Contribution of Agricultural Sciences towards achieving the Millenium Development Goals

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Foreword

All the materials included in this book were originally submitted to the 3rd International e-Conference on Agricultural Biosciences held online from June 1 - 15, 2010. This was an internet based conference designed to enable wide participation of scientists from developing countries. It is recognised that costs, e.g. transportation, hotel accommodation, per diem, visa, etc are one of the major factors hindering participation of scientists from developing countries in international symposia. However, the advent of internet and other web based communication technologies is opening new frontiers, closing the gap between communities in at different levels of development. Through this e-conferencing facility every effort is made to minimise cost related barriers. Participation in this conference is possible from an office, home or any other place with internet access. To widen reach and diversity of presentataion, the participants in the e-confetrences have opportunities to exhibit and publish presentations either as MsWord abstracts, posters or power point slides. In addition, publication of full papaers (after peer review) is possible in the online *Journal of Applied BioSciences* [ISSN 1997-5902] and the *Journal of Animal and Plant Sciences* (ISSN 2071-7024). These are open access journals that are published monthly and are available for free download at http://www.m.elewa.org/journals.php . This book provides an additional way in which scuientists will be able to publish their research outputs. Other proceedings of the e-conference can be accessed at http://www.m.elewa.org/econferenceIeCAB.php.

We believe ours is a small but important effort in helping scientists to communicate on the important research they are carrying out in different parts of the world. It is our sincere hope that more and mopre scientists will appreciate this rather new and more cost-efefctive way of communicating on what they do every day. There is no doubt science will be at the forefront of progress in reaching the goals that nations have set ahead of themselves, e.g. the Millenium Development Goals. Each one of us must play our roles to make this a better world for all. At FaCT publications we are committed to providing an enabling and supportive platform to ensure the ourputs of research are communicated to the rest of the world.

We invite scientists to submit their publications at any time to publications@biosciences.elewa.org, publications.biosciences@gmail.com, japs@biosciences.elewa.org.

Thank you,

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Review of key considerations in application of organic farming for sustainable fruit production

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INTRODUCTION

The WHO/FAO Codex draft guidelines on organically produced foods (WHO/FAO Codex, 2007) defines organic agriculture as "a holistic production and management system which promotes and enhances agro ecosystem health, including biodiversity, biological cycles and soil biodiversity activity". It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system (Codex, 1997). International and regional standards for organic and biodynamic agricultural production methods have been established by the International Federation of Organic Agriculture Movements, the International Biodynamic Association and the EU regulation on organic methods (EC, 1991).

Excessive use of potentially harmful agrochemicals may affect biodiversity, environmental quality, food safety and farmer's health. There is increased interest in more sustainable production systems such as organic farming (Reganold *et al.*, 2001) with minimum use of synthetic pesticides and fertilizers. Organic production can preserve both ground water resources and fragile ecosystems (Mader *et al.,* 2002). Other benefits of organic farming include growers benefiting from special marketing niches and grower-friendly price mechanisms (Athern, 2004). Consumers are increasingly avoiding fruits grown in farms that use synthetic chemical fertilizers and pesticides because of the risks to their health and environment, and this is a major driving force behind increased organic fruit production in the world especially North America and Europe.

The world status of organic products/production and sales for organic products is approximately 20 US billion dollars with an annual growth rate of 20-35% (Organic Trade Association, 2005). In the U. S. A. there were 937,000 hectares of certified organic land in 2003 of which 5626 ha were under organic apples (Delate *et al*, 2008). Similarly, there has been a rapid growth in organic fruit production in the European Union (EU) during the past 15 years with nearly 4000 ha of fruit crops in the total of 48 million ha under organic production (Willer and Richter, 2004). Other countries where organic fruit production has increased are Argentina and Chile for apples (Sanchez, 2005) and New Zealand, also for apples (McCartney and Walker, 2004). In the European Union (EU) there is government support for organic growers. In Europe the main organic fruit growing areas are France, Greece, Italy, Portugal, Spain and Switzerland.

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World production status of Organic Farm produce

The emergence of the term 'Organic farming' to describe the distinct system of agriculture began in North America in the first half of the 20th century. There existed farming methods that maintained their reliance on biological process with particular emphasis on 'healthy' soil (Granatstein, 2002). The general concept that natural materials are preferable to synthetic ones has caused most organic farming certifications to rely on it so that the use of synthetic fertilizers and pesticides have been reduced in organic fruit farming in North America and Europe. The increased expansion of organic production in all crops during the 1990s in North America was due to the fact that there were new biological pest control techniques and more choices of organically approved inputs and expanding information base. In addition consumers' concern for environmental health, food safety and food quality have driven the demand for organic products (Crowshaw, 1977; Organic Trade Association, 2005).

The future is bright for organic fruit producers. Consumer research reports show there is growing interest in improved diet comprising more organic fruits and avoidance of toxins (e.g. pesticides). The increased availability of organic foods in mainstream supermarkets in Europe and North America and other parts of the world is a sign of increased consumption (Weibel, 2002).

In Uganda organic agriculture is developing at a fast pace and more investors and exporters are showing interest in it. In some countries organic products are not certified usually because there is no accredited certifying agency. The main factor promoting organic fruit farming in Uganda is the demand for organic food in industrialized countries and the growing concern among farmers on maintaining fertility and prevention of land degradation (Yussef and Willer, 2003). The constraints affecting organic farming in Uganda include low investment, limited research and inadequate extension services in organic farming (Opolot *et al*., 2007), lack of formalized land tenure system, high costs of international certification, inadequate documentation, lack of organized small holder groups for supplying the market demand consistently, poor marketing infrastructure and lack of organic agricultural policy (Hine and Pretty, 2006).

In terms of production statistics the total dry organic fruit output is 90 metric tones per year and it is believed that only 10-20% of market demand is met (Agona et *al.,*_2002). Currently Uganda exports only 30 metric tones of dried organic fruits annually, comprising of apple, banana, mango, papaya and pineapple while the total world demand for dried organic fruit is estimated at 164,000 metric tones (Tumushable *et al.,* 2007).

Other constraints for fruit farmers in Uganda include the following:

1. Weeds competing with pineapple for growth resources.
2. High costs of getting labour and buying coffee husks for fertilizing and mulching.
3. Absence of niche market for organic fruits since local consumers prefer bigger pineapples but organic farms produce smaller pineapples due to weed competition.
4. Lack of premium price for organic products due to low market demand, accessibility and penetration (Ivaluwairo, 2005).

There is very little awareness among consumers in African; Caribbean and Pacific countries about the benefits of organic agriculture, which constrains the development of viable local organic markets, thus farmers have to rely on export markets for their produce (Chong tham *et al.,* 2010). Besides failure by farmers to separate the best quality produce in order to fetch the best prices, other challenges are lack of appropriate information on alternative marketing and product alternatives, high freight costs during export, inability to comply with export quality standards and price instability in international markets. Local processors are disadvantaged since the better quality fruits

are exported leaving locals with lowest quality fruits. In addition, seasonal variation in production is not enough to supply the local processing factories.

Table 1: Some organic fruit statistics.

Top 10 fresh fruits consumed in the U.S	Market share of organic food and fruit, 2007	Global per capita fruit consumption	share of Global organic temperate fruit area 2007 % of total area cultivated
Pear	Switzerland 5.6 %	=20% of total consumption in US	ITALY 24
Avocado	Germany 7.1 %	98% Denmark	Turkey 13
Pineapple	Australia 5.4 %	37% Switzerland	France 9
Strawberry			USA 8
Grape			Spain 7
Orange			Poland 7
Apple			Germany 7
Melon			Argentina 3
Banana			Others 22
Peach			

CHALLENGES OF ORGANIC FRUIT FARMING

The challenges faced in fruit farming include:

- Choice of correct cultivars of fruits. This has been a problem because the popular fruit cultivars are not suitable to organic farming and breeding fruit trees for this type of farming is cumbersome and costly since tree breeding usually takes many years to produce a cultivar. The balance between market demand and sustainable organic production is difficult to achieve.
- Crop protection problems: There are few efficient plant protection products known in organic farming particularly in the humid areas where disease prevalence is high. Mite problems occur in drier areas. Only neem oil and lime sulphur have a small effect on pests and diseases of organic fruits. This necessitates the application of indirect methods which is costly for the organic producers. Examples of such indirect methods include the use of tolerant cultivars, ecological compensation surfaces to increase orchard biodiversity, larger planting densities, mechanical reduction of the disease and pest inoculum, and measures to increase soil fertility to improve stress tolerance of the tree (Weibel, 2002).
- Weed control: This is especially so difficult with dwarfing rootstocks, where the trees are usually so closely spaced for any mechanical or mechanized weed control to be applied. The alternatives to herbicide application such as mechanical tillage, mulching with bark or straw are expensive in terms of labour, materials and equipments. Because organic growers work with the same rootstocks as in conventional systems trees are very sensitive to weed competition (Weibel, 2002).
- Fruit thinning: It is a major problem for organic fruit producers to achieve high quality fruits of good size and yields. This is due to the absence of suitable flower and fruit thinners. It is therefore difficult to control biennial bearing in organic orchards giving rise to small sized fruits of low quality (Weibel, 2002).

Economics of organic fruit production

It has been reported that high production costs for organic fruit are caused by the high cost of plant protection products such as Neem oil, clay powders, soap or other products (Schimd, 1999 and Storchert, 2000). Organic fruit production is labour intensive but requires fewer inputs per unit of output as compared to conventional production (Mon and Holland, 2006). There has been a higher price premium for organic apple producers in Switzerland (Weibel *et al*, 2004), in California (Swezey, *et al*, 2000) and Washington (Mon and Holland, 2006). Reganold *et al*, (2001) reported that organic apple production was superior to integrated and conventional production in terms of both environmental and economic sustainability.

In 2004, price premiums for organic apples declined due to increased organic orchards. Prices stabilized in 2006 (Peck *et al,* 2005). In New Zealand, organic apples were twice more profitable than conventional apples (Walker and McCartney, 2001). There is increased demand for organic fruits in the European Union (E U) and the EU member countries are importers of organic products (Sayin *et al*, 2005). Marketing of organic fruits is through local and regional outlets and exports are increasing. (Delate *et al*, 2008). Yields have declined for apples in New Zealand for organically grown apples (Hughes *et al*, 2002). Organically grown apples are more energy efficient, sweeter and produce higher profits (Delate *et al*, 2008). Although there has been increases in yields for organic apples in the U. S. A., there have been no differences in yield and quality of the apples in the E U (Roth *et al*, 2005).

There have been mixed reports on fruit sizes, with some workers reporting small fruit sizes in organic orchards of < 8ha, where thinning is inadequate (Swezey *et al*, 2000). In terms of fruit quality, organic production leads to firmer fruits (Weibel *et al*, 2005; Peck *et al,* 2006) higher sugar, malic acid, P and K contents, but no effect on Mg content, while the N amounts were lowered (Peck *et a*l, 2006; Delate *et a*l, 2008) and antioxidant activity increased (Peck *et a*l, 2006).

Sustainable Soil Management for Optimum Organic Fruit Farming

Organic fruit growers are required to maintain or improve soil chemical, biological and physical properties and thus need to integrate biological processes into fertility management. Many growers substitute synthetic inputs with rapid release approved N fertilizers that have little effect on long term soil health and fertility. Improving tree performance via optimal fertility management is a common goal among conventional and organic growers. Further, improving soil health is a requirement for organic growers worldwide.

The concept of soil health is holistic and refers to more than the vigor of soil biota. It considers the chemical, physical, biological and ecological properties of soils and the disturbance and the ameliorative responses by land managers (Sangiga and Woomer, 2009). It is the capacity of a soil to function to sustain biological productivity, maintain environmental quality and promote plant anchorage and health (Doran *et al*, 1996). The soil functions implicated have capacity to supply nutrients, retain optimal water content, support soil food webs, recycle nutrients, maintain microbial diversity, remediate pollutants and suppress plant pathogens (Moore *et al,* 2008).

Cultural practices that enhance soil health are organic matter application and soil conservation, with reduced application of synthetic pesticides which many organic fruit growers substitute with rapid release fertilizers made from various fish and poultry products (Moore *et al*, 2008). This approach is not prevalent because organic growers are required to manage crop nutrients and soil fertility through crop rotation, cover crops and application of plant and animal materials to meet national certification standards.

A related concept to soil health is soil biota which is an essential major fraction of global terrestrial biodiversity (Moreira *et al*, 2008). Soil biota are responsible for the key ecosystem functions of decomposition and nutrient cycling, soil organic matter synthesis and mineralization, soil structural

modification, nutrient acquisition, regulation of atmospheric composition, the production of growth substances and the biological control of soil borne pests and diseases (Woomer and Swift, 1994).
Soil health is very important in organic fruit production and growers rely on slow-release N from high C sources such as manure, compost and leguminous cover crops (Hughes *et al*, 2002). Other organic compliant amendments used are rock phosphate and marine products (Kelp, fish emulsion and sea weed formulations) that are commonly applied to the soil or in a foliar form. Orchard management greatly affects tree health and performance by alternating nutrient availability with crop demand while minimizing nutrient losses. Tree nutrient demands can be satisfied ecologically and efficiently if the soil microbial to plant system is properly managed. This is due to the fact that a lot of nutrients pass through the microbial biomass to higher trophic levels, making them unavailable to plants (Kennedy, 1995). The biological components of the soil convert nutrients from the organic materials into available forms for plant use. Soil management practices such as tillage affect the composition, activity and biomass of soil microbial communities (Deng and Tabatabali, 1996a,b, 1997; Ekenler and Tabatabali, 2003) same as the cropping systems(Acosta-Mortinez *et al*, 2003; Deng *et al*, 2000, manure addition (ACosta-Martinez and Harmel, 2006; Deng *et al*, 2006) ground cover management in orchards (Reganold *et al*, 2001; Kramer et al, 2005,) and choice between conventional and organic production. (Mader *et al,* 2002, Manokrouses *et al*, 2006, Von Diepeningen *et al,* 2006). Farm management decisions can affect soil microbial and faunal populations and this affects soil nutrient demand. Application of mulches, compost, animal manures, cover crops such as green manures or mowing and transforming ground cover materials between trees can assist in developing a farming system that uses inherent soil fertility via enhanced nutrient cycling by the resident soil biological component (Moore *et al*, 2008).
Orchard floor management greatly affects tree health and performance by alternating nutrient availability with crop demand while minimizing nutrient losses. Nitrogen (N) management in particular is emphasized in agricultural systems because of its importance in crop health and yields. Poor management of N in orchards may cause numerous environmental problems (Moore *et al*, 2008). N affects many physiological responses such as overall tree growth, flowering, fruit set, yield, fruit tree growth and quality. Synchronizing nutrient availability with tree demand is essential to ensure optimal tree growth, health and performance and to minimize off site nutrient losses via leaching, erosion or denitrification pathways (Moore *et al,* 2008).
CO_2 evolution and microbial biomass, Carbon (C) and N are more affected by soil depth versus management type (Delate *et al*, 2008). Organic soils have been reported to have lower bulk density which decreases with increasing soil porosity, higher soil infiltration rates and greater earth worm numbers, as compared to conventional soils. Organic soils also have high earth worm abundance and biodiversity (Werner, 1992, Daily, 1994). The use of alfalfa and clover cover crops increases the number of beneficial nematodes involved in nutrient cycling in organic orchards (Forge *et al,* 2003). Organic soils have higher P, K and S levels (Werner, 1997, Swezey *et a*l, 1998, Goh *et a*l, 2000). Overall, organic soils have higher nutrient levels (Delate *et al*, 2008) and have higher soil quality and lower adverse environmental impacts (Reganold *et al*, 2001; Delate *et al*, 2008).
To evaluate the effects of land management practices on soil health the organic fruit grower can use the analysis of soil organic matter content, nematode faunal composition (Ferris *et al*, 2001), enzyme activities (Bandick and Dick, 1999; Acosta-Martinez *et a*l, 2003;; Klose *et al*, 2006) and microbial community composition (Acosta-Marnitez and Harmel, 2006).
Inconsistent organic apple yields have been attributed to stress from sulphur based products, over cropping and nutrient imbalance or deficiencies often resulting from an over estimation of N released from organic fertilizers (Delate *et al*, 2008). Nevertheless, studies to investigate the effect of soil tree nutrition on fruit size/yield in organic systems have produced mixed results. In a study by Berghaman et al, (1999) an association between low yields in organic citrus and N assimilation was

attributed to low N assimilation. Weibel *et al*, (2005) reported 44.5% lower ratio of microbially bound N to C in organic settings. Conversely, Weiner (1997) found no differences in organic and conventional soils in the respiratory ratio of biomass C to total organic C, resulting from C inputs exceeding classes via microbial respiration.

WEED CONTROL STRATEGIES IN ORGANIC ORCHARDS

Fruit trees in orchards are usually not deeply rooted particularly trees in high density orchards. Young trees in particular spread their roots mostly in the top layer, which has abundant nutrients and organic matter. There is therefore competition for nutrients and water between these trees and other plants which may use the same sphere. This may eventually reduce the performance of these trees and cause reduced yields in the subsequent year. Therefore, strong weed competition affects the following years' yield. Skillful weed control methods are therefore required by organic fruit producers.

Optimum tree nutrition with N, apart from fertilizing also assists in weed control. Cultural practices should therefore aim at making the much needed N ready at the period of high plant demand around bud burst. But during periods of low demand, more weed competition can be tolerated without losses of tree performance.

Weed management has been identified as the primary concern of organic farmers (Muraro *et al*, 2003). Practices such as tillage for weed control can degrade soil quality (Cambordella and Elliott, 1993) and alternative methods are needed. Organic orchards require adequate weed control for the same reasons as conventional orchards to minimize competition for nutrients and water to provide acceptable tree growth, high fruit yield and large fruit size and to reduce habitat for rodents (Hogue and Nelsen, 1987; Merwin and Ray, 1999). In organic fruit production of some fruit trees such as citrus, 30% of annual production costs and the majority of the labour costs (Muraro *et al,* 2003) are incurred in discing, mowing and hand labour to remove weeds near trunks of young trees (Granatstein and Mullinix, 2008).

The weed control strategies used in organic fruit farming are tillage, thermal techniques; inert mulches (e.g. wood chips, weed fabric, living mulches, and organic herbicides. The use of irrigation can reduce N losses, in addition to this, appropriate floor management practices within the orchard can also improve N cycling, conserve N or provide fixed N through legumes or microbial fixations. The cultural practices to meet these goals include the use of organic mulches (hay, straw, wood chips, paper, weed fabric) that can facilitate weed control, soil structure improvement and increased tree growth and yield (Forge *et al,* 2005).

Use of vegetative cover or living mulches may suppress weeds by either reducing resource availability (Ngouajio and Mennan, 2005) or by inhibiting weed growth via allelopathy (Reberg-Horton *et al*, 2005). It can also provide soil improvement, nutrient cycling and N (if leguminous) but may compete with trees (Marsh *et al,* 1996, Sanchez *et al*, 2003, Stork and Jerie, 2003, Yao *et al*, 2005). The access to light, nutrients, water and soil as affected by cover crops may affect weed persistence (Ngouajio and Mennan, 2005) and the composition of weed flora (Wright *et al,* 2003). Cover crop residues may also affect soil microbial ecology or increase microbial diversity, resulting in enhanced weed seed predation by soil microorganisms and decreased weed seed vigour (Gallagher *et al,* 1999; Ngouajio and McGiffen, 2002) or may affect weed population changes (Jordan *et al*, 2000). Root exudates are also released by living mulches or cover crops and so are labile residues that can stimulate the soil fauna and improve nutrient cycling and retention (Rovira *et al*, 1990; Wardle *et al*, 2001 and disease control (Forge *et al*, 2000, Gu and Mazzola, 2003).

Other advantages of cover crops are their ability to increase soil C and N content, which regulate soil biological activity (Wager *et al*, 1998) and thus increase beneficial organisms that suppress biological competition such as weeds (Kremer and Li, 2003) ,parasitic nematodes (Wong *et al*, 2006)

and soil pathogens via allelochemicals (Bailey and Lazarovits, 2003). In addition, cover crops conserve soil moisture (Boyter, 1970) and can provide a habitat for beneficial insects (Tedders, 1983; Liang and Huang, 1994) and biological controls (Lacey *et al*, 2006). The above weed control options have disadvantages such as increased rodent populations (Sullivan and Hogue, 1987; Merwin and Roy, 1999), increased diseases (Merwin and Stiles, 1994), nutrient competition and alteration of pests (Granatstein and Mullinix, 2008).

Tillage method of weed control reduces rodents effectively but can degrade soil quality and reduce organic matter content. Flaming as a weed control method reduces weeds around fruit tree trunk and reduces rodents but it is appropriate for older perennial weeds and it uses fossil fuels making it a non-sustainable method. Inert mulches are effective in controlling most weeds and can improve soil quality and conserve moisture but they are costly to apply, can tie up N and may be hard to source. Conversely, living mulches or cover crops add biodiversity, improve soil quality and legumes can fix N. Organic herbicides can control weeds around trunk but are expensive and have inconsistent results. Other advantages of organic herbicides are absence of physical damage to tree, roots and reducing rodent populations.

Traditionally, inert mulches have been used in horticultural crop production, gardening to control weeds and conserve moisture but it has limited application in tree crops due to its high cost compared to herbicides (Merwin, 1995). Plastic or fabric mulch allow weed to grow around trunks of tree. The use of straw mulch increases mortality of young fruit trees as a result of crown root (*Phytopthone cactorum*) (Granatstein and Mullinix, 2008).

Organic growers who have used wood fabric in the tree row for weed control of perennial weeds such as quack grass (*Agropyron repens*) in orchards have reported reduced competition with the trees but a reservoir of weeds remain on the tree alley (Granatstein and Mullinix, 2008). The hoeing of orchards has caused a decline in soil quality and tree performance as compared to other mulches (Nielsen *et al,* 2003). This was due to increased temperatures underneath. A biodegradable paper mulch has been developed, tested and found to enhance tree growth but it was bulky and expensive (Hogue *et al*, 2003). Research is being undertaken to test other biodegradable paper mulches in organic orchards.

The use of wood chips as mulch has increased the population of codling moth larvae mortality when entomopathogenic nematodes were applied. This was due to the fact that the mulch provides an enabling environment needed by the nematodes to survive and locate the target organism (Lacey *et al*, 2006).

Generally, the application of organic amendments such as mulches and compost increases the rate of water infiltration by stimulating microbial activity, which increases the stability of soil aggregates. Infiltration rates are further increased by the decrease in bulk density caused by these amendments. Slow water infiltration is a serious problem in some irrigated soils and can result in plant injury, inefficient water use, and increased run-off and erosion. The impact energy of water drops and water surface stream compacts the upper soil layer and can cause clogging of the pores, immediately beneath the surface (Morin and Benymin, 1977; Agassi *et al*, 1981; Mortens and Franken Berger, Jr. 1992).

The ability of soil to transmit water depends on the soil particles. Soil application of animal wastes, plant residues and green manures has long been employed to induce favorable soil conditions (Khaleel *et al,* 1981; Boyle *et al,* 1989). The application of organic amendments often increases the C content of soil (Khaleel *et al*, 1981). An increase in the C content often leads to an increase in aggregate stability and water holding capacity and a decrease in bulk density (Gupta *et al*, 1977; Webber, 1978; Weil and Kroontje, 1979). Several chemical fractions of the organic C component have been suggested to be responsible for increased aggregate. Chaney and Swift (1980) reported significant correlations between aggregate stability and the total soil organic matter content, total

saccharide content and humic material extracted from 120 soils. Other researchers have suggested that bacterial saccharides, (Dormaar, 1983) and humic materials (Chaney and Swift, 1980) may be responsible for soil aggregation improvement. Gilmour *et al*, (1948) revealed that microbial activity promotes soil aggregation upon the addition of organic materials (Chesters *et a*l, 1957). It is postulated that stable aggregate formation under natural conditions is a gradual process influenced by physical, chemical and biological agents.

It can be concluded that organic growers will increasingly rely on weed control strategies that provide N and other nutrients, conserve water, increase water infiltration and soil aggregate stability and minimize soil disturbance and soil biota. This will ensure sustainable organic production.

INSECT PEST AND DISEASE MANAGEMENT IN ORGANIC FRUIT FARMING

Pests and diseases affect organically grown fruits the same way they affect conventionally grown fruits. The factors affecting insect and disease management in organic fruit farming include interactions among understory vegetation, arthropod populations, soil microbes, tree growth and development (Wholon *et al*, 2005). The methods used to limit pest incidences in organic farms are biological, cultural and physical, methods. Naturally occurring materials are used to limit pest incidences.

Orchard understory species composition can be manipulated to promote plant species that support beneficial insects (Altieri and Schmidt, 1985; Daly, 1994 and Rogers *et al,* 2003). Another way to reduce host sites for insects such as leaf rollers and others is mowing and grazing of understory plants (Thomas and Burnip, 1994). Using mulching, particularly paper-based, mitigates the root feeding nematodes such as *Pratylenchus peritrans* which causes the apple replant disease (Nielsen *et al*, 2004).

With respect to insect pest management the principle of natural enemy conservation by providing food and resting sites for beneficial insects in the orchard by cultivation of suitable cover crops to sustain them is applied. Research is being carried out to establish the ideal ratio of pests and beneficial insects. For organic fruit export, compliance with the importing country's regulations against the potential or actual presence of insects not present in their country is needed so that there is complete adherence to specific quarantine procedures (Neven, 2008).

To treat specific quarantined insect pests low temperature controlled storage of 2% O_2 and 2% CO_2 for a minimum of 8 week have been recommended (Wadded *et al*, 1990). A Controlled Atmosphere Temperature Treatment System (CATTS) technology using moist or vapor forced hot air with controlled atmosphere (CA) has also been discovered to disinfect apples (Neven and Rehfield-Ray, 2006). A good number of non-chemical quarantine treatments involve the application of high or low temperatures (Neven, 2000, 2003 and Wang *et al,* 2006). Other methods which have been applied are combinations of low temperature and controlled atmospheres ((low O_2/elevated CO_2) (Hallman, 1994). High temperature treatments have been used for tropical and sub-tropical fruits (Armstrong, 1994) while low temperatures have been applied for pest control in temperate fruit crops (Neven, 2008). There are some types of temperate fruit crops like apples which can tolerate high temperature treatments. For over a decade a lot of studies have been conducted on CATTS technology (Neven, 2004, 2005, Neven and Drake 2000a, b, Neven and Mitcham, 1996; Neven and Rehfield-Ray, 2000b, Neven *et al*, 2001, 2006). It has been mainly used in sweet cherries, pears, peaches and nectarines.

