1,...,T) \quad (2)$$

This formulation posits that we have a latent variable I*it capturing household utility from microfinance. Equation (2) states that a household's decision to participate in a microfinance program is based on some

[3] *The asset-based measure used in this research was developed by a nonlinear regression of household consumption on its physical and human assets. This measure was constructed by the authors and has been compared (using various methods) to the traditional income measure used in the development literature. This measure was found to be more consistent in predicting the medium- and long-term poverty status ofhouseholds..*

unobservable utility index which depends on a set of explanatory variables (S), as well as time - (T) and village - (V_i) specific effects. Actual participation (I_{it}) is observed as either one or zero, depending on whether the household participates or not. Observed participation, $I_{it} = 1 \text{ if } I^*_{it} > 0$ and 0 otherwise.

Directly estimating equation (1) will lead to simultaneity bias if the error terms, $E1_{it}$ and $E2_{it}$, are correlated as would occur when unobserved household variables affect both I_{it} and TU_{ikt}. To produce unbiased and consistent estimates of technology use, this paper uses the predicted probability of participation from equation (1) in estimating the technology use, equation (2) (Maddala, 1983; Zeller et al. 1997; Vidovic and Khanna, 2007). The second part of this analysis uses a fixed effects model of consumption growth to obtain consistent and unbiased estimates of the coefficients associated with modern technology use and microfinance estimation. This can be expressed as follows:

$$(\Delta Y_{it})_x = (\alpha_{Li})_x + (\beta_{L1} K_{it})_x + (\beta_{L2} Z_{it})_x + (\beta_{L3} A_{it})_x + (\beta_{L4} TU_{ikt})_x + (\beta_{L5} I_{it})_x + (E_{Lit})_x \qquad (3)$$

where $(\Delta Y_{it})_x$ refers to the change in per-capita consumption of household i in poverty class x between time t and t+1. Consumption $(Y_{it})_x$ is measured by log of household percapita consumption expenditure; α_{Li} is a constant term; K_{it} and Z_{it} represent vectors of control variables as used in equation 1, and A_{it} includes additional variables for the value of livestock, farm implements and miscellaneous household items; TU_{ikt} captures household use of technology k, and I measures household participation in a microfinance program. β_L is the vector of estimated parameters and E_{Lit} is the time and individual specific error term. It is assumed that E_{Lit} is an independent and identically distributed random variable with mean zero and variance $\sigma 2_E$.

RESULTS

Participation in Microfinance

Table 1 presents results from equation (1), which estimates participation by household i in a microfinance arrangement at time t. The chi-square test of this regression suggests that the instrument is valid. The results reveal that the determinants of participation vary across poverty classes. For example, female-headed households are less likely than male-headed households to participate in MFI among the never asset poor, but are more likely among the transitory asset poor households. Similarly, from the relative poverty variable we see that within the always asset poor and the never asset poor classes, lower-income households are less likely to participate in microfinance programs. However, lower-income households among the transitory asset poor are more likely to get microfinance support[4]. The coefficients on the time variables in Table 1 indicate increasing participation from 1994 to 1999 for non asset poor households and from 1999 to 2004 for households in all poverty groups. This increase in participation is consistent with governmental and NGO promotion of microfinance since the 1990s. On average, larger households and households with younger household heads are more likely to participate in microfinance programs.

[4] *Due to lack of explanatory power for the transitory asset poor class, participation in Food For Work (FFW) within that class was used as an indicator of relative poverty status rather than the household belonging to the lower third of the distribution of assets used in the other groups. This might explain the positive relationship seen in Table 1, which is believed to be partially driven by the fact that households receiving support in the form of FFW could be more likely to also receive other forms of assistance such as access to credit.*

Table 1. Random effects probit estimates of microfinance (MFI) participation

MFI Participation	Always Asset Poor		Never Asset Poor		Transitory Asset Poor		All Households	
	Coef.	P>z	Coef.	P>z	Coef.	P>z	Coef.	P>z
HH size	0.08***	0.01	0.09***	0.00	0.10***	0.00	0.09***	0.00
Male head	–0.16	0.35	0.21*	0.09	–0.43**	0.01	–0.07	0.42
Relative poverty	–0.57***	0.00	–0.215**	0.05	0.27**	0.08	–0.45**	0.00
1999	0.200	0.27	0.661***	0.001	0.23	0.18	0.38***	0.00
2004	0.74***	0.00	1.72***	0.00	0.54***	0.00	1.10***	0.00
Constant	–1.90***	0.00	–2.61***	0.00	–1.55***	0.00	–1.74***	0.00
No. observations	380		483		352		1215	
Prob>χ^2	0.00		0.00		0.00		0.00	
Pseudo R^2	0.20		0.25		0.19		0.21	

*Notes: Village dummies and other controls were included in the regression but were not reported for space consideration; The dependent variable is household (HH) participation in a microfinance program; *=significant at 10%, **=significant at 5%, ***=significant at 1%. Coef. refers to the coefficients associated with the explanatory variables and P>z refers to the probability of getting a z statistic at least as extreme as obtained from our data if our coefficients were insignificant.*

Technology Use and Participation in MFI

Table 2 summarizes the effect of MFI participation on technology use and participation in non-farm enterprises across different poverty classes. It reveals that participating in microfinance has no effect on fertilizer, chemical or irrigation use for the always asset poor. Compared to 1994, always asset poor households who took loans were less likely to use fertilizer in 1999 even though average fertilizer use in this group was higher in 1999 than in 1994. It appears that when taken, microfinance loans were not used for fertilizer by participants in this poverty class. In contrast, for the never asset poor, household participation in a microfinance arrangement positively and significantly affected use of the various technologies. On average, MFI participation among the transitory poor had no effect on their behavior. However, it was negatively associated with participation in non-farm enterprises. Given that the poorer members of this group were more likely to participate in MFI, this indicates that these households were also less likely to use loans for engaging in non-farm enterprises.

Table 2. Random effects estimates of the impact of participation in microfinance (MFI) on technology use with bootstrapped errors

Modern Technology	Always Asset Poor			Never Asset Poor			Transitory Asset Poor		
	MFI	MFI 1999	MFI 2004	MFI	MFI 1999	MFI 2004	MFI	MFI 1994	MFI 2004
Fertilizer	–3.3	–7.5**	1.8	38.0***	–16.5	–37.6	–0.1	2.0	–2.4
Irrigation	6.9	–10.8**	–1.5	70.2***	–50.1***	–63.2	4.2	–6.6**	–2.1
Chemicals	–4.1	8.8**	4.7	34.6***	–26.3***	–33.2	–1.9	2.6	0.6
Non-farm enterprises	6.1	–8.3	–3.9–	5.2	2.8	5.3	–9.5*	2.8	9.0**
N	380			483			352		
Prob > χ^2	0.00			0.00			0.00		

*Notes: MFI is a dummy variable which is equal to 1 if a household took a microfinance loan and 0 otherwise. MFI 1999 and MFI 2004 are variables that interact the MFI variable with a time dummy for 1999 and 2004 to account for both the direct effect of MFI and changes in the effect of MFI over time. Village dummies and other controls were included in the regression but are not reported. The dependent variable is household use of modern technology; *=significant at 10%; **=significant at 5%; ***=significant at 1%.*

Consumption Growth

The ultimate goal of microfinance programs and improved technology is to increase farmers' incomes. Considering growth in consumption expenditures, results from the fixed effects estimation of equation (3) reveal that technology practices and microfinance programs have different effects on wellbeing across the different poverty classes. Table 3 shows that among the always asset poor, participation in microfinance services had little direct effect on consumption change. Similarly, coefficients on technology use were largely insignificant for this group. The only variables that were positively and significantly associated with change in household consumption were participation in wage labor and non-farm enterprises. Compared with 1994, taking a loan was less likely to increase household consumption in 1999. As expected, household size was negatively associated with increased household consumption.

Table 3. Fixed effects estimation of consumption growth with bootstrapped standard errors

ΔIn consumption expenditure per capita	Always Asset Poor		Never Asset Poor		Transitory Asset Poor		All households	
	Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.	P>t
Household size	–1.1***	0.00	–1.2***	0.00	1.4***	0.00	–1.2***	0.00
Wage labor	0.46***	0.00	0.07	0.63	0.52**	0.05	0.32***	0.00
MFI participation	–0.01	0.96	0.35**	0.05	0.43	0.15	0.23*	0.08
Fertilizer use	–0.04	0.84	0.28*	0.06	0.20	0.33	0.15*	0.10
Irrigation	–0.04	0.86	–0.17	0.35	–0.13	0.65	–0.14	0.25
Other chemicals	0.09	0.56	0.38***	0.00	0.30**	0.05	0.20**	0.02
Non-farm enterprise	0.59***		0.64***	0.00	0.141	0.87	0.30***	0.00
N	380		483		352		1215	
Prob>F	0.00		0.00		0.00		0.00	

*Notes: **Δ**In consumption expenditure per capita refers to household consumption per-capita growth between time t and t+1; Coef. refers to the coefficients associated with the explanatory variables and P>t refers to the probability of getting a t statistic at least as extreme as obtained from our data if our coefficients were insignificant; Prob>F gives the probability of observing the F statistic we got from our model if the R2 in the population was actually equal to zero; *=significant at 10%, **=significant at 5%, ***=significant at 1%.*

Table 3 shows that technology use was an important determinant of consumption growth among the never asset poor households. Fertilizer use, chemical use and engaging in a non-farm enterprise all positively contributed to household consumption. Furthermore, participation in microfinance directly contributed to increasing household consumption. These results indicate that, apart from influencing the use of modern technology, microfinance programs offer other services that benefit rural households in this poverty class. For the transitory asset poor, participation in microfinance appears to have some direct impact on consumption. On average, the relationship appeared to be positive, but was only 'significant' at 15%. Chemical pesticide use was also positively associated with increased household consumption for this group. As can be seen in the last column of Table 3, regression results from pooling the entire sample of households would have obscured the true drivers of consumption growth.

DISCUSSION AND CONCLUSIONS

This research found that microfinance programs in Ethiopia have had some positive impact on farmers' livelihoods. This impact can be seen in the role that microfinance programs play in the use of various improved technologies and in their measured impact on consumption growth when controlling for technology use. The study found that this impact is not uniformly distributed, and is strongest for the never asset poor. Participation in microfinance programs is more likely to lead to technology use for these households. Modern technologies are for the most part significantly associated with consumption growth for the never asset poor and the transitory asset poor, but not the always asset poor. Since even the never asset poor households in this sample generally had very low absolute incomes, reaching them is a valuable achievement. Households classified as always asset poor, however, did not appear to benefit from microfinance programs. The study found no evidence of gender discrimination in the use of microfinance

services among the poorest households. However, among the least poor households, male-headed households were more likely to participate in microfinance programs than female-headed households. Meanwhile, among the transitory asset poor households, there appeared to be some effective targeting by microfinance programs as female-headed households were more likely to participate; as were the relatively poorer households in that group.

The impact of improving agricultural technologies appears to be greater among the less poor households, who might have more long-term potential as efficient producers. The poorest households do not appear to benefit from their use at all. This might be economically rational given the level of their poverty, but requires further exploration. Food-for-work programs or other similar interventions could enable the poorest households to avoid the depletion of their meager assets and build capacity for the potential use of modern technology practices in the future. Alternatively, other interventions could be implemented to enable diversification out of farming. In any case, having multiple programs side by side may be an effective way to alleviate different forms of poverty.

Non-farm enterprises had a significant and positive effect on consumption growth for all classes of households, but microfinance programs did not appear to play a role in household participation in these activities. Expanding the use and effectiveness of improved technology practices, as well as non-farm enterprises, necessitates understanding why poorer households are not apparently benefiting from microfinance institutions or existing technology enhancements.

In addition to revealing the differential impact of institutional interventions on rural farmer behavior and livelihood, this study shows why recognizing target-group differences (e.g. using asset poverty typologies) is an important consideration in program development as well as program evaluation. Not only does it inform the development of appropriate strategies for different kinds of households, but it prevents wrong assessment of government and other development programs.

In much of the evaluation of microfinance programs, focus is placed on recovery rates and number of people served by the program, with little attention placed on the possible differences among participants. As seen from this study's results, a failure to distinguish between participants would have led to the conclusion that MFI had little or no effect at all on modern technology use. However, we find that this is not the case for the relatively better-off households who actually benefit from this service. Similarly, it would have revealed that microfinance programs had a direct positive effect on consumption growth, while we see that this is not the case for the poorest households. Consequently, a conclusion about the success or failure of a program evaluated without distinguishing its effects on different kinds of poor households could be misleading.

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Participatory Development of Improved Groundnut Varieties for East and Southern Africa

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Keywords: breeding, early leaf spot, groundnut rosette disease, Malawi, resistance, Tanzania

Abstract

In Malawi and Tanzania, groundnut production is constrained by diseasesand pests. Scope exists for raising productivity to over 1.0 t/ha on farmers' fields from current levels of 0.4–0.7 t/ha, if farmers are empowered to use available technologies and knowledge. This research utilized varied techniques, including a baseline survey, participatory varietal selection and on-station research, in Malawi and Tanzania to develop high-yielding farmer- and market-acceptable short- and medium-duration groundnut varieties with resistance to foliar diseases. For improved seed production, farmers in both countries were involved in groundnutseed multiplication activities during 2006/07 to strengthen capacities. Results of the baseline survey suggested key interventions, including seed supply, marketing services and extension services. Results from the on-station work revealed three potential new sources of resistance to groundnut rosette disease from a groundnut minicore comprising 192 lines representing the full range of trait variability in the groundnut collection (ICG 6888, ICG 13099 and ICG 14705). Seed-production plots were established on farmers' fields. A total of 1.7 tonnes of variety 'Nsinjiro' and 32 tonnes of variety 'Pendo' were produced. The multi-institutional partnership for technology uptake included farmers, community leaders, researchers and extension agents, and private-sector traders and processors.

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INTRODUCTION

Sub-Saharan Africa is the only region in the world in which per-capita food production has continued to decline since the early 1990s (FARA, 2003). Nutritional deficiencies remain a major concern, with close to half of the children under 5 years old in rural areas of Malawi (49%) and Tanzania (40%) malnourished to such a degree that their development is retarded. Groundnut is high in both protein and oil. However, groundnut productivity remains low (0.49t/ha in 2007; FAO, 2007) due to inadequate use of improved varieties, diseases, pests, poor crop husbandry and poor seed, among others. Foliar diseases are generally considered the major constraint to increased groundnut production. Groundnut rosette disease (GRD), endemic to the African continent (Zimmerman, 1907), induces losses of up to 100% in many fields (Naidu et al., 1999b). The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) estimates losses of US $50–89 million (€38–67 million) each year from GRD alone (Waliyar et al., 2007). Leaf diseases can be controlled by timely applications of fungicidal sprays, but cost of fungicidal application is prohibitive for small-holder farmers, and there is an environmental risk (Naidu et al., 1999a). Therefore, use of resistant crop cultivars provides the most appropriate means of disease control, being easily incorporated into farmers' operations at little extra cost. The objectives of this study were thus to (a) develop with farmers high yielding farmer- and market-acceptable short- and medium-duration groundnut varieties with resistance to foliar diseases; and (b) enhance adoption rates of improved farmer- and market-acceptable varieties in Malawi and Tanzania.

MATERIALS AND METHODS

On-station Trials

Subsequent to a baseline survey, multi-site pedigree breeding and selection were undertaken in disease hotspot locations using improved, local and wild germplasm with farmers' participation. The breeding and selection was aimed at increasing the frequency of desirable alleles for disease resistance, stress resistance, and productivity. Breeding populations at ICRISAT (Chitedze, Malawi) and Naliendele Agricultural Research Institute (NARI, Tanzania) were selected for resistance to diseases and abiotic stresses as initial parents for the breeding programme. Participatory variety selection for acceptability in both countries was undertaken on farm in both countries, and those meeting farmer and/or market criteria were intercrossed to accumulate genes for higher levels of resistance and other useful characters. Selection using the infector-row technique (Bock and Nigam, 1989; Subrahmanyam et al., 2001) was conducted at sites representing the principle agro-ecologies, under disease pressure, to select for resistance to GRD and leaf diseases. Further segregating populations were screened for resistance to GRD, early leaf spot (ELS) and rust in three long disease nurseries with plots of three rows of 6 m, spaced 75 cm apart, with 10–15 cm between plants, using infector-row technique in Latin-square design. Advanced breeding lines were evaluated in replicated plots at several locations under different disease pressures.

Capacity-building

Concurrently, research capacity for groundnut improvement was enhanced among the participating partners (farmers and researchers) through training in seed production and disease management practices, and exchange visits following training needs assessments. Farmers in Malawi and Tanzania were involved in groundnut seed multiplication activities during 2006/07. Thirty-six demonstrations were held on

farmers' fields to support adoption of improved varieties and practices. Sets were planted in a randomized complete block design in four replicates (4 farmers) with each plot consisting of four rows 20 m long spaced as per other plots (see above). The multi-institutional partnership for technology uptake included farmers, community leaders, researchers and extension agents, and private-sector traders and processors.

RESULTS

In the baseline surveys, respondents in Malawi cited inadequate finances for inputs and unfavourable climate as the key crop production constraints (Table 1). Others cited unavailability of seed for crops, lack of management skills and unfavourable soil for crops as the key constraints. Groundnut marketing constraints were reported to be low prices, uncalibrated weighing scales and lack of credit. Respondents suggested key interventions as seed supply, marketing services, and extension services.

Table 1. Production constraints identified by farmers in Malawi and Tanzania

Constraint	Percentage of respondents citing (n=613)
Inadequate finances for inputs	32.5
Climate unfavourable for the crops	27.4
Unavailability of seed for the crops	12.9
Lack of management skills	7.7
Low food/cash value of the crops	5.5
Unavailability of labour	5.2
Soil unfavourable for the crops	4.6
Don't know	4.2
Pests and diseases	2.9
Lack of market	2.8
Lack of fertilizer/unavailability of fertilizer	1.0
Unavailability of land	0.3
Lack of extension services	0.3
Low-yielding varieties	0.2
Late planting	0.2

In Tanzania, farmers considered prevalence of pests and diseases to be the major limitations in groundnut production. Analysis of groundnut variety preferences indicated high preference ratings for variety Pendo, followed by Nyota, Johari and Sawia. According to this study, at least 30% of households' total cultivated area was under groundnuts. Average farm area of groundnuts per household was about 1.5 acres (0.6 ha). At least 50% of the household groundnut farms in the studied villages in Masasi were under improved varieties.

Results from the on-station work revealed three potential new sources of GRD resistance from a groundnut

minicore comprising 192 lines representing the full range of trait variability in the groundnut collections. The new sources are ICG 6888, ICG 13099 and ICG 14705. From the 16 nurseries (F5–F6 in 394 progeny rows), a total of 242 plants were identified for generation advance through single-plant selection (61% of the total number of plants). From these, we identified 73 single-plant selections (from seven of the nurseries) with 0% GRD incidence (18% of the progenies) and an additional 68 plants with rosette incidence of less than 20%. From among 239 F7 progeny rows, 163 lines were identified for promotion to check-row yield performance trials (68%) (Table 2).

From the participatory varietal selections in Tanzania, preference ratings from onfarm trials indicated farmers' preference for ICGV 99555 and ICGV SM 99557. The two varieties showed high yield compared to Pendo, the currently released variety. Other farmer preferred varieties in Tanzania were Nyota, Johari and Sawia. In Malawi, the most farmer/market-preferred varieties were Chalimbana, CG7 and JI24.

Table 2. Results of single-plant selection (SPS) programme for segregating breeding populations in F5–F7 in the rosette disease (GRD) nursery, 2006/07 season, ICRISAT Chitedze Research Station (Malawi)

Nursery	Progeny Rows Planted	No. Single Plants selected	Entries with 0% GRD Incidence Incidence	Entries with <20% GRD
GRV res & conf (virg)-F5SPS	38	33	6	6
Aphid res & conf (virg)-F5SPS	50	34	5	9
GRV res & bold seeded-F6SPS	49	25	12	5
Aphid res × ELS res-F6SPS	129	65	6	33
GRV res × ELS res-F6SPS	53	35	20	6
Aphid res × GRV res-F6SPS	30	13	2	5
GRV res & conf-F6SPS	45	37	22	4
Aphid res backcrosses-F7SPS	29	13	0	4
Aphid res-F7SPS	44	27	0	5
Aphid res inheritance-F7SPS	17	8	0	0
Aphid & GRV res-F7SPS	27	15	0	3
GRV inheritance-aphid × GRV-F7SPS	8	6	2	1
GRV res &dormancy-F7SPS	36	31	2	8
GRV res -F7SPS	46	31	3	6
GRV inheritance-F7SPS	9	9	8	0
Dormancy & GRV res-F7SPS	23	23	0	2

conf = Confectionary; ELS = early leaf spot; GRV = groundnut rosette virus; res = resistance; SPS = singleplant selection; virg = Virginia.

Results of the demonstration trials indicated significant differences in pod and kernel yield. For Virginia

varieties, ICGV-SM 90704 was the most preferred, yielding 1281 kg/ha, while ICGV-SM 99568 (Chitala, a Spanish variety) was the overall preferred genotype across sites with a yield of 1461 kg/ha. Among the elite lines in the pipeline, ICGV-SM 01513 featured in the top four preferred varieties of the 10 tested varieties. Chalimbana ranked poorly compared to the 2006/07 growing season, producing a kernel yield of 819 kg/ha.

Technology communication was also undertaken through farmer field days, seed fairs and meetings. Nine farmer field days (with 393 stakeholders participating) were conducted in Malawi and two in Tanzania (171 farmers) to popularize and disseminate promising groundnut production technologies to farmers and collaborating stakeholders. Two seed fairs (over 2000 participants) were held in Tanzania. In addition, a poster was presented at the Fourth Forum for Agricultural Research in Africa (FARA) Meeting in Sandton, South Africa.

DISCUSSION

There is large potential for improving farmer incomes through increasing groundnut production that has yet to be exploited. Although farmers ranked variety Chalimbana poorly based on criteria provided, it remained popular among farmers for its large kernels. Farmer ranking shows a growing inclination towards Spanish varieties. The short rainy season experienced in these benchmark districts had a significant negative effect on the yield of long-duration varieties, especially Chalimbana. Other farmer preferences could partly explain the continued cultivation of traditional, low-yielding varieties. Unfortunately, in Malawi, the farmer/market-preferred varieties (Chalimbana, CG7 and JL24) are susceptible to all major diseases—GRD, ELS and rust—underlining the need to continue introgression of disease resistance into these farmer-preferred lines. Farmers are aware that use of improved and adapted varieties significantly increases yields, but we believe various other factors, such as poor access to improved seed, remain a constraint, highlighting the need to improve access to seed through seed production and dissemination of improved varieties. Increasing access to improved groundnut varieties (with better disease resistance, yield performance and market acceptability) must be coupled with adoption of improved crop husbandry techniques and accompanying access to markets for significant strides to be made.