For disease management, organic apple growers have to contend with scab, powdery mildew (*Podosphaera lencotricha*) and fire blight (*Evwinia amylovora*). Breeding studies are going on to develop resistant cultivars (Delate *et al*, 2008) for other fruit crops. This should be the solution for pests and diseases, apart from using recommended natural products.

Some of the products which have been used for pest management are lime, sulphur, entrust and Neem oil. Other methods are pruning old branches and twiggy wood, mulching, traps, netting and

dogs. All these methods will control scales, weevils, fruit fly, thrips, caterpillars, leaf rollers, birds and mammals. Diseases can be controlled by Armicarb, Bordeax, and Oxidate. Neem oil also controls some postharvest disorders such as superficial storage scald (; Klein *et al,* 1990; Lurie *et al*, 1990, 1991; Klein and Lurie, 1992; Klein, 1994;;; Scrappa et al, 2008).

There are difficulties posed by temperate fruits inability to tolerate high temperature quarantine treatments due to the way the fruits are harvested with a wide range of sizes which causes thermodynamic and logistical problems (Neven, 2008). This allows for the equilibrium heating of the fruit. As compared to insects plants have a relatively high capacity for anaerobic respiration (metabolism). This makes the presence of O_2 to be important for insect acclimation to heat stress (Neven, 2003). These differences were responsible for the discovery of controlled atmosphere temperature treatment system (CATTS) technology (Neven and Mitcham, 1996). CATTS technology uses combination of the application of a moist-forced high air (MFA) or vapor-forced hot air (VFA) under controlled atmosphere storage (CA) (Neven, 2008). MFA is hot-forced air treatments applied under a non-condensing humidity environment while VFA is hot-forced air treatments applied under a condensing humidity. Horticultural oil which is mixed with water and sprayed onto foliage can also be applied to control pests and diseases in organic fruit farming. It is most effective against soft bodied insects and its ingredients are highly refined petroleum oil, pyrethrins which is also dusted on leaves, insecticidal soap (*Bacillus thuringiensis*), sabadilla which are ground seeds of the sabadilla lily, Rotenone which are derived from the roots of tropical legumes and potassium bicarbonate which is mixed with horticultural oil. In addition to the products listed above the following cultural practices can be undertaken:

- Maintaining a healthy soil: The soil should be managed well to give plants a balanced nutrition. Healthy plants resist pests and diseases. Regular application of organic residues in the form of manure and compost should be done. The broader objectives should be to maintain levels of humus that ensures good soil structure, and to ensure the soil organisms are fed.
- The crops should receive the correct type and amounts of nutrients to ensure a healthy crop.
- Maintain a good population of resistant varieties and wide genetic base. All this is achieved by breeding and there will be disease and pest resistance.
- Good hygiene: All plant debris, live or dead should be disposed of. This may come through pruning and death of branches and their dropping down.
- Soil tillage: This exposes the pests, birds or other predators so that they are more easily controlled.
- Companion planting: Certain plants can be grown to protect other plants from pests or diseases. The pest may be attracted to the companion plant more than it is attracted to the fruit tree. Companion plant can also act as a barrier to other pests (HDRA, 1998).
- Grow attractant plants: These can be grown in the orchard to attract predators and beneficial insects by their flowers. Examples of such plants are minta (*Mentho*), sunflower (*H. annus,* sunhemp (*Crotolaria juncea* as well as local leguminous crops such as beans (HDRA, 1998).
- Use of barriers: These are physical structures that prevent the pest from accessing the tree, e.g. tops of transparent bottles placed firmly on the ground to protect the tree from attack by climbing insects. Building a trench around the orchard can prevent attack by subterranean termite species (HDRA, 1998).
- Use of bait traps: Examples which can be used are equal quantities of saw dust, bran, molasses and enough water to produce a sticky solution which is applied around the base of the tree. The molasses attract the cutworms and they get struck when they try to pass through. The substance dries out in the sun with the pest which dies (HDRA, 1998). Another trap which can be prepared is

mixing 100 grams of bran, 10g sugar, 200g of water, and 5g of pyrethrum powder. When this mixture is spread around the base of the tree the cutworms eat it and die (HDRA, 1998).

- Making of light traps

These are made at night and attract different types of insects. It can comprise construction from wooden poles or bamboo which is pressed firmly into the ground tightly with a lantern on top. Other methods which can be used are fly traps, pheromone traps and direct picking and squashing of insect pests and biological control (HDRA, 1998).

PRESENT STATUS OF ORGANIC FARMING IN KENYA:

Horticultural production in Kenya

Kenya's horticultural industry has had a rapid and sustained growth in terms of domestic and export market in the last 10 years. It is currently the fastest growing agricultural subsector in the country. This progress has been attributed to considerable investment in production infrastructure at all levels, mainly funded by the private sector. The Horticultural Crops Development Authority (HCDA) has been the main body promoting the production and marketing of horticultural produce in Kenya. The industry employs 4.5 million people directly and 3.5 million indirectly through trade and other associated activities (Shah, 2008). According to HCDA the estimated annual production of fruits was 2.0 million metric tones in the year 2006. In the year 2007 the annual production of fruits was 15 million kg. The data in table xxx reflect the volume exported in terms of fruits types

Table 5: Value of fruit exports in 2006 – 2007.

Type of fruit	2006		2007	
	Volume (kgs)	Value (%)	Volume (kgs)	Value (%)
Avocado	586,659,456	34	13,184,489.88	84
Passion fruit	1,032,526,886	59	1,292,280.65	8
Mango	88,643,232	5	962,998.75	6
Others	29,510,282.39	2	232,680.6	2
Total	1,737,339,856	100	1,5671.449.80	**100**

Source; HCDA Newsletter, 2008

Fruit tree farming in Kenya is practiced by both small and large scale farmers, , government corporations, private corporation and departments such as the prisons. Small scale farmers are faced with low input application and mainly do organic farming. They don't manage their orchards well in terms of pruning, irrigation, and rarely plant grafted trees, as they depend largely on indigenous varieties. This has been mainly due to unsatisfactory extension services. Avocado is the main fruit grown in Kenya for domestic consumption and for export. The table below shows Avocado production by provinces from 1996 to 2003.

Table 7: Provincial avocado production statistics, Kenya.

Province			Hectares					
Year	1996	1997	1998	1999	2000	2001,	2002	2003
Eastern	106	1127	1173	1111	1241	1295	1334	1355
Western	319	427	470	475	593	609	633	648
Central	559	572	1491	1466	1232	1463	2031	1980
Rift valley	419	408	474	402	451	454	483	638
Nyanza	144	149	217	458	493	543	282	327

Coast	35	62	73	74	74	80	82	97
Total	2585	2745	3848	3986	4119	4464	4880	5099

Source; Horticulture annual reports, Ministry of Agriculture 1996 – 2003, Nairobi, Kenya

Table 8: Provincial Avocado production statistics

Province			**Production (tones)**					
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Eastern	10,493	16,173	17,401	15,206	15,232	17,030	17,909	18,162
Western	3293	4567	4519	5672	5872	6041	6078	6420
Central	7043	8037	17688	20546	8090	21615	16540	25198
Rift valley	8665	6744	7603	6939	4792	5004	8709	8480
Coast	276	496	450	496	544	640	650	649
Nyanza	1560	1260	1477	4812	7357	3826	4265	11619
Nairobi	21	-	-	-140	240	200	42	21

Source; Ministry of Agriculture annual reports, 1996 – 2003, Nairobi, Kenya

Only 13% of the worlds avocado production is traded internationally with the EU and USA being the principal export markets. Avocado is an important commercial fruit in Kenya and about 30% avocado crop was exported in the year 2003 (Griesbach, 2005). Kenya accounts for 2% of world avocado production but 5% of world exports.

Passion fruits are the second commercially important fruit in Kenya grown for domestic consumption and export. It is mainly grown in the Rift valley region of Kenya. A part from Avocado, Mango, Passion fruits, other fruits grown in Kenya are bananas and citrus. For the case of Mangoes, more that 80% produced in Kenya are the indigenous varieties (landraces) which are rich in fiber and are of little market value.

Banana production is declining over the years due to low soil fertility and pests and diseases such as nematodes, weevils and *Xanthomonas* wilt. Mango production in Kenya has expanded rapidly over the recent years. In terms of hectares under cultivation there has been a decline in Kenya, despite the expansion in demand for fresh fruits abroad. The fruits cannot compete effectively because of unreliable supplies both in quantity and quality (Ngugi *et al.,* 2008). Overall, the constraints to commercial fruit production in Kenya are lack of poorly adopted rootstocks and cultivars causing low yields; lack of clean planting materials, ; inadequate post-harvest handling facilities; poor transport infrastructure causing deterioration of produce and inadequate collection and grading of fruits coupled with lack of proper packaging facilities.

The way forward for fruit production in Kenya

For sustainable organic fruit production in Kenya the following are recommended:

(i) Choice of suitable rootstocks and cultivars

(ii) Correct management practices such as pruning, spacing, irrigation and weed control. Research should be carried out on the management practices of fruit trees under organic farming.

(iii) There should be adequate research – extension linkages to recommend to farmers the best management practices.

(iv) Organic methods of pest and disease control should be devised.

v) More research is needed on the post lowest handling and processing for the organically farmed fruits.

(vi) Research has been on mainly organically grown temperate fruits. There is need to focus on tropical fruits also.
(iv) More market research is needed with respect to consumer demand dynamics.
(vii) More types of organic methods to be researched on i.e. different types of manure, plant products for pest control, different fruit species and cultivars.

History of organic farming fruit farming in Kenya

Initially organic farming was developed by the initiative of private and Non – Governmental organizations (NGOS) and private organizations. These are: The Kenya Institute of Organic Farming (KIOF) established in 1986, Manor House Agriculture Centre, formed in 1992, The Association of Better Land Husbandry established in 1994 : Sustainable Agricultural Centre for Research and Development in Africa (SACRED), Sustainable Agriculture Community Development Program (SACDEP)- established in 1992, and Baraka Agricultural college(Anon,.2005).
Later on in the mid 1990s efforts led to more collaboration among the stake holders leading to the establishment of organizations such as the Kenya Organic Farmers Association (KOFA) which was established by farmers trained by KIOF. This association published organic farming standards for members based on the IFOAM and EU standards. KOFA was keen on searching for local and international markets for the organic produce.
The Kenya Organic Producers Association (KOPA) was later established by larger companies and commercial farmers in the export market. In the year 2005 KOPA and KOFA established an umbrella network KOAN to support the growth of the organic farming sector.

Table 9: The present status of organic farming in Kenya by province.

Province	No. farm enterprises and supply	No. of outgrowers	Available land (ha)	Unused land (ha)	Total (ha)
Central	19	5.418	3.023	40.500	48.801
Eastern	2	474	1.543		2.017
Nairobi	2		16		16
North Eastern	0				
Nyanza	0				
Rift valley	5	154	276	32.640	32.599
Western	3	100	251		351
Total	35	6,480	5.433	73.140	351

Source: KOAN report (2008).

From the table above more than half of the organic produces are in central province while North Eastern and Nyanza have none. Therefore it can be concluded that it has only been practiced in the agriculturally active provinces of Kenya. In central it is practiced in the production of fruits, nuts and coffee. The table below shows the products produced under organic farming in 6 provinces of Kenya.

Table 10: Major organic produce from Kenya's 8 provinces.

No. of farm enterprises	Major products produced	Provinces
19	Beans, peas, sweetcorn, chillies, avocado, baby, salad, baby vegetables, banana, oranges, macadamia, cashew nuts, passion	Central

	fruits, pear, cucumber	
2.	Coconut oil, avocado oil	Coast
3.	Guava, sweet bananas mangoes	Eastern
	tomatoes	Nairobi
2	Vegetables	Rift valley
1	pineapple	western

Source: KOAN Report (2008).

The organic sector is still relatively small but growing fast. Over 182,000 hectares of land are under organic management which accounts for 0.69% of the total agricultural area in Kenya. The total number of farms under organic cultivation is about 30,000 (FOAM & FIBL, 2006). Many of the organic farmers are large scale producers of agriculture and horticulture who are diversifying into organic production (IFOAM, 2003). The domestic market for organic products is small hence they are exported.

Legislation and certification

Organic Farming in Kenya is supported by the Ministry of Agriculture's Food security and soil fertility policy drafts. External certification bodies do most of the certification for the export market. The international certification agencies are Soil Association (UK), Ceres (USA), Ecocert (France), IMO (Germany) and Bio Swiss (Switzerland). The majority of these agencies use locally trained inspectors. In May 2007 the East African Organic Products Standard (EAOPS) was launched to promote organic farming and harmonization of standards in the East Africa region.

All these are for the International markets. Locally, Evicert was established in 2005 to certify organic products for the local market. There are already campaigns in the Kenya press to promote organic farming and eat organic products. For example in the Daily Nation Newspaper of February 15th 2010 there were advertisements about advantages of organic farming products.

The local markets for organic fruits are Karen, Muthaiga, Lavington, and Westlands in Nairobi. They are sold at 'Uchumi' and 'Nakumatt' Supermarkets in Nairobi apart from the main shops called 'Healthy U', 'Green corner shops, 'Organic Green Grocers' and 'Kalimoni Greens'. There are also three organic restaurants in Nairobi. Hotels in Mombasa, Kisumu and Nairobi serve organic products on order (Anon, 2005).

Organic fruit farmers in Kenya still need to collaborate with their counter parts in other parts of the world to learn about the basics of organic fruit farming. It is necessary for the organic farmers to attend Conferences/Workshops to learn the latest techniques of organic farming, share information on research needs, cultivation of specific fruits in the tropics and subtropics, organic production and certification and compilation of technical information on organic farming (Anon, 2005).

Potential for Organic Fruit Farming in Kenya

The horticultural industry in Kenya is the fastest growing agricultural sub-sector in the country. This progress has come due to considerable investment in production infrastructure at all levels, largely funded by the private sector. The sub-sector has further been strengthened by the activities of the Horticultural Crops Development Authority (HCDA), the Fresh Produce Exporters' Association of Kenya and the Kenya Flower Council. The main markets for the Kenya Horticultural Produce are European Union, U. K., the Netherlands, France and Germany. The main fruits grown for export are Avocado, Mangos and Passion fruits (Muthami, 2008).

More than 80% of the arable land in Kenya is semi-arid and arid where dependence on rain fed agriculture and low input application lends itself to low productivity and frequent crop failures. The arid and semi-arid areas have enormous potential for horticultural production. Irrigation is therefore

crucial to the development of the horticultural industry in those areas and can make significant contribution to food security and poverty alleviation (Webule, 1999).

Farmers in the semi-arid areas of Kenya where the average rainfall is in the range of 500-800mm/year often utilise maize-livestock based farming system. Farmers usually intercrop beans, green grams, cowpeas, sorghum and traditional crops or exotic vegetables as annual crops. Tree crops such as mangoes, pawpaws, citrus, cashew, macadamia among others are scattered on the farmland or planted along contours or boundaries in the arid and semi-arid lands.

The production of annual crops such as maize is a risky enterprise due to the low and often erratic rainfall and to the occurrence of mid-season droughts. Therefore, because of these risks of production farmers never apply mineral fertilizers and pesticides on their food crops. The use of fertilizers in these districts is rather low (Njenga and Eckert, 1999). Fertilizer is only applied in cash crop oriented production systems growing vegetables, cotton and tobacco. Since maize is the staple crop and food self sufficiency has the highest priority, in crop decision making extension messages for fertilizer application have been developed to increase the yields and intensify the system. However, few farmers can afford to buy mineral fertilizers for their maize and annual crops. Because of the production and marketing risks extension massages based on the external input application in the arid and semi-arid lands are not economically viable. Therefore these farming systems can be transformed into organic systems easily with tree crop products as an additional source of income and poverty alleviation (Njenga and Eckert, 1999).

Due to production risks of annual crops farmers have already diversified and plant many different fruit and tree crops such as mango (*Mangifera indica*), guava (*Psidium guajava*), and pawpaw (C. *papaya*) (Njenga and Eckert, 1999). The trees are nicely scattered on the farm and around the home steads or are often planted along the plot boundaries or contours. Pruning and watering practices are rarely applied. The fruits are consumed domestically and some sold in local markets. The semi-arid and arid lands are Kitui, Machakos, Tana River, Kilifi and Lamu districts. Areas like Siaya, Bondo, Kisumu, Suba and Koibatek districts can also be included. The agro forestry component of cropping systems in these areas contributes to soil and water conservation. In these areas more efforts should be put on the development of fruit tree crops-livestock based farming systems to enable farmers gain access to the emerging international markets. Products from organic farming can get access to markets in Canada, U. S. A., Germany, U. K. and the E. U. This will earn foreign reserves for the country and increase farmers' income (Njenga and Eckert, 1999).

Postharvest Practices for Organically Grown Fruits

All the fruit quality parameters such as freedom from injury, blemishes, decay, rots and the right colour, shape, texture and flavour must be obtained. The fruit must be harvested at the right stage and cooled well. For a fruit tree being grown for the first time it should be monitored for a number of times to establish the appropriate ripening or storage pattern. To conform to a certified organic system the integrity of the organic product must be maintained from the orchard to the consumer (Perkins-Vezie, 2008). Precautions must be taken to avoid any mixing of organic and conventional fruit in the same packaging. Even the packaging materials used for the organic fruits must be certified so that organic standards are met. The conventional practices and chemicals which can be used for organic fruits are controlled atmosphere storage (CA), sulphur dioxide and ethylene gas. Chlorine can be used for washing organic fruits but the chlorine level should be no more than 4ppm. In order to use wax on the fruits it must be certified by the organic fruit certifying agency.

During processing maximum care should be taken to avoid any contamination of the organic fruit (Plotto and Narciso, 2006). Such processing procedure must be certified by an organic processing agency. It is necessary to disinfect surfaces used for organic fruits during their processing and

preparation. Recommended procedures must be used to avoid non-organic contamination of the organic fruits.

Moreover, precautions must be taken to remove the remains of manure or other organic materials by checking them thoroughly to avoid contamination. The bacterial load in the fruits should also be checked to conform to set organic standards (Mukherjee *et al*, 2004).

The level of antioxidants, nutrients and phyto -chemicals in the organic fruits should be determined using standard methods because this has a bearing on human health (Perkins-Versie, 2008). Research has been conducted severally to relate the production system, i.e. organic versus conventional with respect to antioxidants (Washington, 2000; Magkos *et al*, 2003; Lester, 2006 ;;). Such antioxidants include ascorbic acid, B-carotene and phenolic compounds. It is likely that postharvest practices approved for certified organic fruits may change the products external and internal quality. These should form the basis for future research in organic fruit quality.

CONCLUSION

Organic farming in Kenya should be undertaken because the cost of chemical fertilizers and pesticides is beyond the affordability of the Kenyan farmers and the environmental risks posed by these chemicals, leave alone the food safety concerns, are enormous. As of now the ecological harm caused by the intensified horticultural activities by the multinational companies is already being felt by the death of fish and birds, e.g. in Lake Naivasha of Kenya. Not only will the death of fish hurt the Kenyan economy but the health of the people is endangered when they eat the fish contaminated by the chemicals from the horticultural farms surrounding the lake. Lastly, the fact that organic farming is cheaply undertaken means it will increase the incomes of the Kenyan farmers so that the U.N Millennium Development Goals can be achieved through poverty reduction. There will also be improved health of the people of Kenya.

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Enhancing crop and livestock productivity – learning and planning with local agro-pastoral communities in Nakapiripirit Karamoja region of Uganda

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SUMMARY

This study was motivated by the fact that despite existence of large herds of cattle and goats, adequate feed, human capital and other resources and conditions favorable for improving livestock, poor herd productivity characterizes livestock farming in Nakapiripirit region. The area of study, Namalu sub-county in Nakapiripirit district, is dominated by semi-transhumant agro-pastoralists of Pian ethnic Karimojong tribe. The sub-county was sampled to capture variability in socio-cultural and farming systems settings. The bulk of data used in the study was semi-formally obtained using key informant and focus group discussion procedures. Survey results show that the major crops are maize, sorghum, ground nuts, beans and sunflower. The main crop constraints are drought, difficulty in ploughing, weeds, low soil fertility and delay in seed supply. Cattle, goats, sheep, chickens and donkeys are the priority livestock enterprises. Local breeds of cattle and shoats are commonly open grazed (herded or tethered). Chickens and turkeys are mostly reared on free range system. The main constraints to livestock production are insecurity, drought, anaplasmosis, East Coast Fever (ECF) and heart water. Challenges to production include deforestation, ploughing along slopes, termites, mono cropping, overgrazing, declining land sizes, floods, strong winds and dominance of sandy soils. Extreme conditions of water scarcity (drought) and excessive rainwater (floods) coupled with occurrence of strong winds; presence of sandy soils and the practice of ploughing along slopes are clear manifestations of an area prone to adverse effects of climate change. Experiences and lessons learnt from the study indicate that the common belief that the security situation particularly threat to human life and property is far beyond tolerable limits is highly exaggerated. Isolated attacks, just like highway robberies can occur anywhere, and other risks to human life are not very different from accidents and misfortunes that could befall anyone in other parts of Uganda. Further more, Karamoja region and Karimojong are portrayed to be hostile and non-cooperative. Informal interviews notably FGD discussions confirmed that the Karimojongs are

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interactive, freely participate and contribute good ideas that can guide research and development agenda based on informed opinion, real local needs and circumstances. The communal settlement (Manyatas) system that simulates modern settlements from other economic activities like farming offers the region three major advantages. Crop production and livestock grazing areas can be favorably concentrated in specific areas so that economies of scale are exploited. Besides, common conflicts between cultivators and pastoralists stemming from crop destruction by cattle are avoided. Mobilization and accessing individual households to foster participatory community development are facilitated by the clustered settlements headed by Manyata heads elected and accorded respect by all manyata occupants.

Based on data on farm, land and water management constraints the following strategic interventions are proposed: Promotion of sustainable household and community-wide rainwater harvesting techniques to increase water availability for crop, livestock and domestic uses; Improved soil fertility and conservation technology and skills improvement to arrest causes of soil degradation; Improved input supply for the priority crop and livestock disease and management constraints by NAADS, extension and relevant support systems in the agricultural sector; and establishing inter-district and cross border networks to curb cattle rustling.

INTRODUCTION

Karamoja region of Uganda is a marginal semi-arid area in North-Eastern Uganda. Transhumant pastoral and crop-livestock mixed systems characterize people's livelihood patterns. The communities have large herds of cattle, goats and sheep. The region is characterized by a bi-modal rainfall pattern with excess water during rain seasons causing runoff and other attendant problems such as soil erosion. One of the main problems associated with the semi-arid region is that rainfall patterns have become more and more irregular and much of the precious water is lost as surface runoff due to poor vegetation cover – partly due to overgrazing, bush burning and poor soil and crop management practices on both flat and sloping topography. Another complication is that light and sandy soils commonly associated with these semi-arid areas do not favour sufficient moisture retention.

In some areas, this situation is further complicated by soils that are shallow, with bedrock within one meter from the surface (Aniku, 2001). In addition to other bio-physical challenges like pests, parasites, diseases and climatic variables, declining availability of soil water and nutrients for sufficient crop and pasture development furthermore adversely affect farm productivity. In addition, rapid growth in population in this region has inevitably increased pressure on the scarce water and land resources to provide for subsistence and income needs of producer and dependent households. This has resulted into decline in productivity of agricultural land and scarcity of water for production.

This study set out to provide information necessary for improving application of traditional and improved technologies and to foster participatory and innovative management of land and water sources for sustainable and profitable agriculture in the region. A clear understanding of priority crop and livestock enterprises, relative importance of critical production constraints and potential technological interventions were hence deemed vital for this process.

Research approach

***Study area selection and sampling methods*:** The political/administrative divisions of the district are Chekwii, Pian and Pokot. The sub-counties making up these counties are:

Chekwii County: Chekwii County comprises of Namalu, Kakomongole, Moruita sub-counties and Nakapiripirit Town council. The county is mountainous with water bodies namely River Namalu and some springs and valley dams like Namatata. There is Kadam forest reserve on top of the

mountains. Road infrastructure is dominated by murram roads joining the Sironko – Nakapiripirit highway. The major institutions are schools like Namalu SS, Senior Nakapiripirit SS, Namalu Mixed PS, St Mary's Girls PS; and health units like Tokora health centre 4, Namalu health centre 3. The county is endowed with Pian-upe game reserve (mostly in Namalu) where wild game like antelopes, giraffes, buffaloes, ostriches and leopards are common. Agro-pastoral farming systems shifting towards crop farming is the dominant farming system. Charcoal burning; livestock trading; crop trade; petty businesses; sand excavation, stone quarries, brick making and local brewing are the major economic activities.

Pian County: Pian County comprises of Nabilatuk, Lolachat and Lorengedwat sub-counties. The county is characterized by seasonal rivers, some hills and semi-arid land dotted with shrubs especially of acacia species. It is traversed by Pian-upe game reserve and has Okutot dam. The main institutions are Arengesiep SS, St Kizito Lorengedwat SS, Nabilatuk health centre 3 and Lolachat health centre 2. The main economic activities are transhumance pastoralism, limited crop farms growing sorghum, groundnuts, sesame, livestock trading and other petty trade. Nabwin Zonal Agricultural Research and Development Institute is located in Lorengedwat sub-county.

Pokot county: Pokot sub-county comprises of Amudat, Loroo and Karita sub-counties. The county has some mountains and hills; seasonal rivers and Pian-upe game reserve. It is generally semi-arid with thorny bushes, low and uniform vegetation canopy. Major institutions are Amudat hospital; Amudat air strip; Pokot SS; Karita and Loroo Health centers 2. The inhabitants typically practice nomadic pastoralism with no permanent homes except near trading centers. The only major road is the one leading to Kenya and there are no manyatas. There is limited crop production along rivers. Common businesses are livestock marketing; marble quarries; petty trade and limited charcoal burning near towns mostly by immigrants to the county.

Location of the study area on the map of Uganda is shown in figure 1. Namalu sub-county was sampled to capture variability in socio-cultural, agricultural practices and farming systems. Resource endowment was thus the major selection criterion for the sub-county. Resource endowment is a function of rainfall, population density, cattle ownership, farm sizes of major crops and market access (Scoones and Wolmer, 1999). Based on the above factors Namalu sub-county characterized by mixed crop-livestock agro-pastoral (semi-transhumant) system was selected. Systematic random sampling was used to select Lokomit and Nakiloro villages from Kokuwam and Lokatapan parishes, respectively (table 1). In the Karamojong rural communities settlement clusters, manyatas are named after manyata heads. Corresponding manyatas where the FGDs were conducted are Apaloyem and Longoriluk; and Lorot John and Nangiro Timmothy.

Table 1: Parishes and villages sampled in Namalu sub-county, Nakapiripirit, Uganda.

Parish		**Village**	
		Lokomit	**Nakiloro**
Kokuwam	**Lokatapan**	**Manyata name/heads**	
Kokuwam	Lokatapan	Lochugae	**Lorot John**
Kawuolobu	Naminit	Lokolidepe	Kokoi
Apended	Looborio	**Apaloyem**	Cornelious
Nakwanga	**Nakiloro**	**Longoriluk**	Teko Tito
Napiananya	Lowatachin	Wekesa	**Nangiro**
Nakoyot	Lokiengunete	Jackson	**Timothy**
Kacholikokoi	Lobulepeded	Matia Lochap	Oluange Juma
Lokomoit	Nakuyon		
Lochowangikalei	Komojoj		
Naburikethigiria	Lomorunyangae		

Loringith Namalu T/C Angoleturot Loleliarengan	Lokadongan		

Figure 1: Karamojang herds men drive cattle back to their Manyatas (communal settlements).

Figure 2 : A map of Uganda showing Nakapiripirit district.

Observations, data documentation and analysis: Data were collected from two largely informal sources namely key informants at the district and sub-county and focused group discussions (FGDs). Key informant surveys covered production staff, farmer forum chairpersons, innovative farmers, chiefs and local council members. Information collected included among others, farming systems, soil types, rainfall; agricultural development service providers, farm, water and land management challenges, technology interventions and gaps. Participatory planning techniques based on the principle of exploiting the wealth of local knowledge by local communities (Conroy, 2005) were utilized. Participatory methods were reinforced by triangulation (FAO, 1998) in terms of methods of data collection; information sources; people involved in the process and the multidisciplinarity of the research team composition. Using consensus assisted single list and pair-wise ranking procedures FGDs generated data on priority farm enterprises, production constraints and challenges/threats.

The bulk of data used in this study were qualitative. This included participatory priority rating of major farm enterprises and associated constraints. Data on these variables were examined using single list consensus based ranking ordering and matrix based pair-wise ranking using scoring approaches. In order to link priority constraints on major enterprises to plausible development intervention, existing actors and their roles was assessed using stakeholder profiling. In addition, farmers have devised ways and means of dealing with the constraints inhibiting production.

At the recommendations stage, current status of coping mechanisms were factored into action planning matrices that relate constraints and technology and development needs, and proposed interventions capable of addressing the constraints.

FINDINGS

Priority farm enterprises and constraints: The five major crops were found to be maize, sorghum, ground nuts, beans and sunflower. This implies that cereals, pulses and oil crops dominate crop production in the region (tables 2 and 3). These being annual crops, farmers are compelled to open land every season and ensure timely operations of seed bed preparation, planting, thinning, weeding and harvesting. Judicious crop rotations would also be necessary to ensure cultural control of pests and diseases. The five main crop constraints are drought, difficulty in ploughing, weeds, low soil fertility and delays in accessing quality/certified seeds.

This implies that climatic conditions especially drought poses a challenge to critical timeliness of operations as demanded by annual crops. Weed infestation is further aggravated by the fact that after harvest crop fields are communally grazed. This expands the distribution of weed seed through cattle droppings and hooves. Besides, lack of strict crop rotations leads to proliferation of weeds such as striga that adversely affects all cereals. Soil management through ploughing is complicated by compaction during dry seasons. Besides, land opening is mostly left to women and children because at the peak of the dry season men migrate with the herd in search of pasture and water. In addition, low and increasingly degraded soil fertility due to soil erosion and over grazing compound the poor fertility of the soil.

This region is prone to erratic climatic variability. Droughts coupled with short rain seasons, and occurrence of dry seasons earlier than expected imply that timing of cropping operations has to precisely match the season. It is therefore not surprising that farmers consider input availability a key impediment to improved crop farming. Late provision of especially seed and application of other inputs like herbicides and fertilizers will result into low yields especially in drought prone areas such as Nakapiripirit. Choice of seed should also focus on short duration or drought tolerant varieties.

Table 2: Major crop enterprises in Namalu sub-county, Nakapiripirit District, Uganda.

X	Maize	Sugar cane	Beans	Ground nuts	Bananas	Sorghum	Pumpkin	Sun flower	Sweet potatoes	Simsim	Rice	Yam	Tobacco	Cassava	millet	Total Score	Rank
Maize	x	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	14	1
Sugar cane		X	Beans	Ground Nuts	Sugar cane	Sorghum	Sugar cane	Sun flower	S. Potato	Simsim	Rice	Yams	Sugar cane	Cassava	Millet	3	11
Beans			X	Ground Nuts	Beans	Sorghum	Beans	Beans	Beans	Beans	Beans	Beans	Beans	Beans	Beans	11	4
Ground Nuts				X	Ground Nuts	Sorghum	Ground Nuts	Ground Nuts	Ground Nuts	Ground Nuts	Ground Nuts	Ground Nuts	Ground Nuts	Ground Nuts	Ground Nuts	12	3
Bananas					X	Sorghum	Bananas	Sun flower	S. Potato	Simsim	Yams	Bananas	Bananas	Sun flower	Millet	3	11
Sorghum						X	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	13	2
Pumpkins							X	Sun flower	S. Potato	Simsim	Rice	Yams	Tobacco	Cassava	Millet	0	15
Sun flower								X	Sun flower	Sun flower	Sun flower	Sun flower	Sun flower	Sun flower	Sun flower	10	5
S. Potato									X	Simsim	Rice	Yams	S. Potato	S. Potato	S. Potato	6	8
Simsim										X	Simsim	Simsim	Simsim	Simsim	Simsim	9	6
Rice											X	Yams	Tobacco	Rice	Rice	5	8
Yams												X	Yams	Yams	Yams	7	7
Tobacco													X	Tobacco	Tobacco	4	10
Cassava														X	Cassava	3	11
Millet															X	3	11

Table 3: Major crop constraints in Namalu sub-county, Uganda.

X	**Low soil fertility**	**Drought**	**Floods**	**Poor extension services**	**weeds**	**Low price**	**Difficulty in ploughing**	**Insect pests/**	**Delays in seed supply**	**Damage by birds**	**Damage By Live stock**	**wild life**	**High cost of ploughing**	**Total score**	**Rank**
Poor soil fertility	X	DR	Poor soil fertility	Poor extension services	Weeds	Poor soil fertility	Poor soil fertility	Poor soil fertility	Poor soil fertility	Poor soil fertility	Poor soil fertility	Poor soil fertility	Poor soil fertility	9	3
Drought		X	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	11	1
Floods			X	Poor extension services	Weeds	Floods	Difficult in ploughing	Pests	Delays in seed supply	Floods	Floods	Floods	High cost of ploughing	4	8
Poor Extension services				X	Weeds	Low price	Difficult in ploughing	Poor extension services	Poor extension services	Poor extension services	Damage by livestock	Damage by wild game	High cost of ploughing	3	9
Weeds					X	Weeds	Difficult in ploughing	Pests	Weeds	Weeds	Weeds	Weeds	Weeds	9	3
Low price						X	Difficult in ploughing	Pests	Delays in seed supply	Damage by birds	Damage by livestock	Damage by wild game	High cost of ploughing	1	12
Difficult in ploughing							X	Difficult in ploughing	Difficult in ploughing	Difficult in ploughing	Difficult in ploughing	Difficult in ploughing	Difficult in ploughing	10	2
Insect pest								X	Delays in seed supply	Pests	Pests	Pests	Pests	7	5
Delay in seed supply									X	Delays in seed supply	Delays in seed supply	Delays in seed supply	Delays in seed supply	7	5
Damage by birds										X	Damage by birds	Damage by birds	Damage by birds	3	9
Damage by livestock											X	Damage by wild game	Damage by livestock	1	12
Damage by wild game												X	Damage by wild game	5	7
High cost of poughing													X	3	9

Livestock production priorities (table 4) rank cattle and small ruminants (goats and sheep) as the major species raised in the region. This trend is similar to what happens in other parts of the country except for donkeys and camels that are ranked number five and ten, respectively. Local breeds of cattle and shoats are commonly open grazed in composite herds belonging to several households on communal areas. Most birds (chickens, ducks and turkey) are mostly reared on free range system whereby they are released in the morning to scavenge for feeds with little on no supplementation by the farmer. Donkeys are also reared in neighbouring Kapchorwa district mostly for farm transport but camels are unique to Karamoja region and are not commonly kept in other parts of the country. As observed by Ashley and Nanyeenya (2005) livestock play multiple subsistence (meat, blood and dairy products), income, farm-power, transport and fertilizer supplies, social capital and traditional roles. These are reflected in the uses of livestock for household food provision, cash income generation, dowry settlement for young boys acquiring spouses, animal traction especially for cattle and provision of manure by mostly cattle, goats and sheep.

Table 4: Major livestock enterprises, their uses and ranking in descending order**.**

Livestock type	Ranking order	Main uses
Cattle	1	Traction, subsistence, dowry, cash income, hides/skins, manure
Goats	2	Subsistence, dowry, cash income, skins, manure
Sheep	3	Subsistence, dowry, cash income, skins, manure
Chicken	4	Cash income, subsistence
Donkeys	5	Transport, traction, cash income, subsistence, dowry
Turkeys	6	Cash income and subsistence
Rabbits/guinea pigs	7	Subsistence, cash income
Ducks	8	Subsistence, cash income
Pigs	9	Subsistence, cash income
Camels	**10**	Milk, meat and cash income, dowry

The constraints to livestock production focussed mainly on cattle. Major constraints highlighted in receding order of importance were: cattle rustling, drought, anaplasmosis, East Coast Fever (ECF) and heart water disease. This suggests that insecurity posed by neighbouring communities within and outside Uganda, climatic conditions and tick-borne diseases constitute the major problems affecting livestock farmers in Karamoja.

Scarcity of water does not only limit livestock production but also promotes normadism and abuse of communal watering points (Nanyeenya *et al,* 2009). Many livestock in the zone still trek long distances in search of water. These conditions have in turn precipitated the spread of livestock diseases, overgrazing and land degradation in certain areas, and in some areas insecurity caused by families trying to assert their control and access to water bodies (LSRP, 1999). Inter-district and transboundary steps need to be explored to curb the insecurity alongside vigilance of local communities. Availability of relevant veterinary drugs, treatment and advisory services and farmers' skills in disease control ought to be improved. A key constraint pointed out particularly for goats was Pestes des Petits Ruminants (PPR).

Table 5: Major constraints on livestock production in Namalu sub-county – Nakapiripirit District, Uganda.

X	Wild animals	Insecurity	Drought	Ticks	Worms	Tsese flies/Tryps	ECF	CBPP	Rinder pest	Anaplasmosis	Heart water	FMD	Babesiosis	Anthrax	Retained placenta
Wild animal	X	Insecurity	Drought	Ticks	Worms	TRYPS	ECF	CBPP	Rinderpest	Anaplasmosis	Heartwater	FMD	BAB	Anthrax	Retained placenta
Insecurity		X	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity	Insecurity
Drought			X	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought	Drought
Ticks				X	Ticks	TRPYS	ECF	CBPP	Rinderpest	Anaplasmosis	Heartwater	FMD	Babesiosis	Anthrax	Ticks
Worms					X	TRPYS	ECF	CBPP	Rinderpest	Anaplasmosis	Heartwater	FMD	Babesiosis	Anthrax	Worms
Tsetse flies/Tryps						X	ECF	CBPP	Rinderpest	Anaplasmosis	Heartwater	FMD	Babesiosis	Anthrax	TRYPS
ECF							X	ECF	ECF	Anaplasmosis	Heartwater	ECF	ECF	ECF	ECF
CBPP								X	CBPP	Anaplasmosis	Heartwater	CBPP	CBPP	CBPP	CBPP
Rinderpest									X	Anaplasmosis	Heartwater	FMD	Babesiosis	Anthrax	Rinderpest
Anaplasmosis										X	Anaplasmosis	Anaplasmosis	Anaplasmosis	Anaplasmosis	Anaplasmosis
Heart water											X	Heartwater	Heartwater	Heartwater	Heratwater
FMD												X	FMD	Anthrax	FMD
Babesiosis													X	Anthrax	Babesiosis
Anthrax														X	Anthrax
Retained placenta															X
Total	0	13	13	2	2	4	11	9	5	12	11	7	6	8	1
Rank	14	1	1	12	12	12	4	6	10	3	4	8	9	7	13

Other challenges to farm production include deforestation, ploughing along slopes, termite damage, mono cropping, declining land size, floods, strong winds, and sandy soils. Extreme conditions of water scarcity (drought) and excessive rainwater (floods) coupled with occurrence of strong winds; presence of sandy soils are clear manifestations of an area prone to and already experiencing adverse effects of climate change. The common practice of ploughing along slopes suggests that extension advice in the area is rather weak.

Table 6: Research and development options for major constraints.

Constraint	Coping Systems	Research and Development Needs
Drought	Animals watered in springs, dig shallow wells, migration, avoid bush burning, water vegetables , early planting	Improve extension services (education), accessibility of right seeds in time (no proper traditional household seed saving or commercial seed supply systems), improve on irrigation
Poor soil fertility	Mulch, crop rotation, manure use, fallowing, mix grass in soil (ploughing) use legumes such as ground nuts	Improve extension education , improve use of cover crops to improve on soil fertility
Soil erosion	Soil bunds, plant trees, stonelines, hedge rows	Plant more trees , make more soil bunds
Bush burning	Fire breaks	Sensitization, enact by laws
Difficult in ploughing	Harambee groups especially for women when drought sets in animal migrate with most men; hired labour	Light duty tractors, knowledge & skills on ploughing, bring implements closer to farmers

Information on available local institutions involved in addressing some of the concerns in agricultural development (table 7) confirms that government projects (NAADS), NGOs, CBOs and innovative farmers are making some contribution.

Table 7: Available local capacity on rainwater and soil management.

Soil fertility and conservation
Amaler organic NAADS group Promotes the use of trenches to accumulate silt that is spread to the gardens; and use of organic manures particularly ash, chicken droppings and cattle manure. They operate both on group's farms and individual members' fields.
SVI (International voluntary service): Offers training in crop husbandry – promote use of Leguminous plants particularly multipurpose tree species (MPTs) like Leucaena, Soya, and Grillicidia. They train farmers on animal traction and sell animal draft implements; sell veterinary services and offer advisory services on livestock management; agro-forestry using mangoes and oranges. They supply improved cattle of Sahiwal and Guernsey/Jersey breeds; and Boer and Toggenburg goat breeds to farmers
CIDEPO (Community Integrated Development and Environmental Protection Organisation). They promote tree seedling multiplication; agro-forestry and have a woodlot that supplies mostly building poles. They offer training on nursery management and supply seedlings to World Food Programme (WFP). The WFP in turn supplies tree seedlings to schools and hospitals
Local Government: Offers training on soil conservation. They supply tree seedlings to schools and farmers. They participate in farmer mobilization by Local Councils (LCs), parish chiefs, Community Base

Facilitators (CBF), Community Development Office (CDO), Parish **Coordination Committees (PCCs), and farmers' fora.**
Innovative farmers: Mzee Zakaria promotes use MPTs, and use of cattle manure
Seed availability: SVI, LG (NAADS) and FAO; individual farmers; FOCREV (Friends of Christ Revival Ministries); weekly market for groundnuts, sorghum, sesame and maize
Drought and Difficulty in ploughing: The are privately owned tractors for hire at rate ranging from Uganda shillings 45000 - 65000[3] per acre and taking about 1 hour to plough an acre); oxen/donkeys for hire for hire charge rate per acre ranging from Uganda shillings 25000 -30000 and take about 2 to 3 days to finish an acre.
Irrigation: Common irrigation systems are vegetable watering using watering cans, flood/channel irrigations for other crops. There are treadle pumps from CIDEPO and NAADS for tree nurseries and vegetable growing. One group called NAPAIPO vegetable growers' does irrigation using a motorised pump.
Weed control: SVI uses animals and tractor implements for weeding.

Farm, land management and water harvesting interventions

Proposed remedies for farm and land management constraints returns to investment in soils, crops and livestock are presented in table 8 below.

Table 8: Summary of major constraints and potential interventions.

Constraint area	Options for research interventions and corrective remedies
Weed infestation	Integrated crop management
Tick-borne diseases	Improved veterinary drugs, treatment and advisory services and control skills be farmers
Unreliable seed and farm implement supply	Method and result demonstration on yield benefits and timeliness gains by adopters of improved seed, soil working implement and associated management packages
Soil fertility	Adoption of compost, manures and inorganic fertilizers
	Fallowing, Multipurpose Tree Species (MPTs) and cover crops like mucuna, Soya and lab lab
	Beneficial and judicious crop rotations
Soil moisture	Fast maturing and drought resistant crop varieties
	Conservation tillage (minimum soil disturbance)
	Water retention channels (in-situ harvesting)
	Appropriate intercropping
Soil erosion	Contour/trash/stone lines
	Agro-forestry and mixed cropping
	Establish tree nurseries
Roof catchment	Upgrade rainwater harvesting systems especially on schools, health centers, iron roofed homesteads in trading centers
Surface run-off	Harness rock catchments
	Underground storage tanks

LESSONS LEARNT AND RECOMMENDATIONS

[3] The exchange rate is UGX 1890 per dollar

It is a common belief that the security situation in the study region particularly threats to human life and property is high. These isolated attacks could be minimised if nomads become more sedentary and agro-pastoralists gained stronger commercial orientation. The local community would change their attitude towards strangers and look at them as consumers of their products rather than intruders.

This would require a gradual shift from traditional subsistence to market-oriented systems. Related to this, Karamoja region and Karamojongs are portrayed to be hostile and non-cooperative. Paradoxically, our informal interviews notably through FGD discussions confirmed that Karamojongs are interactive, freely participate and contribute good ideas that can guide research and development agenda based on informed opinion, and articulation of real local needs and circumstances.

Another advantage that traditional systems have established is the manyata system. The communal settlement (Manyatas) system that simulates modern settlements separates homesteads from other economic activities and offers the region three major advantages. Firstly, crop production and livestock grazing areas can be conveniently concentrated in one region so that planning and production activities can be synchronized and economies of scale exploited. Further, common conflicts between cultivators and pastoralists stemming from crop destruction are avoided. Lastly, community mobilization and accessing individual households to foster community development are facilitated by the clustered settlements headed by Manyata heads. Manyata heads are accorded respect by all manyata occupants and messages to community through their heads is commonly treated with respect and adhered to.

Based on findings on land and water management, farm enterprises and constraints the following recommendations for strategic interventions are proposed.

1. Promotion of sustainable household and community-wide rainwater harvesting techniques to increase water availability for crop, livestock and domestic uses and curb soil erosion as well.
2. Improved input supply and farmer adoption of improved soil fertility and conservation including weed control technologies should be boosted to arrest causes of poor crop productivity focusing on drought tolerant crop varieties
3. Concerted efforts in control of livestock diseases namely ECF, anaplasmosis and heart water in cattle and PPR in goats by NAADS, extension and relevant support systems in the agricultural sector,
4. Establish inter-district and cross border networks to curb cattle rustling

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Smut: An increasing threat to maize production in Kenya

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ABSTRACT
Maize smut occurs globally wherever maize is grown. The disease reduces yields drastically through stunting and formation of galls on the above ground parts of the plant especially on the developing cob and the tassel. In the recent past increased incidence of head smut disease caused by *Sphacelotheca reliana* (Kuhn) has been observed in parts of central province of Kenya, where maize is the staple diet. Infection usually becomes apparent when grain filling starts when it is often late to commence intervention measures. The pathogen causes enlargement of host tissues with the grains being converted into inedible structures filled with masses of dark spores of the pathogen. Observations indicate that most of the maize varieties grown in these regions are susceptible to infection with incidence reaching upto 50% in many farms. Infection appears to be exacerbated by the close integration of maize farming and dairy animal production through the zero grazing system in the region. The use of infected maize residues as fodder increases disease spread since pathogen spores pass through animal gut undamaged and are returned to the farm in manure, thus serving as sources of primary inoculum for maize crops in the following season. In addition, the pathogen also infects Napier grass which is also widely grown for fodder in the region. Napier not only provides an alternate host for this pathogen but also plays a key role in the continuity of pathogen cycle. Normally, when there is no maize in the fields, farmers ensure there is napier so as to secure fodder supplies, thus the pathogen is assured of a host continuously. Further, the practice of continous maize cultivation on the same pieces of land (without rotation) also favours disease spread since the pathogen's teliospores can survive in crop debris and in soil, where they remain viable for several years. Considering the increasing incidence and severity of smut infection on maize, and the associated threat to food security, it is necessary that efforts be made to investigate the disease and develop effective management measures. Intervention should consider raising farmer awareness on the management measures, especially the importance of regular scouting and timely removal of the smut galls before they break open and release the spores. Studies are needed to determine the extent of loss being incurred by farmers; to characterize the linkage between dairy farming and smut spread, and to identify resistant maize varieties.

Key words: Maize, Napier grass, smut, dairy farming.

INTRODUCTION

[4] In: Contributions of agricultural sciences towards achieving the Millenium Development Goals. F*a*CT Publishing, Nairobi. 175 pp. Mwangi, M. (Ed.) ISBN: 978 9966 7415 2 6. Published online at http://www.m.elewa.org

Maize is the most important food security crop in Kenya, more so in the densely populated Central highlands of the country. The crop is grown by nearly every small holder farmer for home consumption as boiled maize (mixed with beans), ground into maize flour or roasted on the cob. In the recent past, productivity of maize in Kenya has been on the decline largely due to the impact of adverse climate change characterised by unpredictable prolonged drought, reducing soil fertility and the effects of pests and diseases.

In the past, the most important biotic constraints in Kenya were identified to include the maize stalk borer (*Busseola fusca*), the grey leaf spot disease *(Cercospora zeae-maydis* Tehon & Daniels) and the maize streak virus (MSV). In storage, the maize weevil (*Sitophilus zea-maize*) and mycotoxin inducing fungi (*Fusarium* sp., *Penicillium* sp. and *Aspergillus* sp.) are serious constraints (Poehlman, 1987; Shurtlef, 1986).

In the recent past the maize smut disease has emerged as a significant constraint to production and currently poses a serious threat to food security in the central highlands of Kenya. The fungus attacks seedlings and the mycelium develops systemically, invading undifferentiated floral tissues. Head smut first appears when ears and tassels are formed. The disease is accentuated by nitrogen deficiency and is most common on farms with low soil fertility. Sporulation is most common in the ear, but frequently occurs in the tassel or on an occasional leaf. Smutted ears are rounded and lack silks and hence produces no grain. Plants with smutted tassels are severely dwarfed and excessive tillering is common. The disease damages plants and reduces yields by forming smut sori on the above ground parts of plants. The conversion of grains on maturing maize cobs into smut sori is the most serious threat to food security since grains are the important yield component of the plant.

The pathogen survives in crop debris and in the soil, where it can remain viable for several years. The extended survival of the pathogen in soil complicates management measures especially where land parcels are small and thus opportunities for practicing rotation are minimal. The infection is related to the concentration of teliospores in the soil. When conditions are favourable the fungal spores in the soil (teliospores) germinate and produce a new generation of spores (basidiospores).

Although systemic infections, in which the pathogen moves from an infected part of a plant to a healthy part on the same plant occur occasionally in very young seedlings, galls in older plants are often the result of seed infections. The number of smuted plants determines the yield loss realised. Galls on the ears cause losses of up to 100% and observations in the field suggest the extent of yield loss varies with variety and prevailing climatic conditions. The maize smut disease occurs worldwide wherever the crop is grown, but is more prevalent in warm areas. Due to this association with warm areas, it is anticipated that prolonged drought and temperature increases due to climate change effects will aggravate the disease and increase its importance as a constraint to maize production in central Kenya.

a) b) c)

Figure 1: Head Smut symptoms (a) and (b) maize ears (c) ears

In addition to factors that are inherent to the biology of the smut pathogen, farmer practices appear to play important roles in pathogen survival and dissemination. In central Kenya, the small holder dairy sector is closely associated with maize production with maize providing fodder for zero grazing units while manure from the cows is returned to the farms to improve soil fertility. The intensive system is characterized by land scarcity and cattle are kept in confinement. From a soil fertility improvement perspective this is an ideal practice. However, feeding cows on maize stalks from a crop that is infected with *Sphacelotheca reliana* (Kuhn) spores contributes to pathogen spread since the spores pass through the animals guts undamaged and hence continue to infect crops once the manure is taken back to the farm. Mwendia et al. (2007) reported 62.8% smut incidence on Napier grass in Central Kenya, causing yield reductions of between 25 – 50% in fodder yield. Napier grass is the main fodder crop and is grown by over 70% of the smallholder dairy farmers (Bayer, 1990).

In addition, many farmers combine Napier grass strips within or adjacent to the maize farms to ensure availability of fodder supplies when maize stalks are not available. This practice has serious implications since Napier grass, especially the flowering types, are suitable hosts to the maize smut pathogen. Thus, even during periods when maize is not growing in the field the pathogen finds refuge within the Napier.

Clearly maize smut is a serious threat to food security and the observations in the field prove there is urgent need to institute effective and affordable management measures to contain this disease. No maize varieties are known to be completely resistant to the pathogen, though several hybrids have been identified that show moderate tolerance. After evaluating 580 varieties for resistance to the pathogen, Njuguna (2001) reported that most lines were susceptible but a few expressed moderate to high resistance levels. This indicates there is potential to identify sources of resistance that could be used in breeding programmes. Reports (Agrios, 2005) indicate that new races of the smut pathogen appear constantly, which makes partial resistance the major type of resistance selected for in breeding programmes. Sanitation measures such as removal of smut galls before they break open, and crop rotation have been suggested (Kenya Maize Handbook, 2007) but these are considered impractical and unworkable in Central Kenya where land sizes are increasingly diminishing as population increases.

RESEARCH APPROACH

To develop effective management measures for maize smut, research should ideally commence with an asessement of disease incidence and a study to document farmer practices that influence spread of the pathogen. Understanding of the preferred maize varieties in different agroecological zones would be important as this may be closely related to disease occurrence and pathogen diversity. To enable selection and utilization of resistant germplasm, germplasm screening techniques that are effective and deliver outcomes rapidly are a necessity. The choice of screening technique is particularly important considering that large amounts of maize germplasm are available and evaluating each line may require considerable resources in space, time and labour. The screening of Napier grass varieties may not be as achallenging since fewer varieties exist.

Germplasm screening trials would require utilization of smut inoculum from different regions of the country to ensure the exisiting diversity pathogen races is captured. To reduce resource requirements, studies could assess use of in vitro experimental set ups such as have been used with other pathosystems, including tomato-*Fusarium* wilt (Mwangi et al., 2008) and banana-*Xanthomonas* wilt (Tripathi et al., 2009). This would require determination of optimal growth conditions for the pathogen and recreating these to increase chances of success. Besides using actual pathogen inoculums, toxic metabolites or molecules produced by the pathogen may be harnessed and applied to the plant to determine if these evoke any kind of response.