At Chitedze (Malawi), the GRD pressure was high, resulting in over 90% infection in the spreader rows and susceptible checks. Observed resistant progenies were to a great extent reflective of genetic resistance in the populations. Two modes of resistance to GRD have been confirmed (Bock et al., 1990). The first is resistance to groundnut rosette virus (GRV, available in ICGV-SM 90704) and the second is resistance to the aphid vector (available in ICG 12991). The resistant lines identified in this study go a long way in boosting sources of resistance to GRD. Further confirmation of the value for these lines will be done through greenhouse experimentation.

CONCLUSION

The findings of this research demonstrate that farmers are able to effectively participate in plant breeding programmes. Farmers' identification of susceptible genotypes correlated well with researchers' results for disease attributes. The findings also indicate that use of on-farm demonstrations can be an important tool in

the evaluation process to ensure that input from farmers is obtained. The screening of genotypes on farm further facilitates identification of possible parents that combine disease resistance, acceptability and adaptability to the local growing conditions. It is hoped that this will increase the adoption of improved groundnut production technologies, as farmers' preferred traits would be incorporated into current and future breeding programmes. Promotion of integrated disease management strategies, such as early planting, use of resistant varieties, and correct plant spacing, should be intensified, promoted and popularized among smallholders through field days and demonstrations, to increase awareness among the smallholder farmers. The findings from this work underscore the importance of farmers in participatory plant breeding.

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Morphological Characterization of Tomato (Lycopersicon esculentum) Germplasm in Ghana

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Keywords: diversity, TYLCV, breeding, determinate, indeterminate, descriptor list, varieties

Abstract

The low diversity of tomato varieties in Ghana coupled with numerous pests and diseases, poses a serious threat to tomato production in the country. Recognizing the importance of the crop to the economy made it necessary to collect and characterize available germplasm from Ghana and beyond as a first step to its improvement. Twenty-eight accessions of tomato were assessed for morphological traits using the World Vegetable Center (AVRDC) descriptor list. The experimental design was a randomized complete block with two replications. Data were collected on plant growth habit, leaf attitude, leaf type and exterior color of immature and mature fruit, fruit shape and brix (sugar level). The AVRDC and International Seed Company (ISC) lines were generally uniform within accession for all the characters observed, while the Crops Research Institute (CRI) and local lines showed variation. It was also observed that the AVRDC lines could be stored for many days. Almost all the accessions showed symptoms of Tomato yellow leaf curl virus (TYLCV), with some of the CRI materials and the local material generally indicating some degree of tolerance to the disease.

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INTRODUCTION

Tomato is one of the most commonly grown vegetables in the world (Tweneboah, 1998). It is a naturally self-pollinated crop with only 4% outcrossing (Hanson, 2005). It also has the ability to survive in diverse environmental conditions (Rice et al., 1987). It is a very important and popular vegetable crop in Ghana, consumed on a nearly daily basis by every Ghanaian household (Horna et al., 2006). The fruit has high levels of vitamins A, B, C and E, and nicotinic acid (Davies and Hobson, 1981). More money is spent on tomato than on any other vegetable (Wolff, 1999). Tomatoes are eaten in fairly large amounts as flavoring in stews and soups, and in raw state in pepper sauces and occasionally in salads. Its economic importance is further reflected in the increasing quantities that are being processed by factories into secondary products such as tomato paste, tomato puree and ketchup.

Despite tomato's importance in Ghana, local production is not able to meet the domestic demand and tomatoes are often imported, mainly from Burkina Faso. This situation is attributed to a number of constraints in the tomato production and marketing chain. At the farm level, biotic and abiotic stresses limit yield increases. There are a number of pests and diseases that affect tomato production in Ghana. Climatic stress is another limiting factor to tomato production in southern Ghana. The low diversity of varieties also poses a serious threat to Ghanaian tomato production, because there are not enough materials that are resistant to the pests and diseases. Previous work on tomato in Ghana has concentrated on agronomic problems. This has not had any significant impact on the tomato industry or marketing chain. Recognizing the importance of the crop to the economy made it necessary to collect and characterize available germplasm in Ghana and beyond as a first step to its improvement. The objective of this study was therefore to characterize lines collected from Council for Scientific and Industrial Research Crops Research Institute (CSIR-CRI) Ghana, World Vegetable Center (AVRDC, Taiwan) and International Seed Company (ISC, Taiwan) for use in future breeding work.

MATERIALS AND METHOD

Twenty-eight accessions of tomato were assessed for differences in morphological traits: 5 accessions from CSIR-CRI; 17 accessions from AVRDC; 5 accessions from ISC (Green Seeds) and a local landrace (Bibiani pimpilifolium) (Table 1).

The study was carried out in the major and minor cropping seasons of 2006 at the Kwadaso station of CSIR-CRI, Kumasi. A randomized complete block design with two replications was used. The number of replications was limited to two due to limited quantity of seeds for most of the accessions. A single row 3 m long spaced at 0.6 m between and 0.3 m within rows constituted an experimental plot. Seedlings from each accession were transplanted 3 weeks after sowing. Standard agronomic practices such as weed control, fertilizer application (250 kg of 15–15–15 NPK/ha) and watering were adopted. An AVRDC descriptor list (AVRDC, 2001) was used in scoring characters. Data were collected on plant growth habit, leaf attitude, leaf type and exterior color of immature and mature fruit, fruit shape and brix (sugar content). The Numerical Taxonomy and Multivariate Analysis System (NTSYS version 2.11s; Rohlf, 2000) was used to produce a dendrogram showing the distinct clusters among the 28 accessions characterized.

RESULTS

In general, the AVRDC and ISC lines were uniform within accession for all the characters observed, while the CSIR-CRI and local material lines segregated. The AVRDC materials also had a long shelf life. Almost all the accessions showed symptoms of Tomato yellow leaf curl virus (TYLCV), with some of the CSIR-CRI materials and the local material indicating some degree of tolerance to the disease.

Vegetative Characters

1. Growth Habit (Fig. 1). Just over a third of the AVRDC accessions were dwarf type (CLN2623A, ARP365-1, PT4722A, ARP365-2-5, CLN14668 and CLN2070A). A little under half (42.9%) of the AVRDC accessions were determinate (CLN1621C, CLN2679C, PT 4664, CLN1462A, CLS4915.206 and CLN2545B). The remaining (21.4%) AVRDC accessions were semi-determinate.

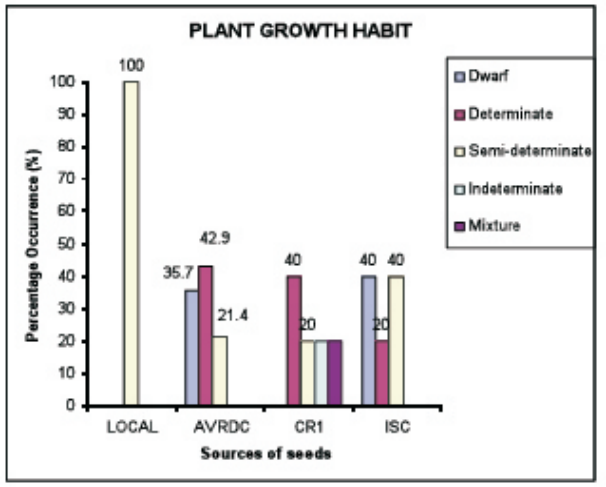
Forty percent (40%) of the CRI accessions (WS273.3 Large and WS White) were determinate, while semi-determinate (WSP27F7(3)P2), indeterminate (WSP27F7(3)P3) and a mixed (WSP2F7(3)P3) type accounted for 20% each. Forty percent (40%) of ISC accessions were of the dwarf type (KT002 and KT003), 40% were semi-determinate (TF1C1and TF2C4), and one ISC accession (20%) was determinate (TF2T1).

Table 1. Vegetative and fruit characters of accessions studied

Group	Accessions	Source	Leaf Attitude	Leaf Type[1]	Fruit shape	Immature Fruit Colour	Mature Fruit Colour	Brix
A	Bibiani pimpilifolium	Local	Semi-erect	6	Slightly flat	Light	Red	5
	CLS4915.206	AVRDC	Drooping	5	High round	Light	Green	5.2
	ARP365-1	AVRDC	Drooping	5	Round	Light	Green	5
	WS White	CRI	Mixture	5	Round	Light	Green	5
	CLN14668	AVRDC	Drooping	5	High round	Light	Green	2.2
	Kt002	ISC	Semi-erect	5	High round	Light	Green	5
	WS273.3 Large	CRI	Drooping	3A	High round	Light	Green	5
	ARP365-2-5	AVRDC	Drooping	5	Round	Light	Green	5
B	PT4664	AVRDC	Drooping	3A	Heart-shaped	Light	Green	6
	TF2T1	ISC	Drooping	2C	Heart-shaped	Light	Green	6.2
	CLN2026D	AVRDC	Semi-erect	3A	Heart-shaped	Light	Green	6
	KT003	ISC	Semi-erect	3A	Plum-shaped	Mixture	Green	6
	Ch154	AVRDC	Drooping	5	Plum-shaped	Mixture	Green	6
	CLN2498D	AVRDC	Drooping	3A	Plum-shaped	Mixture	Green	6
	WSP27F7(3)P2	CRI	Semi-erect	5	Slightly flat	Light	Green	6
	WSP27F7(3)P3	CRI	Mixture	5	Slightly flat	Light	Green	6
	TF1C1	ISC	Drooping	5	Slightly flat	Light	Green	6
	CLN2070A	AVRDC	Drooping	3C	Plum-shaped	Mixture	Green	5
	WSP2F7(3)P3	CRI	Mixture	5	Mixture	Light	Mixture	5.8
C	CLN1621C	AVRDC	Drooping	5	Round	Light	Green	6
	CLN2679A	AVRDC	Drooping	5	High round	Light	yellow	6.5
	PT4722A	AVRDC	Drooping	5	High round	Light	Green	6.5
	CLN2545B	AVRDC	Drooping	5	High round	Light	Yellow	6.7
	CLN1462A	AVRDC	Drooping	3A	High round	Mixture	Green	6
	CLN2679C	AVRDC	Drooping	3A	High round	Light	Green	8
	CLN2545A	AVRDC	Semi-erect	3A	Round	Light	Yellow	8
D	CLN2623A	AVRDC	Drooping	5	Plum-shaped	Light	Green	7
	TF2C4	ISC	Semi-erect	5	Pear-shaped	Mixture	Green	7

[1] *See Fig. 3.*

Fig. 1. (a) Plant growth habit of accessions; (b) determinate (above) and indeterminate (below) growth habits

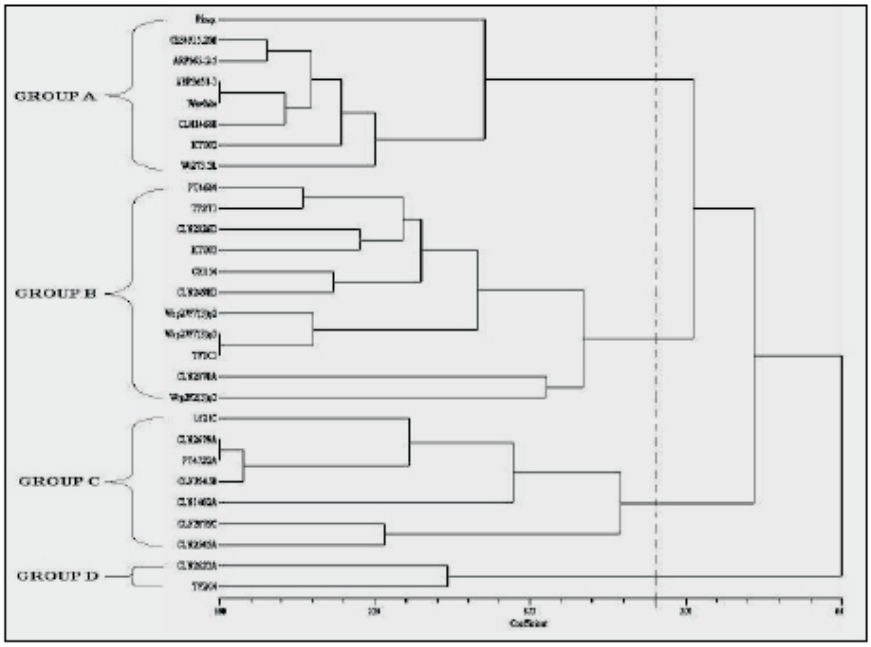


(a)

(b)

2. Other Characteristics (Table 1). Over half (57.1%) of Group A accessions in the dendogram (Fig. 2) had drooping leaf attitude, while 28.57% of the same group had semierect leaf attitude (Table 1). Six leaf types were observed within the population (Fig. 3). The leaf types in group A were 5, 3A and 6 comprising 71.4%, 14.3% and 14.3%, respectively.

Fig. 2. Dendogram produced from Numerical Taxonomy and Multivariate Analysis System based on vegetative and fruit characters



In group B, 54.5% had drooping leaf attitude, and leaf types 5, 3A, 2C, 3C were represented by 45.5%, 36.4%, 9.1% and 9.1%, respectively (Fig. 3; Table 1).

In group C, 85.7% had drooping leaf attitude, with 14.3% semi-erect. Leaf types were 5 and 3A, represented by 57.1% and 42.9%, respectively.

In group D, where there were only two accessions, there was one each of drooping and semi-erect leaf attitude. Only leaf type 5 was represented in this group.

Fruit Characters

Six fruit shapes were present in the accessions characterized (Fig. 4).

Over half (57.1%) of the accessions in group A had high round fruits, and 14.3% were slightly flattened (Table 1). The immature fruits of accessions in group A were all light colored; 85.7% being green at maturity, and 71.4% having a brix of 5.

Over a third (36.4%) of the accessions from Group B had plum-shaped fruit, with just over a fourth (27.3%) each heart-shaped and slightly flattened. Almost half (45.5%)

Fig. 3. Various leaf type of tomato (AVRDC, 2001)

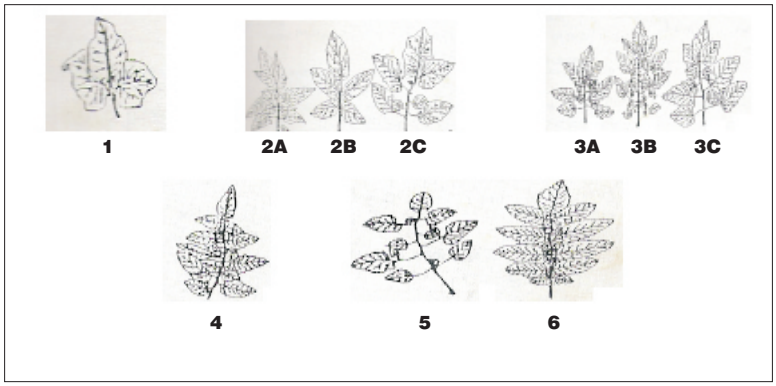
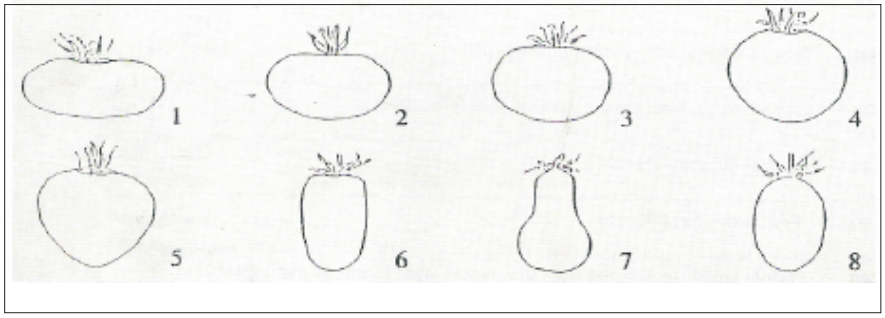


Fig. 4. Different fruit shapes within tomato accessions studied (AVRDC, 2001)



had light immature fruit color in this group, while 90.9% had green mature fruits, and 72.7% had a brix of 6.

Nearly three-fourths (71.4%) of accessions in group C had high round fruit, and 28.6% round. Immature fruit color in this group was mainly light (85.7%), while mature fruit color was green (57.1%) or yellow (42.9%), and dominant brix scores were 8, 6.5 and 6 (21.4% each).

The fruit shapes in group D were plum-shaped (50%) and pear-shaped (50%). Immature fruit color in this group was light (50%) or a mixture (50%), while mature fruit color was green and brix 7 (Table 1).

Clusters

Cutting the dendrogram (Fig. 2) at a co-efficient of 4.78 produced four main groups of tomato accessions.

In group A, ARP365-1 and WS White were the most similar accessions, with similar leaf type (5), fruit shape (round), immature fruit color (light), mature fruit color (green) and brix (5) (Table 1).

Likewise in groups B and C, accessions WSP27F(3)P3, TF1C1 and CLN2679A, PT4722A share some similarities.

The similarities in Group B lie in leaf type (5), fruit shape (slightly flattened), immature fruit color (light), mature fruit color (green) and brix of 6 (Table 1).

In group C, the similarities are based on the leaf attitude (drooping), leaf type (5), fruit shape (high round), immature fruit color (light) and brix (6.5) (Table 1).

In group D, similarities occur in leaf type (5), mature fruit color (green) and brix (7) (Table 1).

DISCUSSION AND CONCLUSION

The AVRDC and ISC lines were far more uniform than the CSIR-CRI and local lines, because the latter are landraces while the former are inbred materials. The CRI materials and the local material showed some degree of tolerance to TYLCV, confirming that they have some resistance to the viruses (Hanson, 2005). Thus, they will serve as a genetic base to improve the other accessions, which can be stored for long periods, but are much susceptible to TYLCV.

Vegetative Characters

Different genotypes have different growth habits. The commonest growth habit among the accessions from AVRDC (42.9%) and CSIR-CRI (40%) was determinate. This character might have been selected for over the years because it rarely requires staking and pruning. Moreover, it is able to combine large numbers of fruit with many plants per unit space, which is an indicator for high yield (Hanson, 2005). Breeders could incorporate determinate growth habit in their improvement program. More than 30% of the AVRDC and ISC accessions had dwarf growth habit. This suggests that fruits harvested from these accessions have high chances of fruit rot, since they easily touch the ground/soil and get rotten or damaged. Also, their fruits are produced over a short period of time, which is another disadvantage. Nevertheless they require no stakes or pruning. The indeterminate growth habit found in some of the CSIR-CRI accessions gives longer harvest period. This is an advantage if prices fluctuate.

Fruit Characters

The majority of the AVRDC materials had high round fruits, which is very desirable in the Ghanaian market. This character can therefore be selected for breeding by incorporated into the local materials that are high yielding but lack such desirable shape. Heart-shaped and plum-shaped fruits would be a very good for processing. The accessions with these fruit shapes also had high brix level, which is an indication of good taste. Thus, such accessions (irrespective of their source) can be used to increase brix level of tomato materials for industrial canning and processing into ketchup and tomato paste (among other products). There was considerable variation within the plant and fruit characters observed. The AVRDC accessions had almost all the categories of tomato fruit shapes, with the exception of slightly flattened shape, which are present in the local, CSIR-CRI and ISC materials.

Acknowledgments

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Vertical Farming for Rwanda Small-scale Tomato Farmers: COPARIMENA Tomato Growers Cooperative

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Key Words: vertical farming, small scale tomato farmers, demographic trend, indeterminate crops

Abstract

By the year 2050, nearly 80% of the earth's population will reside in urban centers. Applying the most conservative estimates to current demographic trends, the human population will increase by about 3 billion people during the interim. An estimated 109 hectares of new land will be needed to grow enough food to feed them, if traditional farming practices continue as they are practiced today. At present, over 80% of the world's land that is suitable for raising crops is in use (FAO and NASA data). With 8 million people and only 26,388 km2, Rwanda has an overall population density of more than 300 people per km2. Farming vertically is a potential solution to this problem, even if it is not new. What is new is the urgent need to scale up this technology to accommodate millions of people in the coming years. After 6 years working in horizontal tomato farming, the role of vertical tomato farming was recognized, and 793 farmers (members of COPAR–IMENA grouped in 45 associations) are being helped to introduce vertical farming as a future household tomato-farming technology. This study presents an environmentally sound vertical farming system for tomatoes in peri-urban areas and identifies its potential advantages.

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INTRODUCTION

Rwanda is a small, densely populated country in East Central Africa, with a total area of 26,338 km2, of which about 1,400 km2 is water. Known as the land of a thousand hills, Rwanda enjoys a mild climate despite its location. The most important and fundamental natural resource of the Rwandans is land. Agriculture occupies more than 90% of Rwandans in rural areas. Rwanda has a very high population density (the highest in Africa) with an average of 0.6 ha/household (Ndayambaje, 2008). Cooperative de Production Agricole au Rwanda (COPAR-IMENA) is a cooperative of 793 farmers from six tomato-growing zones in Gasabo and Kicukiro Districts. Established in 2002, COPAR-IMENA's mission is to become a market leader in tomato production and marketing in Rwanda (Ndayambaje, 2007).

In order to achieve its mission, COPAR-IMENA plans to increase the quantity and quality of tomatoes produced by its members, as well as broaden its customer base to include big hotels and supermarkets through production of year-round fresh tomatoes. COPAR-IMENA members grow tomatoes on individual fields. The tomatoes are collectively sold to one main buyer, SORWATOM, a tomato-processing factory, under a supply agreement. Through this arrangement, SORWATOM supplies inputs to the farmers on condition that all the tomatoes produced will be sold to it; the company also sets the price. This relationship is not favorable to the cooperative farmers, as SORWATOM often pays below market price. As a result, the cooperative would like to break SORWATOM's monopoly and explore other market opportunities. In order to achieve this, the cooperative needs to significantly increase the quantity and quality of tomatoes produced by its members by adopting greenhouse tomato-production technology. The proposed greenhouse tomato farming is in conjunction with the introduction of a simple vertical farming technology, where farmers are adopting an indeterminate variety called ANA F1. This variety is popular because it is disease resistant and gives yields often three times that of the determinant varieties, which will increase productivity without expansion of production area. COPAR-IMENA obtained United States African Development Foundation (USADF) support to invest in a pilot project for greenhouse tomato production. The grant is helping farmers to promote greenhouse tomato farming as well as vertical farming.

The objective of this paper is to present the environmentally sound vertical tomato farming in rural areas and identify the potential advantages of vertical tomato farming.

MATERIAL AND METHODS

We used Participatory Learning and Actions (PLA) to learn about communities. This approach places equal value on the knowledge and experience of local people and their capacity to come up with solutions to problems that affect them. Each association was contacted beforehand, to find out more about its context, to discuss the purpose of the activity and to confirm practical arrangements. Any sensitive issues relating to the service were identified during the liaison process and these were discussed with the Board members of COPAR-IMENA to ensure that they were dealt with appropriately, or avoided, in the PLA sessions (for example, lack of literacy skills among the elders). We identified 10 members from each zone who had not been evaluated in any other areas of the evaluation strategy related to COPAR-IMENA.

In general though, the act of participation itself was taken as consent, since nobody selected was

constrained to take part.The main tools used were timelines to explore and share perceptions of what happened; when and why; with whom; and with what impact. They were also used to compare past and present, to explore causal factors and to look toward the future. The visualization helps to concretize people's experience and its significance. This was followed up by sharing and summarizing, where the facilitator asks for contributions and writes up responses. Papers written by various stakeholders in COPAR-IMENA were reviewed.

RESULTS

In order to fully assess the successful implementation of the vertical farming in various locations, five determinants were examined - geography, economics, government, environmental consciousness and community impacts.Vertical farms do not necessarily have to be built on land. An extremely innovative revolution of vertical farming would be to build the farms at sea in the form of a ship.

The process of promoting vertical farming should start with the introduction of an indeterminate variety to the region. Certain interest groups presented opposition during the initial adoption of vertical farming for various reasons. They believed that their livelihoods would be harmed, or they were opposed to such a dramatic move from traditional farming.

Potential Advantages of Vertical Farming (Feasibility)

- Year-round crop production
- Eliminates agricultural runoff (the worlds' greatest source of pollution)
- Dramatically reduces use of fossil fuels
- Makes use of abandoned or unused properties
- No weather-related crop failures (such as those caused by drought, flood)
- Sustainability for urban centers
- Converts 'black' water to potable water
- Adds energy back to the grid via methane generation
- Offers new employment opportunities
- Could dramatically reduce incidence of some tropical infectious diseases
- Returns farmland to nature, restoring ecosystem services.

Within 6 months, COPAR-IMENA received 500 farmers who came to ask about vertical tomato farming, how to construct greenhouses, and how to obtain seeds - a considerable result for this program.

DISCUSSION AND CONCLUSION

It took humans 10,000 years to learn how to grow most of the crops we now take for granted. Along the way, we despoiled most of the land we worked, often turning verdant, natural ecozones into semi-arid deserts. Within that same timeframe, we became a predominantly urban species—60% of the human population now lives 'vertically' in cities (Vertical Farm Project, 2009). This means that the majority of people are protected against the elements, yet we subject our food-bearing plants to the rigors of the great outdoors and can do no more than hope for a year of good weather. However, more often than not (due to a rapidly changing climate regime) that is no longer what follows.

Massive floods, protracted droughts and severe monsoons take their toll each year, destroying millions of tons of valuable crops. Don't our harvestable plants deserve the same level of comfort and protection that we now enjoy? The time is at hand for us to learn how to safely grow our food vertically because of shortage of space. If we do not, then in just another 50 years, the next 3 billion people will surely go hungry, and the world will become a much more unpleasant place in which to live.

COPAR-IMENA has started: 793 members will be able to return 409 ha of farmland to nature and the production will be three times higher than before, which is a good contribution to the Millennium Development Goals.

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While the benefits of vertical farming are undeniable, a number of issues must be overcome before the farms can be successfully adopted in various locations (Reitano et al., 2006). Vertical farming will be region-specific according to economics, geography, government and culture, as the issues presented by the change cannot be uniformly addressed. Some issues and challenges that each location must consider include: obtaining funding; how best to involve traditional farmers, who might otherwise be harmed by an influx of vertical farms; a probable shift in politics with regard to the agricultural sector of the economy, as well as a temporary shift in trade; farms must be situated in locations that are relatively free from risk of environmental hazards or disasters. Policies and strategy elements need to be taken into consideration in the design and implementation of a sustained vertical farming program in Africa.

Acknowledgements

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Strategies to Improve the Productivity of the Industrial Tomato Crops in the Senegal River Valley, 2002–2005

Daouda Mbodj[1]

Keywords: industrial tomato, producers, training, yield, demonstration, seed, didactic support

Abstract

Industrial tomato (Lycopersicon esculentum) production was started in the Saint-Louis region of Senegal in the mid-1970s. In 2002, average yields had reached only 25 t/ha, despite the use of enormous quantities of inputs, especially seed. Insufficient understanding of appropriate production techniques was the main cause of weak performance. The desire to increase yields (and income) motivated the tomato producers to request support. The current programme aims to find answers to the producers' problems. Demonstrations followed by training resulted in an over 60% reduction in quantities of seed used, and yield increases in 50% of the meadows. The main innovation was mass training, which allowed a maximum number of potential producers and farm villages to be reached. Land areas used for tomato cultivation practically doubled. In order to perpetuate the experience, didactic audiovisual support materials are given to peasant farmers who have attended rural training sessions in industrial tomato production (so that they can support other farmers in their communities).

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INTRODUCTION

Origin of Programme

Industrial tomato producers in the Saint-Louis region of Senegal organized their industry around a transformation plant that bought their total harvest. The producers knew that their yields had been low since tomato was introduced to the region in 1974, i.e. an average of 25 t/ha until 2002, despite enormous quantities of inputs. The establishment of the Agence Nationale de Conseil Agricole et Rural (ANCAR) in the region was followed by a tomato-productivity improvement programme using the following procedure:

- demand was expressed by the producers via the chairman of the Tomato Committee;
- the request was analysed with the applicant, who was also asked about constraints, producers' expectations and advisable activities;
- after listening to the communities, a draft programme was prepared. Proposals were made on the basis of technical feasibility and concurrence between the proposals and ANCAR's objectives and its technical, financial and methodological procedures. The strategic options and the modus operandi focused heavily on the immediate objectives;
- once prepared, the draft programme was amended and validated by the requesting party (i.e. the Tomato Committee).

Context

The rural areas around Saint-Louis are characterized by food insecurity due mainly to chronically low farm incomes.

Tomato production is a major challenge for the region, because:

- it had a high, unexploited production potential that could increase income and hence combat poverty;
- surplus production can contribute to improving food security significantly through cereal purchases;
- large-scale tomato production is a pre-condition to consolidating a dynamic, secure, employment- and resource-generating industry.

There are also many technical problems in tomato cropping:

- because the producers did not fully understand the nursery techniques, they used 500 g of seed per hectare, while the recommended rate is 150 g;
- in some zones, tomatoes cannot be grown because of plant diseases, especially viral ones;
- the farmers used large quantities of phytosanitary products such as pesticides;
- there was a big gap between the best yields and the average yields (42 versus 26 t/ha) despite the producers' claim that they had good control over their crop thanks to long experience and ancient practices.

To meet this challenge successfully, most strategies were based on simple practical solutions for the farmers, rather than being aimed at the peasant leaders. Stress was placed on communication tools and educational support that producers can easily understand. The Saint-Louis region benefits from experience in this field. The demands of intensive tomato cultivation required capacity building to enable producers to reach their expected performance level (over 40 t/ha). This inspired the producers to request demonstrations and high-quality training

Objectives

The objectives were to train producers in intensive cropping techniques for industrial tomato production. Specifically, to:

- increase average yields to 40 t/ha and stabilize them, while at the same time decreasing the quantity of seed needed by over 60%;
- increase the amount of farmed land up to 3,500–4,000 ha;
- extend the annual campaign to make it last 5–6 months.

MATERIALS AND METHODS

The programme aimed to make industrial tomato more productive and therefore needed to meet short-term requirements (2002–2003 season) and fit in with prospects for future growing seasons.

This line of logic was central to the programme's technical and methodological proposals.

All the materials and methods used were keyed to overcoming the constraints and achieving the results indicated in Table 1.

Table 1. Constraints to be overcome and outputs expected

Constraints to be overcome	Outputs expected
• Uneven technical level of producers (yields vary between 16 and 40 t/ha) • Insufficient understanding of cropping practices recommended by research and the Tomato Committee • Average yields low considering recommended intensive farming techniques • Too much seed used (500 g)	• Producers able to establish and produce industrial tomato crop in compliance with technical recommendations on production intensification • At least 60% reduction in seed quantities • Increase in average yields by 50% in 2 years and 75% in 5 years
• Only few farming models respect recommended farming practices • Absence of farmers capable of extending production techniques • Producers insufficiently self-reliant in technical and technology-transfer skills	• Identification and training of 50 extension-producers
• Absence of educational audiovisual material adapted to farming techniques for industrial tomato production in the valley	• Production of audiovisual material on industrial tomato production techniques in the valley

Materials

1. Plant material. Angela, Madona and Xina varieties were used. Angela and Madona are hybrid varieties that farmers were reluctant to plant. Xina is a well-established variety.

2. Audiovisual material. Video and photo cameras to make documentary films and slides. These supports were made available to producers and extension-farmers (who were then be able to extend the practices to other farmers in their communities) for future discussions and meetings.

Methods

1. Train producers and establish demonstration plots. A vast training campaign on techniques and supply control was organized for producers, since greater technical skills will contribute substantially to increasing yields and production quality. This fitted in with the ambitious objectives of the committee for the year 2004, namely to:

- increase and stabilize average yields at 40 t/ha
- increase farmed areas to reach 3,500–4,000 ha
- extend the production season to 5–6 months
- control the pressure of pests and diseases.

Technical capacity-building involved both the creation of audiovisual supports on the techniques of industrial tomato production and training of the producers and extension agents.

The request for mass training was innovative in itself, since this is a zone where training is usually provided only to the leaders. The training scheme was designed to build up the producers' capacities, centring on:

- rural activities on the topic of the day, with well-adapted audiovisual supports;
- a demonstration followed by practice exercises in targeted areas.

This activity was intended for about 12,000 producers living in 30 villages in the delta and middle valley areas.

Training was paced according to the main cropping activities (sowing, irrigation, fertilization, crop protection, harvest) and depending on the crop-season calendar drawn up by the committee.

2. Training extension-farmers. To promote local farmers' knowledge and strengthen the producers' technical independence, 50 producers, in other words, two farmers per site, were trained in tomato production techniques.

3. Production of educational supports. Well-adapted educational support materials must be created if results-oriented tomato production plans, which are more or less new in this area, are to be achieved. With this in mind, the programme produced:

- a video film and slides on a crop management plan (itinéraires techniques) for industrial tomato crops;
- a producers' manual of good practices (in French, Wolof and Pulaar);
- a technical description of the tomato in the local language.

RESULTS

The following results were achieved:

- a drop in per-hectare seed requirements from 500 g to 200 g, with some achieving 150 g;
- installation of 15 demonstration plots (average yields of 58 t/ha);
- substantial reduction of seed damping-off and clear understanding of nursery techniques;
- (thanks to lower seed requirements) greater on-farm utilization of hybrid varieties that are more resistant to viral infections and are affordable;
- increase in average yields from 25 to 42 t/ha, with a maximum of 78 t/ha;
- tripled production (which led to the creation of a second tomato transformation plant);
- larger sown areas;
- loans on rice crops paid off with profits from tomato crops;
- recruitment of temporary workers on a considerable number of tomato farms, thus leaving farm children free to study better;
- production of a video-film and slides.

DISCUSSION AND CONCLUSION

The farmers have a better understanding of nursery techniques, especially with sowing on loosened soils, thanks largely to the installation of demonstration plots. This means using less seed than in former times, and results in less fungal disease and more vigorous plants. The decrease in seed quantities encourages farmers to use the high-yielding hybrid varieties that are more or less resistant to tomato yellow leaf curl virus, which is an endemic disease in the area.

Mass training made it possible to reach the producers themselves and not just the leaders, which led to much higher average yields, larger cropping areas and tomato production figures that have been growing steadily year on year since 2002. Another result has been the installation of a second tomato transformation plant (at Dagana) and loan repayments of over 98%.

These results have been achieved through teamwork, strong participation of the producers from the very beginning, and the use of films and well-adapted support materials. Forums, workshops and other meetings provided a good opportunity to transmit technical and commercial information. For one month, we went on the air at RTS, the regional radio broadcasting system, and invited all the partners and producers to discuss themes that had been the focus of training sessions and demonstrations.

Manuals on good practices, translated into the local languages, were distributed to the producers, together with technical description forms based on the training sessions.

Audiovisual support materials covering the farming techniques, with focus on good practices, have been produced. Among other things, they are useful for the trained extension-farmers who can use them in rural gatherings to provide better assistance to their fellow farmers.

Acknowledgements

I should like to thank my partners, especially the CNCFTI producers (2000–2002 technical description forms as documentation). I also want to thank all my colleagues at ANCAR, especially Mr Ismaila Mbengue, all of whom contributed so actively to the success of this endeavour.

Efficacy of Teak Bark Water Extracts against that of Conventional Preservatives

Amina Hakeem Baidoo[1], Akwasi Asamoah[2], and Charles Antwi-Boasiako[3]

Keywords: eco-friendly, standardization, percentage hardness loss, percentage mass loss, visual durability rating

Abstract

Conventional preservatives are not only toxic to wood bio-deteriorators, but also to humans and animals. In an effort to find preservatives that are non-toxic to humans and animals, efficacy of water extract of teak (a highly durable timber species) bark (0.0174 g/ml), was compared with that of chromated copper arsenate (CCA, 0.058 g/ml), Pyrinex 48EC (0.5% v/v) and creosote (100% v/v) on heartwood of Ceiba pentandra and Celtis milbraedii by pressure impregnation and buried in a termite-prone field for 5 weeks following EN 252. Teak-bark water extract was standardized on the basis of visual durability ratings, percentage hardness and mass losses of impregnated Ceiba and Celtis after burial. Regardless of retention level, single treatment with teak bark water extract did not improve the natural durability of Ceiba and Celtis to the same extent that CCA, Pyrinex 48EC and creosote did at experimented preservative concentrations. Indications were that teak-bark water extract alone could be used to adequately improve the durability of Ceiba and Celtis only with multiple treatments (three or more) at a higher concentration (1.74 g/ml = 100×0.0174 g/ml), or mixed with CCA (5% v/v) on single treatment at experimented concentration (0.0174 g/ml). Eighty per cent and 83% of Anloga furniture-makers who tried teak-bark extract unmixed or mixed with CCA, respectively, showed a high likelihood of adoption.

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INTRODUCTION

Over the years, wood users have treated wood with conventional preservatives such as pentachlorophenol, tri-butyl-tin oxide, creosote, and Pyrinex 48EC. Creosote, an oil-based preservative, is acknowledged as one of the oldest and most effective industrial wood preservatives (Wood Preservation Canada, 2008). Pyrinex 48EC (chlorpyrifos), a well-known and effective agricultural insecticide, is a good choice against insect attack on wood, particularly termites (Wood Preservation Canada, 2008).

These conventional preservatives are not only toxic to bio-deteriorators of wood, but also to humans and animals. Even chromated copper arsenate (CCA), the most widely used preservative in Ghana (Ofori and Bamfo, 1994), which was thought to be non-toxic to humans and animals because of its permanence and stability in wood (Wood Preservation Canada, 2008), is now known to leach into the environment over time (Richardson, 1978). Some of the hazards of conventional preservatives to humans and animals are damage to liver and foetuses (Findlay, 1985). These hazards have necessitated increased research into alternative preservatives that are equally effective as conventional ones, but harmless to humans and animals in a chance contact.

One promising way of avoiding wood-preservative hazards is the use of extracts from durable wood species such as *Milicea excelsa* (odum), *Tectona grandis* (teak), *Azadiracta indica* (neem), *Erythropleum suaveolens* (potrodom) and *Piptadeniastrum africanum* (dahoma), which contain polyphenols such as tannins, lignans, lapacols, tectoquinones and terpene acids (Lame and McAnn, 1985) to preserve less durable wood. Asamoah et al. (2008) impregnated heartwood extracts of teak and dahoma into stakes of *Celtis zenkeri* and partially buried them in a termite-prone field for 8 months. After exposure, stakes impregnated with teak extract at 0.65 g/ml (120 kPa, 123°C, 2 hours) were resistant to termite attack. Opoku et al. (2007) impregnated *Antiaris* and *Bambusa* blocks with 1% and 0.5% w/v of teak bark, seed and leaf water extracts and partially buried them in a termite-prone field for 2 months. Blocks impregnated with bark extract (both dosages; 120 kPa, 123°C, 1 hour) were resistant to termite attack.

This study was conducted to standardize the efficacy of water extract of teak bark (a highly durable timber species) against CCA, Pyrinex 48EC and creosote on heartwood of *Ceiba pentandra* and *Celtis milbraedii*, which are perishable in the ground (Addae-Mensah et al., 1989) and resistant to impregnation (Findlay, 1985) by pressure impregnation following European Norms 252. Likelihood of adoption of teak-bark water extracts unmixed or mixed with CCA (5% v/v) was ascertained from two groups of 100 Anloga furniture-makers (one group for each kind of extract).

MATERIALS AND METHODS

Bark granules of teak were dried and milled to 40–60 mesh size. Extracts were removed from meal by gentle warming on hot plate at 60^{o}C or lower (Rudman and Da Costa, 1959) for 3 hours. Teak-bark meal (1250 g) was steeped in 10,250 ml distilled water. Extracted solution was decanted into a plastic drum and stored in a conditioning room to maintain its concentration. Mass concentration of extract was determined by evaporating a 3 ml aliquot on a water bath to solute.

Five litres of teak-bark water extract (0.0174 g/ml), CCA (0.05769 g/ml), Pyrinex 48EC (0.5% v/v) or creosote (100% v/v) was used to impregnate 250×25×12.5 mm air-dried (25–30% moisture content [MC]) heartwood stakes of Ceiba and (separately) Celtis. For each species, 18 stakes were used for each of control (untreated), teak-bark water extract, CCA, Pyrinex 48EC and creosote. Impregnation was by pressure (120 kPa, 123°C, 2 hours).

Ninety minutes after impregnation (to allow for fixation), stakes were reweighed to the nearest 0.5 g to determine the mass of preservative chemical absorbed. Retention of chemical preservatives (g/mm^3) in each stake $(R1)$ was determined as $[\mathrm{R1} = (q2 - q1)/\mathrm{v}]$ (Asamoah et al., 2008), where $q1$ is the mass of air-dried untreated stake, $q2$ is the mass of air-dried treated stake, and v is the volume of air-dried untreated stake. Consequently, mean retention (Rn) was determined as, $[Rn = (R1 + R2 + R3...Rn)/n]$ where Rn is the nth treated stake in a charge of 36 stakes (one treatment-chamber load).

After reweighing, stakes were buried (to accelerate attack) in a termite-prone field for 5 weeks.

Teak-bark water extract was standardized on the basis of visual durability ratings, percentage hardness and mass losses of impregnated *Ceiba* and *Celtis 5* weeks after burial. Stakes were rated visually on a scale of 0 to 4 (0 = no termite attack, 1 = sight attack, 2 = moderate attack, 3 = severe attack, 4 = failure) and the average rating for each charge calculated. Hardness of stakes were taken with Proceq Pilodyn (0 being no penetration [highest hardness] and 40 the deepest penetration [lowest hardness]).

Percentage hardness losses of stakes were calculated on air-dried hardness instead of oven-dry hardness of stakes as Hardness loss $=[(Rh - Ih)/Ih] \times 100\%$, where Ih is initial hardness of stakes and Rh is final hardness of stakes.

Percetage mass losses of stakes were calculated on air-dried mass instead of oven-dry mass of stakes as Mass loss $= [(I - R)/I] \times 100\%$ (Kumi-Woode, 1996), where I is initial mass of stakes and R is the final mass of stakes.

Setup was completely randomized (CRD) with visual durability ratings, percentage hardness loss or percentage mass loss as a single-factor (efficacy response) in which corresponding control, CCA, Pyrinex 48EC, creosote and teak-bark-water-extract-treated values were treatments (levels of each single factor). Not discriminating Ceiba from Celtis, differences between means of treatments of each single factor were analysed for real significance using least square difference (LSD) at 5% significance level with SAS (2008) software.

To ascertain likelihood of adoption of teak-bark water extracts mixed (0.0174 g/ml; treated once) or unmixed (1.74 g/ml=100×0.0174 g/ml; treated thrice) with CCA (5% v/v) by Anloga furniture-makers, two groups (100 individuals each, one group for each kind of extract) were asked to treat their freshly made Ceiba and Celtis wood furniture against powder post beetle attack for 5 weeks by brushing.

RESULTS

Typical of resistant timbers (Ofori and Bamfo, 1994), chemical preservative retention in *Ceiba* and *Celtis* varied, with Pyrinex 48EC being retained the most and creosote the least (Table 1). Teak-bark-water-extract-treated *Ceiba* and *Celtis* recorded a high visual durability rating (i.e. most susceptible to attack), while Pyrinex 48EC-and CCA-treated *Ceiba* and *Celtis* recorded the lowest visual durability rating (i.e. least susceptible to attack) (Table 2). Teak-bark-water-extract-treated *Ceiba* and *Celtis* showed the highest percentage hardness loss (i.e. most susceptible to attack), while Pyrinex 48EC-treated *Ceiba* and *Celtis* showed the lowest percentage hardness loss (i.e. least susceptible to attack) (Table 3). Teak-bark-water-extract-treated *Ceiba* and *Celtis* recorded a high percentage mass loss (i.e. most susceptible to attack), while creosote-treated *Ceiba* and *Celtis* recorded the lowest percentage mass loss (i.e. least susceptible to attack) (Table 4).

Indications were that teak-bark water extracts could be used unmixed to adequately improve the durability of *Ceiba* and *Celtis* only with multiple treatment (treated three or more times) and at a higher concentration (1.74 g/ml = 100×0.0174 g/ml); or mixed with CCA (5% v/v) in single treatment at experimented concentration (0.0174 g/ml).

Some 80% and 83% of Anloga furniture makers reported that teak-bark water extract unmixed or mixed with CCA, respectively, resisted powder post beetle attack in furniture made from *Ceiba* and *Celtis* wood.

Table 1: Least squre differences for retention of chemival preservatives in Ceiba and Celtis

Treatment	Mean	No. stakes	Treatment grouping
Pyrinex 48EC	0.0007179	36	A
Teak	0.0003189	36	A
CCA	0.0002639	36	AB
Creosote	0.0000794	36	B
Control	0.0000000	36	B

Treatment means with the same treatment grouping are not significantly different

Table 2. Least square difference for visual durability rating of Ceiba and Celtis treatment

Treatment	Mean	No. stakes	Treatment groupings
Control	1.5833	36	A
Teak	1.5556	36	A
Creosote	0.0278	36	B
Pyrinex 48EC	0.0000	36	B
CCA	0.0000	36	B

Treatment means with the same treatment grouping are not significantly different

Table 3. Least square difference for percentage hardness loss of Ceiba and Celtis treatment

Treatment	Mean	No. stakes	Treatment grouping
Teak	61.15	36	A
Control	47.98	36	A
CCA	38.8	36	AB
Creosote	29.28	36	B
Pyrinex 48EC	27.57	36	B

Treatment means with the same treatment grouping are not significantly different.

Table 4. Least square difference for percentage mass loss of Ceiba and Celtis treatment

Treatment	Mean	No. stakes	Treatment grouping
Control	29.064	36	A
Teak	23.786	36	A
Pyrinex 48EC	10.573	36	B
CCA	10.103	36	B
Creosote	7.672	36	B

Treatment means with the same treatment grouping are not significantly different.