One of the difficulties frequently encountered in germplasm screening trials is inability of researchers to precisely determine how much inoculum is required to trigger reaction in the host. Inadequate inoculum dosage may be overwlemed by the plant's defense mechanisms while over applying inoculum may mask any attempts by the plant to express tolerance. In diseases where multigenic effects are essential for management, even minor responses froma plant would be important to document and harness. An ideal inoculum quantity may be one that mimics events as they occur in nature.

Besides determining the right amount of inoculums, it is necessary to determine the appropriate part of the plant on which the inoculums should be placed. Although some pathogens can infect the plant from any of several organs, plant pathogens may have preferences with regard to tissues that are more easily penetrated and possibly where plant defense barriers are likely to be least encountered. With regard to screening maize Andnapier germplasm for resistance to smut, it would be necessary to identify the ideal parts of the plant for inoculation. For pathogens that survive in the soil and may also be spread through water or airborne mechanisms, variations in inoculums density and infection courts presents additional challenges.

In addition to identifying resistant varieties, research is also needed to evaluate the effectiveness of other smut management options. These may consider identifying chemical products that can be applied through seed dressing to prevent infection of seedlings. Previous work has suggested use of pesticides in azole group (Kenya maize handbook, 2007). Considering the possibility of a large diversity of races of smut pathogen being in existence, it would be prudent to assess the available pesticides against a wide collection of smut races from diverse regions of the country where smut has been observed to be a problem.

Other measures that could be available for addressing smut could target to reduce pathogen inoculum density and viability of spores in the soil. This could be achieved through treatment of soils with pesticides; and perhaps selection of plant varieties that could trigger suicidal germinationof the pathogen spores. There is no previous report of similar approach to managing this pathogen, but it may have good chances since farmers often grow numerous crops that are from unrelated botanical families.

To break the dissemination path that is dependent on manure, effective strategies could be developed for reducing the viability and longevity of pathogen spores in manure. For example,

raising the temperature in cow dung through solar heating may enhance death of the spores or at least reduce their ability to germinate and cause infection. For trapping solar heat, one could use black polythene sheets that are easily available in local shops. Such polythene sheets are suitable and ideal since they would still have other uses within the farm. In addition to relying on solar heating, spores in manure could also be inactivated through application of pesticides (fumigants) to treat manure or other organic resides. Biological control could also be exploited through identification and use of microbes that anatagonise smut spores and prevent or hinder their germination. Identifying compounds that can be applied to shift the pH dynamics in manure to conditions that are harsh for the survival of smut spores may also be a viable alternative.

CONCLUSION

Despite concerted efforts to promote other food crops, maize remains the most important food security crop in Kenya. Besides its importance as a food crop, maize is also playing important roles in providing livestock feed. The threat presented by smut to both food and fodder availability requires urgent intervention.

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What affects efficiency of small holder dairy enteprises in rural Kenya?

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ABSTRACT
Dairy cattle farming is a major economic activity in Kenya contributing 3.5% of the national gross domestic product (GDP), and income, employment and food to many small-scale farmers. The country's dairy herd size is the biggest in sub-Saharan Africa. Kenya enjoys preferential market access for its products in the eastern and southern African region. However, the country's milk consumption level is low, at 76Kg per capita against the World Health Organization's recommendation of 210Kg. Kenya's milk is not sold in economic quantities beyond its borders; partly due to comparatively low per cow average daily production of 6 kg and unsustainably high cost of production. Questions on the milk production efficiency especially technical and cost efficiencies arise. These issues are being investigated in an ongoing study whose obejective is to assess and document the technical and cost efficiencies of dairy farmers, and relate these parameters to the farm gate price of milk and how this affects demand.
Key words: Technical efficiency, cost efficiency, cost leadership, per capita consumption

INTRODUCTION
Dairy production is a major farm activity in Kenya, where it accounts for about 14% of agricultural gross domestic product (GDP), 3.5% of the National GDP, and contributes to the livelihoods of many dairy farmers through income, employment and food (Omiti *et al*, 2006) and the attaintment of Kenya Vision 2030. The country's dairy cow population is approximated to be about 6.7 million, the biggest in sub-Saharan Africa, (SDP, 2006). Kenya's membership to the regional trade blocks provide its products such as milk preferential market access within them, notably, the East African Community (EAC) and the Common Market for Eastern and Southern Africa (COMESA) (GoK, 2007).
Available data indicates that Kenya has not fully taken advantage of its privileged position. The country's per capita milk consumption averages 76Kg (SDP, 2006), which is way below the World Health Organization's (WHO) recommendation of 210Kg (FAO, 2007). This undesirable situation is related to the country's low production per cow, at only six (6) Kg [an average of 1,800 Kg per lactation cycle], over the last thirty years, (Gichungu, 2009), compared to global average of 6000Kg under best practice conditions (Karanja, 2003).
Previous studies have focused on understanding genetics (Kahi, 2004), production systems (Bebe, 2003), and nutrition (Ongadi, 2006). Several studies (Staal, *et al*, 1997; 1998; 2008; Thorpe *et al*, 2000; SDP, 2006, 2005; Ngigi, 2002; Moll *et al,* 2001; Muriuki and Thorpe, 2003; Karanja, 2003) have dwelt

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on the dairy cow milk and milk marketing. Studies on farm-level milk production include SDP, (2006, 2007), Baltenweck (2006), Staal, (1997); Kimenju and Tscherley, (2008), Gamba, (2006); Romney *et al*, (2005), among others. A few studies on farmers' adoption of production technologies include Makokha *et al*, (2007), and Hooton, (Undated).

PRODUCTION EFFICIENCY

Production efficiency is concerned with the relative performance of the process used in transforming inputs into output. The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources or certain level of output at least cost. The economic literature on production efficiency typically distinguishes two types of efficiency: technical efficiency and allocative efficiency. Farrell (1957) proposed that the economic efficiency of a firm consists of two components: technical (or physical) efficiency and allocative (or price) efficiency.

Technical efficiency in production is defined as the ability of the farmer to produce at the maximum output (frontier production), given quantities of inputs and production technology (Aigner *et al.,* 1977). The greater the ratio of production output to the factor input, the greater the magnitude of technical efficiency and vice versa. Variation in technical efficiency of producers might arise from managerial decisions and specific-farm characteristics that affect the ability of the producer to adequately use the existing technology.

Allocative efficiency represents the ability of a firm to utilize the cost-minimizing input ratios or revenue-maximizing output ratios. Allocative inefficiency occurs if the ratio of marginal physical products of two inputs does not equal the ratio of their prices. Therefore, a firm is allocatively efficient if it uses the optimal combination of inputs with respect to their prices. Similarly, first-order conditions from revenue maximization can be used to determine optimal output ratios based on output prices and marginal costs. The economic efficiency of the firm is the product of technical and allocative efficiency. Hence, in order to be economically efficient, a firm must be both technically and allocatively efficient.

Review of literature on factors affecting dairy cow milk production efficiency

Farm size: The size of the farm on which dairying is practiced affects the dairy farm's efficiency (Tzouvelekas *et al,* 2001; Paul *et al*, 2004). Mishra and Morehart (2001), Short (2000), and McBride and Greene (1997) agree that farm size has significant, positive impact on the financial success of dairy farms. Gardebroek (2002) found farm size in the Netherlands to explain significant variation in the choice to farm organically, highlighting the importance the acreage base plays in organic dairy management. Nivievskyi and Taubadel (2008) found the size of the farm to have a strong, positive and non-linear effect on competitiveness. Marek *et al.* (2007) in a study in Poland found an increase in herd size and average milk yield to improve milk production profitability as well as to increase the agricultural income per cow.

Herd size: Many researchers agree that the size of a dairy herd has a positive correlation with the farm performance. Bhuyan and Postel (2009) found the number of milking cows to have a positive impact on the net farm income. An additional milk cow typically added 119cwt of milk to annual production in 2005. It can be noted here that such addition would generally not mean an addition of proportionate cost to the herd in the short term. Others (Sahin, 1993, Sanar, 1993), (Headley *et al*, 2002)), and El-Osta and Johnson (1998) found herd size to be the most significant contributing factor to net farm income among dairy farms. According to Bebe (2003), milk production in Kenya can be increased through keeping more cows by between 14 and 47 percent. Nivievskyi and Taubadel (2008) in a study in Ukraine found the farm size to have a strong positive and non-linear

effect on competitiveness. These studies appear to have dwelt only on the economies of scope of dairy cattle keeping, leaving a gap on yields per cow.

Farm income-activity diversification: Diversification of farm activities with a view to get extra income has been found to be a factor in dairy farm performance. Mishra and Morehart (2001) found diversification to negatively correlate with dairy farm profitability. The detraction from specialization, they suggested, had a negative impact on conventional U.S. dairy farm profitability.

Farm technology: Integrating new technology into a dairy enterprise may offer several advantages. Short (2000) and El-Osta and Johnson (1998) agreed that more advanced milking parlors were positively correlated with U.S. dairy farm profitability. Staal *et al* (Undated) noted that improved technology would reduce production costs and induce shifts towards more commercial systems; adapting to changes in other factors would be dependent on the availability of technological alternatives, either existing or new. Therefore, technology measures are hypothesized to have a positive impact on the smallholder dairy farm profitability.

Dairy breed: Staal et al, (Undated) found genetic improvement to have a dramatic impact on development and growth. Ratuki (2004), after finding the Fiji cow's average productivity to be low, advised on the need to increase cow productivity, farmer productivity and land productivity through integrated measures.

Feeding: El-Osta and Johnson (1989) and Nivievskyi and Taubadel (2008) recommend dairy farms to produce most of their feed themselves and keep arable land per animal equivalent as low as possible to increase the farm's competitiveness. Owuor and Ouma (2009) found fertilizer and feeds to be major constraining factors in enterprise productivity among the resource poor farm households in western Kenya.

Farmer experience: Experience is expected to have a positive impact on performance. Sipil'ainen and Lansink (2005) found a significant learning effect in analyzing the efficiency of organic versus conventional dairy farms in Finland, estimating roughly seven years as the inflection point. Using age as a proxy for the dairy farmer's experience, Lucila *et al* (2005) found it to have a significant effect on the cost efficiency of dairy farms. In this case, age was shown to be inefficiency reducing, implying that more experienced farmers are less cost-inefficient than their younger counterparts.

Farmer's age: An operator's age may influence the way one manages the farm operation. El- Osta and Johnson (1998), Wubeneh and Ehui (2006), McBride and Greene (1997), are in agreement that age positively correlates with the costs of dairy farms. In a different study results on age indicated that older farmers were not able to use up to date farm management methods or are less adaptive to modern technologies. They prefer to be associated with older methods of production thus reducing efficiency (Owuor, 2009). On the contrary, Bhuyan and Postel (2009) found the operator age to have a significant and positive impact on net farm income.

Farmer education level: A successful dairy farm manager must have ability to plan well and possess a thorough knowledge of livestock production. Hashmi, (2004), and Tzouvelekas, Pantzios, and Fotopoulos (2001), are in agreement that farmer's age and education have significant power in explaining variation in economic efficiency. Wubeneh and Ehui (2005) found a significant difference in milk produced and marketed between farmers who had training in livestock production and those who hadn't, while there was no difference in number of cows they own, use of feed and veterinary services. Udomsak and Khanna (2004) found the production efficiency of dairy cattle farming in Thailand to be low because of long calving interval of 450 to 500 days. They attributed this to lack of education and knowledge by farmers to manage the dairy cattle.

Mishra and Morehart (2001) found that farmer's education and use of cooperative extension agents had a significant and positive impact on financial success of U.S. dairy farms. Contrary to expectations, Owuor (2004) found education to increase inefficiency, in a study amongst smallholder farmers in western Kenya.

Length of time a farmer is expected to be in dairying business: It is hypothesized that the longer a dairy farmer expects to continue the current operation, the greater the level of enterprise performance would be. This is because a primary operator's expectations about the future of the dairy enterprise may affect certain management decisions that subsequently may have a positive impact on performance. Bhuyan and Postel (2009) found future expectations in farming to be positively correlated with dairy farm performance.

Farm labour: Nivievskyi and Taubadel (2008) found labour intensity in dairy farms to have a negative effect on competitiveness. Hashmi (2004), in Pakistan, and Chang (2004) in Korea found the cost of labour around the urban areas increasing which led to the increase in cost of growing fodder. The importation of fodder made milk production costs to rise. FIAS (2006) found the labour input to be approximately 740 hours/animal/year (consisting of the farmer's own labour as well as hired labour).

Milk production efficiency: Milk production efficiency is affected primarily by cow performance, direct and indirect costs as well as by milk price at collection points. Although producers have no direct influence on milk price, they can make efforts to provide best-quality milk, to improve the milk productivity of cows and to reduce production costs, including labor costs and especially the costs of feed (Jasiorowski, 2000; Okularczyk, 2001). Short (2000) found more profitable U.S. dairy farms to produce more milk per cow than less profitable dairy farms, required less feed per unit of milk sold, used less labour hours per cow, and had lower variable costs. One additional ton of milk per cow per year increased competitiveness by over 50 times as much as increasing the herd size by one cow does. Kimenju and Tscherley (2008) after a study in Kenya recommended that future increase in total milk production need not continue to depend on enlarged dairy herd.

Productivity data from recent studies: Kaijage (2004) found the overall per capita milk availability in Tanzania to be low (20–22 kg/annum) compared to Kenya (85kg/annum). The average for Africa is 35 kg/annum and the world average is 105 kg/annum. Karanja (2003) found the average yield per cow in smallholder farms in Kenya to be as low as 1,300litres per year as compared to the best world practice of 4000-6000 litres. FIAS (2006) found milk yield per animal in Pakistan to range between 1,300 and 2,400 kg of milk per year. The same body added that data from even dual purpose cattle in farms in Austria, Germany, and Czech Republic indicated a fairly better performance, at milk yields of up to 6,000 kg/animal/year.

Staal *et al* (1998) in a study in Kenya found the dairy cow performance to be relatively poor around Nairobi, averaging 7.2 litres per day and an average calving interval of 591 days. He attributed this to continued under-nutrition. . Udomsak and Khanna (2004) found the production efficiency of cattle in Thailand to be low due to long calving interval of 450 to 500 days which they attributed to lack of education and knowledge by farmers to manage the dairy cattle. Pastures were found to be limited and overgrazing to have had deteriorated the land. A milk production appraisal by Felber (2003) in Rungwe district Tanzania revealed an average daily milk production per crossbred cow of 6.6 litres. Jong (2004) in a study in Korea found the national average yield to be less than 10 kg as compared to the average of 20-30 kg in developed countries, and attributed this to poor herd management, nutrition, and poor farmer training.

Cost efficiency in dairying: Jong (undated) while analyzing efficiency of small dairy farms in Korea, revealed that the most efficient dairy farm had the highest level of income per head and applied lower quantities of concentrate feeding and family labor hours. The optimal rate of application of concentrate feeds and family labour hours was much lower than the general rates on dairy farms. In order to increase the efficiency of dairy farm production and the level of farm income, he suggested that the application of concentrate feeding and family labour hours should be decreased.

Some cases to indicate the status of dairying costs: Lucila *et al* (2005) found cash that feed costs accounted for 63% of the total costs on all farms on average, which is more than half of the total cost of dairy production while the cost of roughage accounted for a larger percentage (11%). Khanna (2004) found the cost of milk production in India to be low at 20 cents (Indian currency) a litre, the farm-gate price of milk in India was said to be one of the lowest in the world. Karanja (2003) indicated Kenya's dairying costs to be 26% higher than in New Zealand. FIAS (2006) found small scale dairy farmers in Pakistan to compare favourably with the lowest cost producers of the world like Argentina, Brazil, and New Zealand, which have per kg costs in the range of US$0.07 - $0.17. This study indicated that animal husbandry constituted 87% of the total value chain. Feed consisted of (55.1%) and labour (43.9%) both being the main value addition components of animal husbandry. The labour input was approximately 740 hours/animal/year (consisting of the farmer's own labour as well as hired labour.

CONCLUSION

In the ongoing study the technical and cost efficiencies will be determined to establish relationships to the high milk retail prices and corresponding lower consumption levels in Kenya, as well as Kenya's milk competitiveness in export markets. The average price of milk globally is $0.27 while it is about $0.40 in Kenya. The results of the study are expected to spark action by dairy industry stakeholders to improve the sub-sector's performance.

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Distribution of *Mycosphaerella* spp. Diseases on banana in Côte d'Ivoire

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INTRODUCTION

Bananas and plantains are attacked by several fungi. The most notorious of these fungi belong to the genus *Mycosphaerella* of which 3 species are known to be responsible for Sigatoka on banana leaves (Leach, 1946, Rhodes, 1964; Carlier *et al*., 2000). The first mention of Sigatoka caused by *M. musicola* in West Africa is relatively old, dating back to 1940 (Roger, 1953; Meredith, 1970). Black Sigatoka or black leaf streak disease (BLSD), caused by *M. fijiensis*, was observed in Zambia in 1973 (Raemarkers, 1975) and in Côte d'Ivoire in 1985 (Mourichon and Fullerton, 1990). The latter is more virulent and has a wide range of hosts (Jones, 2000). The only evidence of its presence was the observation of characteristic lesions of Sigatoka on plantains. The pathogen has gradually spread into most banana cultivation areas, giving the impression of a displacement of yellow Sigatoka by this disease.

The two forms of Sigatoka are found on banana leaves, but their distribution is not stable. Since its entry from the East, Black Sigatoka was previously reported to be moving westward of the country (Mouliom, 1996; Kone, 1998). The authors have determined the moving front of the disease to be between the 5 and 6 °W longitudes, where only the yellow Sigatoka was observed on bananas. Since the work of Mouliom *et al.* (1996) and Koné (1998), various evolutionary trends have been observed. Carlier *et al.* (2000) described another fungus species (*M. eumusae*) related to the first two species.

Considering relationships such as substitution-competitions between these species on banana leaves, this study was undertaken to assess the evolution of black Sigatoka on plantains and establish the relative prevalence of the three forms of the disease in Côte d'Ivoire.

RESEARCH APPROACH

Field visits, observations and Sigatoka damage ratings were conducted from August to October 2006. Observations were made along the main roads at 30 km intervals in the southern forest sector distributed as follows:

1) Abidjan Aboisso-Noah; 2) Aboisso-Bianouan-Abengourou; 3) Agnibilékrou-Abengourou-Akoupé-Azaguié-Abidjan; 4) Akoupé-Kotobi-Dimbokro-Toumodi-Oumé-Gagnoa; 5) Gagnoa-Lakota-Divo-Tiassalé-Abidjan; 6) Agboville-N'Douci-Yamoussoukro-Bouaflé-Daloa-Issia Soubré-San Pedro; 7) Grand Bereby-San-Pedro Sassandra-Dabou-Abidjan. Banana orchards selected for the study had a minimum size of 0.25 ha each. The plantain plants were selected based on their vegetative stage characteristics. For each phenological stage, 3 plants were chosen.

At each observation point, GPS data were recorded. The observations were made at between 0 to 250 m above sea level at 50 m intervals. The longitude values ranged between 2° and 7° W, with 5

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classes obtained and three different latitudes were observed [4-5°], [5-6°], and [6-7°] N. The observations were made based on the INIBAP method (Orjeda *et al.*, 1998). The following parameters were measured: number of standing leaves (NSL), youngest leaf affected "YLA" counted starting from the cigar leaf (Orjeda, 1998), youngest leaf spotted "YLS" the first leaf showing at least 10 spots with necrotic center (Stover and Dickson, 1970) and the youngest entirely necrotic leaf "YENL", the youngest leaf whose blade was all necrotic (Koné, 1998). The severity of the disease was assessed using the infection index "II" the necrotic leaf area on the entire banana leaves (Stover and Dickson, 1970). The infection index was assessed using the modified Stover Gauhl scheme for the severity of the disease (Gauhl *et al.*, 1993). The percentage of leaf surface showing symptoms was reported on a rating of 0 to 6 where 0 = no symptoms of the disease; 1 = <1%; 2 = 1-5%; 3 = 6-15%; 4 = 16-33%; 5 = 34-50%; 6 ≥ 50% symptoms. This index, depicting the severity of the disease, was assessed using the following formula:

$II = 100 \times \Sigma nb / [(N-1) \times T]$

Where;

n = number of leaves for each grade of the scale,
b = grade of the scale,
N = number of grades of the scale used (7),
and T = total number of leaves scored.

The index takes into account the age of necrotic leaves, which is useful in assessing the overall intensity of the disease (Stover and Dickson, 1970). Data were analyzed using GenStat and means were separated using LSD.

STUDY FINDINGS

The selected cultivar showed greater sensitivity to black Sigatoka. The rank of YLA ranged generally between 2 and 3 (Table 1), but these attacks were encountered on leaves of rank 1 for some observation points in Aboisso, Agboville, Gagnoa and San Pedro (Table 1). The necroses were observed on leaves (YLS) of ranks 3 through 6. The YLS category 3 was encountered in the localities of Moussadougou (San Pedro), Aboud Mandéké (Agboville) Ahigbé Koffikro, Akressi and Noah (Aboisso). Very high YLS ranks (8 to 9) were reported on some bananas trees in Aprompronou (Abengourou), Yamoussoukro and Bonon (Bouaflé). The youngest entirely necrotic leaf (YENL) ranked between 4 (Aboisso) and 14 in the Agnibilékrou area (Table 1).

The ranks of YLA and YLS were lower at lower altitudes (Table 1). The rank of YLA was about 2 at 100 m altitude and ranged from 2.5 to 2.7 above this level. For YLS, the values ranged from 4.6 to 4.7 below 100 m and approximately 5 between 100 and 250 m altitudes. The number of banana leaves (NSL) and rank YENL showed distributions similar to those of YLA and YLS. The index of infection showed a decrease with increasing altitude, but no significant differences between classes. The rate was 30% below 100 m, while it varied between 27 to 28 % between 100 and 250 m.

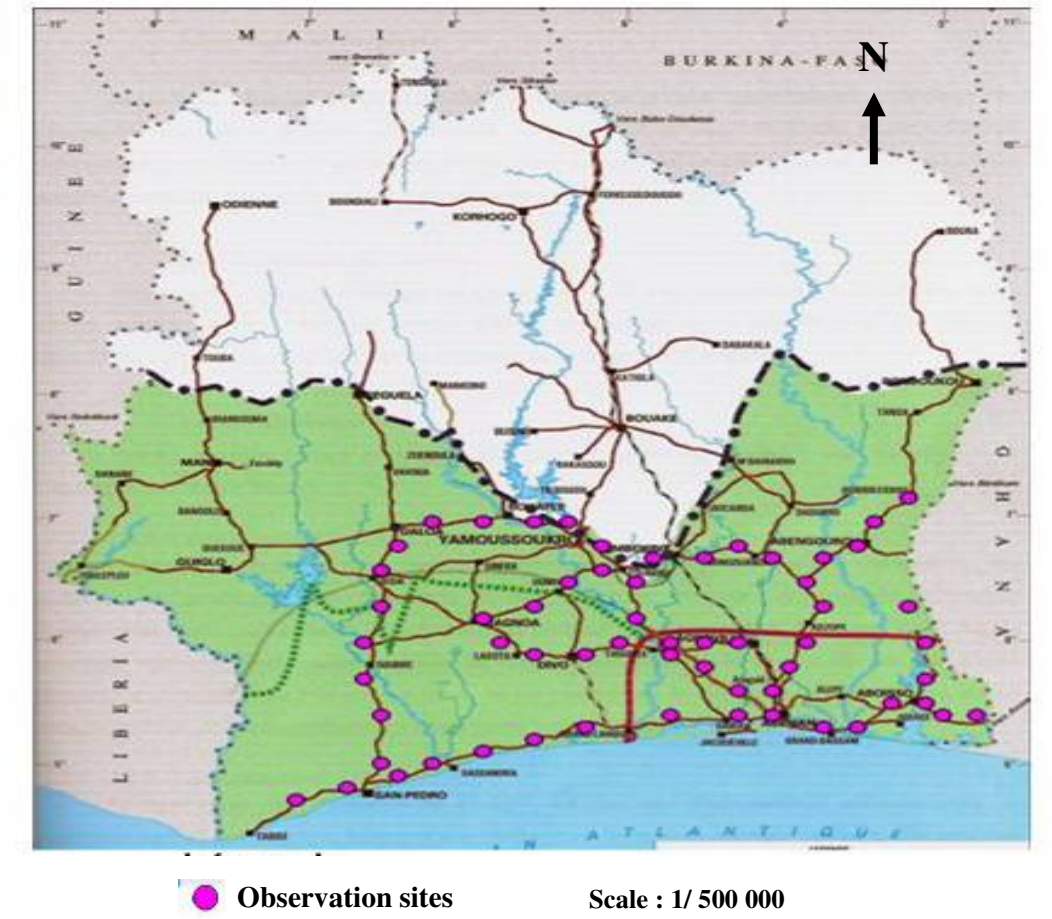

Figure 1: Distribution of observation sites of Mycosphaerella diseases of plantain in Côte d'Ivoire.

Toumodi **San Pédro**

Figure 2 : Black Sigatoka symptoms on plantain (Horn 1) leaves in Toumodi and San Pedro, Côte d'Ivoire.

Aboisso **Oumé**

Figure 3 : Yellow Sigatoka symptoms on Figue Sucrée cultivar in Aboisso and Oumé, Côte d'Ivoire.

Effect o f longitude :YLA varied from 1.8 for class [2-3] to 2.9 for the class [3-4 [(Table 2), while YLR was higher (5.5) in banana [5-6] than for plantain [3] located in the class [2-3] (Table 2 A). YENL increased considerably with longitude. It was 5.5 for the lowest longitude and 9.4 for the highest longitude (Table 2). The trend was the same for the number of erect leaves (Table 2). The infection index showed significant differences with change in longitude. The rate was 38.2% in the class [2-3] and 26.1% for class [6-7] (Table 2).

Effect of latitude: The pathological parameters of black Sigatoka varied with altitude. For YLA, YLS, YENL and NSL, values were lower in the median class of latitudes ranging between [5-6] (Table 3).

Table 1: Parameters of black Sigatoka disease observed on Horn 1 plantain cultivar in Côte d'Ivoire as a function of altitude.

Altitude classes	YLR	YLS	YENL	NSL	II
[0-50]	2.1 b	4.7 bc	8.8 bc	8.9 bc	30.1 a
[51-100]	2.2 b	4.6 bc	8.0 c	8.0 c	29.8 a
[101-150]	2.7 a	5.0 ab	8.2 c	8.5 bc	27.8 a
[151-200]	2.6 a	5.3 a	9.1 b	9.2 b	28.3 a
[201-250]	2.5 ab	5.3 a	11.3 a	11.1 a	26.7 a

Within each column, values followed by the same letters are not significantly different at the 5 % PPDS level. YLA : youngest leaf affected; YLS : youngest leaf spotted; YENL : youngest entirely necrotic leaf; NSL : number of standing leaves; II : infection index.