Pyrinex 48EC was well retained in Ceiba and Celtis because it is water-based (Richardson, 1978), so its water formed a continuum with the water of Ceiba and Celtis wood and a diffusion gradient caused movement of its active ingredients (possibly of low molecular weight) into the wood. Consequently, Pyrinex 48EC-treated Ceiba and Celtis recorded less attack by visual durability rating, percentage hardness loss and percentage mass loss. Creosote was retained in Ceiba and Celtis least because it is oil-based—the oil did not form a continuum with wood water or a diffusion gradient, thereby preventing the diffusion of its active ingredients (possibly of higher molecular weight) into the wood. Nonetheless, creosote made Ceiba and Celtis less susceptible to attack (recorded by visual durability rating, percentage hardness loss and percentage mass loss) because it formed an oily coating (barrier) around the wood, which repelled water (a factor essential to attack) from the environment. Teak-bark water extract and CCA followed Pyrinex 48EC in retention in decreasing order, as their active ingredients' molecular weights may be progressively less than that of Pyrinex 48EC. However, Ceiba and Celtis treated with teak-bark water extract recorded more attack by visual durability rating, percentage hardness loss and percentage mass loss, which confirmed its moderate toxicity compared to Pyrinex 48EC, CCA and creosote. That 80% and 83% of Anloga furniture-makers reported success with teak-bark water extract unmixed or mixed with CCA, respectively, reflected the potential of botanical extracts as alternatives to conventional preservatives.

Regardless of preservative retention levels, teak-bark water extracts did not adequately improve the natural durability of Ceiba and Celtis in a single treatment as much as CCA, Pyrinex 48EC and creosote did at tested preservative concentrations. Teak-bark extract mixed with CCA recording 83% shows that it may have acted synergistically with the CCA (Richardson, 1978).

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Application of Organic Pesticide Technologies for Improved Agriculture and Rural Livelihoods in Uganda

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Keywords: application, organic pesticides, technologies, improved agriculture, rural livelihoods

Abstract

Organic pesticide technologies (OPTs) are perceived by Ugandan farmers as the positive road to sustainable agriculture and development of rural communities that derive their livelihoods from agriculture. Farmers have long sat on the margins of Ugandan society, constrained by crop pests and diseases, and the absence of cheap control measures. In response to this, in 2004, young professionals of Practicing Environmental Managers' Organization (PEMO) designed a scientific but cheap strategy that uses locally available materials to manufacture organic pesticides. The major objective of this project was to improve agriculture in Uganda through the use of OPTs. Mukono district was identified as one of the areas infested with pests and diseases; Ngogwe and Ntunda sub-counties were selected out of the 12 sub-counties within the district. Farmers have been educated on organic pesticides and how these can be made locally. Community-based organizations and model farms were formed in each of the selected sub-counties to help implement strategies within the wider community. Farmers have managed to save their incomes, which they used previously to spend on expensive agrochemicals. Results are communicated to farmers by PEMO researchers through community workshops and the media. More scientific research is needed on numerous pests and diseases, and the benefits of OPTs need to be extended to other agricultural areas of Uganda, and other agricultural countries within Sub-Saharan Africa that are infested with pests and diseases.

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INTRODUCTION

As in many other Sub-Saharan African countries, agriculture forms the backbone of Uganda's economy: 80% of Ugandans directly depend on it for their daily survival (UNDP, 2007). In 2007, agriculture contributed 61% of all exports and 70–80% of all export earnings, as well as 40% of Gross Domestic Product (GDP). Yet this agriculture is on the decline; for instance, livestock contribution to Uganda's GDP has declined from 25% to a mere 5% since the late 1970s. In 2006, Uganda exported only US $134 million (€268,000) worth of food and imported over US $154 million (€308,000) worth of food.

The over 88% of Ugandans who live in rural areas and depend on agriculture for their livelihoods are the most poverty stricken according to welfare indicators (MAAIF and MFPED, 2000). On poverty eradication in Uganda, MAAIF and MFPED (2000) point out major causes of the worsening poverty situation in the country to include; slower growth in agriculture and a decline in farm-gate prices. The slower growth in agriculture is attributed to pests and diseases, and absence of dynamism within the agricultural sector to invest in indigenous science and technological research—for example, the Republic of Korea spends 2.6% of its GDP on science and technological research related to both the primary sector and the manufacturing sector, while Uganda spends just 0.8% of its GDP on these sectors (UNDP, 2007). It is not surprising therefore that the 31% of Ugandans who live on less than a dollar a day are mainly in agricultural households. To combat this poverty situation and improve rural livelihoods, we need to improve agriculture through the use of affordable indigenous technologies. To this end, in 2004, Practicing Environmental Managers' Organization (PEMO) designed a scientific but cheap strategy that uses locally available materials to manufacture a variety of organic pesticides with proven preventive and curative abilities against pests and diseases.

Statement of the Problem

While Uganda (like many other Sub-Saharan African countries) is predominantly an agricultural country, various pests and diseases have continued to limit the development and performance of its agricultural sector. Pests and diseases in Uganda include: maize stalk borer, mealy bugs, aphids, banana wilt, nematodes, ticks and rodents. Although the Ugandan climate favors many agricultural pests and diseases, only 3.4% of farmers in Uganda use agrochemicals. A lot of agricultural produce is therefore lost at the farm and in stores due to absence of affordable pesticides. This situation may not be limited to Uganda, but is highly likely to be the case in many other Sub-Saharan African countries.

Uganda's agriculture registers among the lowest yields in the world, despite favorable climatic conditions. For example, the average yield of cotton in Uganda is 600 kg/ha, compared to 2500 kg/ha in Israel. The most prevalent problem attributed to this poor performance still is pests and diseases (NPA, 2008). Though the development of a natural-resource-based country like Uganda requires a strong indigenous technological base, it is estimated that only 14% of all Uganda's exports are produced using scientific and technological innovations (UNDP, 2007). This contrasts with 55% for Malaysia. To boost poverty-stricken rural livelihoods that largely depend on agriculture in the face of rampant pests and diseases, stringent measures based on cheap and locally available resources (such as organic pesticide technologies, OPTs) are needed for farmers, who have sat on the margins of global economy for a long time.
Objectives of the Organic Pesticides Project

The objectives of the project were:

1 To create awareness of and practical skills in the use of organic pesticides towards sustainable agriculture;
2 To increase the number of farmers that use organic pesticides from 6% to at least 30% by 2020;
3 To improve rural livelihoods through improved agricultural output in rural communities of Uganda.

Purpose of the Project

The project aims at developing scientific innovations in OPTs through research, and communicating the results to farmers for improved agriculture and rural livelihoods in Uganda.

Scope of the Project

This project focuses on OPTs. Since 2004, the project has been implemented in Mukono district of Uganda. Mukono is one of the areas most heavily affected with pests and diseases, and was the most accessible agricultural district (given the project's financial resources). The project covers two sub-counties of the district, Ntunda and Ngogwe.

Literature Review

We can draw on a range of schools of thought on how best to increase agricultural productivity and improve rural livelihoods, especially in a developing country. Thirwall (1983) observes that the quickest and cheapest way to raise productivity depends on the reasons for the low productivity and constraints to agricultural growth, which vary from country to country and from region to region. The major constraints to agricultural growth in Uganda are pests and diseases, poor farm-gate prices and inadequate capital to invest in productive agriculture (KARI, 2003). Thirwall (1983) further contends that, in some cases, it is an inappropriate labor-to-land ratio combined with a lack of appropriate and complementary inputs that constrains agriculture; in other cases, it is the structure and organization of agriculture, and in many cases it is a combination of the two coupled with unfavorable natural factors. Kalirajan et al. (1996) complements this line of argument by asserting that as long as farmers are not operating on their frontiers, due to various non-price and organizational factors—which is the case in Uganda—, technical progress cannot be the only source of total factor productivity growth. A substantial increase in productivity under these circumstances can still be realized by improving the method of application of the given technology. Kalirajan et al. add that it is important to know whether technological progress is stagnant over time and whether the given technology has been used in such a way as to realize its full potential. Certainly, the yields of selected crops in Uganda indicate that productivity of maize has fallen, as has that of finger millet (KARI, 2003). These results further indicate that Ugandan farmers are operating below their frontiers and therefore available technologies are not being used to their full potential. While Africa is the only developing region where crop output and yield growth is lagging seriously behind population growth, there is very little literature on measurement of productivity in this region, essentially due to lack of reliable data. Savadogo et al. (1994) show that, since the spate of African farm management studies in the 1960s and 1970s, soils have degraded rapidly, access to land has become increasingly constrained, and factor and credit markets have changed structurally. They further point out that these changes should affect productivity across farm types, suggesting the need to revive attention on farm-level analysis. Such analyses are important for Uganda, given the emphasis the country is putting on agriculture, not only for improving rural livelihoods, but also for general economic growth and poverty reduction.

MATERIALS AND METHODS

Methodology

In establishing the use of organic pesticides, researchers in PEMO reviewed the (published and unpublished) literature on both agrochemicals and organic pesticides. This helped to give an insight into the effects and effectiveness of the two types of pesticides on agriculture and the environment. This was followed by investigations on the most recurring pests and diseases in the endemic areas; and testing of the organic pesticides on animals, and on different crops and vegetables in farmers' gardens affected by various pests and diseases. A descriptive survey on farmers' gardens in the two sub-counties of Mukono district was carried out to identify the existing control methods used by farmers, factors influencing adoption of such methods, and the impacts of such methods on both soil quality and agricultural output. Qualitative analysis was used and data were analyzed on a daily basis and then coded according to themes. The different themes and sub-themes were given codes that later aided in report writing. That is to say, content analysis was used to analyze the data. Table 1 shows materials used, name of the pesticide, and procedure.

Table 1. Name of pesticide, materials used and production procedure Name Materials and production procedure Application

Name	Materials and production procedure	Application
Chili pepper (pilipili) pesticide	(1) Boil 3 L of water; (2) once boiling, add 0.5 kg of thinly sliced or pounded ripe pilipili; (3) boil for further 15–20 minutes and remove from heat; (4) add 30 g soap; (5) stir to make the solution soapy; (6) add 3 L cold water	Used on vegetable gardens against caterpillars, aphids, flies, ants, mealy bugs and nematodes. Applied once a week if there is no rain, 2–3 times a week if it rains
Pawpaw pesticides	(1) Chop 1 kg of fresh pawpaw leaves; (2) place into a container with 10 L water; (3) add 2 tablespoons of paraffin; (4) leave for at least 3 hours, and then strain out the leaves	This is used on crops against a variety of pests
Tobacco pesticide	(1) Boil 3–4 L water; (2) add 300 g dry tobacco leaves; (3) boil for 15–20 minutes, then remove from heat; (4) add 30 g soap and stir until bubbles are formed; (5) add 3– 4 L cold water; (6) cover and leave to cool, and then filter through a light cloth	Applied to maize or sorghum to kill stem borers. Can also be brushed on the hides of sheep, cattle or goats infested with ticks. Can be applied on bedding through soaking to kill bed bugs
Onion bulb	(1) Pound 5 onion bulbs; (2) add 3–4 L water; (3) leave to ferment for 2–3 days	The smell of the solution repels many pests
Tomato leaves	(1) Boil 3–4 L water; (2) add 300 g of pounded dry tomato leaves; (3) boil for 15– 20 minutes, then remove from heat; (4) add a handful of ash; (5) add 2 liters of dilute animal urine; (6) add 0.5 kg of red pepper; (7) add 3–4 L cold water; (8) cover and leave to cool, and then filter through a light cloth after 2 days	Applied to banana plants to control nematodes.

Communication Strategies Used

Workshops were carried out in different villages through an interactive approach where experts from PEMO passed on knowledge and skills to farmers on how organic pesticides are manufactured using locally available materials. Media are used in an ongoing strategy where information and knowledge about organic pesticides is broadcast to farmers every Saturday between 7:00 a.m. and 8:00 a.m. on Impact Radio. The farmer audience is now more knowledgeable about the use of organic pesticides, and how organic pesticides can be manufactured through simple scientific techniques.

RESULTS

Mukono was identified as the district most affected by pests and diseases—caterpillars, nematodes, armyworms, mole rats, aphids and mealy bugs. In effect, PEMO researchers successfully developed five types of organic pesticides to control these pests and diseases (see Table 1). Farmers in these areas have used these pesticides for 3 years. Farmers apply these liquid pesticides using watering cans or by dipping leafy twigs into the solution and sprinkling onto plants and animals against a variety of pests and diseases.
Farmers in the selected areas were taught about organic pesticides and how these can be made locally. For sustainability, we helped form community-based organizations (CBOs) that now implement strategies and provide extension services to other farmers within the wider community. In Ntunda sub-county, Ntunda Community Organic Pesticide Farmers' Organization was formed with 28 executive members (12 men and 16 women). In Ngogwe, Ngogwe Agricultural Development Organization was formed with 20 executive members (11 men and 9 women). At least one model organic farm that uses organic pesticides was developed in each of the two sub-counties.

Soil fertility, crop productivity, and livestock quality have greatly improved in the 3 years since OPTs were introduced in Mukono district. Through the CBOs, farmers have managed to widen the market for their agricultural produce by convincing buyers in the urban centers about the organic nature of their agricultural produce. One farmer interviewed by PEMO researchers during monitoring and evaluation on the effectiveness of organic pesticides in Ntunda sub-county, in April 2008 had this to say:
Production and income have greatly improved since I started using organic pesticides in 2007, I now sell a good looking pawpaw at Uganda Shillings 700 [€0.35] yet before I used to sell each pawpaw at only 42 Shillings [€0.021].

Farmers in the two sub-counties have managed to save their income, which they previously used to spend on expensive imported agrochemicals. In 2006, farmers in Ntunda sub-county started a farmers' microfinance organization, called Ntunda Farmers' Savings and Credit Cooperative Society, for their socioeconomic development.

DISCUSSION AND CONCLUSION

An overview of this research project shows that, among other measures, OPTs were identified as the positive road to sustainable agriculture. They require the use of locally available materials, from which they are made through simple step-by-step techniques affordable to the economically constrained farmers in rural settings. Mukono district was identified as one of the most pests and disease infested areas in Uganda

and also one of the areas where agriculture is predominant (engages over 80% of the population). The project used (and uses) community workshops and media (Impact Radio-98.5FM) to communicate results on the effectiveness of OPTs and how these can be manufactured to control a variety of pests and diseases.

Project farmers in the selected sub-counties greatly improved their agricultural productivity due to the quality of their agricultural products; their incomes have also improved and they have started saving part of their income. Thus, OPTs have enabled farmers to reduce the infestation of pests and diseases and save some of their meager incomes. It should be noted, however, that organic pesticides would not be of any good if they were not introduced to our farmers. Thus, more scientific research and development, including dissemination of such scientific results to our farmers, are significant.

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Extension of Biodigester Construction to Produce Domestic Gas and Organic Compost on Family Farms

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Keywords: adaptability, biogas, organic waste, digestate, energy, liquid manure

Abstract

Peasant households face several limitations for efficient biogas production, including low livestock production and population density. Lack of energy infrastructure also constitutes a major constraint in rural areas. To solve this problem, farmers could combine energy and manure production to optimize use of waste. The aim of this study was to identify conditions in which a biodigester could be sustainably built and used by farmers to optimize biogas and organic-manure production in an integrated crop–livestock system. The energy requirements of the main rural households was calculated and their agricultural structure determined. The yield was 413 litres of biogas and 12 kg of organic manure per quarter for a community farm of 20 pigs. A field trial using organic manure at the rate of 12 t/ha showed a growing yield response of between 175 and 560 kg/ha for maize. Groundnut yields also responded to the manure, but not to the same extent. In this experiment, each quarter the farmer earned €133.39 from maize production and saved a further €191.91 that would otherwise have been spent on fuel—the total of €325.30 constituted 46% of the investment cost for biodigester construction. A peasant community with 20 pigs recovered its investment cost of €702 after two 6-month agricultural cycles. The economic yield from biodigester construction was observed in Sub-Saharan African community farms. However, the study must be considered with caution, considering the high rate of fires associated.

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INTRODUCTION

The natural assets of Cameroon have promoted the country's agricultural development. However, potential assets for development have faced constraints. Indeed, even where there is a biological balance, important issues are at stake. Peasant households face several limitations for efficient biogas production, including low livestock production (three pigs) and population density (150 people/km2). The management of crop residues, soil degradation and energy infrastructure for low-density areas are highly problematic for rural households. Therefore, populations use huge quantities of natural fuels for cooking, and deforestation remains an increasing concern. Environmental preservation requires local-level innovations and good practices (Riedacker et al., 1999). Lagrange (1979) explains that farm waste is a major source of the most harmful greenhouse gases, methane (CH4) and nitrogen dioxide (NO2). According to Ganry (1991), the addition of compost allows minerals to be returned to the soil up to a level of 1.5–2 t/ha. Similarly, biological sources can be used to produce energy (Farinet and Sarr, 1989). Our research focused on maximizing the use of farm residues and the simultaneous production of energy and organic fertilizers.

Research Issues

The assumption that principles of industrial ecology can be applied at the local family-farm level leads to the following research questions:

- Can the production of biogas contribute to creating village 'pockets of sustainability' and serve as a path to sustainable development?
- What are the minimum requirements for rural biogas and compost production to be effective in a farm unit?
- How can the energy produced be used?
- What are the effects of organic fertilizers on rural farm productivity?

Objectives

The hypothesis of this study was that the adaptability of biodigester technology depends on the production cost and the participating farm unit. The main objective was to identify conditions in which biodigesters can be built and used sustainably in a rural environment. More specifically, this meant:

- experimenting with the construction of digesters, using simple building tools and available materials;
- optimizing animal dung, especially pig manure, and plant waste found in rural farms;
- evaluating the quantity of inputs required (bio-wastes, human time and skills, financial resources) to launch efficient biodigesters.

MATERIALS AND METHODS

Materials

The preparation was done by hand using simple materials (pickaxe, shovel, plumb line, etc.). Rock covered by at least 10 cm of cement was used as an embankment. Wooden templates were used for measuring. The biodigester was gradually covered with mortar. Earthen bricks were used for the base. Water-drenched bricks were used to construct the 50° slope. The (PVC and galvanized) pipes were scraped with a metal saw to ensure maximum adhesion and were then attached with barbed wire to prevent any movement. The reservoir was covered with a sheet of metal and a block of cement. A stirrer, made with a metal rod with a

metal disc welded to one end, was installed at the opening of the reservoir. The digester had an average capacity of 2 m^3.

Fig. 1. Construction of the chamber of biodigester

Methods

The methodology used was based on action research in partnership with rural producers. The brief was to collect data by reviewing secondary data on the question, and by semi-structured surveys, field experience with technical supervisors and activity reports, to analyse the technology-transfer process and its adaptability. Data were collected at the same time as the simplified 'biodigester' technology was being transmitted through technical training sessions for producers.

Trials were carried out in the initial project site areas located in community pig farms in Omog, Boumyebel and Matomb villages, Nyong and Kellé Division, Centre Province, Cameroon. Bougrier (2005) feels that the optimal volume of biogas production can be achieved (0.925 m3 of biogas per tropical livestock unit per day) and the investment can be made profitable with about 20 sows. Hence, choices concerning the pigsties were based on the production-capacity criterion (between 18 and 24 animals to be able to count on a quantity of excrement of between 3,600 and 4,800 kg per quarter).

Training for community farms was given to groups averaging 12 farmers and was structured as practical exercises that emphasized manure collection and storage, construction of a biodigester, spreading compost, recovery and possible uses of energy produced (cooking gas, lighting, etc.).
The digestate (residues from biodigesters) was mixed with plant residue and stored for a final 4-month aerobic finishing phase. Farm trials were carried out for three consecutive seasons (March and August 2007, March 2008) in order to provide compost for an associated maize–groundnut crop (3 t/ha per season).

Choice of Sites for the Study and Experimental Units

The experiment was laid out in completely randomized blocks with three replicates. Local varieties of maize and groundnut were used for calculations of fertilizer quantities and yields. The compost made from the biodigesters was composed of organic manure derived from plant and animal waste. The compost was analysed. The experimental unit was 7 m ×5 m, i.e. 35 m2. Four levels of compost were tested. The compost was provided at the beginning of the production cycle, then spread after the land had been lightly tilled. The effect of the compost was evaluated at the end of the growing season. To measure the volume of the biogas, it was recovered in a tube buried 50 cm underground and connected to a gas cooker. There

were two valves on the cover, one to regulate the biogas flow to the gas cooker and the other connected to the manometer. Data were collected on the quantities of biogas and compost produced.

The data were analysed using qualitative and factorial analysis tools (Excel and SPSS software).

RESULTS

Simplification/Adaptability of Process

The simplified technology functioned well. Technical suggestions for improving the farmers' biodigestion systems are known (materials, reservoir entrances and exits, inspection panel, mixture area, etc.). The results from the three sites varied according to the material types and the composition of the farm and household wastes. This initiative also facilitated extension of research findings by providing rural populations with a simplified technology for producing environmentally-friend energy.

Cost of Construction of Artisanal Micro-biodigester

Labour needed amounted to 24 work-days (wd) to prepare the terrain, 180 wd for the construction work, 36 wd for plumbing and 120 wd for finishing work over an average period of 4 weeks. A 2 m $\times$3 m biodigester made by non-qualified labourers cost €702 and the average production was 413 litres of biogas for from 1.22 kg of manure per day. The average energy production potential was 2.29 kW/m^3.

Characteristics of Products Obtained

The system is based on daily fermentation of a large organic mass composed mainly of pig manure, in the presence of anaerobic bacteria. To improve farm hygiene, the manure has to be properly managed. In these experiments, we obtained an average of 12 kg of organic compost. A tonne of compost derived from this methanation contains about 0.65 kg of nitrogen compounds, 9.8 kg phosphate compounds and 1 kg organic carbon; its value to agriculture is undeniable, as these are good levels of minerals. This simplified biogas-production system can be used to produce methane, as a replacement of wood, for cooking. After getting rid of the first gas, the gas that was obtained had a clean blue flame. In the beginning, the flame burned for 20 minutes and then went out. We obtained better raw materials and production normalized. Table 1 shows improvements in biogas production after 18 test days.

Table 1. Improvement of biodegradability and biogas production

Locality	Substratum used	Biodegradability	(Increase in) Biogas production
Omog	40% pig manure 60% plant waste	40 $\pm$ 4%	338.52 L per kg of suspended volatile material
Boumyebel	60% pig manure 40% plant waste	54 $\pm$ 6%	17%
Matomb	90% pig manure 10% plant waste	59 $\pm$ 8%	36%

Waste with a high concentration of pig manure had a higher methane yield (Table 1).

Average maize yields obtained after the application of manure from the biodigester varied between 1.87 and 3.25 t/ha (Table 2). Gains thus earned over fallow system without organic fertilizer averaged 0.89 t/ha (Table 2).