Table 2: Parameters of black Sigatoka disease observed on Horn 1 plantain cultivar in Côte d'Ivoire, as a function of longitude.

Longitude classes	YLA	YLS	YENL	NSL	II
[2-3[	1.8 b	3.0 c	5.5 c	6.6 c	38.2 a

[3-4[	2.9 a	4.8 b	8.1 b	8.6 ab	26.6 c
[4-5[	2.3 b	4.9 b	8.2 b	8.2 b	30.8 b
[5-6[	2.5 ab	5,5 a	9.2 a	9.2 a	27.8 bc
[6-7[	1.9 b	4.6 b	9.4 a	8.6 ab	26.1 c

Within each column, values followed by the same letters are not significantly different at the 5 % level. YLA : youngest leaf affected; YLS : youngest leaf spotted; YENL : youngest entirely necrotic leaf; NSL : number standing leaves; II : infection index.

Table 3: Parameters of the black Sigatoka disease observed on the Horn 1plantain cultivar in Côte d'Ivoire, as a function of latitude classes

Latitudes classes	YLA	YLS	YENL	NSL	II
[4-5[	1.8 c	5.1 ab	9,2 a	9.5 a	30.7 a
[5-6[	2.4 b	4.5 b	8.0 b	7.9 b	29.3 a
[6-7[	2.6 a	5.4 a	9.3 a	9.2 a	27.0 a

Within each column, values followed by the same letters are not significantly different at the 5 % level. YLA: youngest leaf affected; YLS : youngest leaf spotted; YLEN : youngest entirely necrotic leaf; NSL : number of standing leaves; II : infection index

DISCUSSION

Yellow and black Sigatoka diseases were identified throughout the forest zone of Côte d'Ivoire, from Aboisso near the Ghana border to Grand Bereby and running into Liberia.

The black leaf streak was observed in Côte d'Ivoire in 1983. Ten years later, in 1994, the evolution front of the disease spread to an area between Yamoussoukro and Bouaflé, and between Divo, Lakota and Gagnoa (Mouliom *et al.* 1996; Koné, 1998). This direction corresponded to the 5.5° W longitude. A decade later, in 2006 (results of this work), the entire forest area was infested past the 7°W line (except in Man region, not shown). The disease seems to have expanded very rapidly, probably due to favorable climatic conditions throughout the year.

The 2 diseases coexist on the banana with the prevalence of black Sigatoka. For a banana variety susceptible to the two diseases, symptoms of the MNR were very visible because of more rapid development. Therefore, the yellow leaf spot has been identified on the cultivar Figue Sucrée which is partially resistant to BLSD. The presence of *M. eumusae*, responsible for banana septoria reported from Asia, (Carlier *et al.*, 2000) was not confirmed. However, its presence was suspected on leaves of some banana species (Kobenan, personal communication). In the traditional plantations, plantain was the most encountered banana and dessert varieties were usually spontaneous. Therefore the Horn 1 cultivar was selected for evaluating the BLSD effect. It was not possible to assess the effect of yellow leaf spot because of the very limited number of stands of Figue Sucrée cultivar.

Altitude had a significant effect on the susceptibility of banana to infection. The low altitudes (0 to 100 m) increased susceptibility, especially on leaves of lower rows (2.2 YLA and 4.7 per YLS). On the other hand, at altitudes higher than 150 m, values were higher (2.7 YLA and 5.3 per YLS). The results show that the sensitivity of plantain cultivars to yellow Sigatoka, in relation to in Man (Kone, 1998) is, in part due to the absence of BLSD in this area. Indeed, the very rapid development of the BLSD actually masks the symptoms of yellow leaf spot. Necroses of yellow Sigatoka were clearly identified on the leaves of cultivar Figue Sucrée, which is partially resistant to BLSD. The severity of the disease decreased from the East (Aboisso) to West (San Pedro). The rate of infection was 38%, as compared to only 30% for the rest of the country. These observations were made in parallel with the duration of the disease in the area and the presence of industrial plantations making use of fungicides that fostered the emergence of the most pathogenic strains (Kobenan *et al.*, 2006). A

survey of farmers (Traoré *et al*., 2009) showed that the life of plantain was relatively shorter in Aboisso (2 to 3 cycles) than in Gagnoa (6-10 cycles). Soil type may be the reason for this difference.
The study has demonstrated the distribution of banana Sigatoka diseases in Côte d'Ivoire. Black leaf spot disease and the Sigatoka are both present in banana cultivation area with a dominance of BLSD which attacks all banana and plantain cultivars. Sigatoka disease was observed on leaves of Figue Sucrée, partially resistant to BLSD. BLSD showed a high severity on Horn 1 cultivar in eastern region of the country and lower altitude zones.

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Passion fruit production in Kenya: Opportunities and constraints

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ABSTRACT
Passion fruit is ranked third in importance among the horticultural crops in Kenya. In recent years, the fruit has gained high demand due to activities of beverage producing companies. The fruit has dynamically changed the lives of most farmers, being their source of livelihood. Its wide usage makes it an economical fruit to produce i.e. almost all its products (vines, leaves, pulp, juice and seeds) are useful. In recent years, various challenges have led to low supply threatening the passion industry with collapse. The major challenges are diseases and pests and the effects of climate change. These have led to a 50% decline in fruit production in the past 4 years. Research activities have gathered considerable information but a lot remains to be done to effectively revive the passion fruit sector. This paper discusses some of the issues that should be addressed to support the passion fruit value chain.

INTRODUCTION
Passion fruit is indigenous to Brazil though it is wide spread in most South American countries like Colombia, Argentina and Venezuela. The fruit interestingly got its name from the early South American missionaries who saw in it the implements of crucifixion i.e. crown of thorns (corona), five wounds (five anthers), nails (divisions of the pistil), whip and cord (tendrils and vine) and the spear (leaf), (Morton, 1987).

The plant can be described as a perennial, vigorous, climbing woody vine that produces edible round or ovoid fruit with many small seeds. The fruits are yellow or purple- depending on variety- when mature and the flower color ranges from violet to pink in the purple passion and cream to yellow with a pink shade on the inside in the yellow variety. The leaves are alternate and are characteristically deeply tri-lobed when mature and finely toothed. Their color ranges from bright green in seedlings to dark green in old leaves of mature plants

Passion fruit falls under the family ***Passifloraceae*** and genus ***Passiflora.*** The major species grown in East Africa for commercial purposes include; ***Passiflora edulis Sims*** (purple passion) and ***Passiflora edulis f. flavicarpa*** (yellow passion). The other type grown for the local fresh fruit market is the ***Passiflora quadrangularis*** (granadilla). Due to effects of pests and diseases in East Africa, several hybrid varieties have been developed. The Kenya Agricultural Research Institute (K.A.R.I.) has developed three yellow hybrid varieties that are disease tolerant and that also suit the market. These are KPF 12, KPF 11 and KPF 4. In Uganda the disease tolerant hybrid variety developed is known as Kawanda (Mukiibi, 2001).

The fruit was introduced in Africa by the European settlers in the 19th century. In Kenya it was introduced in 1933 in the white highlands and its growing was expanded in the 1960's to other areas (Morton, 1987). Initial plantations were destroyed by pests and diseases leading to reduction in

size of the land under passion fruit production and hence the small sized farms characterizing passion fruit production today.

The fruit has a wide range of environmental conditions suitable for its growth, these however are variety dependent. The purple variety does well in subtropical and tropical highlands which are characterized by high rainfall and relatively low temperatures. The yellow type, on the other hand is suited to tropical or near tropical areas and low lands which have low rainfall, and high temperatures. Both varieties do well in many soil types but grow best under light to heavy sandy loams, medium textured and with medium pH of 6.5-7.5. The soils should however be well drained, otherwise the fruits succumb to soil borne diseases. The fruits also require an environment that is well sheltered from strong winds.

Passion fruit does well in the warmer wetter regions of East Africa like the Lake Victoria shores of Uganda (Acland, 1971). In Kenya passion fruit is grown in three ecological zones. These include:

1. Lowlands which are characterized by low altitude of 0-800m ASL, medium amounts of rainfall (900-1200mm pa) and with high temperatures averaging at 26^{o}C. These include areas like Matuga and Taita Taveta.
2. Mid zones which have an altitude of 800-1200m ASL, relatively low rainfall (150-900mm pa) and temperatures averaging 20^{o} C e.g. Thika and Kitui.
3. Highlands that have an altitude of 1200-2200m ASL, with high rainfalls (1800-2800mm pa) and low temperatures averaging at 16^{o}C e.g. Sotik, Laikipia, Meru and Embu.

The yellow variety thrives well in the lower ecological zones (0-800m ASL), while the purple type is suited to the highlands (1200-2200m ASL). Both varieties perform relatively well in the mid ecological zones.

Seed preparation and seedling establishment

Passion fruit vines are usually grown from seeds. The seeds are extracted from mature ripe fruits and dried under sun for 6-7 days or until the pulp can easily be rubbed off the seeds. It is advisable to wash off the pulp and juice from the seeds. This enables efficient seed drying and reduces fungal infection due to the sugar content of the juice. The pulp can also be used to make home-made juice and hence reduce wastage. Blending should not be done to avoid destroying the seeds.

Seeds are then planted on a seed bed or directly in seedling bags. These will then germinate after a period of 10-20 days. Seeds are planted 1/2 to 1 inch deep in beds or into 6 cm wide by 22.5cm high polyethylene bags filled with sterilized soil to eliminate root knot nematodes, soil borne diseases and other harmful organisms. Sterilization may be through solarization (using sun) or by use of steam (Kahinga, 2008). Alternatively, the seedlings can be allowed to develop until when 10 inches high, when they can be transplanted to the field.

In the field, the seedlings are planted in holes measuring 1m×1m and their roots covered with topsoil well mixed with manure. The holes should also be made at a distance of 10 ft (3 m) from the estimated distance of vine to vine and 6 ft (1.8 m) between rows. Recent 3-year trials in Kenya of 4 ft (1.2 m) between rows, with light pruning the 2nd and 3rd years, resulted in the highest yield (50% increase of the crop being made the first year). But it is recognized that such close planting can lead to disease and pest problems (Morton, 1987).

Plants can also be propagated by layers or cuttings of matured wood with 3 to 4 nodes. Rooting may be hastened by hormone treatment especially Gibberellins. Cuttings should be well rooted and ready for setting out in 90 days. Grafting is an important way of propagating hybrids since hybrid seeds do not produce true-to-type plants, and reducing nematode damage and diseases by utilizing the resistant yellow passion fruit rootstock. Scions of healthy young plants are grafted to

seedlings, making sure the diameter of the scion matches that of the rootstock. Either a cleft graft, whip graft or side-wedge graft may be made (Kahinga, 2008).

Production and uses

The land under passion fruit production in Kenya in 2007 was estimated to be 5193ha yielding about 71 000 tons of fruit worth Kshs 2.1 billion (HCDA/MOA, 2009 unpublished). However, both the level of production and the area under cultivation is estimated to have reduced by 50% by 2009 due to pests and diseases, which in turn have reduced the income generated from passion fruit sales.

Passion fruit is utilized in a number of ways. Since the fruit is rich in proteins, carbohydrates, fiber, minerals (calcium, phosphorus, iron, sodium, potassium) and vitamins (thiamine, riboflavin, niacin, ascorbic acid), it is supplied to the local fresh fruit market where consumers eat it raw and hence contributes directly in human nutrition. The pulp is used in making fruit salads, pies, candies and cake icings. For commercial purposes, the juice is extracted and packaged for local consumption as a beverage or in cocktails. The juice and pulp extracts also have a ready export market especially in European and Asian countries.

Passion fruit also has a great potential in phytomedicine production. The glycosides contained in the young fruits have been extracted to make sedatives and tranquilizers in Brazil and Italy, and to make digestive stimulants and for treating gastric cancer in Madeira (Morton, 1987). In Costa Rica, the juice is fermented and processed into wine while in Fiji the oil is extracted from the seed. The rind has also been used in animal and poultry feeds in major passion fruit producing countries. The vines and flowers are of aesthetic value and can be used for live fencing. These arrays of uses can be utilized in Kenya to maximize benefits from the fruit.

A number of beverage companies aim at using locally available fruits. These companies include Delmonte, SUNMANGO and the most recent being the Coca cola Company and the East African Breweries Limited. With such large scale processors in the field, the demand for the fruit will definitely increase. The livelihood of the producers will also improve and their produce will have an assured market.

PRODUCTION CONSTRAINTS

The Kenyan passion fruit industry has faced a number of challenges. These constraints have set the industry on a downward trend and the demand currently outweighs supply. First, certified seeds and seedlings are unavailable to farmers. Few seed companies stock the passion fruit seeds for commercial purposes. The farmers therefore rely on private growers and other farmers for seeds or extract from their own fruits. Since these seeds are- in most cases- not certified, the chances for viral diseases transmission via seeds are high. The KARI station in Thika has the mandate for horticultural crops, and as well produces clean seeds and seedlings that are available to farmers. However, due to its limited production capacity and difficulties in accessibility, it cannot serve all the farmers in Kenya satisfactorily.

Secondly, due to poor farming practices in Kenya over the years, the soil fertility has drastically gone down. Few farmers can afford fertilizers or have knowledge on use of compost and other soil improvement methods to increase fertility. This has reduced the potential of the land to produce enough fruit for the markets.

Thirdly, the European markets where most Kenyan agricultural products are exported require high quality products. The fruits required should be unblemished and should also contain low amounts of chemical residues. In order to produce high quality fruits that meet these standards, farmers use a lot of money in production which leaves small profit margins.

In the past, communication on various issues regarding agriculture was an important constraint to farmers but today this problem has reduced with the coming up of community radio stations where

farmers can call and ask questions or talk with experts. Availability of mobile phones to almost every household in Kenya today has also provided farmers with additional ways of accessing information especially on market trends for their produce.

Climate change is another factor that has contributed to the decline of passion fruit just as in every other agricultural sector. The prolonged drought period has increased disease and pests incidences, coupled with the erratic rainfall patterns; these have adversely affected the passion fruit industry.

Aside from the above, the greatest challenge in passion fruit production in Kenya is pests and diseases. These are further discussed below.

PESTS AND DISEASES AND THEIR MANAGEMENT

Recent stakeholders meeting have consistently ranked diseases as the most serious threat in addition to scarcity of certified seedlings and prolonged drought (Otipa, 2009; Embu workshop, 2010). Reduced production has adversely affected the livelihoods of growers and industrial processors, with many operating below installed capacity, e.g. SUNMANGO company which has capacity to process 100 ton/week is currently processing less than 25 ton/week, while others are importing pulp, e.g. Delmonte importing from South Africa and Brazil (Otipa, 2009).

DISEASES

The major diseases reported in Kenya include:

a) **Fusarium wilt**

This is a soil borne disease caused by a fungus known as ***Fusarium oxysporium*** f. sp**. *passiflorae***. The purple variety is the most susceptible to this disease (most yellows are resistant) and succumbs to the disease 1-2 years after planting. The symptoms on an infected plant include chlorosis, necrosis and defoliation; followed by splitting of the trunk and separation of the bark. The roots become progressively discolored and red rays extend to the surface of the soil (Morton, 1987). Highest incidences of the disease have been reported in Thika, Nakuru and Kirinyaga districts (Mbaka et al., 2006). This disease is however widespread in all passion growing areas in Kenya.

This disease has been considerably managed through grafting of scion of the purple variety on root stock of the yellow variety. Alternatively, hybrid varieties (KPF 12, KPF 11 and KPF 4) that are resistant to the disease have been developed by KARI. These hybrid varieties are yellow in color, but characteristically sweet compared to the native yellow variety which is bitter. Grafted certified seedlings can be obtained from the horticultural section KARI-Thika. The hybrid varieties are also supplied here at an affordable price to the farmers. Private nurseries also carry out grafting and seedling dissemination, but their seedlings are in most cases not certified.

Soil fumigation though attempted is not effective and is also costly and hence not affordable to most farmers. Use of seeds as the primary planting material have been cited as a possible mode of fusarium wilt control as it has been shown that seeds do not harbor the fungus. However more research should be carried out to ascertain this.

The major challenge in fusarial wilt control is the availability of clean planting materials. The clean materials from KARI cannot reach all passion fruit farmers in Kenya due to distance and the cost of the seedlings. Most farmers therefore obtain grafts from the already established plants in their fields or from neighbor's fields and private nurseries. Most often, these materials are infected and hence spread the disease.

Farmers also do not observe the requirements for grafting. A graft should be made at least 45cm above the ground. They however make the union too low to the ground where rain water splashes the fungal spores from the soil hence infecting the plant. The tools used should also be sterilized to avoid infection during grafting and pruning which often the farmers do not observe.

b) **Fusarial canker** is caused by ***Fusarium solani*** and has been determined to be the organism girdling the collar zone and bringing on sudden wilt of the purple passion fruit vine. This disease is most prevalent in Meru, Kirinyaga and Taita Taveta districts (Mbaka et al., 2006).

2. Brown spots

Brown spot is caused by ***Alternaria passiflorae*** and it is a major affliction of the purple passion fruit in East Africa (Morton, 1987). The disease is evidenced by small brown spots that appear first. Later, these spots enlarge, develop a lighter-colored central area, and become irregular or angular in shape. On stems, elongated dark-brown lesions appear, usually near leaf axils or where stems have rubbed against the supporting wire. Infection spreads from these points and whenever the stem becomes completely girdled the shoot suddenly wilts and fruits collapse. On fruit, spots first appear as pinpricks, which enlarge into sunken circular lesions with brownish centers. Eventually the rind round the diseased area becomes wrinkled and the fruits shrivel and drop. The disease is prevalent in all passion fruit growing areas in Kenya. It has been effectively managed through spraying of plants with copper fungicides during the early growth stages, hence not a big challenge.

3. Passion woodiness viral disease

This disease is caused by the passion fruit woodiness virus. Infected fruits are deformed, have a hard rind, have no little or no pulp and have no juice. When plantlets are infected at early stages, they usually have stunted growth and do not produce fruits. On leaves it causes yellow spots, flecks or mottling, and there is crinkling or distortion. It also shows shortened internodes on the stems, bunching of foliage and stunted growth. On fruit it causes thick, hard, distorted woody rinds, often with characteristic scabs and cracks. Pulp yields are much reduced. The lower zones are more affected by the disease than the higher zones, indicating a possible higher incidence due to high temperatures and low amounts of rainfall.

The most common management practices include uprooting and burning the infected plants. Farmers are also advised to start with clean planting materials. In nurseries, proper screening should be done to avoid the insects- especially aphids- from spreading the disease. The vectors should also be well controlled in the field. Sterilizing of pruning and grafting tools should also be done. The major constraint in the control of the woodiness virus is the scarcity of clean planting materials. Few seed companies stock the passion fruit seeds for commercial purposes and hence farmers extract and dry their own seeds for planting. These uncertified seeds hence transmit the virus.

4 Die back disease

This is a new and highly virulent disease that has emerged and it is spreading rapidly causing 100% loss and reducing orchard lifespan to less than 2 years. Preliminary investigations indicate it is a complex, possibly involving several organisms. The disease is characterized by the progressive death of the plant starting from the crown towards the roots. Unfortunately, adequate effort is yet to be made to tackle this new threat, which stakeholders have prioritized as the most serious threat to the passion fruit value chain, (Otipa, 2009; Embu stakeholders' workshop, 2010).

Growers have reported increased dieback severity in times of drought, which suggests linkage to climate change effects, while some agronomic practices are suspected to accelerate disease spread. For example, Otipa et al. (2009) found that 88% growers regularly prune but only 17 % disinfect the pruning tools. Pruning creates wounds that can facilitate pathogen entry while contaminated tools can carry pathogens from infected to healthy plants. Research is therefore needed on the impact of climate change on passion fruit diseases, e.g. drought and its management, and also improving farmer practices as part of IPM.

PESTS

Pests cause damage to crops in various ways. They chew and suck sap from the leaves, bark and fruits of plants. They also bore, tunnel and cause galls and abnormal growths. Some inhabit the plant tissues where they lay eggs and form webs. The most important aspects of pests however are disease transmission in plants, whereby they act as vectors.

Natural methods of pest control are most advocated for it is cheap and does not leave residues in crop products like with chemical use. However, natural control is slower and may not be effective in control of large insect infestations. It is therefore advisable to combine several methods in insect control.

The major pests of passion fruit include:

1. **Fruit flies**

   There are various types of fruit flies in Kenya but the major ones include the ***Ceratitis spp*** and the ***Bactocera spp***. These insects belong to order Diptera and are polyphagous in nature .i.e. they are pests of all fruits. Damages caused by fruit flies include fruit rots and the fruits also drop on the ground. Infested fruit part becomes soft and cause premature coloring. The damages caused by the fruit flies lower the quality of the fruit.

   Major ways of managing fruit flies include; collection and destruction of fallen fruits through burning or burying 50cm deep in the soil, thus the larvae do not reach the surface. Overripe fruits should also be picked since they attract fruit flies. A number of insecticides provide good control of the flies. Pre-harvest intervals should however be observed. Bait trapping has proven effective but attractants (lures) have to be imported and are expensive. Heavy attacks may be treated with baits sprays, consisting of an insecticide mixed with sugar (molasses).

2. **Aphids**

   There are numerous species of aphids in Kenya but the major species of passion fruit are ***Aphis gossypii*** and ***Myzus persicae*.** Aphid attacks are most severe during hot dry periods. The pest sucks sap from the plant leaves and in the process cause leaf curling, wrinkling and also transmits diseases. Attacked plants are also characterized by contamination with caste skins, honeydew and fungal growth. This reduces the photosynthetic capacity of the leaves and hence reduces the overall productivity of the plants.Aphid incidences can be reduced by overhead irrigation of plants during dry seasons. Heavily infested plants can also be uprooted and buried or burned. A number of chemicals can also be sprayed on the affected crops, but pre-harvest interval should be observed.

3. **Thrips**

   Thrips are also common in Kenya, the most common being the western flower thrips ***Frankiniella occidentalis***. Nymphs and adults cause damage by sucking plant sap which leads to streaking, distortion and spotting of flowers, leaves and stems. Damage to fruit is characterized by pale to brown discoloration of the rind with visible black spots. Thrips control is difficult once they have established on the crop. Early detection of adults by use of blue or white sticky traps and regular scouting for nymphs and adults is essential for control of this difficult pest.

   The pests are managed by use of biological pest .i.e. use of natural control methods. These include use of ladybirds and other predatory bugs. Flower thrips are difficult to control with chemicals since they hide in buds and leaf sheaths and also inside the flowers. Adult thrips can be trapped by hanging blue sticky boards in the orchards or in the nursery. Use of chemicals should be restricted to a minimum and also used when heavy infestations occur.

4. **Nematodes**

Nematodes are partially responsible for the short life of many passion fruit vines. The root-knot nematodes ***Meloidogyne incognita***, ***M. javanica*** and ***M. arenaria***, are the most serious on passion fruit. Symptoms of root-knot nematodes infestations include formation of galls or knots on roots, yellowing of leaves, stunting and wilting of the affected plants. Some root-knot nematode control measures include crop rotation and the use of tolerant rootstocks of the bitter yellow variety. Applying herbal chemicals like Neem and Pyrethroid extracts during transplanting is also helpful.

5 Mealy-bugs

Mealy-bug species that infect passion fruit include ***Planococcus citri*** and ***P. kenyae***. They are 3-5 mm long, soft, elongate oval and somewhat flattened. They suck and pierce leaves and young fruits. These are minor pests and hence of low economic importance. They can however be serious pests in warm seasons or if natural enemies, which usually control them are destroyed by spraying with pesticides.

Meal-bugs are usually controlled by a wide range of natural enemies like the lady bird beetles and preying mantis. However, use of pesticides may kill these natural enemies leading to mealy-bug outbreaks hence there is need to conserve natural enemies.

6 Bugs

Several species of sucking bugs feed on passion fruit. The most important include the green stinkbug ***Nezara viridula***, and the brown stinkbug ***Boerias maculata***. Bugs suck sap from the growing tips or developing fruits. The bugs pierce the terminal buds, which eventually wilt and die back. Young plants may be killed if the attack is severe. The punctured young fruits develop localized hardened spots that remain on the fruit reducing their market value.

Control measures include hand picking in small orchards, irrigation during dry weather and destruction of plant remains in the field.

7. Leaf miners

The major species are the ***Lyriomyza* spp.** Leaf miners lay eggs on plant leaves where they hatch into larvae that burrow into the leaf forming tunnels within the leaf. The tunneled area is also discolored. This reduces the leaf photosynthetic area and hence reduces the overall production capacity of the plant. Heavily infested leaves may fall off.

Control measures that can be employed include use of natural enemies, deep ploughing to help expose pupae to desiccation and natural enemies and applying herbal chemicals like Pyrethroid and Neem.

CONCLUSION AND RECOMMEDATIONS

The passion fruit industry in Kenya has a great potential in contributing to the economy. Fruits produced by farmers and growers have a ready market both locally and in outside markets. However, various constraints have limited production such that fruit demand greatly outweighs supply. In order to set this industry on the upward trend, the constraints should be addressed.

A lot of information is available on pests and diseases that pose a challenge to passion fruit production. However, this information barely reaches the farmer. The government through the ministry of agriculture should devise means of disseminating this information to farmers through field extension officers (FEO'S). These FEO's should also train the farmer/growers on the importance of observing hygienic practices throughout the production process .e.g. disinfection of tools during pruning and grafting. Farmers should also be equipped with practical and affordable ways of controlling pests and disease. With the changing global climate that is adversely affecting agriculture the government should look into providing farmers with incentives so that they can

irrigate their lands during dry periods. Mid altitude areas which have high production potentials but receive low rainfalls should also be provided with irrigation water to boost farming.

Since availability of clean planting materials is the biggest challenge towards disease control, the government should participate more to encourage private sector investments in the sector and offer a channel through which farmers can obtain certified and clean seeds and seedlings. These services should also be easily accessible and affordable to farmers.

Passion fruit seeds are mainly the by-products after the pulp is processed. A lot of these seeds are thrown away as waste yet they can yield cooking oil. This oil has been shown to contain very low or no cholesterol. Investments in extraction of oil from these seeds should be made in order to maximize benefits from passion fruit.