Table 2: Effects of added compost to maize yield (t/ha)

Location	Manure (t DM/ha)[1]			
	0 (new plot)	8 (without fallow)	16 (without fallow)	24 (without fallow)
Omog	1.66	1.88	2.57	3.30
Boumyebel	1.69	1.85	2.58	3.26
Matomb	1.69	1.87	2.59	3.18
Average	1.68	1.87	2.58	3.25

[1] *The data points are averages of both replicates and years (mean of 9 trials each).*

Groundnut yields, after application of compost, varied on average between 1.81 and 1.88 t/ha (Table 3).

Table 3. Effects of added compost to groundnut yield

Location	Manure (t DM/ha)[1]			
	0 (new plot)	8 (without fallow)	16 (without fallow)	24 (without fallow)
Omog	1.78	1.83	1.84	1.89
Boumyebel	1.76	1.79	1.81	1.86
Matomb	1.77	1.82	1.83	1.88
Average	1.77	1.81	1.83	1.88

[1] *The data points are averages of both replicates and years (mean of 9 trials each).*

Tables 2 and 3 show that maize responded more to manure application than groundnut did. During 3 years, maize and groundnuts gave good response to manure. We can assume that at least the middle-term productivity of amended soils with manure is ensured. Furthermore, we see that productivity rises with compost applications of between 0 and 24 t/ha. It seems conceivable that maximum yields have not been reached with this dose.

Biodigester construction in Sub-Saharan African community farms was economical because, each quarter, the farmer earned €133.39 (19%) from maize production and saved €191.91 that would have been spent on fuel (without the biodigester). The total of €325.30 represents 46% of the investment cost for biodigester construction. So, investment costs of €702 are covered after two 6-month agricultural cycles.

DISCUSSION AND CONCLUSION

A biodigestion unit can be optimized through 90 days of biomethanization in a farmer's pigsty with about 20 sows. During that period, biogas production goes up. Waste with a high proportion of pig manure produces up to 2.7 times more biogas than waste of mainly plant origin. However, it is important to know the

plant/animal matter ratio that allows for optimal biogas production.

Compost requires good storage and fulfils a small part of the crops' requirements for nitrogen, phosphorus, calcium, magnesium and trace elements. The application of organic manure contributes to considerable increases in maize yields. With bags selling at €21.34 (Hatcheu, 2003), the farmers earn €855 per hectare of maize planted. For groundnut, the manured plots yielded little more than the fresh field. Although the fact that there was little difference in groundnut yields between manured plots and fallowed plots, it seems that producers can use manure to maintain the fertility of the soil and reduce deforestation by stabilizing cropping areas.

ISF (2004) suggest that small rural households need an average of 20 kWh/month. Assuming a production level of 137 kWh/month, the biodigester could supply six rural households. Since an average family spends around €655 on energy per year (ISF, 2004), a biodigester pays for itself in five quarters, but due attention has to be given to the capacity/needs ratio to convince rural areas to implement integrated artisanal biogas-production systems.

There are no definite conclusions on profitability. Parameters other than biogas production have to be borne in mind. Determining whether the biodigester is economically viable requires a preliminary estimate of labour costs for the collection of organic waste.

On the other hand, a higher rate of fires can be associated with the volatilization of biogas when inappropriately used by less skilled people. In order to protect peasant populations from fires risks, further studies on adequate risk-reduction strategies must be considered.

Acknowledgements

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Design, Construction and Test-running of a Biodiesel Pilot Plant

J.N. Nwakaire[1] and C.J. Ohagwu[2]

Keywords: beniseed oil, centane index, palm kernel oil, viscosity index, flash point, caloric value

Abstract

The production and utilization of biodiesel as an alternative fuel for diesel engines have continued to gain worldwide attention and world output has increased. For Nigeria, as a developing nation, the implication of utilizing this emerging technology is highly positive. In this work, the design and construction of an efficient biodiesel pilot plant were considered. The gains from such consideration resulted in the construction of a 30 liter per hour pilot plant. The various systems were carefully designed and selected after application of principal equations, like the heat-capacity, volume of a cylinder and cone equations. After careful construction, the plant was tested with beniseed oil and palm-kernel oil. The resultant biodiesel from the vegetable oil was characterized in order to determine the fuel properties of the biodiesel. Cetane index of the fuel was calculated using ASTM (American Society of Testing and Materials) cetane index equation (D.4737). The cetane index of palm-kernel biodiesel was 51.824, while that of beniseed biodiesel was 60.69. The viscosity, flash point and caloric value of palm kernel biodiesel were 3.4 mm2/s, 143.5

C and 128,244.27 J/L, respectively, while those of beniseed biodiesel were 2.97 mm2/s, 139.87 C and 132,283.46 J/L, respectively. Thus, the fuels produced met with international standards of ASTM and United States Soydiesel Development Board. This work is a major breakthrough in Nigeria's quest to be renewable energy complainant in the aspect of biodiesel production.

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[2] *The two-way problem was to achieve oil viscosity equivalent to that of diesel fuel and producing oil that has the properties of diesel fuel that does not clog the nozzles of the injector, thus removing impurities like sulphur oxide.*

INTRODUCTION

Simply defined, biodiesel is a diesel fuel made from vegetable oil, alcohol and a catalyst. It is the only alternative fuel that has passed all of the Environmental Protection Agency's clean-air fuel requirements. Biodiesel was produced due to the need to solve a two-way problem2 identified during the analysis of the use of vegetable in combustion engine (Dr Rudolf Diesel tested a diesel engine on peanut oil, which can be called straight vegetable oil).

Biodiesel production plants are designed to reduce the bottlenecks encountered between the discovery of a process and the eventual scaling up of the production process. Therefore the need to establish a pilot plant in Nigeria cannot be overemphasized. The processes and production of biodiesel (methyl ester) from vegetable oil and animal fat feedstocks remain a strong growth market in the USA and Canada, as well as in the European Union. Most reports on capacity and consumption are generalized due to lack of formal reporting in some national markets, companies' secrecy about plant capacity and production, and the moving-target nature of pinning these down (Bockey, 2002).

Statement of the problem

The fundamentals of biodiesel production are well known. However, in Nigeria, most research on the production process has been on batch processors. Therefore, there is a need to establish a pilot continuous-flow biodiesel production plant, which is a stepping stone for full industrial production plant. Thus, the design and construction of a continuous-flow biodiesel pilot plant will strengthen the research and development of the biodiesel industry in Nigeria.

Objectives of the Study

The main objectives of the work are:

- To design, construct and test-run a 30 L/h continuous biodiesel production plant using beniseed oil; and,
- To characterized or determine experimentally the fuel properties of the biodiesel produced and compare results with international standards for biodiesel

Biodiesel Production Process

Vegetable oil is used for production of biodiesel. A titration is performed on the vegetable oil using sodium hydroxide (NaOH) as a catalyst, and methanol or ethanol as a reagent. The process of biodiesel production is called transesterification (Tickell, 2002). Sodium hydroxide and methanol were mixed to form a strong base, sodium methoxide, with a significant amount of exothermic heat. Caution and proper safety equipment must be used in this stage of biodiesel production. The mixture of sodium methanoxide is then added to the vegetable oil pre-heated to approximately 45^{o}C. This mixture is then thoroughly mixed or stirred for about 30 minutes to one hour, and allowed to settle for about 8–10 hours. In a successful reaction, glycerin settles to the bottom of the processor with the lighter ester (methyl ester) forming the top layer. The pilot plant is thus designed to handle this set of processes. Biodiesel can also be produced from waste vegetable oils.

According to the (US) National Biodiesel Board (2006), the mixture ratios most effective for the production process is one part of methanol to five parts of vegetable oil, and 0.35 g sodium hydroxide pellets to one litre

of vegetable oil, for example, 1 L alcohol + 1.75 g NaOH + 5 L oil. According to Chevron (1998), for a biodiesel fuel produced to meet international standards, such properties as cetane number, flash point, viscosity index, pour and cloud point, and caloric value, should be analysed. The improved equation for calculating cetane index (CCL) for diesel fuel known as ASTM D. 4737 is (Chevron, 1998):

$$CCL = 45.2 + (0.0892)\,(T_{10N}) + [0.131 + (0.901)\,(B)\,[T_{5ON}] + [0.0523(0.420)\,(B)\,[T_{90N}] + [0.00049]\,[T_{10N})^2] + (107)\,(B) + (60)\,(B^2)$$

Where, $B = [(e^{(-\ 3.5)})\ DN] - 1$, D = Density of biodiesel at 15°C, $DN = D - 0.85$, T_{10} = 10% recovery temperature as measured by D86[3] in °C, $T_{10N} = T_{10} - 215$, T_{50} = 50% recovery temperature as measured by D86 in °C, $T_{50N} = T_{50} - 260$, T_{90} = 90% recovery temperature as measured by D86 in °C, $T_{90N} = T_{90} - 310$.

The parts of the biodiesel plant are: reaction tank, the heating system, supporting system or frame work, the separation system, mixing system, transferring equipment, and storage system (Technologies International, 2007). According to Paul (2006), the material's compatibility is required for producing a standardized biodiesel, and he mentions some materials that were termed 'good' for biodiesel production (aluminium, stainless steel, fluorinated plastics, Teflon, Viton, nylon, and fibre glass). Another important area of consideration is the capacities of the materials that will be used in the production process. According to Noureddini et al. (1996), material capacity is especially important with respect to equipment used in mixing, transferring and heating. The appropriate selection of pump size required to perform an operation depends on the power required for the operation and pipe diameter. According to Onwualu et al. (2006), the equation for determining the pump power is:

$$P = \frac{WxH}{t}$$

Where, W = weight of fluid to be pumped (kg), H = pressure head to be overcome (m), t = time required to pump the fluid(s). However, pump size is calculated on the basis of the pump power and pump efficiency: Ps = P/e, where Ps = pump size (hp), P = pump power (kW), and e = efficiency (%) (Onwualu et al., 2006).

MATERIALS AND METHODS

The pilot plant was designed and constructed after applying the basic design equations. Tables and averages were used in the analysis of results. Three tests were carried out on three samples of each of the biodiesels produced. The properties tested were cetane number, flash point, viscosity index, pour and cloud point, density of the fuel, and caloric value. The basic mixing proportions used was 1 L alcohol + 1.75 g NaOH + 5 L oil.

Laboratory tests were conducted to determine each of the properties of the fuel. The Obukpa community in Nsukka Local Government Area of Enugu State, Nigeria was shown a sample of the fuel and the village head organized some agro-processors to see this new type of fuel they can use. The interactive session

[3] *D86 is a standard test method for distillation of petroleum product at atmospheric pressure.*

was illustrated using an overhead projector. They were also urged to cultivate more oil seeds like Jatropha and beniseed.

RESULTS

The completed biodiesel plant is shown in Figure 1, and a design diagram of the tanks is shown in Figure 2. The results of the test conducted on the beniseed and palm-kernel oil biodiesels to determine their fuel properties are summarized in Table 1. The cetane index of palm-kernel biodiesel was 51.824, while that for beniseed was 60.69. The viscosity, flash point and caloric value of palm-kernel biodiesel were 3.4 mm2/s, 143.5^{o}C and 128,244.27 J/L, respectively, while those of beniseed biodiesel were 2.97 mm2/s, 139.87^{o}C and 132,283.46 J/L, respectively. The fuel produced met international standards from ASTM (2003) and United States Soydiesel Development Board (2004).

The local community embarked on mass planting of oilseeds in order to boost biodiesel production. The university community also benefited. The university came first in the area of science and technology in the 2008 National Universities Research and Development Fair, Lagos, Nigeria. The work was displayed during the 2008 Special

Fig. 1: The completed 30 L/h biodiesel pilot plant

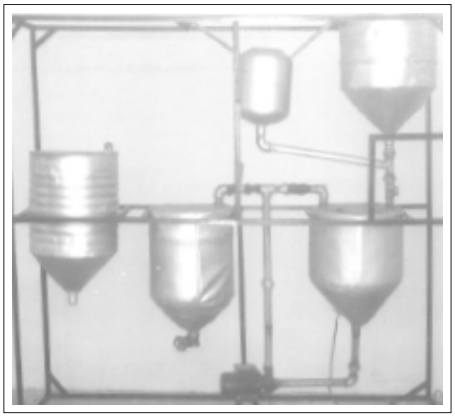
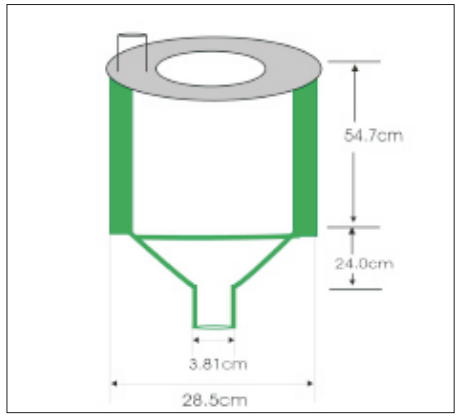


Fig. 2: Design diagram of the reservoir



Convocation Ceremony at the University of Nigeria, Nsukka. There is an ongoing collaboration between the researchers and Biodiesel Nigeria Group.

DISCUSSION AND CONCLUSION

One major property of diesel is its cetane index or number. We used the ASTM equation for calculating the index. The calculated cetane index for palm-kernel biodiesel is 51.824 (Table 1). This value is within the stipulated standard of ASTM which is 47 minimum for biodiesel. Thus, the fuel met international standard. Physical observation during the test- running of the fuel on an R-175 4-hp engine in the Department of Agricultural Engineering showed zero soot production.

Table 1. Summary of the fuel properties of palm-kernel oil (PKO) and beniseed oil biodiesel

	PKO Beniseed	Biodiesed biodiesel	Biodiesed Standard
Viscosity (mm2/s at 40ºC)	3.41	2.97	1.9-6.0mm2 (ASTM 06751 – 03)
Cetane index	51.824	60.69	≥47 (ASTM 06751-03)
Flash point (ºC)	143.5	139.87	>130ºC (ASTM 06751-03)
Pour point (ºC)	–21.44	–21.56	(Report to customer, ASTM)
Cloud point (ºC)	–10.37	–10.64	(Report to customer, ASTM)
Relative density (at 15ºC)	0.894	0.872	0.88 (USNSDB)
Caloric value (J/L)	128,244.27	132,283.46	128,000 (USNSDB)

ASTM: American Society of Testing and Materials (2003); USNSDB: United States National Soydiesel Development Board (1994).

The engine started smoothly and ran noiselessly.

The design and complete construction of the 30 L/h biodiesel pilot plant is a significant breakthrough in Nigeria's quest to join the biodiesel league. It is significant to note that this pilot plant is the first continuous biodiesel plant built in Nigeria.

Built with local materials, it is portable, and suitable for small-and medium-scale entrepreneurs.

The grand mean viscosities of 2.97 mm2/s for beniseed biodiesel and 3.4 mm2/s for palm-kernel biodiesel, fit within the international ASTM standard of 1.9–6.0 mm2/s.

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Development of Spiral Pump Technology

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Keywords: irrigation, small-holder farmer, alternative, operation, pressure heads, motorised

Abstract

Foundation for Irrigation and Sustainable Development (FISD), a local non-governmental organization, has developed and tested a spiral pump with low torque requirements. The pump has been designed specifically to be mounted in a river and driven by paddle wheels by aid of water current. This pump, which can easily be built by local welders, has low maintenance and operation costs as it pumps water without the need of either fuel or electricity, provided there is a flowing stream or river. It can also be hand-turned or otherwise driven to provide a low-cost, efficient pump. The pump is made from a series of locally available metal paddles attached through spokes of steel to a central hollow axle mounted on ball-bearings. The polythene pipe is arranged to form a spiral fixed to the sides of the wheel. Water enters the spiral tube through an enlarged pipe, which collects water as it rotates and is dipped into the flowing river. A core of water is picked up on each revolution of the wheel followed by a core of air. So an alternating series of cores of air and water enter the coils, and then passes along the pipe as the coil turns on the wheel. The innermost spiral of the tube delivers water into the wheel axle and there it is led through a pipe up to the field for irrigation under pressure created by the compressed cores of air and water.

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INTRODUCTION

Malawi irrigates only 72,000 of its 400,000 hectares of irrigable land. Up to 90% of Malawi's agriculture is rain-fed. The country derives up to 70% of its foreign-exchange revenue from agricultural production and 85% of the country's population depends on the same sector for its livelihood. Seven out of 10 households in Malawi typically run out of food before the harvesting season, mainly because of drought and floods. With current population increase and erratic rainfall pattern (which is expected to be further exacerbated by climatic change), Malawi's hope for achieving food security and a stable economy is to jump-start its agricultural production by dramatically increasing the use of irrigation. This calls for technology advancement for water abstraction options for irrigation from water sources that are lower than the command area, bearing in mind that the great majority of the potential 400,000 hectares falls into this category.

Foundation for Irrigation and Sustainable Development (FISD), a local non-governmental organization formed by three young Malawian graduates from University of Malawi in 2005, has developed and tested a spiral pump along Shire River in southern Malawi. The pump has low torque requirements, for pumping water at no cost. The spiral pump project was initiated to derive an alternative water-abstraction option that has no operation costs as compared to motorized pumps widely used to abstract water from large rivers, where building of water abstraction structures like weirs is expensive and difficult. The pump has been designed to be mounted in a river and driven by a paddle wheel in a current of four feet (1.22 m) per second or greater. This easily built, low-maintenance spiral pump can be used to pump water without the need for fuel wherever there is a flowing stream or river. It can also be hand-turned or otherwise driven to provide a low-cost, efficient pump.

MATERIALS AND METHODS

The project underwent processes of pump design; this stage was conducted together with extensive review of (mostly informal, e.g. Internet) literature. Pump design was in line with locally available materials and calculated water requirements for the available 7 acre (2.83 ha) plot. This was in line with the elevations of the area to be commanded (fed) by the pump. After the pump was designed, the project identified locally available materials, and then assembled and tested the pump. Plans are underway to disseminate the technology to farmers and stakeholders. Through targeted training, local welders in all the three regions of Malawi will be informed of the technology and this new business opportunity created for them. The project has had three phases, of which only one is completed. The first phase was the pump design and identification of local materials and beneficiaries to manufacture the patented pump. The second phase is to develop a demonstration farm for the technology, and the third will be the dissemination phase.

Pump Design and Identification of Local Materials for Construction

In this first prototype, 13 spirals totalling about 40 metres of 50 mm polythene pipe were coiled on each side of the pump. Two water collectors were made of 150 mm PVC pipe, each about 0.8 m long. The ends of the innermost coils were connected to the axle through polythene elbows. The axle was mounted through two sealed ball-bearings mounted on the 3 mm angle iron supports at the side of the spiral.

To determine whether the designed pump could be built by a local welder with basic working instruments, one welder was identified who was then involved in constructing and assembling the pump throughout the phase.

Demonstration Plot

Being a new technology, to aid quick adoption, the next phase after constructing the pump and testing it was to acquire land and develop a demonstration farm. This phase is expected to run until the end of 2009. The farm, apart from aiding quick technology diffusion, is to be used in identifying likely challenges to be faced by small-holder farmers when using the pump and subsequently devise ways of modifying the pump.

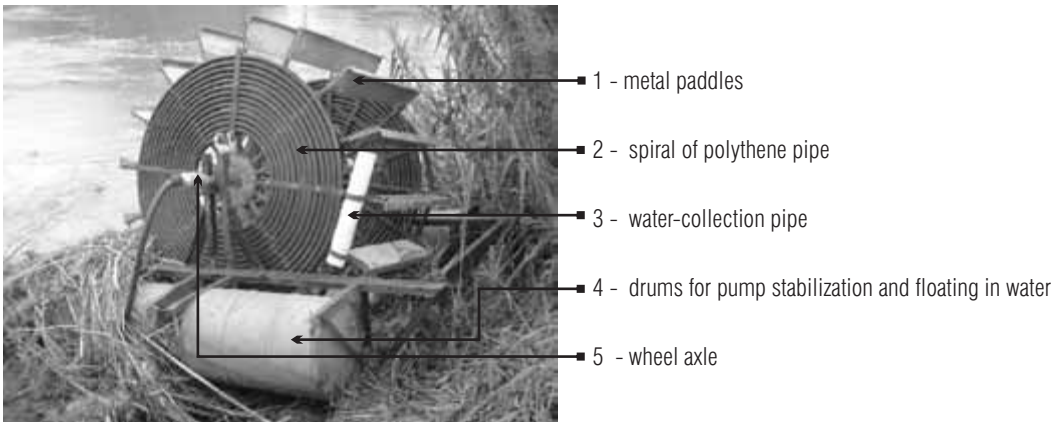
Dissemination Phase

As the technology has to be understood by policy-makers and different stakeholders in irrigation, FISD is preparing comprehensive documentation of the technology and is organizing a field show in March 2010, where different modes of this water-driven pump will be demonstrated. This we believe will enable government to substitute motorized pump distribution to resource-poor farmers with this technology, considering the current price of fuel. The technology will benefit two categories of resource-poor Malawians—small-holder farmers who cannot manage motorized pump irrigation interventions and low-income welders. The latter will be identified in the dissemination phase and, together with the welder who has been helping to develop the pump, this group of beneficiaries will be trained on spiral-pump construction and maintenance.

PROJECT RESULTS SO FAR AND DISCUSSION

Through the project, a pump has successfully been designed and constructed. When this technology is promoted, it is expected to provide a much more reliable alternative of pumping water to methods that require fuel or human power. As the technology is simple (Fig. 1), it is further expected that the technology will easily be replicated through numerous local welders around the country, whom we expect to train as soon as funds are available under phase 3 of project implementation.

Fig. 1. The prototype spiral pump .



The spiral pump is made from a series of locally available metal paddles (Part 1) attached through spokes of steel to a central hollow axle mounted on ball-bearings. The 'spiral tube' water pump itself consists of a length of polythene pipe so arranged that it forms a spiral fixed to the sides of the wheel (Part 2). In this water wheel, two spiral pipes are used and these are horizontally opposed. Water enters each spiral tube through an enlarged pipe which acts as water collector (Part 3). The collector picks up water as it dips into the water flowing down the river, stream or canal—like a scoop. Enough water is picked up to half fill each coil. Thus, a core of water is picked up on each revolution of the wheel, followed by a core of air. So an alternating series of cores of air and water enters the coils, which pass along the pipe as the coil turns on the wheel. The innermost spiral of the tube delivers water into the wheel axle (Part 5) and there it is led through a simple water seal to the field for irrigation. As the wheel 3 1 2 4 5 revolves, a pressure head develops within each coil of the spiral tube, water in the rising coils being higher than that in the descending coils. These cores of water in the spiral tube compress the air between them as they travel around the spirals and both water and air are expelled under pressure into the axle. The flow of water up to the irrigation field is also accelerated by the compressed air escaping and expanding from the outlet at the axle of the wheel. This is the effect that helps to lift water uphill.

Theoretically, the highest point to which water could be pumped may be influenced by the number of spirals of the polythene pipe and the diameter of the spiral. This is the next stage of experimentation. Generally, looking at how the pump works, the head upon which the pump may be able to deliver scooped water is directly proportional to the number of spirals and their diameter, but this relationship has yet to be established. The volume pumped can be clearly seen to depend on the amount of water picked up by the scoop and retained by the pipe during each revolution. Several spiral tubes could be fitted to the same wheel, the ideal number being two. With a single spiral, air and water are expelled alternately at the outlet. Unlike a single coil, double coils (as in Fig. 1) create continuous pressure along the spirals and, hence, better results. With two horizontally opposed spiral tubes fitted to a single wheel, air and water rise through the pipe in more regular bursts.

Considerable pumping heads can be achieved if necessary by using an appropriate number of coils on a suitable sized wheel placed over a canal or river system of adequate water power. The power delivered to the paddles must be sufficient to overcome the weight of water held in the rising segments of the spiral and so this is a limiting factor. If the weight of water held in the rising coils is much larger than the weight held in the descending coils, the wheel may stop turning if the power delivered to the paddles is insufficient. A balance must be struck between the power delivered by the water on the paddles, the wheel diameter, the pipe size, number of coils, and required head of water to be delivered. If the number of coils in the spiral is insufficient to pump water to the desired height, water flows over from one coil to the next without achieving any pumping, hence no discharge is achieved.

CONCLUSION

The great advantage of the spiral-pump system is that once it is worked out, the mechanics are very simple and reliable. The pump has less operational and maintenance costs than the widely used motorized pumps, which are not viable for most of Malawi's small-holder farmers, who live on less than a dollar a day. While the first pump has been built and tested successfully, we are still developing the technology further by

carrying out the tests for subsequent modelling and simulation for documentation and replication by looking at the capacity of the pump at different speeds, the effect of the size of the scoops (water collectors) and the relationship between the size and number of coils with reference to the level to which water could be delivered. This will help in standardization and specification of the constructed pumps.

Impact of Forested *Zaï* on the Evolution of Biodiversity and the Biological Parameters of Soil in Burkina Faso

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Keywords: Yatenga, soil rehabilitation, forested zaï, biodiversity

Abstract

Forested zaïis a technology for soil rehabilitation which is being increasingly used in Yatenga (Burkina Faso). The technology allows the restoration of vegetation on degraded soils. The main objectives of this research were to characterize the evolution of chemical and microbiological parameters of fallows in order to determine the factors that influence biodiversity in forested zaï. The study was carried out in the village of Gourga, department of Oula, Yatenga province. The results showed an increase of floristic richness in the different fallows of increasing ages. Several interrelated parameters affected the biodiversity of the zaïecosystem: the heterogeneity of the fallow, various human actions on the environment, and the soil topography.

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INTRODUCTION

Burkina Faso, an agro-pastoral country, is located in the Sahelian part of West Africa. Its economy is mainly based on agriculture. The agricultural sector accounts for 40% of the GDP (Gross Domestic Product), procures over 65% of the country's income from exports (Adda, 1999), and employs close to 90% of the working population. Burkina Faso agriculture is subsistence agriculture based on food grains (sorghum, millet, maize), which cover over 88% of the sown lands each year (Yonkeu et al., 2003). The degradation of natural resources is accelerated as a result of the objectives of agriculture and livestock production, that is, production increases to ensure food security, a vital element in poverty reduction.

The elimination of the plant cover is accompanied by a concomitant physico-chemical and biological loss of soil fertility (Pieri, 1989). This leads to a more or less general drop in agrosystem productivity (Hien, 1995; Sangaré, 2007). Faced with problems of soil degradation, accelerating soil-fertility decline and overall loss of biodiversity, Burkinan farmers developed various cropping techniques for soil and water management, including the zaï system that combines the control of run-off, using stone bunds, and a soil preparation technique composed of organic matter (compost or manure) that is put into seed holes dug, before the rains, in places where specific plant species are cultivated (Roose et al., 1993a; Delaite and Pastor, 1997). The zaï is a complex soil-restoration system using organic matter localization, termite-boring channels in the crusted soils, and run-off capture in micro-watersheds. Termites play an important role in this system both to incorporate available residue and to facilitate infiltration of rainwater (Roose, 1989).

There is abundant literature available on farmers' techniques and technologies for combating soil degradation (Ouedraogo and Kaboré, 1996; Ambouta et al., 2000; Roose et al., 1993b), but most of this work focuses exclusively on the comparative increases in yields obtained, without really questioning the long-term evolution of soil fertility or the consequences of these changes in land use on the organic matter and the biological interactions in the soil at both the plot and village-land (terroir) levels.

Furthermore, the dynamics of organic matter are highly dependent on the activity of micro-organisms (Ndiaye, 2003). Hence, biological activity continues to be essential in soil fertility, which means that measuring microbial activity is an important factor in soil-quality studies. This study fits in with the issues described above and aimed to examine the effects of forestry zaï on the evolution of soil biodiversity. In this study, we have given preference to a functional approach, starting with a given function and ending with the responsible organisms. We studied two biological aspects of the microbial population:
(1) microbial activity, and (2) microbial abundance.

MATERIALS AND METHODS

Study Site

The study was carried out in the village of Gourga, 8 km from Ouahigouya, chief town of the Yatenga province (13°06′– 14°26′N; 1–3°W), Burkina Faso. The Soudano-Sahelian climate is marked by a long dry season, whose dryness is accentuated by the harmattan, the dry winds from the Sahara. Furthermore, it has two seasons:

- a rainy season, from May to October, with rains often poorly distributed in time and space;

- a long dry season, which lasts 8–9 months and is composed of a cold period from November to February (14–36°C) and a hot period (23.7–47.3°C).

Between 1921 and 2004, annual rainfall varied between 400 mm and just under 900 mm. The study site was composed of zaï-forest plots of various ages established by an innovative farmer. The plots had been planted using zaï technology, and were then left fallow and closed off for several years. At the time of the study, these plots were between 14 and 30 years old. The study site, thus, provided an excellent opportunity to study the impact of zaï on biodiversity and especially microbial diversity at the village-land (terroir) scale.

Sampling

The terrain extended around a hardpan table. The work plan was to sample the environment on the basis of the hardpan table by laying out four transects according to the four compass points and the toposequence. The sample squares were spaced regularly (3 m, starting at the beginning of the transect) and followed four transects (north, south, east, west). Soil samples were removed at a depth of 0–5 cm and 5–10 cm and sifted through a 2 mm mesh sieve.

Twenty-eight soil samples (depth of 0–5 cm) were taken from small (0.5 ×0.5 cm) squares for use in the microbial behaviour analysis.

Two analyses were made as part of the microbial behaviour study at the Laboratoire d'écologie microbienne des sols et agrosystèmes tropicaux (LEMSAT-IRD, Dakar, Senegal).

Measuring the Potential of Soil Respiration

1. Principle. Soil respiration was determined by measuring carbon dioxide released in relation to total air volume and as a function of time, using a soil sample incubated in an enclosed area.

Measurements were made every day through direct injection into a gas micro-chromatograph (MTI P200, Microsensor Tecnology Inc., Fremont, CA, USA) equipped with a Poraplot column. Helium was used as the carrier gas. Results are given as percentages of flask volume and were calculated in relation to initial quantity of CO2 (T0). Daily measurements define the kinetics of CO2 releases.

2. Operating Method. Soil samples of 25 g were put in 120 ml glass bottles, with three repetitions, and were wetted to a maximum of 100% of the soil's water-retention capacity. The bottles were sealed and shaken vigorously before measuring T0 (initial quantity of CO2).

Each day, for 7 days, the content was read by CPG (gas chromatography) injection.

Microbial Biomass

The quantity of CO2 in the soil sample was measured each day. On day seven, the microbial biomass was measured using the Fumigation-Extraction method (Amato and Ladd, 1988; Wu et al., 1990). This technique uses chloroform vapours and doses of soluble carbonate compounds. The difference in soluble organic carbon between the fumigated and the unfumigated samples gives the quantity of 'extractable' carbon of microbial origin; the quantity of carbon is directly proportional to the biomass. The method gives a

global measurement that represents the quantity of carbon 'living' in the soil.
The α-aminated nitrogen in the micro-organisms is obtained through incubation in a medium saturated with chloroform (fumigation), which is supposed to kill the organisms living in the soil. The α-aminated nitrogen appears during fumigation through the lysis of soil micro-organisms that have been killed by chloroform. The quantity of α-aminated nitrogen is a function of the quantity of micro-organisms in the soil prior to fumigation.

The Fumigation-Extraction method is used to determine the α-aminated nitrogen obtained through incubation with chloroform then extracted using potassium chloride (KCl). Ninhydrin reagent is added to the quantities extracted (T0, T10). The amount of carbon in the biomass is calculated by multiplying the gain in the α-amino nitrogen released during incubation by a factor of 21 (Amato and Ladd, 1988).

The results are expressed in μg /g of dry soil. The value of the microbial nitrogen per soil sample is obtained using the following equation:

$$Nm = \frac{((N_{T10} - N_{t0}) \times 75)}{(P - (P \times H))}$$

Where, Nm = microbial nitrogen (μg/g of dry soil); NT0 = α-aminated nitrogen measured in the KCl extracts at time T0 (μg N/ml); NT10 = α-aminated nitrogen measured in the KCl extracts after 10 days of incubation (μg N/ml); 75 = volume of KCl used for the extraction (ml); P = weight of fresh sample (g); H = moisture content of sample (%) = ([fresh weigh – dry weight] ×100) / dry weight.

Statistical Analysis

The data collected were processed in an Excel spreadsheet (Microsoft). For the variance tests, the statistical analyses were made using XLSTAT software.

RESULTS

Soil Chemical Parameters

The largest quantity of carbon was observed in the 20-year old *zaï* (14.35 mg C/g soil) followed by the 24-year old *zaï* (12.05 mg C/g soil) (Table 1). The 21-year old *zaï* had the lowest amount of total carbon. These results lead us to deduce that total carbon and nitrogen rates do not change as a function of plot age. As concerns assimilable phosphorus, rates tended to be significantly higher in the 30-year old zaï ($P \leq 0.005$).

There was no significant difference in the C/N ratio among *zaï* plots.

Table 1: Total carbon, total nitrogen, assimilable phosphorus, C/N ratio, water pH and KCl pH of soil samples according to age of *zaï*, in the 0–5 cm soil horizon

	Age				
	14 years	20 years	21 years	24 years	30 years
C-total	10.15 ab	14.35b	9.6a	12.05ab	10.4ab
N-total	0.92a	1.09b	0.79a	1.07ab	0.98ab
P-assimilable	2.27bc	2.41bc	1.38a	2.12b	3.13c
C/N	10.98a	10.92a	12.07a	11.31a	10.72a
pH water	6.25a	5.84a	6.27a	6.12a	6.04a
pH KCl	5.21a	4.80a	5.15a	4.81a	4.53a

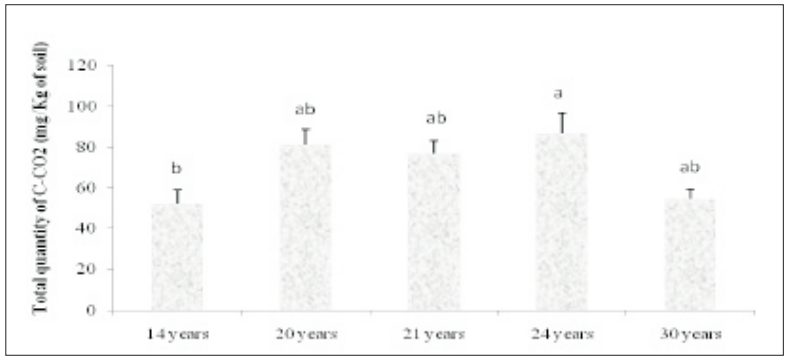
Significant difference between two means for each row is indicated by the different letters, based on the Fisher test (P<0.05).

Intensity of Soil Respiration

Figure 1 shows total quantities of C-CO2 (mg/kg of soil) released in a 7-day period by microbial respiration. The largest quantity of C-CO2 was observed in the 24-year old plots, i.e. 87 mg C-CO2/kg soil. The 14-year old plot had the lowest quantity (52.24 mg C-CO2 /kg soil).

The variance analysis showed that the quantity of C-CO2 was higher in the 24-year old plot.
Comparing averages, there were differences between the 20-, 21-and 30-year old plots. The difference ranges between 22.21 and 26.57 mg C-CO2/kg soil. However, the observed differences are not statistically significant.

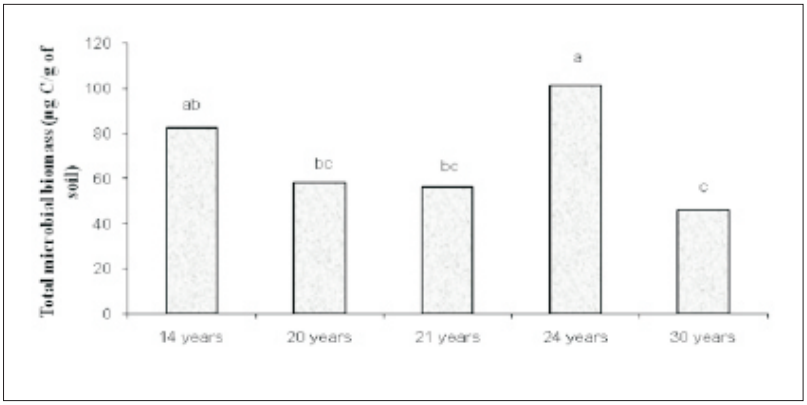
Fig. 1: Total quantity of C-C02 released from the soil, depending on *zaï* plots



Total Microbial Biomass

The highest total microbial biomass was observed in the 24-year old *zaï* (101.33 µg C/g soil) followed by the 14-year old zaï (82.42 µg C/g soil; Fig. 2). The lowest amount of biomass was found in the 30-year old zaï (46.18 µg C/g soil). Variance analysis showed a significant difference between the 24-and 30-year old plots (P<0.01) and between the 24-year old plots and the 20- and 21-year old plots (P<0.05).

Fig. 2. Quantity of total microbial biomass (µg C/g of soil) per zaï plot



Bars with the same letter are not significantly different according to one-way ANOVA ($P \leq 0.05$).

Metabolic Quotient

The highest metabolic quotients were found in the 21-, 20-and 30-year old plots (Table 2) although they did not have the highest microbial biomass; the 14-and 24-year old plots had the highest microbial biomass. These results indicate that large quantities of microbial biomass are not always synonymous with strong respiratory activity. The quality of the microbial populations is extremely important. This explains the need for frequent functional diversity tests.

Table 2: Metabolic quotient according to age of *zaï*

Age of zaï	Microbial biomass (µg C/g soil)	Metabolic quotient
14 years	82.42	0.039
20 years	58.33	0.140
21 years	56.42	0.156
24 years	101.33	0.067
30 years	46.08	0.132

DISCUSSION

Results show that respiratory activity that may accompany the degradation of organic material is not always connected to the total microbial biomass. A low level of microbial biomass can produce strong respiratory activity, and an active metabolism means high metabolic quotient. This suggests population rejuvenation, since the metabolic quotient of young organisms is higher than that of older ones (Anderson and Domsch, 1978). Furthermore, the soil carbon in each plot provides an explanation for the high levels of C-CO2 and microbial biomass. The higher the soil organic-car bon content, the greater the microbial populations and their activities. Numerous studies have indicated that microbial population dynamics depend on the amounts of soil carbon (Degens et al., 2000). Garcia-Gil et al. (2000) have shown that the abundance of microbial communities correlates positively with the quantity of carbon available to satisfy their energy demands.

Furthermore, the quality of the microbial populations can induce different respiratory activity. The quality of the soil populations is reflected in their diverse aptitudes for metabolizing the substrata (Garland and Mills, 1994).

CONCLUSION

Microbial compartmentalization is essential for the *zaï* ecosystems, because of its role in controlling mechanisms for the decomposition and recycling of elements that are nutritious for the plants.
This study has shown that:

- zaï is an agro-sylvo-pastoral technique that provides for sustainable soil-fertility management and reduced pollution from mineral fertilizers;
- zaï is an excellent tool not only for restoring (rehabilitating) degraded lands, but also for biodiversity conservation.

Yet, this study needs to be rounded out by a more inclusive study that includes the study of the effects of manure quality on micro-organisms (activity and diversity). It would also be worthwhile going further into microbiological characterization through more in-depth analyses—for example, bacteria and fungi counts and catabolic diversity analyses.

Acknowledgements

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Status and Prospects of Stingless Bee-keeping in Kenya

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Keywords: conservation, income, farmers, meliponiculture

Abstract

Stingless bee-keeping (meliponiculture) is a unique eco-friendly agro-practice with the potential for environmental amelioration, employment and income generation. Meliponiculture would be ideal for generating of supplementary income for resource-poor farmers around forests, in addition to conserving stingless bees. This project assessed the folk knowledge, honey quality and antibacterial effect of stingless-bee honey. Assessment of the folk knowledge of stingless bees by communities in Kenya indicated that different tribes have knowledge stingless bees, but they do not undertake any active conservation measures. The communities identify stingless bees by their morphological features, nesting architecture, and the taste, smell and colour of their honey. Honey from five bees (Hypotrigona gribodoi, Meliponula bocandei, M. ferruginea [black], M. ferruginea [white] and Plebeina hildebradti) varied in composition. Moisture content was higher than that of Apis mellifera. Studies on antimicrobial activity of the stingless bees against five strains of bacteria (Pseudomonas aeruginosa, Salmonella typhi, Escherichia coli, Staphylococcus aureus and Bacillus subtilis) indicated susceptibility of the bacteria to the honey. Escherichia coli and P. auregnosa were the most susceptible bacteria. Moreover, honey from P. hildebrandti and M. ferruginea (b) showed the highest antibacterial effect. This project forms a foundation of meliponiculture Kenya as incentive for forest conservation and income generation for resource-poor farmers.

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INTRODUCTION

The number of people living in poverty is ever increasing and the rate of poverty growth continues to rise. The external debt-servicing burden has greatly reduced the ability of mainly African countries to address the issues of poverty in an adequate manner. Poor people often have no option but to use the environment in non-sustainable ways. A degraded environment cannot sustain continued use of its natural resources and hence cannot sustain food production, wild animals or natural pollinators (Raina, 2004). It is against this background of non-sustainable use of the environment and the need for strategies to develop linkages between diversity of resources and sustainable livelihood through income-generation options that this study was initiated on stingless-bee farming in Kenya.

Stingless bees are social bees in the family Apidae. They live in permanent colonies that often contain many thousands of bees (Michener, 2000). There are about 400–500 species of stingless bees in the world (Crane, 1990). In Africa, 19 species of six genera of stingless bees are known to occur (Eardley, 2004). In Kenya, six species have been identified (Macharia, 2007).

For sustainable utilization of stingless bees, there is a need to utilize the traditional knowledge of the local communities (Byarugaba, 2004; Macharia, 2008), especially in taxonomy and honey. Stingless bees produce honey which is relished as human food, but the official definition of 'honey' is restricted to the honey of A. mellifera by the Codex Alimentarius Commission (Vit et al., 2004). Official methods for honey standards have been developed for A. mellifera (Bogdanov, 1997). There are no standards for stingless bees' honey worldwide. Besides promoting knowledge regarding honey from stingless bees, this work is a contribution for the data bank to adjust the quality standards of honey from stingless bees, especially in Africa. Honey from stingless bees is considered in folk medicine to be more powerful than honeybee honey for use in the treatment of common diseases (Vit, 2001; Garedew et al., 2004, Macharia et al., 2007). Beekeepers and honey enthusiasts alike have long reported the medicinal qualities of honey (Ransome, 1986; Crane, 1990; Molan, 1997). Most of these studies have been conducted using honey produced by A. mellifera.

The purpose of this study was (1) to review and document folk knowledge on stingless bees; and (2) to suggest standards for stingless bee honey and the antibacterial effect of these honeys.

MATERIAL AND METHODS

Study Area

The project was carried out mainly in three regions in Kenya: Kakamega rainforest located in the west, Mwingi dry forest and Arabuko Sokoke coastal forest.

Folk Knowledge

A survey using a questionnaire was carried out on folk knowledge and conservation status of stingless bees in three regions in Kenya—Mwingi, Kakamega and Arabuko Sokoke.

Honey Analysis

Honey samples were collected from the nests using a syringe. The methods used to analyse the 120 samples of honey were based on those of the Association of the Official Analytical Chemists (AOAC, 1990) and International Honey Commission (Bogdanov et al., 1997; Bogdanov, 1999). The percentage of moisture in honey was determined using a hand-held honey refractometer. Hydroxymethylfurfural (HMF) content was determined using the spectrophotometric method (White, 1979). Diastase activity of each honey sample was quantified by spectrophotometric method (Schade et al., 1958). Free acidity was quantified by volumetric-titration. Proline was quantified using spectrophotometric method.

Antibacterial Effect

Five bacterial strains were used in the study—*Pseudomonas aeruginosa, Salmonella typhi, Escherichia coli, Staphylococcus aureus* and *Bacillus subtilis* - all obtained from Inoclaine International, Nairobi, Kenya. The agar disc diffusion method was used (Allen et al., 1991) to evaluate the antibacterial activity of honeys from stingless bees and honeybee against the test bacteria.

Statistical Analysis

In honey analysis, all the determinations were repeated at least three times and the means determined. Analysis of variance (ANOVA) was used to compare antibacterial effect of the different honeys. The Tukey-Kramer multiple comparison test was used to separate significant means at 5% level of significance.

RESULTS

Five tribes in Kenya have local names for stingless bees depending on the species. Luhya tribe names them *ikore, iwele, inanasa, viuyiya, vusit;* Kamba tribe names them *ngilu and mbua*; Pokomo name them *mabwata*; Giriama tribe names them *urombi or oza;* Kalenjin name them *kesomei.* These communities use different characteristics in identifying stingless bees. These characteristics include: body size, colour, shape of the nest entrance, taste and quantity of honey produced by different species.

The means for the quality variables analysed (moisture, HMF, diastase, proline, free acidity and reducing sugars) are summarized in Table 1. Mean constituent values were 21.0–27.0% moisture, pH 3.28–4.12, 34.8–46.70 meq/kg free acidity, 3.72–18.80 mg HMF/kg, diastase 8.62–22.80 Schade units, 75.0–396.2 mg proline/kg, 58.1–70.3% reducing sugars, and 2.0–5.2% sucrose.

A summary of the antibacterial activity (expressed as inhibition zones) of stingless bees' honey is presented in Table 2. Generally, larger zones of inhibition were exhibited on Gram-negative bacteria, P. aeruginosa and E. coli, as compared to the Gram-positive bacteria, B. subtilis and S. aureus.

DISCUSSION

In Kenya, several local tribes have a good knowledge about native species, including stingless bees. Such knowledge when collected is important in linking the folk knowledge with classical taxonomy. Such studies can be used in the process of choosing bee species as potential pollinators and in the development of a stingless-bee management strategy. This study established a foundation of folk taxonomy of stingless bees.