Effects of dieback (left: early stage of orchard infection; right: early fruit fall)

Viral infections (left: on leaves and, right: on fruit)

Different stages of fruit infection due to brown spot

Phytophthora infection

Orchard with fusarium wilt infected vines

Fruits with insect bites (stink bugs)

Leaves destruction due to leaf eater feeding

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Banana production, constraints and their propagation methods

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INTRODUCTON

Banana (*Musa* species) is an important food crop worldwide (Robinson, 2007). About 70 million people in East and West Africa are estimated to derive more than one quarter of their food energy requirement from plantains (Rowe, 1998). Bananas are chiefly eaten raw as desert fruit, because in the ripe state they are sweet and easily digested. In their unripe state they are used as starchy fruits cooked before eating. They are usually boiled, fried or roasted. The unripe fruits are peeled, wrapped in banana leaves and steamed. They are then pounded into a porridge and eaten, the starchy dish being called Matoke`. Unripe or ripe fruits may sometimes be baked, roasted or fried. In Uganda and Tanzania a nutritious beer is also brewed from plantains and large quantities of this are consumed in the region.

Plantains and cooking bananas also form part of the daily diet of people in the Caribbean and Latin America .Apart from their major uses as desert fruits eaten raw, or as starchy fruits cooked before eating, only a relatively small proportion of bananas and plantains are processed to other products. Bananas and plantains do not lend themselves readily to processing because the lack of acidity makes preservation difficult and the year-round availability of fresh fruits also makes preservation unnecessary (Gowen, 1988). In addition there must be sufficient surplus fruits available as rejects from the fresh fruit market, steady supply of such fruits at low price maintained throughout the year, a viable alternative market because fresh fruits are available throughout the year, processed products must receive value-added return compared to fresh fruits because factory infrastructure and labor costs have to be covered. The different products which can be processed from bananas and plantains, and the different procedures involve canning, drying, freezing, extraction, drying or fermentation.

Bananas are also used as a source of income. *Musa (AAA)* dessert banana are produced commercially in sub tropics and Mediterranean climates, these includes New south Wales, Western Australia, South Queensland, South Africa, Israel, Taiwan, the Canary Island, Egypt and parts of Brazil. Such localities are situated at latitude above 20^0 N and S, and are characterized by wide seasonal variation in rainfall and temperatures. These industries are intensive but small, being limited by the size of the local markets. Export is usually not possible due to either quality, economic or logistical constraints.

However, some short -distance export does take place to traditional markets for example, from Taiwan to Japan. Compared with volume of fresh fruits exports, processed banana products

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represents a minor proportion of 0.003% (Robinson, 2007). In the humid tropics, a wide range of plantains and cooking bananas is grown for local cash cropping.

Bananas are not only used as a food or cash crop but have other uses. After harvesting the banana fruits the mother plant can be used as animal feeds. These are chopped into small pieces and fed to animals. In addition they are used as mulch or utilized to make compost manure which can be applied in the field to provide plant nutrients. Banana plants also control soil erosion; they grow to cover a large area as suckers continue sprouting, formed canopies that reduce direct impact of rainfall on the soil. Mature banana plants reduce wind speeds as well as reducing sweeping of soil as dust, thus reducing soil erosion.

Banana leaves are locally used as thatches, adding to the value of utilization of banana plants for beautification; they are planted as flowers on residential and official grounds, where in a mixture of other flowers they are known to blend so well to give an attractive view. In some communities banana fruits have very important cultural values, as they are used as important component in ceremonial aspects of life and celebration. For example bridal gifts, new born celebrations, a sign of special recognition or even marking special occasion in life.

GENERAL REQUIREMENTS

Climate

Major banana growing areas of the world are situated between the equator and latitude 20^0N and 20^0 S. Climatic conditions in these areas are mainly tropical with only small diurnal or seasonal temperature fluctuations. Banana growing areas of subtropics are situated 20^0 and 30 ^{0}N or S of equator. Dominant climatic characteristics in the subtropics have wide temperatures fluctuations both diurnally and seasonally, high and low temperature extremes in summer and winter respectively and low rainfall which are poorly distributed. The rate of growth and development is determined by temperatures. On basis of mean daily temperatures (maximum + minimum /2) the optimum mean for photosynthesis (growth) and flower initiation is 22^0 C, where as the optimum mean for plant development and leaf emergence is 31^0 C (Turner and Lahav, 1983; Robinson and Anderson, 1991). Growth (assimilation) and development (leaf emergence) is 27^0 C (Robinson, 2007). Rainfall is also a determining factor to where banana should be grown.

The crop has a high water demand (25mm/week) minimum and an evenly distributed rainfall of 2000 mm annually is required for optimum growth if the total water requirement is supplied solely by rainfall (Robinson 2007).

Soil

Bananas are grown in a wide variety of soils (Simmonds, 1955). According to (Delvaux, 1995), the soil factors important for root growth of banana and plantains are porosity and mechanical impedance, aeration and natural drainage, water holding capacity and temperature. Banana roots are highly sensitive to compaction; this affects both root density and penetration, enhance water logging then depletion of air spaces in banana soils, oxygen starvation and root death can easily follow. Banana plantations require large quantities of water for maximum productivity. Its important that the soil retain large volume of water at field capacity, but still low for adequate aeration.

Soil temperatures are also very important optimal day/night temperatures for banana development process (root emergence and root extension rate) are in the region of 33/26 C (Turner and Lahav, 1983; Robinson and Alberts, 1989).

Soil chemical requirement has three main aspects;

(1) Cation balance, leading cations being: phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Banana crop has high K demand and it`s removed from the soil in large quantities,

this makes it very sensitive to cation imbalance (Lahav, 1995). In particular K/Mg and K/Ca/Mg ratio are very important, and K deficiency symptoms are observed when Mg or Ca reserves are high.
(2) Soil acidity, for optimum results the soil pH measured in water, should be 5.8 and 6.5, very low pH (high soil acidity) causes Ca and Mg deficiencies, Aluminum (Al) toxicity and accumulation of minor elements to toxic levels for example manganese. Excessive salinity on the other hand increases sodium (Na) content of the soils which reduces K uptake and decreases yields.

BANANA MANAGEMENT PRACTISES

Several management practices are required for good growth and development of banana crop;

a) **Weed control**- this is an important constraint for farmer in two main ways; the weeds compete for nutrients with the crop and can harbor pests and diseases. Weed control should be applied from planting time onwards. Methods of weed control in banana plantation include; hand hoeing, chemical sprays, mulching, cover crop. In steep slopes mulching, cover cropping and chemical mowing are very important.
b) **Sucker management is important**, unwanted suckers must be removed regularly to prevent them from becoming too large and unmanageable and too competitive with the selected follower. A common management problem is to allow excess suckers to grow around mother plant to be used later as planting materials. This depresses plant yield of the ratoon plant, increase leaf diseases, depletes root volume and causes plantations to be unmanageable (Robinson and Nel, 1990).
c) **Mulching** - mulching in banana plantations has various benefits namely, retention of soil water in the upper zone and reduction of soil compaction, reduction of soil erosion, surface runoff and surface crusting, increasing soil temperature in winter and decreasing it in summer, addition of organic matter and increasing nutritional value (depending on the mulch used).
d) **Leaf pruning** is also an important practice due to three main reasons; removal of old leaves which are senescent with collapsed petiole and which hand down the pseudostem, this is to increase light penetration to sucker and to the ground. These leaves can be used as mulch. Disease control can be enhanced through removal of spore producing leaves to reduce inoculums and disease spread.
e) **Prevention of mechanical damage to the bunch**, this is improvement of fruit quality by scarification of young healthy leaves rubbing and scarring fingers on the developing bunch.
f) **Intercropping with other food crops**. It is a common feature of subsistence farming due to decrease in agricultural land in these areas (Robinson, 2007). But with intensive commercial banana production, intercropping is rare.

CONSTRAINTS IN BANANA PRODUCTION

Main banana growing areas are divided into four distinct zones.
1. The humid tropics
2. The hot ,semi and tropics
3. The warm ,arid subtropics
4. The cool subtropics

Floods that are most associated with tropical banana regions experiencing severe storms may result to oxygen starvation, root die back and eventually leaf yellowing.
Drought periodically reduces or removes the sources of water resulting to plant damage and this is so in banana areas where plantations are normally grown through irrigation. Wind causes different types of damage from uprooting newly established plantations to leaf tearing in already established

plantations. In addition hot and dry winds induce water stress and temporary wilting by increasing the vapor pressure deficit and disturbing the leaf boundary layer, thus damaging the plant physiologically.

Marketing is also a constraint, although Musa (AAA) desert banana are produced commercially in sub tropics and Mediterranean climates. According to Robinson (2007), the industries are intensive but small, being limited by size of local markets and export is not possible due to either quality, economic and logistical constraints. Many farmers rely on natural regeneration which is less efficient in producing high number of seedlings.

Across Africa, expansion of banana cultivation is greatly hindered by weeds (Ndubizu 1883), which compete with the crop for nutrients there by reducing the yield; drought and organic status of the soil that is low soil fertility due to continuous cultivation.(Awodoyin, 2003), poor suckering ability (Ndubizu, 1985), poor agronomic practices and post harvest constraints (Robinson, 1996). A common limiting factor to large-scale production of bananas and plantains, and/or expansion of existing plantains is difficult in obtaining planting materials (Tezenas du Montcel 1985; Schill et al.,1997; Baiyeri and Ajayi 2000; Schill et al., 2000; Nkendah and Akyeampong, 2003) due to poor suckering ability of naturally regenerated suckers (Robinson 1996).

PROPAGATION METHODS

Most banana farmers depend on natural regeneration of existing plants to obtain seedlings, which is a slow process and quite often does not yield adequate amounts (Faturoti et al., 2002). Naturally produced suckers can be a source of soil borne pathogens such as nematodes and banana corm weevils *(Cosmopolites sordidus*). Although tissue culture (TC) propagation is efficient in terms of quantity and quality, its adoption is constrained by high capital and skill needs leading to high seedling cost, (Sahijram et al., 2003). Thus tissue culture as a method of generating planting materials is not an option for small scale farmers who are major stake holders in the *Musa* production in the humid tropics, so there is need for cheap and simple technique (Lopez, 1994). Consequently, the Plantain and Banana Improvement Program (PBIP) of International Institute of Tropical Agriculture (IITA), Nigeria, advanced use of macropropagation for increasing sucker multiplication at farm levels (Faturoti *et al.,* 2002). Macropropagation techniques have been used successfully in other African countries including Cameroon. In East Africa, macropropagation was piloted under crop crisis control project (C3P) that supported farmers recovering from the banana *Xanthomonas* wilt pandemic (Mwangi *et al.,* 2007). In Kenya there is limited evaluation of this technology (Mwangi, 2008). To promote acceptance and adoption of macropropagation more information is required especially on key quality control points to ensure production if healthy high quality seedlings especially where bananas are grown under diverse agro ecologies with varying biotic threats. In the following section different seedling propagation methods commonly used in Africa are discussed.

(a) CONVENTIONAL PLANTING MATERIALS

Conventional method although practiced it is not recommended, implications are; fruit yield is reduced, sucker excavation damages roots of the mat and sucker removal becomes systematic method of spread nematodes and soil-borne diseases Robinson and Nel (1990)

There are several types of propagating materials used in establishment of plantain plantations (**fig. 1**) but they vary in their suitability (Ndubizu and Obiefuna 1982; Baiyeri and Ndubizu 1994; Baiyeri *et al* 1994)

Fig.1

A B C D E

F

A: early sucker, B: water sucker, C: Early and late sword suckers, D: Peeper, E: Butt, F: Bits

Source; Baiyeri,K.P. and Aba,S.C. (2007)

A study by (Obiefuna 1883) on plantain (*Musa* AAB cv. `Agbaagba`) revealed that early and late sword suckers yields better than other propagules (**Table 1**)

Table 1 Mean bunch weight (kg/plant) of the parent crop derived from five different types of plantain propagules.

Plantain propagules						
Planting depth (cm)	**Peeper**	**Early sword sucker**	**Late sword sucker**	**Bit**	**Maiden**	**Mean**
10	8.50	10.10	10.10	9.70	9.90	9.64
22	7.50	11.00	11.03	9.40	8.80	9.60
30	11.10	10.30	11.33	10.20	8.80	10.34
Mean	**9.03**	**10.47**	**10.87**	**9.77**	**9.17**	

Source: Obiefuna (1983)

LSD at 5% for depth of planting means = 1.34

LSD at 5% for propagules means = 1.00

Sword sucker: just emerged from the soil surface. Have narrow leaves and large rhizome.

These are chosen as mother plant because they have Strong physical and physiological connection with the parent. A large volume of storage reserve in there rhizome and been derived directly from the mother. Greater survival ability and vigor when detached from mother plants as compared to water sucker.

Sword sucker is simply detached from the parent and planted as whole, or with pseudostem is excised about 100mm above the rhizome collar, and the roots and outer layer are pared away to expose the white tissue.

In most plantains and banana cultivars, emergence of new suckers follow a hierarchical pattern and natural regeneration is somewhat slow due to strong hormone- mediated apical dominance exerted by the main plant (de Langhe *et al.,* 1983; Swenmen *et al.,* 1984). In addition it may inadequate to

meet the need for medium and large scale production at the recommendation population of 1600-2500 ha^{-1} (Awodoyin, 2003).

Advantages

- Easy to practice since it does not require a lot of skills and equipments
- Cheap since planting material are directly from an established field.

(b) TISSUE CULTURE

It has been used commercially for production of banana planting materials as an alternative to conventional planting material in some countries, since about 1986 (Robinson, 2006). Rapid production of propagating materials can be achieved through various vegetative multiplication methods, including micro propagation (Vuylsteke 1998; Tipathy *et* al., 2007). Micropropagation (i.e. meristem/tissue culture) ensures more rapidly production of healthy, vigorous, and disease free planting materials (Swenmen, 1990), but requires more sophisticated techniques, skill and care to handle (Vuylsteke and Talengera 1998).

This process involves the micro propagation of sucker growing points under sterile conditions (Israel et al., 1995) a sucker is detached from the parent plant and brought to the laboratory. To initiate the culture the outer layer of leaves and the corm tissue of the sucker are removed. A piece measuring 10cm by 6-7 cm in diameter is cut and washed in 75% alcohol solution .The sheath and the base of the leaves are then be trimmed to expose the meristem region. Then is decapitated and a block of tissue measuring 1.5cm by 1.5cm and 1cm are excised and inoculated on sterile multiplication media. The media ^{pH} is adjusted to 5.8 and it`s sterilized by autoclaving at 121^0C. Multiplication of adventitious buds is carried out by inducing meristem tissue and dividing them into smaller pieces then are sub-cultured into a fresh medium. The multiplication rate of the buds depends on the cultivar and the concentration of cytokinin and the number of sub-cultures.

Tissue culture procedure: fig. 2

(Invitro) rooting and multiplication stage

(Invivo) transferred into polythene bags

Hardening process

Established tissue culture materials in the field

After rooting they are transferred into small polythene bug (in vivo condition). It takes 6-8 weeks and plants are relocated from small polythene bags to nursery bags in a netted shed house (acclimatization).After another 6-8 weeks plants are ready for establishment in the field.

Advantages of using tissue culture

- **Rapid multiplication**-It is quick compared to other methods, up to 1000 individual plants can be produced from a single growing point over a year of sub-culturing, whereas only about 10 conventional suckers can be produced from a plant within a year. So with availability of a new cultivar or a disease resistant mutation it can be rapidly distributed throughout the industry by tissue culture.
- **Hygienic and healthy planting materials**- by use of apical meristems through tissue culture technique, elimination of all fungal spores, bacterial, and nematodes is achieved. Viruses are still transferred to progeny via tissue culture, thus virus indexing is needed for all mother plants.
- **Depletion of plantations**- tissue culture eliminates the necessity to harvest suckers from a commercial plantation, which severely reduces the yield potential (Robinson and Nel, 1990).
- **Uniformity**- selection of uniform nursery plants gives uniform growth, flowering and harvesting, which can not apply with plants from suckers.
- **Physiological vigor**- tissue culture plants have inherent high level of juvenile vigor which renders them photosynthetically more active than plants derived from suckers, thus initial growth is faster (Robinson, 2007). It also has vigorous rooting system and produce more suckers at an early stage of development than conventional suckers (Eckstein, 1994).
- **Yield increase**- through comprehensive trial, tissue culture plants has been proved to have higher yields as compared to conventional suckers (Robinson, 1994).
- Easy transfer of planting material since no special permit is required to deliver a tissue culture plants from laboratory to farmers

Disadvantages of tissue culture

- The initial cost to establish tissue culture planting materials are very high, sophisticated equipments are needed, special medium and controlled environment. For this reason growers have to pay more for in vitro plants.
- Somaclonal variation: the occurrence of off-type plants during in vitro propagation of banana has been widely reported. The frequency ranges from 50 % (Daniell, 1988a) to 1% (Arias and Valverde, 1987).
- Transmission of viruses: since viruses such as banana bunchy top and banana streak are not eliminated during laboratory process, there is a risk of transmitting the virus from infected to non-infected areas of the world via in vitro material. Mother should be indexed before transfer from one country to another.
- Extra care at planting and establishment: young in vitro plants are very tender and sensitive to stress after establishment. They have no nutrient reserve and they have to receive optimum management to reduce damage or stress.

(c) MACROPROPAGATION

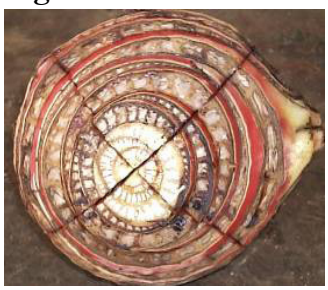
This technique is not different from natural regeneration, however slightly more seedlings can be realized. Natural regeneration is slow due to hormone mediated apical dominance of the mother plant. In macro-propagation the apical dominance is repressed mechanically to stimulate lateral bud development and increased suckering rate. Two different methods are used;

Field decapitation techniques: This generally involves two method; false decapitation and total decapitation. The two decapitation methods involve stimulating lateral bud production by destroying the active growing points (apical meristem) in the pseudostem (Wilson *et al* 1985; Swenmen, 1990; Awodoyin 1997; Faturoti *et al* 2002; Tenkouano *et al* 2006). The rate of suckering per plant ranges from 9-14 suckers per annum. It should be noted that these techniques when carefully applied on the mother plant (without damaging the root systems) could still bear it`s bunch normally. The

technique also makes it possible to obtain in 8 months, propagules that are practically free from pest and diseases when healthy plants are selected from the field (Baiyeri and Aba 2007)

Detached corm technique: This can be done through complete or partial decapitation or by detached corm technique (Faturoti et al., 2002) then stimulation of lateral growth of multiple buds in a corm within a chamber whose humidity is maintained at 60-70% and 50% shade and warm temperature. This is possible due to the fact that a banana corm contains several auxillary buds with meristems at different stage of development (Tenkouano et al., 2006; Kwa, 2003).Sword sucker as well as corms from preflowered and harvested could be used in detached corm multiplication techniques. A corm can produce 10-30 plantlets in four months but the productivity may vary with cultivar and bud manipulation. After sprouting healthy banana seedling are transferred from growth chamber and placed in polythene bags for hardening before transplanting. Corm technique can either be in form of split-corm or whole corm, whole corm technique, the apical meristem of pared corm are scarified, either by making two cross-wise incision on the buds (Kwa, 2003; Tenkouano *et al.,* 2006) or by mechanical removal by screwing with a sharp knife (Baiyeri and Aba 2005) **fig. 3**, then they are placed on saw dust media in the growth chamber.

Figure 3



Cross wise initiation

Screwing

In nematode or weevil infested soils, it is recommended that the pared corms are sterilized in 10% solution of household bleach, `JIK` (3.5% a.i., sodium hypochlorite, NaOCL) and allowed to air dry and cured for three days before planting to avoid dissemination (Baiyeri and Aba 2005).

<u>Macropropagation procedure: figure. 4</u>

Picture 1: corms

Picture 2: growth chamber and corms planted on saw dust media

Picture 4: Established macropropagation material

Picture 3: suckers sprouting from a corm where they will be separated transferred into polythene bags then hardened.

Advantages of macro-propagation

- ❖ Simple and easier to grasp compared to tissue culture.
- ❖ It's not expensive- macro propagation materials are locally available; for example saw dust used as medium can be cheaply obtained from carpentry workshops, Growth chambers are usually constructed using affordable and locally available materials
- ❖ Have uniform size and tolerate post establishment stress better than tissue cultured plants (Tenkouano et al., 2006).

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Propagation of healthy banana seedlings in relation to pest and disease management

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INTRODUCTION

Origin and Cultivation of Bananas

Modern day edible bananas are a mix of wild and cultivated species and hybrids associated with *M. acuminata* and *M. balbisiana* (Daniels et al., 2001). The center of diversity is thought to be Malaysia or Indonesia (Horry et al., 1997). Clones of the diploids were cultivated in wetter parts of South East Asia (Valmayor et al. 2000). Development of vigorous seedless triploid cultivars was the result of chromosome restitution (Raboin et al, 2005) and or crosses between edible diploids and wild *M. acuminata* (Daniels et al., 2001). Most cultivars of the edible bananas derive from collections of spontaneous mutations in wild plants that were brought into cultivation and multiplied vegetatively. Hybridizations and mutations have occurred many times over (Helson-Harrison and Schwazacher 2007).

East and West Africa represent two main secondary centers of *Musa* diversity as a result of a long history of cultivation in these regions (De Langhe, 1995). There are approximately 60 cultivars of African Highland bananas unique to East Africa. The most widely distributed banana cultivar is "Dwarf Cavendish" (Ploetz et al., 2007). It is likely that it was developed from tall members of the Cavendish subgroup (Constatain and Russel, 2001).

Importance of bananas in Kenya

Bananas (*Musa* spp.) are predominantly grown by small scale farmers for food, nutrition security and income generation (Njuguna and Wambugu, 2008). The fruit is a rich source of vitamins A, B, and C. Carbohydrates 22% and minerals are Calcium, Potassium and Iron. Bananas play a major role in the diets of the people and the economy of Kenya. It is an important food crop providing carbohydrates for both rural and urban households. East African countries (Burundi, Kenya, Rwanda, Tanzania, and Uganda) are the largest banana producing and consuming region in Africa.

They are a source of income for the majority of smallholder growers. The crop is also environment-friendly, preventing soil erosion on hilly slopes, and readily lends itself to intercropping and mixed farming. The year-round fruiting habit of the crop ensures food security at household level with a potential of sustaining food supply to urban markets especially in periods between cereal crop harvests thus bridges the "hunger-gap" (Frison et al., 1998). This potential coupled with the environmental conservation attributes of the plant makes banana an ideal crop for economic growth and sustainability of the agricultural resource base (Reddy et al., 1998).

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Commercial uses

Bananas and plantains are the world's fourth most important food crop after rice, wheat, and maize (INIBAP, 2000). The banana fruit can be eaten raw or cooked. It can be processed to flour and can be fermented for production of beverages such as banana juice, vinegar and wine (Pillay et al., 2002). Banana leaves are used for wrapping food, polishing floors and thatching (Nelson et al., 2006). Fibers from the pseudo stem are used for making. Leaf fibers are used for making strings, cordage and ropes. The sap of banana plants particularly the Fe'i cultivars that have a distinctive reddish-violet sap (Sharrock, 2000) has been used as dye and ink (Nelson et al. 2006; Pillay and Tripathi, 2007). Various parts of the plant are also used for medicinal purposes. Root sap can be used to treat mouth thrush in children and skin warts. Banana peels have been found to have antibiotic properties (Nelson et al. 2006).

Banana production and area

Banana is grown in more than 100 countries, with annual production estimated at 88 million metric tons (Escalant and Jain, 2006). In sub Sahara Africa, banana provides more than 25 % of the carbohydrates and 10 % of the calorie intake for approximately 70 million people.

Annual banana production in the world is estimated at 1.011 million tons, of which less than 10% enters the commercial market, indicating that the crop is more important for local consumption than for export (FAOSTAT, 2006). Approximately one-third of the bananas produced globally are grown in sub-Saharan Africa, where the crop provides more than 25% of food energy requirements for more than 100 million people. Uganda is the world's second largest producer after India, with a total of about 1.1445 million tons (FAOSTAT, 2004).

Bananas are important in the Great Lakes region, not only in Uganda, but also in adjacent countries, where they are both a food security and a cash crop (Edmeades et al., 2007). Food security studies reveal that in Uganda, Rwanda, and Burundi, bananas constitute more than 30% of the daily per capita caloric intake, rising to 60% in some regions (Abele et al. 2007). Bananas also provide a major source of cash income for the farmers in the Great Lakes region (Oketch et al., 2004).

The area under banana and plantain cultivation in Kenya was 115 500 ha in 1989 and this has increased to 125 000 ha in 1997 with a corresponding production of 520 000 and 595 000 metric tonnes, respectively. This gives only a production output of between 4.5 to 4.8 tons/ha which is quite low (Wabule, 1998). In the highlands of the central, eastern and coastal regions, dessert cultivars are very popular, especially Cavendish and Gros Michel while in the higher, western regions, the East Africa highland bananas (*Musa* AAA, Matooke and Mbidde cultivars) are more common. In Kenya, banana is a major fruit crop for both subsistence and commercial use. In priority setting exercise for horticultural crops research undertaken in year 1996, banana was ranked as the most important crop among the fruit crops.

Main production areas

Banana is estimated to cover 74,000 hectares (about 2 % of total arable land), (MOALD, 1997) ranging from sea level to 1800 m above sea level. In terms of production, over a million tons are obtained per year. Nyanza and Western Provinces account for 64.4 % of production while Central and Eastern Provinces account for 26 % of production. Hence the rest of the Provinces in the country can be classified as being minor producers, with Rift Valley Province accounting for 3.9 % and Coast Province accounting for 5.5 %. The crop is predominantly grown by small-scale farmers who have an average holding of 0.3 hectares making up to 13 % of the total farm area (Qaim, 1999). Dijsksra and Migori (1994) reported that banana accounted for over 70% of farmers income in Kisii. Recently, banana has become an important cash crop for semi-intensive medium scale farmers who supply the urban markets in the country. This is more so where the income from traditional cash

crops, especially coffee, has drastically reduced. Continuous availability of harvestable bunch from a banana stool is especially important for farmers, who are mainly women, because it contributes to the year round security of food and income. The commonly grown varieties are East Africa Highland bananas and Apple bananas in Western and Nyanza Provinces and Cavendish and Kampala in Central and Eastern Provinces (Nguthi *et.al.,* 1999).

Constraints to banana production

In Kenya constraints affecting banana production have been identified based on surveys and rapid rural appraisal studies. This has been necessary to understand production constraints as perceived by both farmers and researchers. From this, it has been clear that constraints are both abiotic and biotic in nature (Seshu Reddy et al., 1998). They include the banana pests (banana weevil *Cosmopolites sordidus* Germar, a complex of nematodes and thrips) and diseases (black Sigatoka, Fusarium wilt, cigar-end rot, Banana Xanthomonas wilt and viral diseases), declining soil fertility, poor crop management, lack of clean planting material, poor marketing infrastructure, postharvest losses, competition with other crops for land, labour and capital, genetic erosion, drought and lack of inputs/credit facilities. Pests alone cause between 30-80 % of banana losses depending on variety (Speijer and Fogain, 1999). Low yielding cultivars which are susceptible to diseases, particularly Fusarium wilt (Panama) caused by *Fusarium oxysporum* fsp *cubense* (Kung'u 1995) cause losses to farmers.