Comparing the data of stingless-bee honey analysed with the international standards for A. mellifera honey (Codex, 2001), the honey from the different stingless bees varied in composition. Moisture content of the samples of stingless-bee honey from Kenya was higher than the standard for A. mellifera honey (maximum 20% moisture content). These observations agree with other findings (Vit et al., 1994, 2004; Torres et al., 2004; Lubertus et al., 2006). The combination of HMF, diastase and invertase enzyme levels indicate the extent of heat and storage damage of honey and can be used as markers of honey freshness and adulteration (White, 1994). All the samples in this study had HMF within the acceptable limits, agreeing with the results of Vit et al. (2004).

It is hoped that the results of this study will constitute a starting point for creating a solid database of stingless-bee honey, including all parameters useful for honey quality control in Africa. A honey quality-control campaign directed to stingless-bee keepers is needed, for harmonization of analytical methods. This will allow the control of this valuable product, leading to the setting of quality standards and marketing systems for income generation.

Table 1: Physicochemical composition (means ± SE) of stingless bees honey samples collected from different areas in Kenya

Area and species	Moisture content [≤21%]	pH	Free acidity [≤50 meq/kg]*	HMF [≤40 mg/kg]*	Diastase [≥8DN]*	Proline [≥180 mg/kg]*	Reducing sugars [≥65%]*	Sucrose [≤5%]*
Kakamega forest								
M. ferruginea	25.4	3.41	34.8	6.47	22.80	284.00	60.0	4.30
(n=17)	± 0.53	± 0.12	± 4.09	± 2.65	± 4.60	± 78.0	± 12.07	± 1.71
M. bocandei	26.20	3.36	38.20	7.42	18.80	396.20	59.1	2.10
(n=13)	± 0.34	± 0.13	± 5.54	± 2.97	± 6.21	± 127	± 8.70	± 0.32
H. gribodoi	21.00	4.12	44.00	6.65	8.62	75.00	61.00	3.80
(n=10)	± 0.21	± 0.11	± 2.02	± 2.90	± 1.70	± 43.0	± 11.98	± 1.78
Mwingi								
M. ferruginea	22.20	3.61	42.00	8.40	15.30	240.00	65.00	5.20
(n=10)	± 1.80	± 0.28	± 0.92	± 3.38	± 2.18	± 56.7	± 4.97	± 2.01
Arabuko Sokoke								
H. gribodoi	26.20	3.28	38.60	18.80	13.00	206.00	58.10	3.50
(n=10)	± 0.48	± 0.31	± 3.81	± 1.24	± 2.40	± 42.40	± 3.12	± 0.13
W. Pokot								
Melipona sp.	22.20	3.40	46.70	6.16	10.10	234.00	68.10	4.60
(n=6)	± 0.02	± 0.11	± 0.85	± 1.03	± 1.09	± 63.40	± 1.38	± 0.67
Tana								
Unknown sp.	27.00	3.29	42.00	3.72	13.40	208.00	70.30	2.00
(n=2) ± 0.43	± 0.15	± 2.14	± 0.53	± 1.78	± 52.1	± 1.16	± 0.12	

***** *Honey quality standards of the Codex Alimentarius for floral honeys (Codex, 2001).*

Table 2: Antibacterial activity (expressed as inhibition zones) of stingless-bee honey against 5 bacteria strains (B. subtilis, S. aureus, P. aeruginosa, E. coli and S. typhi)

Species	Inhibition zones (mm ± SE)				
	B. subtilis	E. coli	S. aureus	S. typhi	P. aeruginosa
	Local isolate	STD 25922	ATCC 20591	ATCC 2202	ATCC 27853
M. ferruginea (b)	8.25 ± 0.16	12.20 ± 1.44	9.70 ± 0.15	9.25 ± 0.37	12.00 ± 0.77
M. ferruginea (w)	0	15.51 ± 0.50	9.00 ± 0.00	0	10.50 ± 0.50
H. gribodoi	0	17.31 ± 1.93	9.50 ± 0.50	0	13.62 ± 1.53
P. hildebrandti	9.33 ± 0.67	10.00 ± 0.41	10.31 ± 0.25	8.75 ± 0.25	9.00 ± 0.41
M. bocandei	0	10.00 ± 0.91	9.75 ± 0.25	10.00 ± 0.41	12.83 ± 1.11
Streptomycin	21.00 ± 3.00	22.51 ± 0.50	20.32 ± 0.67	16.30 ± 0.33	17.24 ± 1.69

Local people in Kenya value honey from stingless bees is highly as it is believed to be a panacea for many ailments and to have more value compared to honey from *A. mellifera* (Macharia et al., 2007). Many authors (Molan and Russell, 1988; Bogdanov 1997; Selçuk and Nevin, 2002) have confirmed the antimicrobial activity of honey. Most of these studies have been conducted using honey produced by A. mellifera. The results of this study indicate that Gram-negative bacteria (E. coli and P. aeruginosa) and Gram-positive bacteria (S. aureus) are susceptible to stingless-bee honey, in various degrees, which agrees with studies by Vorlová et al. (2005). It can also be concluded that different honey from stingless bees has different strengths in antibacterial effect. The traditional use of stingless bees' honey in Kakamega as a panacea against different illnesses is rational if the infection to be treated is caused by bacteria.

Stingless bees have the potential to become an integrated part of rural development and local economy in Kenya, particularly concerning their role as pollinators of human food plants. Knowledge of African stingless bees is rudimentary; therefore a concerted effort has to be made to improve our understanding of these bees, exchange information on African stingless bees, start research cooperation both on applied aspects of stingless-bee biology and on applied pollination. Once we have filled the gaps in our knowledge of these bees, we can promote their use in local initiatives and potentially even in commercial organic farming systems.

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Enhancing Livestock Production in HIV/AIDS Infected and Affected Households in Uganda

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Keywords: small-holder dairy, labour-saving technologies, improved cattle feed, milk production, forage chopper

Abstract

HIV/AIDS is very detrimental in crop and livestock production as it kills and weakens the active age groups that provide labour for production. Livestock production is crucial in households infected and affected by HIV/AIDS as it provides nutritious food such as milk and income for these households. However, inadequate feed was identified as a major constraint to livestock production, especially in dairy cattle production. A project was designed to improve food and feed production for humans and livestock production through utilization of improved livestock technologies. Project identification and implementation was a participatory process. *Calliandra*, elephant grass–legumes intercrop and maize–lablab intercrops were introduced to HIV/AIDS infected and affected households. Manual forage choppers were also given to weak farmers and orphans to reduce the drudgery effort associated with chopping of elephant grass. There was a 20% feed increase on farm. On average, milk production increased by 29%, 38% and 30% for cows fed on *Calliandra*, elephant grass–legumes intercrop and lablab–maize intercrop, respectively. There was also an increase in household monthly incomes by 36,250, 47,500 and 37,500 shillings for households who fed their cows with *Calliandra*, elephant grass–legumes intercrops and lablab–maize intercrop, respectively. It is very important to involve the target group in the whole research process so that the research is relevant and beneficial to them. Involving sick people in research and introducing to them simple, user-friendly improved livestock technologies can have a big positive impact on lives of people living with HIV/AIDS.

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INTRODUCTION

HIV/AIDS is a major challenge in crop–livestock production as it kills and weakens the active age groups that provide labour for production. Household members who look after the sick have less time to put into production. In addition, sickness and death of parents disrupts the transmission of both traditional and modern knowledge and farm management skills between generations. This has led to a devastating impact on rural women, men, youth and children, and has resulted in reduced food production and income. Livestock have proved to be important, especially for women, particularly in communities where men have either died of AIDS, or have become too sick to work. Livestock offer women the opportunity to earn money (InfoAgrar, 2005). Livestock products are excellent sources of protein and some key micronutrients that are generally scarce in grain and root staples. These are highly valuable in the nutrition and health of HIV/AIDS-affected people as they can help to boost their immune system (Garí, 2003). In addition, livestock play a role of enhancing social cohesion and social support, which is relevant for food security and HIV/AIDS mitigation.

Inadequate feed was identified as one of the major constraints limiting production of livestock, especially dairy cattle (Mubiru et al., 2003; Nakiganda, 2004). This necessitated an intervention if dairy was to thrive, especially in households affected and infected by HIV/AIDS.

A project was designed to improve food and feed production for humans and livestock through utilization of improved livestock technologies. Another objective was to promote and disseminate labour-saving technologies among HIV/AIDS infected and affected households. The third objective was to promote inclusion of HIV/AIDS infected and affected households in research, development and training programmes. The infected persons are women, men, youth and children living with HIV/AIDS. The affected persons are children orphaned due to HIV/AIDS and household members who care for those infected with HIV/AIDS.

MATERIAL AND METHODS

The project implementation was participatory and it involved all stakeholders in all the project phases. The project operated in Mafubira and Kakira sub-counties of Jinja district. The project was implemented by the National Crops Resources Research Institute, Jinja District Extension Department, Jinja District Farmers' Organization and Jinja Women HIV/AIDS Heifer Project. The project started with planning meetings between researchers, Jinja District Farmers' Organization staff, Extension Department staff and farmers. The study area and target group were identified. This was followed by farmers' needs assessment in three focus groups of women, men and the youth. The focus groups identified the major livestock and crop enterprises. These were ranked using pair-wise ranking. Constraints to the priority enterprises were also identified and ranked. Potential solutions for solving problems were identified together with the farmers and these were implemented later during the study.

Labour-saving technologies, particularly manual forage choppers, were identified and sourced from the Agricultural Engineering and Appropriate Technology Research Centre (AEATREC). A baseline survey was carried out to understand farmers' status and resources. Contact farmers were identified and on-farm

fodder demonstrations were established on 30 farms. These included Calliandra, maize–lablab intercrop and elephant grass–siratro–Centrocema intercrop. Seventeen farmers planted Calliandra, 6 farmers planted maize–lablab intercrop, and 7 farmers established elephant grass–siratro– Centrocema intercrop (choice depending on the farmers' land size). The maize intercropped with lablab was cv. Longe 5, a high-quality protein maize. Ten manual forage choppers were acquired and distributed to the weak farmers and orphans. These were meant to reduce work-effort associated with chopping the elephant grass. Farmers were trained on fodder establishment, management, conservation and utilization. They were also trained on how to operate and manage the forage choppers. On-farm fodder demonstrations were monitored and data collected. Farmers were given simple data-recording forms with which to record milk yields and feed given to the cattle. Dairy farmers from non-participating sub-counties (Butagaya and Busedde) visited contact farmers in participating sub-counties to learn from them what they were doing.

The project is planning to have a feedback workshop and to prepare a farmers' manual and leaflets. The data analysis was both qualitative and quantitative. The quantitative data were analysed using descriptive statistics by Genstat computer package.

RESULTS

Feed Interventions

A total of 300 farmers were as trained in pasture establishment, management, conservation and utilization. This has led to improved pasture management on farm. There has been a general increase of cattle feed by 20% on participating farms.

The increase in balanced feed on farm, especially in the dry season, led to an increase in milk production per cow. Cows fed on *Calliandra* had 29% average increase in milk production, while that of those fed on elephant grass–legumes intercrops increased by 38%. For people who are struggling with HIV/AIDS, this is a big achievement, as they can now get milk both to drink and also some for sale. The increases in milk sales (Table 1) have boosted the monthly incomes of farmers suffering from HIV/AIDS by 47,500 shillings (US $25)/household per month and 36,250 shillings (US $19)/household per month for farmers who use elephant grass–legume mixture and *Calliandra,* respectively.

Table 1. Effect of feed interventions on milk production and farmers' income

Feed intervention	Average (%) increase in milk production per cow	Increase in income per household per month (Uganda Shillings)[1]
Calliandra	29	36,250 (US $ 19)
Elephant grass–legumes	38	47,500 (US $ 25)
Lablab–maize	30	37,500 (US $ 20)

[1] *US $1 = 1900 Uganda Shillings.*

Labour-saving Technologies

Ten manual forage choppers were bought and distributed to 10 households. The criteria for receiving a forage chopper were that the farmers must be weak or orphans who had limited time as they combined studying and looking after the cattle.

Nine farmers who received the forage choppers acknowledged that they have been very useful and handy to them. The benefits that farmers got from the forage choppers were as follows:

- They use less energy to chop the grass, such that even weak people can chop the grass;
- They no longer feel chest pain while chopping grass;
- They spend less time chopping grass, so that they can use the remaining time on other activities;
- They chop the grass while standing and no longer need to bend;
- It makes the work easy such that children enjoy chopping the grass;
- The forage chopper chops small pieces of grass, such that the cows eat everything and there is no more feed wastage;
- Farmers no longer cut their fingers.

However, one orphan was experimenting with the forage chopper, changing its settings to cut longer pieces of elephant grass. Most of the time, he was giving uncut elephant grass to the cow on the ground. This young farmer lacked a feed box and that may be why he never made use of the forage chopper.

DISCUSSION

Cattle feed on the demonstration farms increased by 20%. This was a good achievement, as these farmers were always hit by drought and always had feed shortage. Jinja district farmers grow a lot of maize, which is used as food; however, the maize stover was not being used by farmers as feed for dairy cattle. Farmer training and incorporation of lablab in the maize stover helped to improve the feed value of maize stover—hence the 30% increase in milk of the cows fed on the maize stover–lablab feed package. Farmers who planted Calliandra benefited from it because it resists drought and provides feed in both rain and dry periods. In addition, it can be planted on boundaries, takes little land and requires minimal labour. This was therefore suitable for HIV/AIDS infected and affected farmers with limited land. According to Nakiganda et al. (2006), the majority of farmers in the study area had very small land holdings.

Improved feed on farms of HIV/AIDS affected and infected persons led to increased milk production; for example, cattle fed on Calliandra had average 29% increase in milk production, while those which fed on elephant grass–legumes intercrop increased by 38%. When farmers get more milk, they consume some of it and sell the remainder. This helps to improve their nutrition and helps their bodies to fight the disease. This agrees with literature which indicates that improving and maintaining good nutrition may prolong health and delay HIV disease progression (RCQHC et al., 2003). Farmers ate the grains of of Longe 5 maize, while they fed the stover to the cattle. The quality protein maize also helped to contribute to balancing the farmers' diet in terms of proteins.

The manual forage chopper helped to reduce effort associated with chopping elephant grass;—90% of farmers noted that the chopper required less energy, so that even the weak ones could chop the grass.

Children also helped in this work, as they enjoyed using the forage choppers to chop the grass. The choppers also helped to reduce feed wastage, as they cut small pieces of grass and the cows would eat everything. On the farm where the forage chopper was not very successful, there was an orphan staying with an old grandmother, where management of the cow was very poor. The cow had no feed box and the orphan farmer used to throw unchopped elephant grass on the ground for the cow to feed on. He experimented with the chopper a lot, adjusting it so that it cut very long pieces of elephant grass. In the end, he kept the chopper in the house instead of using it. This shows that in order for improved technology to succeed, other management aspects of the cow must also be appropriate.

CONCLUSION

The lessons learnt from this project are that it is very important to involve the target group in the whole process of technology development—for example, from problem identification up to the end of the project—so that the project is relevant and beneficial to the target group. All relevant stakeholders need to be involved in the project process and there is a need to respect one another. Involving sick people in research and introducing to them simple, user-friendly improved technologies can have a big impact on the lives of people living with HIV/AIDS. However, for the improved livestock technology to succeed on farm, the other management practices of the cattle must be appropriate. It is also very important to work in multidisciplinary teams, as these help to address farmers' problems as a whole.

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Evaluation of Spineless Cactus (*Opuntia ficus-indicus*) as an Alternative Feed Resource for Ruminants in Eritrea

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Keywords: cladodes, barley straw, digestibility, water intake, feed intake, sheep

Abstract

Throughout East Africa, animal feed resources fluctuate seasonally and are often of limited availability. Finding alternative feed resources that can sustain animal production during the long dry season is an essential need. Cactus is a drought-tolerant and succulent feed resource available throughout the year in Eritrea. This study was conducted to evaluate the effect of increasing levels of spineless cactus (Opuntia ficus-indica) inclusion on feed and water intake, apparent digestibility and body-weight change in sheep fed a base diet of urea-treated barley straw (UTBS). Twenty-four fat-tailed Highland male sheep with mean live weight of 21.1 kg were randomly assigned into four treatments (T1–T4). Animals in T1 received ad libitum amount of barley straw treated with urea (5%) alone, while those in T2, T3 and T4 received ad libitum UTBS supplemented with 175 g, 350 g and 525 g of spineless cactus (dry-matter basis), respectively. Spineless-cactus cladodes were high in water content and ash, but low in crude protein and crude fiber. With increasing level of cactus, there were significant increases in dry-matter consumption (DMI) ($P<0.001$) and body-weight performance ($P<0.05$), while water consumption decreased ($P<0.001$). The highest DMI was found in the T3 and T4 (101.8 and 96.5 g/[kg body weight]0.75 per day, respectively) as compared to T1 and T2 (94.4 and 87.6 g/[kg BW]0.75 per day). Sheep in T1 consumed more water (2 L/day) than the other treatments (0.85, 0.51 and 0.15 L/day for T2, T3 and T4, respectively). The highest body-weight gain (51.9 g/day) was found in T3, while the lowest was in T1 (26.8 g/day). The metabolism trial demonstrated that available-energy intake (digestible organic-matter intake or total digestible-nutrient intake) was directly related to animal performance in the feeding trial. In conclusion, feeding cactus with UTBS can significantly increase animal performance and feed intake, and reduced water intake.

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INTRODUCTION

Shortage of animal feed and water are major constraints for the livestock sector in arid and semi-arid regions of East Africa. The major feed resources are rangeland pasture and crop residues. The quality and availability of these feed resources decreases rapidly following the rainy season. This fluctuating pattern of animal-feed supply results in a pattern of gain and loss in animal growth and performance. In a country like Eritrea, where feed shortage is such a serious problem, utilization of multipurpose trees and shrubs that can cope with low and erratic rainfall, high temperature, poor soils, and require few inputs can serve as an alternative strategy to reduce the chronic shortage of animal feed and water. Spineless cactus (Opuntia ficus-indica) possesses important characteristics for animal feed in drought-prone regions, including high dry-matter (DM) yields, drought tolerance, nutritive value and palatability for animals (Tegegne, 2001). Spineless cactus is a fast-growing xerophytic plant. It has high water use efficiency due to its crassulacean acid metabolism (CAM) photosynthetic pathway. Cacti serve as an extremely important fodder in water-scarce semi-arid regions (Felker and Inglese, 2003). It is well adapted to marginal land with poor soil fertility and low, erratic rainfall conditions. Cactus remains succulent during the long dry season and can serve as a source of feed and water during this period. Furthermore, cactus is suitable as human food, as fuel, for medicine, as bee forage, and in rangeland rehabilitation projects (Barbera et al., 1995). The aim of this research was to assess the potential of spineless cactus as an alternative source of feed and water for ruminant animals fed poor-quality roughage during the dry season.

MATERIAL AND METHODS

The experiment was carried out in the highland of Eritrea, which is characterized by a semi-arid climate. A randomized complete block design was used to allocate 24 fat-tailed Highland male sheep with initial mean live weight of 21.1 kg into one of two replications for four feed treatment groups (T1–T4), consisting of six animals per group. Animals in T1 received ad libitum barley straw treated with urea (5% by weight) alone, while those in T2, T3 and T4 received ad libitum urea-treated barley straw supplemented daily with 175 g, 350 g and 525 g of spineless cactus (DM basis), respectively. Diets were offered twice daily, aiming at 20% refusals (i.e. 20% excess). At the end of the feeding trial, four sheep were transferred to metabolic crates, where digestibility trials were conducted for each diet over 7 days of feeding and collecting. Data were analyzed using standard analysis of variance (ANOVA) and general linear models (GLM) with GENSTAT statistical software. The results were disseminated through demonstrations, on-farm trails, posters, leaflets written in local languages, and training of farmers and experts

RESULTS

Chemical Composition of Spineless Cactus Cladode

The chemical composition (proximate analysis) of the spineless cactus and urea-treated barley straw is presented in Table 1. Spineless cactus cladodes (stem segments) were high in water and ash, but low in crude protein and crude fiber content. In this analysis, cactus had 65% more digestible energy than urea-treated barley straw.

Effect of Supplementation on Feed Intake

The performance characteristics of sheep fed urea-treated barley straw supplemented with increasing level of spineless cactus are presented in Table 2. The amount of cactus in this study was restricted; however, it was a highly palatable feed. Except for T2, there was a highly significant ($P<0.001$) increase the total dry-matter consumption (DMI) with increasing spineless-cactus levels in the diet, and (as expected) a comparable reduction in straw DMI. The highest DMI expressed on metabolic weight basis (102 g/[kg BW]$^{0.75}$ per day)[3] was found in sheep that received 350 g spineless cactus (T3) and the difference from the other treatments was highly significant ($P<0.001$).

Table 1. Chemical composition of experimental feed ingredients

Feedstuff	DM (%)	CP (% DM)	CF (% DM)	EE (% DM)	NFE (% DM)	Ash (% DM)	Digestible energy (MJ/Kg DM)
Spineless Cactus	12.9	4.7	15.8	0.9	61.6	16.7	13.2
Urea-treated barley straw	69.4	10.2	46.5	1.1	34.8	7.2	8.0

DM = dry matter; CP = crude protein, CF = crude fiber, EE = ether extract, NFE = nitrogen-free extract.

Table 2. Performance of sheep supplemented with increasing level of cactus

Parameter	T1	T2	T3	T4	LSD
Initial body weight (kg)	21.25	21.25	21.08	21.25	ns
Final body weight (kg)	23.67b	24.25b	25.67a	25.50a	0.832
Weight gain (g/day)	26.8b	33.3b	51.9a	47.2a	12.26
Cactus DMI (g/day)	0	175	350	525	–
Total DMI (g/[kg BW]$^{0.75}$ per day	94.35b	87.57c	101.81a	96.48b	3.418
Water intake (L/day)	1.98a	0.78b	0.57c	0.18d	0.03
DOMI (g)	541.8	504.8	667.8	656.3	–
DCPI (g)	61.2	51.8	61.5	42.6	–
TDNI (g)	542.0	588.2	672.0	663.1	–

Means with different superscripts (a–d) in the same row differ significantly ($P<0.001$). LSD = Least significance difference, ns = not significant, DOMI = digestible organic-matter intake, DCPI = digestible crude-protein intake, TDNI = total digestible-nutrient intake.

Effect of Supplementation on Water Intake

There was a clear and significant ($P<0.001$) reduction in water consumption with increasing intake of cactus (Table 2). Sheep in T1 consumed more water (2 L/day) than sheep in the other treatments. Compared to those fed urea-treated barley straw only (T1), sheep in T2 drank of 50% less water per kilogram of feed intake. Sheep in T4 approached zero water consumption.

[3] *Metabolic weight = [body weight (kg)]$^{0.75}$.*

Effect of Supplementation on Animal Performance

There was a significant difference in body-weight gain in sheep with cactus supplementation to urea-treated barley straw based diets (Table 2). The live body-weight gain was significantly ($P<0.05$) higher for sheep on T3 and T4 diets, compared to the control diet (T1). The highest body-weight gain (51.9 g/day) was found when sheep received 350 g DM of cactus (T3), while the lowest was in the control T1 diet (26.8 g/day). Even though the total dry-matter intake of the sheep in the control was higher than that of sheep in T2, sheep in the latter group performed better (in terms of body weight, though not to an extent that was statistically significant).

Apparent Digestible Nutrient Intake

A digestibility study was conducted, and apparent digestible-nutrient intake was determined (Table 2). Increasing the level (or proportion) of spineless cactus in the diet increased the energy value of the diet. Therefore, supplementation of cactus tended to increase energy intake (Total Digestible Nutrient Intake or Digestible Organic Matter Intake). In contrast, increasing the level (or proportion) of cactus decreased the amount of crude protein (CP) in the diet. Thus, supplementation of cactus tended to decrease CP intake. The digestible CP intake was highest in diets T1 and T3, and lowest in diet T4.

DISCUSSION AND CONCLUSION

Chemical Composition of Spineless Cactus Cladode

The high water and low CP content of spineless-cactus cladodes found in this trial are similar to values reported by other authors (Nefzaoui and Ben Salem, 2001; Flachowsky and Yami, 1985) for cactus grown on poor soils. The protein content of cactus was below the general minimum of 7% CP required for normal microbial activity in the rumen (Misra et al., 2005). Therefore, animals fed with cactus-based diets need appropriate protein supplementation. This study confirms that urea treatment of low-quality forage can be a suitable protein source (10.2% CP on DM basis). In semi-arid regions, where water is a very scare resource, the high water content can be considered as a benefit. To develop a feeding system using locally available feed resources, sources of abundant and cheap energy are very important (Preston and Leng, 1987). This makes cactus highly valuable for its energy content.

Effect of Supplementation on Feed Intake

Voluntary dry-matter intake is related to the intake potential of the feed and the nutrient demand of the animal (Coleman and Moore, 2003). Cactus is a highly palatable feedstuff. Higher total DMI in T2 could be associated with the higher consumption and digestibility of cactus. Tegegne et al. (2005b) found that total DMI increased for sheep progressively from 77 to 100 g/[kg BW]0.75 per day when the cactus supplement was increased from 0 to 60% in pasture-and hay-based diets. In the current study, the gradual decrease in DMI of urea-treated barley straw can be explained by the substitutive or associative effect of feed when replaced with a highly soluble source of carbohydrate. In this study, there was no digestive disturbance or health effect observed even at highest cactus inclusion rate that substituted about 50% of the dry-matter intake. Ben Salem et al. (1996) observed that spineless cactus could be fed without any digestive disturbance up to 55% of the total DMI. This would help farmers to economize on straw. The absence of a negative effect, coupled with higher digestibility and water content would facilitate a rapid disappearance of cactus from the rumen (Nefzaoui and Ben Salem, 2001).

Effect of Supplementation on Water Intake

Water intake was high when sheep were fed urea-treated barley straw alone. However, there was a significant decrease in water intake with the progressive increase of cactus. The declining water intake of sheep was in good agreement with pervious work (Ben Salem et al., 1996; Tegenge et al., 2005b), which reported that water intake decreases significantly as the level of cactus intake increases in diets of low-quality roughages. Sheep drank negligible amounts of water when the cactus supplementation reached 525 g/day. In line with this finding, Ben Salem et al. (1996) indicated that sheep stop drinking water when the cactus intake reached 600 g/day. In the tropics, the dry season is characterized by higher temperatures, decreased supply of water and higher dry matter of herbage. Therefore, animals that are sustained on poor-quality dry roughages are in need of large amounts of water to facilitate digestion. Animals travel long distances to reach water points, spending more energy and losing body weight. In East Africa during the dry season, the distance traveled to watering point increased by 43–52% for small ruminants (Ndikumana et al., 2002). In countries where water is a vital resource during the dry season, the high water content of cactus could play a significant role in mitigating drinking-water shortage. It may also reduce rangeland degradation as animals converge on water points during drought.

Effect of Supplementation on Animal Performance

There was a significant difference in body weight gain when urea-treated barley straw was supplemented with spineless cactus. This result was in accordance with pervious work (Tegegne et al., 2005a) on supplementation of cactus to sheep fed urea-treated wheat straw. The higher performance of sheep in T3 and T4 as compared to the control (T1) diet can be correlated with associative effects of high total DMI of the sheep in those treatments and the higher readily digestible carbohydrates content of spineless cactus. Even though the total DMI of the sheep in the control (T1) was higher than that of sheep in T2, sheep in the latter group performed marginally better. This could be attributed to the lack of readily fermentable organic matter for sheep that were fed urea-treated barley straw alone. The DM digestibility of the urea-treated barley straw was higher when it was supplemented with cactus than when it was fed alone. Therefore, the value of cactus as a cheap source of energy for efficient utilization of non-protein nitrogen is also important in improving the nutritive value of poor-quality roughage. A 22% body-weight improvement was achieved in this study, at a time when animals normally lose body weight (during the dry season), although cactus pear is abundant and succulent in this season. A much higher improvement (72%) in body weight gain was reported when cactus was supplemented with a bypass protein source (i.e. protein that is not digested in the rumen) (Shoop et al., 1977).

Apparent Digestible Nutrient Intake

The digestible-nutrient intake data of the metabolism trial is in agreement with the feeding trail. Increasing spineless-cactus supplement to the urea-treated barley straw based diet resulted in improvement of the energy density of the diet (higher total digestible nutrients). Body-weight gain as a measure of animal performance was highly correlated with DMI and its energy concentration, and these results are consistent with those of other researchers (Moore et al., 1999). The higher performance of sheep in T3 and T4 as compared to T1 and T2 may be explained through the increase in available dietary energy and through an associative effect. In this associative effect, the addition of cactus improves the total digestibility of the diet, including the digestibility of the straw. With increasing level of cactus in the diet, there was an increase in the energy concentration of the diet, while the protein concentration decreased. Besides the slight

improvement in performance of sheep in T2, cactus supplementation at the lower level (175 g DM) did not result in a significant difference as compared to the control diet (T1). This might be because, although T2 shows an improvement in energy, there is both a decreased percent dietary protein and lower daily digestible-protein intake. The crude-protein intake of the animals was lower for this group (T2) than for either T1 or T3. Supplementation of 350 g DM spineless cactus (T3) seems to be the optimum supplementation rate. At this level, the animals are able to maintain protein intake, so that they can benefit from the extra energy, thereby optimizing growth. Therefore, animals in T3 had a higher total digestible-nutrient intake as compared to the other groups, illustrating a more optimal balance of protein and energy. Inclusion of cactus at higher rate (T4) was still better than T1 and T2, which is attributed to additional energy, but it may have begun to decrease due to low protein intake.

In conclusion, feeding cactus with urea-treated barley straw can significantly increase animal performance and feed intake, and reduce water intake. One of the positive impacts of this work is that it initiated spineless-cactus plantation by the ministry of agriculture on the rangelands, and currently about 200 ha is planted with cactus in Anseba zone as a pilot project. On-farm research is also underway on cactus silage making on the RAM private farm. Continuous training has been given to experts and farmers on the use and feeding of cactus. A leaflet has also been distributed in local language. Although the adoption rate has not been measured, farmers' awareness of the feeding value and levels of cactus is increasing. Therefore, utilization of cactus as an animal feed could play a vital role in promoting sustainable livestock production by providing an alternative feed and water source.

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Evaluation and Promotion of Cambrough Breed of Pigs for Improvement of Livelihoods in the South Western Agro-Ecological Zone of Uganda

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Abstract

Pig farming is an emerging enterprise in south-western Uganda. A 5-year longitudinal study to evaluate and promote pig production for livelihood improvement was conducted in the South Western Agro-Ecological Zone (SWAEZ) of Uganda, targeting the Cambrough breed of pigs recently imported from South Africa. Birth weights of piglets were 1.5–2 kg, while weaning weights at 2 months ranged from 8 kg to 12 kg. Mature live weights at 2 years were 180–200 kg and 160– 180 kg for boars and sows, respectively. Age at first farrowing was 9–10 months, followed by a period of 4 weeks between farrowing and next conception. A farrowing interval of 6–8 months was observed. Litter size ranged from 7 piglets at first farrowing to 13 piglets at fourth farrowing, with culling recommended at seventh farrowing. The non-conventional locally available feed resources recommended to farmers included sweet potato root tubers and vines, pumpkins and banana peelings. This study observed that strategic treatment of piglets of one month old, then at 2-month intervals, using ivermectin injection (subcutaneously administered) significantly reduced mortalities from Ascaris suum infection compared to the conventional treatment using piperazine. Results revealed that pig production is a viable enterprise in the south-western Uganda; with an average gross margin of 5.95 million Uganda shillings (€2,380) per annum. This has a strong bearing on the management level—inputs, especially feed resources, and ability to minimize costs without compromising production. The findings of this study indicate that pig production, especially of the Cambrough breed, has potential to improve household incomes and bridge the animal protein gap for the resource-poor, who are largely women, youths, elderly, persons living with HIV/AIDS and their households, in rural settings.

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INTRODUCTION

The technology of introducing and adapting the improved Cambrough breed of pigs in Uganda has been conducted for a period of 5 years (2003–2008) at Mbarara Zonal Agriculture Research and Development Institute (MbaZARDI). The institute is mandated to provide research services to the South Western Agro-Ecological Zone (SWAEZ), which covers the districts of Mbarara, Ibanda, Isingiro, Kiruhura, Ntugamo, Bushenyi, Lyantonde, Ssembabule and Rakai. This zone has a very fast-growing population which in the year 2007 was estimated at 7 million people (UBOS, 2006). With increasing population, the demand for animal-based protein source of foods, and the need to venture into enterprises that have quick income turnover cannot be overemphasized. The Meat Master Plan (MAAIF, 1998), Farming System and Livelihood Analysis (Twinamasiko et al., 2003) and Zonal Priority Research Setting (MbaZARDI, 2007) all pointed to the lack of improved breeds as one of the major constraints to livestock productivity in the zone and this has crippled efforts to improve the livestock industry in the country.

Under the Capacity Building for High Yielding Germplasm project, supported by the Government of Japan, the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) helped MbaZARDI to establish a nucleus pig breeding unit and stock it with Cambrough breed of pigs (ARDC, 2003). The introduction of the Cambrough pig required a study to provide urgent research-based information for farmers.

The main objective of this study was to evaluate and promote the introduced Cambrough pigs for livelihood improvement of households in the SWAEZ. The specific objectives included: (i) to determine the growth patterns; (ii) to establish reproductive indices; (iii) to evaluate the utilization of locally available feeds; (iv) to provide a strategy for managing the worm burden in piglets due to Ascaris suum infestation; (v) to find out the economic viability of rearing pigs; and (vi) to promote the adoption of pig rearing.

MATERIALS AND METHODS

MbaZARDI is located in the South Western Rangelands of Uganda around 0°35′S and 30°35′E. Annual rainfall is between 1000 and 1200 mm (bimodal). Intensive pig management system was adopted. The study used a longitudinal approach over a period of 5 years (2003–2008) with Cambrough breed pigs imported from South Africa. The Institute started with 15 two-month-old weaners (13 females and 2 males) (ARDC, 2003). Each of the objectives was addressed in one of six studies. The studies were carried out on both the parent stock and their offspring (2003–2008). Hygiene was maintained through daily cleaning of the sty. The piglets, the weaners, the porkers and the culls that were not utilized in the studies were disposed off.

Study 1: To Determine Growth Patterns

Piglets were weighed at birth, and then subsequent at fortnightly intervals. This continued until the piglets were one-year old. The piglets were sampled from the litters produced. The weighing of piglets, in a bag, was carried out using a spring balance, in the morning before feeding. The mature weight at 2 years was determined using the heart girth tape also in the morning before feeding.

Study 2: To Establish Reproductive Indices

The piglets were monitored for reproductive performance from maturity. Breeding was by natural services using two boars. The boar was introduced to the female pigs after attaining reproductive maturity, determined by age and size for the first conception. Thereafter the boars and sows were kept together. During the study, records were kept for every sow from first conception up to the time of culling.

Study 3: To Evaluate the Utilization of Locally Available Feeds

The pigs were fed on a wide range of feeds, namely: (1) commercial feeds (sow and weaner); (2) agro-processing by-products (maize bran); (3) milk products (soured milk and whey); (4) non-conventional locally available feeds—including bananas and banana peelings, sweet potato tubers and vines, lablab herbage, greens (e.g. Wandering Jew Commelina species). Pigs were provided with red anthill soils rich in iron. Commercial feeds were fed alone. Agro-processing by-products were fed in combination with soured milk or whey and with the local feedstuffs. Piglets were allowed to suckle up to weaning (8 weeks) and access the red anthill soils and the feeds of the adults. Feeding was administered once a day, with ad libitum water for drinking. Feeds were largely qualitatively evaluated. The feeding value was assessed on the basis of the productive performance (growth response, reproductive response and absence of observable nutritional deficiency).

Study 4: The Strategic Health Management of Worm Burden in Piglets due to *Ascaris suum* Infestation

Fifteen (15) piglets were selected for each of three treatment groups: ivermectine (Noromectine®), piperazine (Ascarex®) and control. A total of 45 piglets were selected for the study. Each of the three groups was put in a pen and each piglet was given a numbered ear-tag for follow-up purposes. Conventionally, deworming is carried out on a quarterly basis. During this study, however, deworming was carried out bimonthly. Baseline worm load per gram was first established for the three treatment groups and the two drugs administered to the two groups; the control did not receive any treatment.

Feacal egg count was done using a McMaster technique counting chamber before and after treatments with drugs, and the reduction in egg counts were noted after 7 and 14 days.

Study 5: Economic Viability of Rearing Pigs in the Zone

The inputs included feeds, drugs, water, maintenance-repair, transport costs and labour. The outputs were piglets, weaners, porkers, culls and manure. Data from inputs and outputs were recorded and analysed for gross margin analysis to establish the economic viability of rearing pigs to provide relevant information to farmers and extension workers and other stakeholders.

Study 6: Promotion of Adoption of Commercial Pig Rearing

The Plan for Modernization Agriculture (PMA) (MAAIF, 2000), the Farming Systems and Livelihood Analysis (Twinamasiko et al., 2003) and the Priority Setting (MbaZARDI, 2007) identified the urgent need to improve food security and increase the household incomes of the rural poor. Local papers, radio, information disseminated via workshops, participation in Annual National Agricultural Shows (Annual World Food Days) and trade fares (Uganda Manufacturers Association), farmers' groups, schools, extension workers' visits, and industrial training were all used as channels for creating awareness about the Cambrough breed of pigs.

Data Analysis

Data were collected on body weight, reproductive variables, worm-egg counts, feeds (largely qualitative), inputs used and outputs produced, and dissemination (channels). Data were analysed using Social Package for Social Scientists (SPSS) version 12 to reveal growth, reproductive performance, feeding value, worm control, profitability of the pig enterprise, and adoption of the technology. T-tests were performed to look into the significant levels of worm control using the two dewormers ivermectin and piperazine.

RESULTS

Growth Patterns

The following growth parameters were documented (averaged over the 5-year period): birth weight was 1.5–2 kg per piglet; weaning weight at 2 months was 8–12 kg; and mature live weights attained were 180–200 kg for boars and 160–180 kg for sows at 2 years of age.

Reproductive Indices

The following reproductive parameters were documented (averaged over the 5-year period): age at first farrowing, 9–10 months; period from farrowing to conception, 4 weeks; farrowing interval, 6–8 months; litter size: first farrowing, 7 piglets, second farrowing, 9, third farrowing, 10, fourth farrowing, 13, fifth farrowing, 12, sixth farrowing, 9, and at seventh farrowing culling is recommended; age at first mating was 6 and 7 months for a young sow, while age at weaning was 8 weeks for both sexes.

Evaluation of the Utilization of Locally Available Feeds

The study found that a combination of agro-processed by-products (maize bran), milk processing by-product (soured milk or whey) and greens (Wandering Jew or lablab herbage) offered a complete, affordable feed ration for weaned and growing pigs. It was established that feeding a combination of 70 kg of maize bran, 40 litres of soured milk and 100 kg of greens (Wandering Jew) was sufficient to maintain 10 mature pigs, 54 weaners and 20 piglets per day. Therefore, the recommended energy requirement would be about 2 kg, 0.74 kg and 0.5 kg of maize bran per day per adult pig (8 months and above), weaners (2–8 months) and piglet (2 weeks to 2 months), respectively. The water requirement would be about 6 and 8 litres per weaned pig per day during wet and dry seasons, respectively.

Strategic Health Management of Worm Burden in Piglets due to *Ascaris suum* Infestation

Strategic treatment of one-month old piglets, at an interval of 2 months, using subcutaneous ivermectin injection reduced mortality due to Ascaris suum (and other helminthes) infection from 30% to less than 1%. The reduction of worm-egg counts before and after ivermectine treatment was highly significant ($P=0.006$) compared to piperazine treatment ($P=0.018$).

Economic Viability of Rearing Pigs in the Zone

Seventeen sows, 19 young sows, 2 boars and 300 piglets were studied, among which there was less than 5% mortality. The sources of revenue were: sale of piglets and culled sows. Feed, drugs and maintenance-repair were variable expenses, while labour was a fixed expense. Total revenue for one year was 19.05 million Uganda shillings (€7620; €1 = 2500 Uganda shillings, 2007) and total variable costs were 13.1 million shillings (€5,240). Thus, net profit was 5.95 million shillings (€2,380).

Promotion of Adoption of Commercial Pig Rearing

During the 5-year period (2003–2008), about 5000 piglets were distributed to farmers who had taken a keen interest in commercial pig farming. The Institute has become a centre of attraction to students pursuing agriculture and veterinary medicine courses at the Makerere, Kyambogo and Mbarara Universities. In 2007, the institute hosted 500 primary pupils, 4000 secondary school students, 200 tertiary and university students, and 100 farmers and extension workers. All these were provided with information on pig rearing. The same trend continued in 2008. The Institute participated in public field shows and trade fares, where mature pigs were exhibited in order to scale up technology dissemination to a wider community. Dissemination has been done through posters, brochures, flyers and working documents for farmers and other stakeholders in the zone and beyond.

DISCUSSION

The genetic and environmental interactions have impact on performance related to birth weight, weaning weight, and eventually weight at maturity for both female and male pigs (Mugerwa, 2001). Nutritional level and provision of supplements are key to enhancing the efficiency in reproductive indices. It was observed that feeding pigs on commercial feeds (sow and weaner) was not sustainable and therefore not cost-effective; this concurs with the results of other studies (Twinamasiko, 2001). This study established that provision of maize bran and soured milk offered adequate nutrition for pigs with no nutritional deficiencies.
It was observed that feeding red soil rich in iron from anthills offered an alternative source of iron for the pigs. Greens, e.g. Wandering Jew (Comellina species), were an alternative source of minerals and vitamins. The non-conventional feed resources recommended for farmers include sweet potato root tubers and vines, pumpkins, bananas and banana peelings. This study noted that providing maize bran without adding a protein source in the diet was not enough, as the growing pigs suffered stunted growth. This agrees with the result of other studies (Twinamasiko, 2001).

The study found that the use of ivermectin bimonthly was more effective than the traditional quarterly application to control worms, and also more effective than piperazine administered bimonthly. This effectiveness of the ivermectin was mainly due to mode of administration (subcutaneous injection)—piperazine is normally mixed in feeds. Also functionally, ivermectin paralyses the parasitic nematodes leading to eventual death by affecting the chloride channels independent of gamma-amino butyric acid (GABA) as observed by Urquhart et al. (1996), whereas piperazine causes narcosis of the worms and they are expelled out of the body by peristalsis (Brander et al., 1977; Georgi, 1980).

The economics of input and output relationships must be balanced to ensure viability of the enterprise to guide allocation of funds. Annual budgets should guide expenditure, recording of inputs and returns put into practise, and strategic marketing instituted, so that costs do not outweigh benefits (Ddumba-Ssentamu, 2004; Lutwama, 2004).

Finally, getting the right channels and means of disseminating information is key in up-scaling technology to the wider community of the area and the region to create impact.

CONCLUSION AND LESSONS LEARNED

This study concludes that production of Cambrough pigs bridges the animal protein gap and provides quick returns for the resource-poor in rural areas. Women and youth in particular, and persons living with HIV/AIDS have benefitted the most. The study recommends further research to determine the cost-effectiveness of feeding strategies for pigs using the non-conventional and locally available feeds and their combinations, comparative performance evaluation of other breeds of pig, and carcass-quality studies under Uganda SWAEZ conditions.

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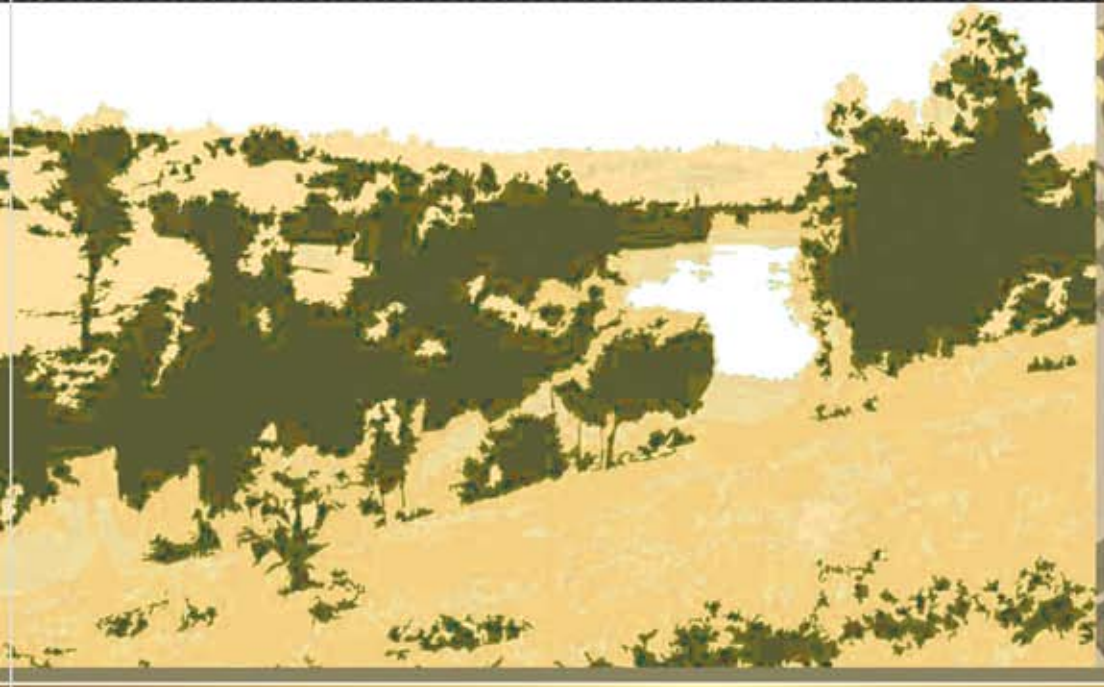

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