Banana pests

Infestation of the banana weevil *Cosmopolites sordidus* was recorded in all the banana growing areas in Kenya and the percentage coefficient of infestation (PCI) was more than 20% in all the districts surveyed. In Kwale and Embu districts, upto 100% PCI was recorded. In coastal and central provinces, silver corky scab caused by thrips on the raw fruits was observed (Prasad *et al.,* 1999). On the shores of Lake Victoria, weevils such as *Temnoschoita nigroplagiata*, *T. erudita* and *T. basipennis* were observed feeding on the decaying banana plant material.

A complex of banana nematodes (*Pratylenchus goodeyi*, *P. coffeae* , *Radopholus similis*, *Helicotylenchus multicinctus*, *Meloidogyne* spp.) were common in many banana fields in Kenya. At the coast, up to 200 masl, *H. multicinctus* and *Meloidogyne* spp. were observed in high densities. In the western region, *H. multicinctus* was common, although generally in moderate densities. *Radopholus similis* was observed in central and western regions. In the central and western regions, higher than 1000 masl, the lesion nematode, *P. goodeyi* was the dominant species and it was also observed on a Matooke cultivar grown at Kilifi, coast region. In the central region, in Muranga district, where coffee is being replaced with banana, *P. coffeae* is commonly found. In addition, *Rotylenchus clavicaudatus* (in high numbers in Homa Bay district), *Scutellonema* spp., *Criconema* spp., *Xiphinema* spp., *Hemicycliophora* spp., and a new *Trophurus* sp. were recorded (Seshu Reddy *et al.* 1997).

The banana weevil: The banana weevil is a pest of considerable importance in Africa and significantly affects banana and plantain production (Fogain et al., 2002). The weevil has been associated with rapid decline of banana plantations in east Africa (Gold et al., 1999b). Banana weevil damage can reduce yield and plantation life, and heavy infestation can lead to crop failure in newly planted fields (Gold et al. 2001). The adult weevils are free living, have a nocturnal habit, and rarely fly. Their eggs are deposited at the base of the pseudostem or on exposed corms. Upon hatching, the larvae tunnel through the corm to feed and develop (fig 1.1). The tunneling damages the corm and weakens the plant, reduces water and mineral uptake, reducing bunch weight (yield) and causing plant toppling during windstorms (Kiggundu et al., 2003).

Fig 1.1: Larvae of banana weevil in a corm.

Fig 1.2: Adult banana weevils

Management

Cultural control methods of the weevil include use of clean planting material, intercropping and systematic trapping of adult weevils to control population build-up. In addition, field sanitation is practiced where residues that may form breeding grounds for the weevil are removed. Other methods of control include botanical or synthetic pesticides (Gold et al., 2001), and mass trapping with pheromone lures (Tinzaara et al., 2002). The pest status of the banana weevil can vary depending on local agroecological conditions and *Musa* cultivars (Gold et al., 2001).

Nematodes

Burrowing nematode (*Radopholus similis*) is the most damaging nematode in banana producing countries. It is an endoparasite, completing its entire life cycle within the root and causing decay of the whole root cortex. *Radopholus similis* is a common cause of banana plants falling over, a condition known as "toppling disease" (fig 1.1). This nematode can also burrow from the roots into the rhizome. The disease caused by this nematode is variously known as Radopholus root rot, blackhead, toppling disease or decline.

Fig 1.1: Symptom of toppling over disease.

The abundance of two predominant endo-parasitic species (*R. similis* in the East African Highland banana cropping systems is related to altitude. *Radopholus similis* prevails in warmer lower altitudes (<1300m) (Gowen, 1995). Vertical and horizontal distributions of banana nematodes in soil are related to root growth and nematode migrations in soil. Because of their small size (<1 mm), the absolute distances the nematodes can move are small and do not exceed a few dozens of centimeters per year (Boag & Yeates, 2004). Plant parasitic nematodes use water to move in soil. Because of adhering to the substrate, they stop moving when the water film in the soil evaporates (Warton, 2004).

The life cycle of the banana affecting nematodes generally lasts 1 month when the temperature is optimal (Gowen & Quénéhérvé, 1990). After egg hatching, all nematodes species affecting banana moult four times into subsequent juvenile stages with the first moult usually occurring in the egg (Lewis & Perez, 2004). The length of the life cycle of the nematodes varies and is strongly controlled by environmental factors (Barbercheck & Duncan, 2004). *R. similis* is the most aggressive species and is also the one developing most rapidly: 20-25; 25-30 and 39 days (from egg to egg) (Karaka, 2007).

Banana root dynamics and plant phenological stage affect nematode populations (Tixier et al., 2006). During harvest time, the nematodes are forced to move to the emerging suckers for invasion (Speijer & De Waele, 1997).

Management

Mulching and intercropping are the most common management practices (Talwana et al., 2003a). Mulch alters soil microclimate by cooling the environment conditions. Shifting temperature may affect the reproduction of various plant parasitic nematode species.

BANANA DISEASES

Banana Xanthomonas Wilt

The banana Xanthomonas wilt (BXW) disease caused by the bacterium *Xanthomonas vasicola* pv. *musacearum* endangers the livelihood of millions of farmers in East Africa (Tushemereirwe et al., 2004). The causal organism is a motile, gram-negative, rod-shaped bacterium possessing a single polar flagellum. The effects of banana Xanthomonas wilt (BXW) are rapid. The economic impact of BXW is due to death of the mother plant that would otherwise contribute to the ratoon plant production cycles (Tripathi et al., 2007). Fields infested with *X. vasicola* pv. *musacearum* cannot be replanted with banana for at least 6 months due to carryover of soilborne inoculum (Turyagyenda et al., 2007). Management of BXW has several problems. These include, producers probably begin to manage the disease too late. Second, there are no curative measures for BXW. Third, the disease affects banana populations quite rapidly, so that by the time the farmer begins to respond, it may be too late (Biruma et al., 2007).

Symptoms

Affected banana plants develop symptoms characterized by a progressive yellowing and wilting of leaves (fig 1.2), and uneven and premature ripening of fruit (fig 1.4) with sections showing unique yellowish blotches in the pulp and dark brown placental scars (Tushemereirwe et al., 2004). Symptoms on floral parts include wilting of bracts, shriveling and rotting of the male buds (fig 1.4), and yellow brown flower stalks. Cross-sections of diseased pseudostems reveal yellowish bacterial ooze (Tripathi, 2005) (Fig 1.3).

Yellow or brown streaks occur in the vascular tissues of infected plants (Fig 1.1). Eventually, infected plants wither and the plant rots. Symptom development is rapid under favorable conditions and typically evident within 3 to 4 weeks under field conditions and 2 to 3 weeks after inoculation under screenhouse conditions (Tripathi et al., 2008).

Symptom expression varies depending on cultivar, growth stage, and the mode of disease transmission (Mwangi, 2006). Flowering plants can be infected by insect-transmitted bacteria. Plants can also be infected by *X. campestris* pv. *musacearum* before flowering, usually as a result of transmission through contaminated tools (Addis et al., 2008). Soil borne infection can also occur through the roots (Mwangi 2007).

Generally, symptoms seem to progress faster during the wet season than during the dry season. The time taken to reach different stages of symptom expression may differ with cultivar and environmental conditions, but generally plants show symptoms within 3weeks of infection (Tripathi et al., 2009).

Fig 1.1 Brown streaks in the fruit tissues

Fig 1.2 Yellowing and wilting of leaves

Fig 1.3 Bacterial ooze from the pseudostem

Fig 1.4 uneven ripening of fruit

Management

The recommended measures for BXW management involve a mixture of approaches combining exclusion, eradication, host resistance, and protection. Control of BXW and similar bacterial diseases of banana depends on prevention of disease spread (containment), reduction of disease impact in affected farms (management) and rehabilitation of previously affected areas. Where insect vectors are important, disease spread can be contained by removal of the male flowers and bunch of infected plants to reduce sources of inoculum. Eventually, entire infected mats should be removed to ensure that no infected suckers reach flowering, providing a source of inoculum for insect vectors. Where contaminated tools are the main means of pathogen dissemination, they should be disinfested after use. Resistant varieties are a cost effective way of managing the disease.

In areas where disease incidence exceeds 70% (post-epidemic phase), there is very little chance of harvesting anything. It becomes necessary to remove the infected mats so the land is available for alternative crops or livestock integration. This starts the process of pathogen reduction in the soil, which is essential if banana is to be replanted in the same field. The most appropriate replacement crops are annuals that are nonhosts of *Xanthomonas,* including beans, cassava, maize, sweet potato, sorghum, tobacco, or napier grass (Tripathi et al., 2009).

Fusarium wilt

Fusarium wilt of banana (panama disease) is the most destructive disease of bananas in the world. It was first reported in East Africa in 1950's and is now widely spread in the region (Sebasigari and Stover, 1988). It is present in major banana growing areas of Kenya and affects many economically important varieties. Major banana growing areas affected are Kisii, Homa Bay, Kisumu, Kakamega, Busia, Murang'a, Embu, Coast region and Taita taveta. Dessert banana varieties are most affected. These include; Kisukari, Muraru, Gros Michel, and Bogoya where up to 80% of plants in an orchard may exhibit symptoms of the disease (KARI, 2005).

The causal organism *Fusarium oxysporum schlecht* f. sp. *cubense* survives in the soil and on plant debris from where it enters the roots of the banana plant often through bruises. It then spreads through the tissue of the plant upward throughout the pseudostem. Fusarium may spread very quickly throughout the entire stool. Suckers may look healthy but they are infected. Fusarium has different forms known to cause panama disease in banana and these differ in ability to infect differing varieties. Fusarium types 1and 2 have been confirmed in Kenya.

Symptoms

Banana plants affected by Fusarium wilt show yellowing of leaves starting with the oldest leaves. Yellowing progresses toward the midrib and extends to younger leaves (Ammar, 2007). Petioles of some leaves may buckle causing the leaves to droop and become dry. Other petioles may remain erect but will soon become yellow then brown and eventually brown and torn (KARI, 2005). The most characteristic symptom of the disease is brown-reddish discoloration of the internal vessels of the pseudostem (Ploetz and Pegg, 2000) Fig 1.1. In some cases the pseudostem may split longitudinally near the soil level. Plants affected by Fusarium generally do not develop sufficiently for a mature bunch to be produced and the disease can cause total crop loss. Bunches are small, short with thin fingers (Ammar, 2007).

Tissues of corms of affected bananas exhibit discoloration which appeared as a brownish blotch rot areas when transverse or longitudinal cuts are made. Rapid rotting extends through the entire leaf sheaths of the pseudostem (Ammar, 2007).

Fig 1.1 Banana pseudostems showing characteristic discoloration

Management

Control methods include; quarantine, crop hygiene, cultural control and planting resistant varieties. The most effective approach is use of plant resistance. Bananas that are more resistant and grown commonly in Panama prone areas include; Giant Cavendish, Chinese Cavendish, Grand Naine and Gold Finger (KARI, 2005). There are no effective chemical control measures. Fumigating soils with

methyl bromide is short lived as soils can be re-infected in 2 or 3 years in fields with susceptible cultivars (Ploetz and Pegg, 2000).

Banana Bunchy Top Disease

Banana Bunchy Top Disease (BBTD) is the most serious disease of banana and plantain worldwide (Thomas et al., 1994). Banana Bunchy Top Virus (BBTV) is consistently associated with the disease. BBTD is transmitted locally in a persistent circulative manner by the banana aphid *Pentalonia nigronervosa.*

Symptoms

During the advanced stages, there is a rosetted appearance with narrow upright and progressively shorter leaves giving rise to the common name 'bunchy top'. The leaf edges roll upwards and show marginal yellowing. Dark green streaks are often found on the midrib extending down to the pseudostem. There are characteristic short dark green dashes and dots along the minor leaf veins which form hooks as they enter the edge of the midrib. Plant that are affected early rarely produce bunches. With later infections, distorted bunches may be formed.

Banana streak virus

Banana streak virus (BSV) is a badnavirus that causes a viral leaf streak disease of banana and plantain (Musa spp.). Identified in essentially all Musa growing areas of the world, it has a deleterious effect on the productivity of infected plants as well as being a major constraint to Musa breeding programmes and germplasm dissemination (Harper et al., 2003). Banana streak virus (BSV) species are naturally transmitted by several mealybug species in a semi persistent mode and by activation of endogenous sequences integrated in the genome of Musa balbisiana, one of the progenitors of synthetic and natural hybrids (Dallot et al., 2001). The occurrence of BSV in banana and plantain is likely to have an adverse effect on the international exchange of Musa" germplasm. This is particularly true of the tetraploid hybrids recently produced by several Musa" breeding programs.

Symptoms

The symptoms of viral leaf streak consist of broken or continuous streaks which vary in color from yellow to brown to black. (Fig 1). Isolates of BSV differ widely in the severity of symptoms produced. Symptoms may vary from faint broken chlorotic lines to lethal systemic necrosis of emerging leaves, internal necrosis of the pseudostem and plant death. The pseudostem splits and abnormal emergence of the bunch from the middle of the pseudostem, bearing fewer fruits of smaller size (Jones & Lockhart, 1993).

Management

Approaches for detection of BSV have been compromised by the very high degree of both serological and genomic heterogeneity that exists among isolates of the virus (Lockhart and Olszewski 1993). The high degree of genomic heterogeneity that exists among BSV isolates can be explained by the mechanism of replication of badnaviruses. The virions of these viruses contain a ds DNA which is replicated by reverse transcription via an RNA intermediate. This process is inherently prone to the generation of genomic variants. Because these variants are maintained and disseminated by vegetative propagation, there is little selection pressure applied against these variants. Therefore, use of virus-free stock plants for propagation by suckers or in vitro" plantlets and avoiding the introduction of BSV into banana breeding lines can help manage the disease.

Fig 1: Photo showing Banana streak virus symptoms

MARKETING CONSTRAINTS

Bulkiness

Bananas have a relatively low value compared to their volume/weight which influences transportation costs, making commodities with higher value but lower volume and/or weight more attractive.

Perishability

Bananas are a perishable crop with limited time between harvest and the onset of deterioration.
The constraints of perishability and bulkiness have led to efforts to reduce bulk and improve storage through drying and value addition, e.g. alcohol production.

Poor infrastructure

Those involved in transporting bananas have highlighted feeder roads as areas for attention as they become impassable in times of rain. The declining yields of plots close to main roads and planting of new areas with poorer transport access will increase the importance of feeder roads.

PLANTING MATERIALS

A common limiting factor to large-scale production of bananas and plantains and or expansion of existing plantation is the difficulty in obtaining planting material(Baiyeri and Ajayi, 2000), due to poor suckering ability (Robinson, 1996). Most farmers rely on natural regeneration. This is a slow method with the risk of spreading diseases. Tissue culture has been introduced in Kenya but its adoption is still low due to the high cost of the seedlings.
Recently, IITA advanced the use of a macropropagation method for increasing sucker multiplication at farm level. The method generates plantlets from sword-sucker corm utilizing sawdust as plantlet initiation medium. This is an effective and practical way of producing banana seedlings to address the gap in provision of affordable healthy planting bananas. The pioneering trials and validation of the macropropagation technology have been done largely in Cameroon and Nigeria, and recently spread to other West African countries including Ghana and Ivory Coast, and to Uganda, Rwanda and Tanzania in East Africa.
Macropropagation relies on simple cost effective methodology that could be easily implemented with good training and few resources. Since 2007, FaCT Limited (a private company) has been implementing the macropropagation technology on a pilot basis in Kenya. Initial activities have focused on assessing the potential and challenges to implementation as well as to gauge market response. (Mwangi and Muthoni 2008). More extensive trials on this technology have been initiated in 2010 in Central and Eastern Kenya by Kenyatta University.

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Interactions entre deux nématodes endoparasites migrateurs *Radopholus similis* et *Pratylenchus coffeae* sur le développement de vitroplants du bananier *Musa* (AAA) cv « Williams »

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RESUME
Les types d'interaction entre *Radopholus similis* et *Pratylenchus coffeae*, deux nématodes endoparasites migrateurs du bananier ont été étudiés sur le développement du bananier (*Musa AAA*) cultivar Williams. Différentes combinaisons de dose d'inoculum de *R.similis* et *P. coffeae* ont été mise au point en effectuant des inoculations simples et mixtes. En inoculation simple *P. coffeae* s'est multiplié plus rapidement que *R. similis*. En double inoculation la reproduction de *R. similis* a été inhibée par la présence de *P. coffeae*. Individuellement chacune des deux espèces de nématode a causé des dégâts importants sur développement du bananier cultivar Williams. Mais *P. coffeae* a été plus virulent que *R. similis*. Par contre inoculées concomitamment les deux espèces ont eu une action pathogène moins important que la somme des actions individuelles.
Mots clés: Bananier, Nématodes, Parasites, développement, Côte d'Ivoire.

SUMMARY
The effect of interactions between *Radopholus similis* and *Pratylenchus coffeae*, two migratory endoparasitic nematodes were studied on the banana (*Musa AAA)* cultivar Williams's growth. Different inoculum's combinations of *Radopholus similis* and *Pratylenchus coffeae* were used to make simple inoculation and concomitant inoculation. In simple inoculation, *Pratylenchus coffeae* showed faster multiplication than *Radopholus similis*. When the two nematodes were together, reproduction of *Radopholus similis* was suppressed by *Pratylenchus coffeae*.Each nematode caused important damage on the development of banana cultivar Williams, but *Pratylenchus coffeae* was more virulent than *Radopholus similis*. Nevertheless when both were inoculated concomitantly, each species limited the virulence of the otehr.
Keywords: Banana, Nematodes, Parasites, development, Côte d'Ivoire.

INTRODUCTION

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La Côte d'Ivoire produit en ce qui concerne la banane dessert près de 270.000 tonnes (Anonyme, 2004). Elle est tenue par des multinationales qui pratiquent la monoculture intensive et approvisionnent annuellement le marché européen. En monoculture intensive, la culture de bananiers couvre en Côte d'Ivoire une superficie estimée à 5500 hectares et emploie en pleine production, environ 10000 salariés (Anonyme, 2002).
Cependant la culture des bananiers est menacée par de nombreux parasites et ravageurs. Parmi ces parasites, les nématodes sont très redoutés dans la plupart des zones de production bananière et sont à l'origine de dégâts extrêmement importants entraînant des pertes de productions annuelles moyennes de l'ordre de 20% (Sasser et Freckman, 1987). En Côte d'Ivoire, *Radopholus similis* était l'espèce la plus abondant et la plus redoutée (Adiko, 1989).
Mais en 1988, *Pratylenchus coffeae,* une espèce voisine de *Radopholus similis* a été découverte en Côte d'Ivoire dans les bassins de production d'Aboisso-Ayamé au Sud Est du pays (Adiko, 1988; Quénéhervé, 1989). Les attaques racinaires de *P. coffeae* provoquent des nécroses qui sont identiques à celles de *R. similis* (Bridge *et al*, 1997). Sur le continent africain, *P. coffeae* est associée à des dégâts importants en Afrique du Sud et au Ghana où les plantations de bananiers plantain enregistrent des pertes de production allant jusqu'à 60 % (Bridge *et al*, 1997).
Les récentes prospections entreprises par le laboratoire de nématologie du CNRA (Gnonhouri et Adiko 2008) a révélé que la distribution géographique de *P. coffeae* a évolué et cette espèce cohabite avec *R. similis* dans 50,2 % de la superficie totale emblavée en Côte d'Ivoire. Or en les bananeraies industrielles en Côte d'Ivoire, les traitements nématicides ne sont déclenchés que lorsque le seuil de population de *Radopholus similis* atteint 5000 individus / 100g de racines.
Pour mieux lutter contre ces nématodes des bananiers il convient de déterminer les types d'interactions entre *Radopholus similis* et *Pratylenchus coffeae.*

METHODOLOGIE D'ETUDE

Cette étude a été réalisée au Centre National de Recherche Agronomique (CNRA) à la station de recherche de Bimbresso située à 5°31 longitudes nord, 4°15 latitudes Ouest. Elle a été mise en œuvre pour apporter un élément de réponse à la préoccupation de la filière banane de dessert sur l'évolution de la nématofaune en Côte d'Ivoire et ses conséquences sur la production.
Des vitro plants de bananiers de la variété Williams appartenant au groupe de bananiers Cavendish triploïdes *Musa* AAA en phase de grossissement, débarrassés de feuilles et de racines ont servi de matériel végétal. Ils ont été repiqués dans des seaux de 6 litres à raison d'un pied/seau. Chaque seau a été au préalable rempli de sable stérilisé à la vapeur selon la méthode de Bergerac (Messiaen et Lafon, 1970).
Deux espèces de nématodes endoparasites migrateurs ont servir d'inoculum: (i) *Radopholus similis*, le nématode du bananier le plus repandu et le plus redouté en Côte d'Ivoire (Adiko, 1989); (ii) *Pratylenchus coffeae* qui une espèce émergeante dans la nématofaune ivoirienne et dont les dégâts sont aussi importants que ceux de *Radopholus similis.* Des racines déjà infestées par les deux espèces de nématodes ont servi d'inoculum les niveaux moyens d'infestation après extraction par la technique de centrifugation-flottaison ont été évalués.
L'inoculum de *R. similis* provient de la plantation industrielle située à Songon route de Dabou (LUMEN) et niveau d'infestation évalué à 15717 individus / 100g de racines soit 1000 et 5000 individus dans respectivement 6,37 g et 31,75 g de racines. L'inoculum de *P. coffeae* provient de la plantation industrielle située à Bassam (SBM). Le niveau d'infestation évalué à 1442 individus / 100g de racines soit 1000 et 5000 individus dans respectivement 69,35 g et 346,75 g de racines contaminées. Après avoir obtenu les quantités de racines servant d'inoculum, différentes combinaisons ont été faites en effectuant des inoculations simples ou doubles de comportant huit les traitements.

Traitements et observations

Huit traitements ont été réalisés avec témoins non inoculés.

- Inoculations simples : Témoin sans nématodes (T0), 1000 *R. similis* (T1), 1000 *P. coffeae* (T2), 5000 *R. similis* (T3), 5000 *P. coffeae* (T4).
- Inoculations doubles : 1000 *R. similis* + 5000 *P. coffeae* (T5), 1000 *R. similis* + 1000 *P. coffeae* (T6), 5000 *R. similis* + 1000 *P. coffeae* (T7).

Chaque traitement a été répété 9 fois, soit 72 plantules de bananiers pour l'ensemble de l'étude, rangées en bloc aléatoires complet. L'ensemble du dispositif a tété conduit en serre à la température ambiante. Il y'a eu 3 dépotages de plants qui ont eu lieu respectivement à 30, 60 et 90 jours après inoculation.

Il s'agit de déterminer le comportement de chacune des deux espèces de nématodes *R.similis* et *P.coffeae* à savoir la dynamique de population par la détermination des populations finales et le taux d'accroissement. A chaque dépotage les taux d'accroissement (TC) de population de nématodes est évalué selon la formule $TC= \frac{Pf - Pi}{Pi}$ où *Pf* désigne la population finale au dépotage et *Pi* désigne la population initiale de nématodes. Les nématodes ont été préalablement extraits des racines et des bulbes puis denombrés.

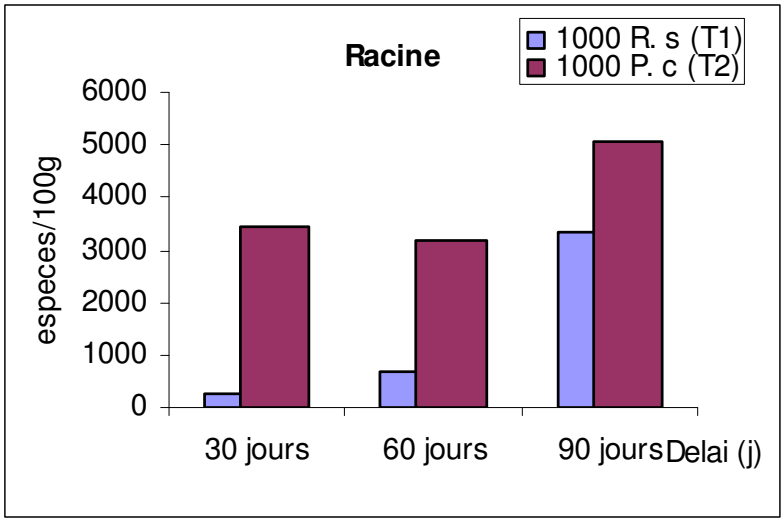
Les mesures des paramètres agronomiques ont porté essentiellement sur (i) la hauteur du pseudo tronc (à partir du collet jusqu'au «V » formé par les deux dernières feuilles, (ii) la longueur (L) et la largeur (l) du limbe de la 2^{e} feuille à partir du cigare afin de déterminer la surface foliaire (S F) selon la formule SF= L x l x 0.8, (iii) le poids des racines à l'aide d'une balance de précision SARTORIUS, (iv) le nombre total de racines saines et infectées par un simple comptage.

Les données collectées ont été analysées en utilisant les procédures ANOVA du système d'analyse statistique XLSTAT, à un niveau de confiance de 5 %. Le test de Newman Keuls a été utilisé pour séparer les moyennes des traitements pour chaque paramètre étudié.

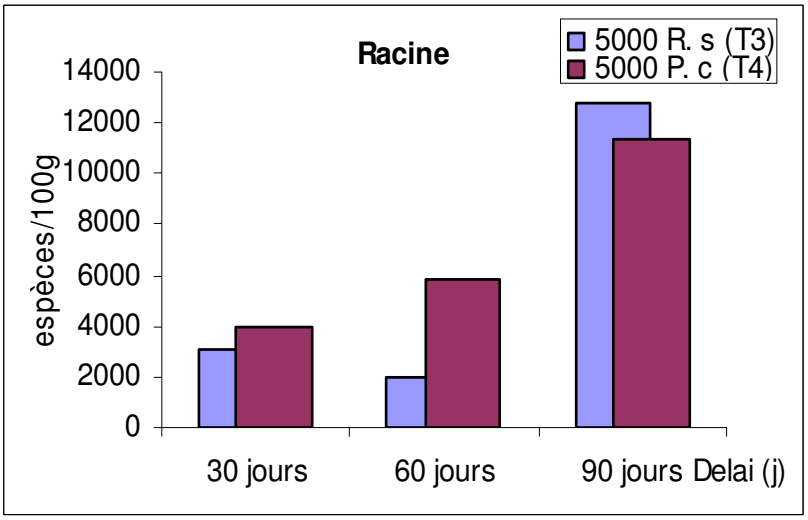
RESULTATS

La population totale de nématodes dans les racines était plus importante que dans les bulbes avec un taux de 85% contre 15% dans les bulbes. Au faible taux d'inoculum (1000 *R. similis* et 1000 *P. coffeae*) la population de *P. coffeae* s'est montrée supérieur à celle de *R. similis* dans les 3 dépotages c'est-à-dire à 30, 60 et 90 jours après inoculation. Chez *P. coffeae* le niveau de population était de 5080 individus à 90 jours près inoculation. Par contre la population de *R. similis* à cette même date était de 3360 individus (Figure 1 A).

Chez *R. similis* les populations à 30 et 60 jours sont restées inférieures à 1000 individus (262 et 702 individus). C'est seulement à 90 jours après inoculation que la population de *R. similis* a atteint 3360 individus (Figure 1 A). Au fort taux d'inoculum (5000 *R. similis* et 5000 *P. coffeae*), les populations ont augmenté pour les deux espèces de 30 à 90 jours après inoculation. Chez *P. coffeae* les populations étaient de 3930 ; 5883 et 11354 individus à 30, 60 et 90 jours après inoculation. Chez *R. similis* les populations étaient de 3065 ; 1994 et 12820 individus à 30, 60 et 90 jours après inoculation (Figure 1 B).



A : 1000 *R. similis* et 1000 *P. coffeae.*



B : 5000 *R. similis* et 5000 *P. coffeae*

Figure 1 : Population de nématodes dans les racines en inoculation simple à 30, 60 et 90 jours après inoculation

Populations de nématode dans 100 g de racines en inoculation mixte

1000 *R. similis* + 5000 *P.coffeae* (T5)

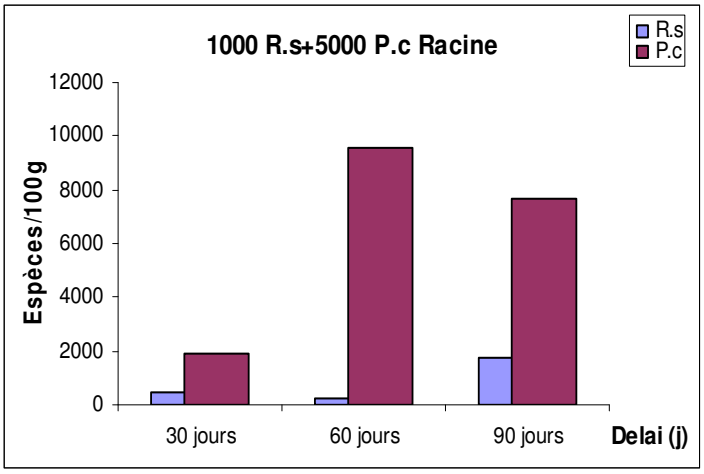
Les populations de Pratylenchus coffeae étaient de 1928 individus à 30 jours après inoculation, 9567 à 60 jours et 7707 individus à 90 jours après inoculation. Quant à *Radopholus similis*, les populations sont restées inférieures à la population initiale 30 et 60 jours après inoculation. C'est seulement à 90 jours que cette population est passée à 1710 individus. (Figure 2 A).

1000 *R. similis* +1000 *P. coffeae* (T6)

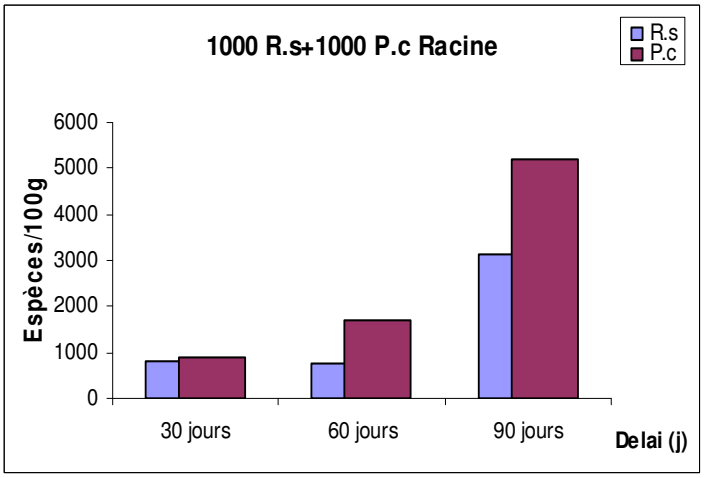
Les populations Pratylenchus coffeae étaient de 912 ; 1698 et 5189 individus à 30, 60 et 90 jours après inoculation contre 814 ; 769 et 3145 individus pour *Radopholus similis* pour la même période (Figure 2 B).

1000 *R. similis* + 5000 *P. coffeae* (T7**)**

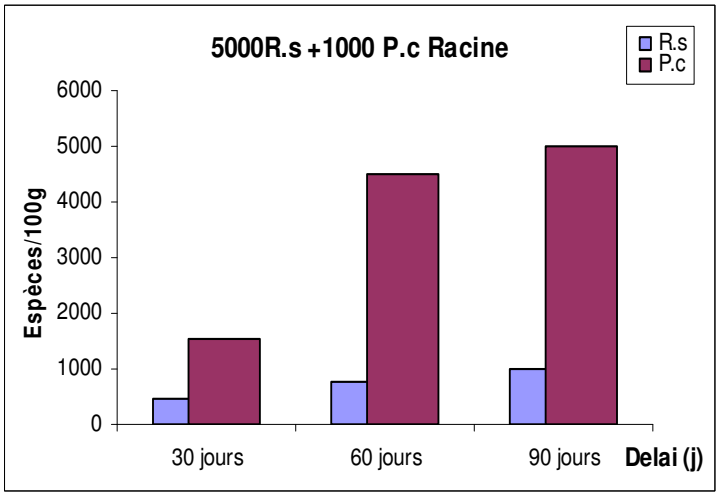
Les populations de *Pratylenchus coffeae* étaient de 1522 ; 4515 et 4996 individus à 30, 60 et 90 jours après inoculation tandis que celles de *Radopholus similis* étaient de 444 ; 770 et 1011 individus (Figure 2 C).



A : 1000 *R. similis* + 5000 *P. coffeae*



B : 1000 *R. similis* + 1000 *P. coffeae*



C : 5000 *R. similis* + 1000 *P. coffeae*

Figure 2 : Population de *Radopholus similis* et *Pratylenchus coffeae* dans les racines de bananier en double inoculation à 30, 60 et 90 jours après inoculation.

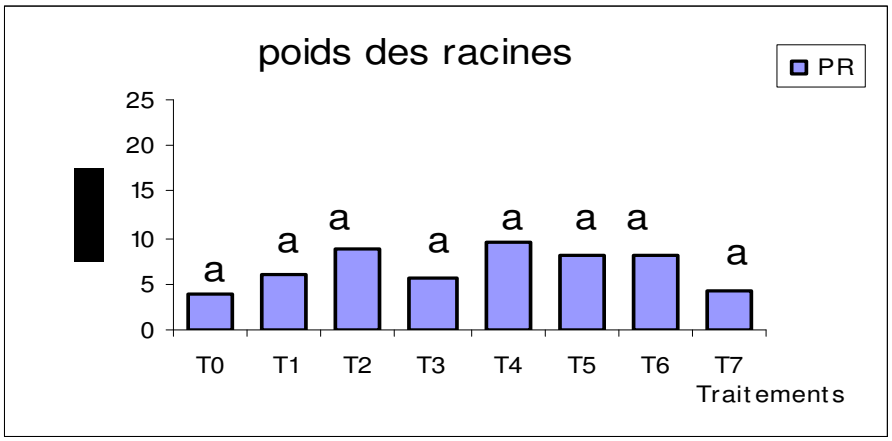
Taux d'accroissement de la populations de nematodes :
Inoculations simples: Les taux d'accroissement pour les 2 niveaux d'inoculum ont montré les taux les plus élevés chez *P.coffeae* (1,63 et 0,20) contre 0,10 et 0,06 chez *Radopholus similis* (Tableau 1).
Inoculations concomitants: Les taux d'accroissement pour les 3 combinaisons d'inoculation ont montré des valeurs qui sont toutes négatives pour *Radopholus similis* (-0,20 ; -0,26 et -0,69) et positives (0,279 ; 2,677 et 1,600) pour *P. coffeae* (Tableau 1). Les taux d'accroissements chez *P. coffeae* sont significativement supérieurs de ceux de *R. similis* pour les traitements T5 et T7 (Tableau 1).

Tableau 1: Taux d'accroissement général de *Radopholus similis* et *Pratylenchus coffeae* pour les trois dépotages.

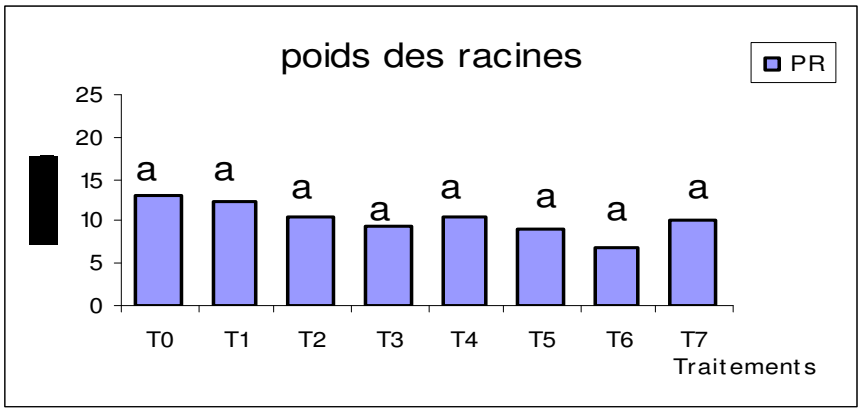
Inoculation			**Taux d'accroissement**	
R. similis	**P. coffeae**	**Objet**	**R. similis**	**P. coffeae**
Simple				
1000		T1	0,10 bc	
5000		T3	0,06 bc	
	1000	T2		1,63 ab
	5000	T4		0,20 bc
Double				
1000	5000	T5	0,20 bc	0,28 bc
1000	1000	T6	0,26 bc	2,68 a
5000	1000	T7	0,69 c	1,60 ab

Les valeurs suivies des mêmes lettres ne sont pas significativement différentes

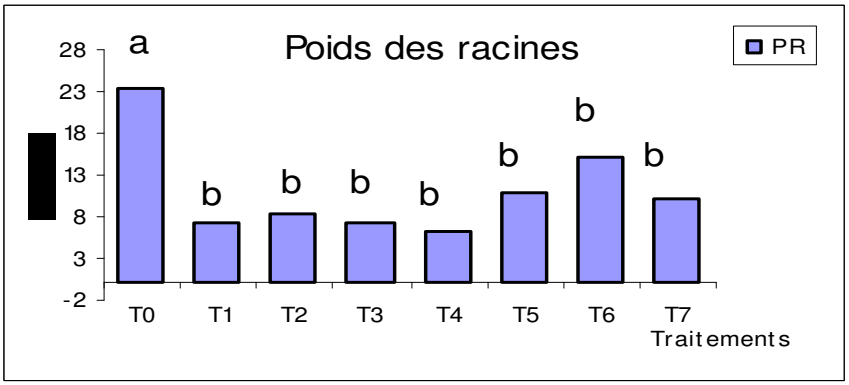
Aspect agronomique : Les effets des traitements sont variables en fonction des paramètres agronomiques étudiés (nombre de racines, poids des racines, surface foliaire, hauteur du pseudo tronc, poids des plants et le nombre de racines nécrosées) et en fonction des dates de dépotage.
Poids des raciness: A 30 et 60 jours après inoculation, les plants inoculés n'ont présentés aucune différence significative par rapport au témoin. (Figure 3 A, B). A 90 jours après inoculation, on observe une différence significative entre le témoin et tous les plants traités. Les plants les plus affectés sont ceux inoculés avec 5000 *P. coffeae* (T4) avec une diminution du poids de 75% (Figure 3 C).



A : 30 jours après inoculation



B : 60 jours après inoculation

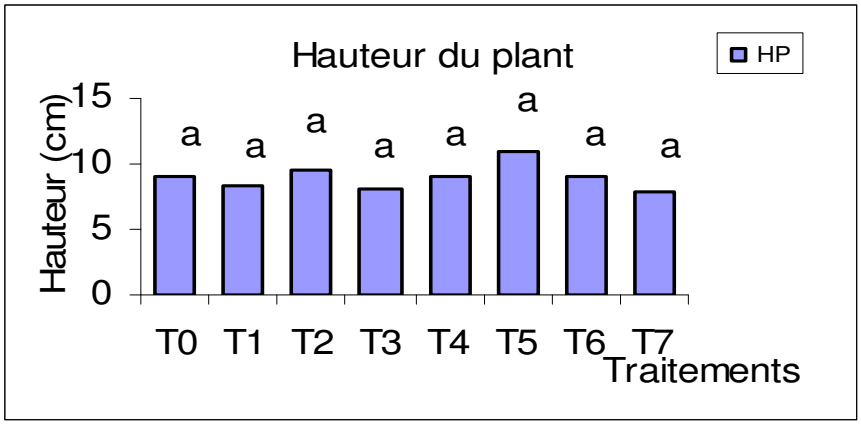


C : 90 jours après inoculation

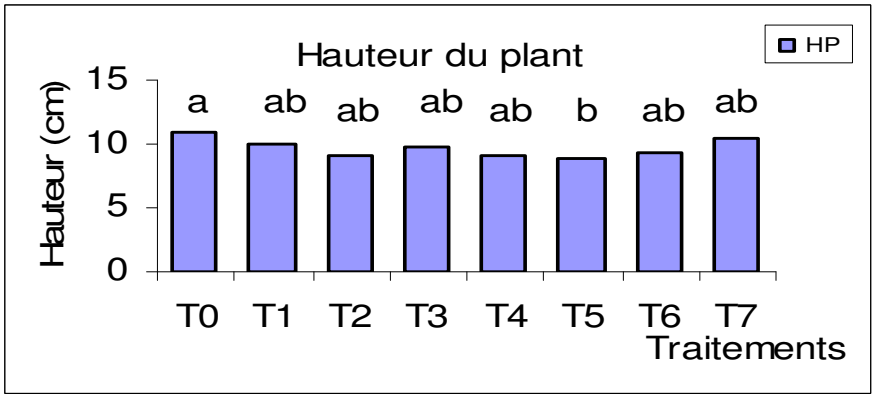
Figure 3: Poids des racines des vitroplants de bananiers aux différentes dates de dépotage.

*Les valeurs suivies des mêmes lettres ne sont pas significativement différentes.

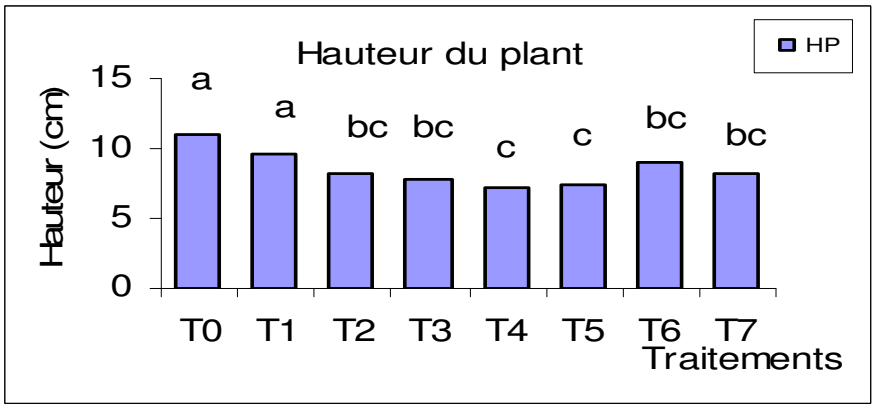
Hauteur du pseudo tronc : Il n'y a pas eu de différence significative entre les traitements à 30 jours après inoculation. (Figure 4 A). A 60 jours après inoculation, on observe une différence significative entre les le témoin et le traitement (T5) induisant une réduction de 20 % par rapport au témoin. A 90 jours, l'effet des traitements était plus marqué. Les plants inoculés avec 5000 *P. coffeae* (T4) et 1000 *R. similis* + 5000 *P. coffeae* (T5) ont été les plus affectés avec une réduction de 36,4% présentant une différence significative avec le témoin (Figure 4 C).



A : 30 jours après inoculation



B : 60 jours après inoculation

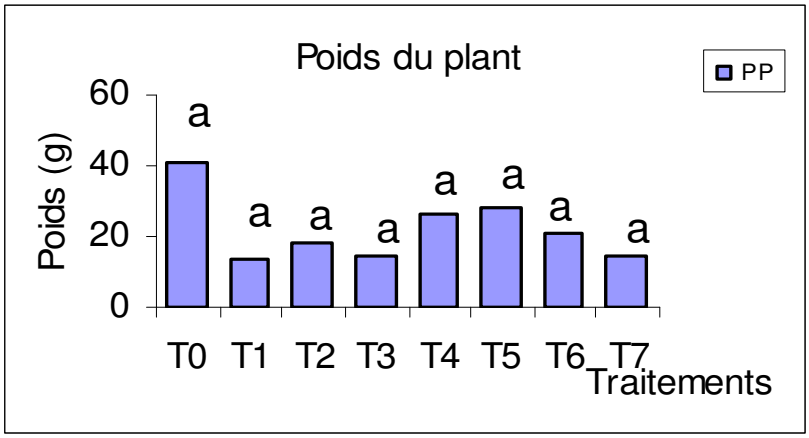


C : 90 jours après inoculation

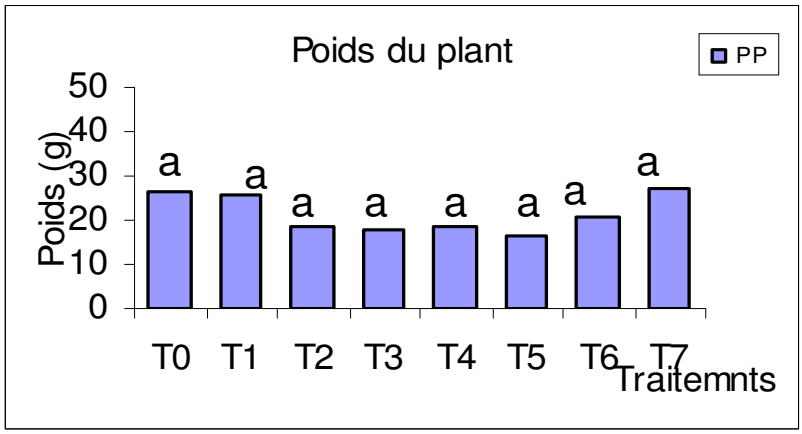
Figure 4: Hauteur du pseudotronc des vitroplants de bananiers aux différentes dates de dépotage de bananiers

*Les valeurs suivies des mêmes lettres ne sont pas significativement différentes.

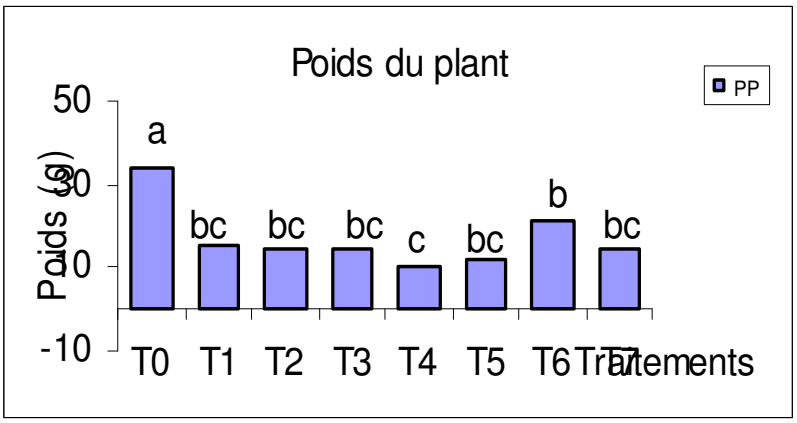
Poids frais du plant :A 30 et à 60 jours après inoculation, les différents traitements n'ont pas eu d'effets significatifs sur les poids des plants inoculés. (Figure 5 A, B). A 90 jours, l'effet des différents traitements était nettement marqué. Tous les plants inoculés ont subi de forte diminution de poids et étaient tous significativement différentes du témoin. (Figure 5 C)



A: 30 jours après inoculation



B: 60 jours après inoculation.

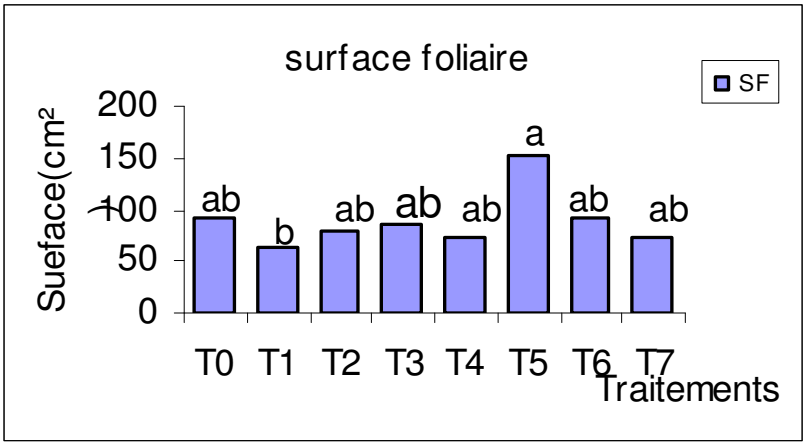


C : 90 jours après inoculation

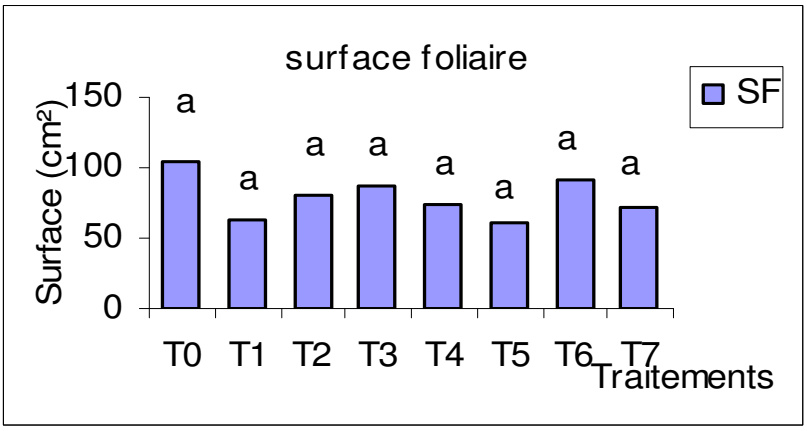
Figure 5 : Poids frais des vitroplants de bananiers aux différentes dates de dépotage de bananiers

*Les valeurs suivies des mêmes lettres ne sont pas significativement différentes

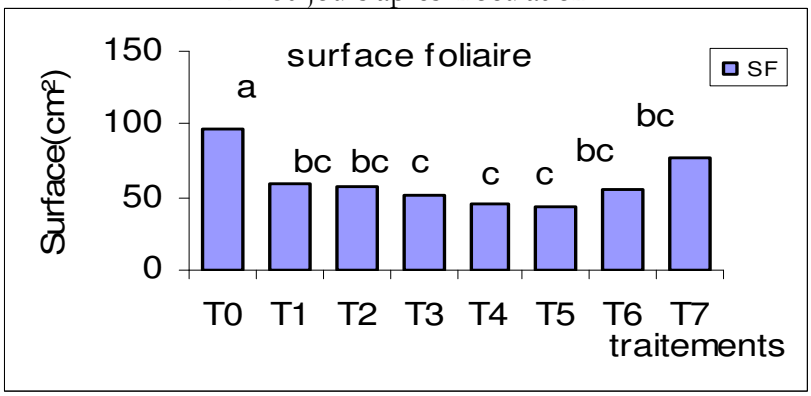
Surface foliaire : A 30 et 60 jours après inoculation, la surface foliaire des plants témoin est sensiblement égale à celle des plants inoculés (Figure 6 A, B). A 90 jours, il existe une différence significative entre la surface foliaire des plants témoins et celle des plants traités. Les effets les plus importants sont causés par les traitements 1000 *R. similis* + 5000 *P. coffeae* (T5) et 5000 *P. coffeae* (T4) qui ont subi une réduction respective de 54,6 % et 53,6 % qui significativement différents des autres plants traités. (Figure 6 C).



A : 30 jours après inoculation.



B : 60 jours après inoculation



C : 90 jours après inoculation

Figure 6 : Surface foliaire de la 2eme feuille des vitroplants de bananiers aux différentes dates de dépotage de bananiers

.

DISCUSSION

Lorsque *Pratylenchus coffeae et Radopholus similis* sont inoculés individuellement et à dose égale d'inoculum, les populations finales de *Pratylenchus coffeae* sont nettement supérieures à celles de *Radopholus similis* aux différentes dates de dépotage. Les populations de *Pratylenchus coffeae* sont 2 à 4 fois supérieures à celle de *Radopholus similis* selon les traitements. Cette facilité de multiplication de *Pratylenchus coffeae* par rapport à *Radopholus similis* serait due au substrat car *Pratylenchus coffeae* se multiplierait plus facilement dans les sols à texture fine par rapport à *Radopholus similis* selon les travaux de Sundararaju et Jeyabaskaran, (2003).

Lorsque les deux nématodes sont inoculés concomitamment, *Pratylenchus coffeae* se multiplie et se reproduit plus rapidement au détriment de *Radopholus similis*. Cette inaptitude de *Radopholus similis* à se multiplier facilement en présence de *Pratylenchus coffeae* est confirmée par les taux d'accroissement négatifs (-0,203 ; -0,258 ; -0,686) montrant ainsi que les populations finales de *Radopholus similis* sont inférieures aux populations initiales. Des observations similaires ont été faites par Ferris et collaborateurs en 1967 avec *Pratylenchus penetrans* et *Pratylenchus alleni*.

En ce qui concerne l'incidence des différents traitements sur le développement du bananier, en simple inoculation toutes les deux espèces semblent avoir des effets néfastes sur la croissance et le développement des plantules de bananiers. Les plants inoculés avec *P. coffeae* présentent les plus faibles paramètres agronomiques. Les moins atteints sont ceux inoculés avec *R. similis* donnant l'ordre de virulence suivant: 5000 *P. coffeae* >1000 *P. coffeae*> 5000 *R. similis*>1000 *Radopholus similis*. Sur le cultivar Williams *P. coffeae* serait plus virulent que *R. similis*. Les résultats similaires ont été obtenus sur le cultivar Grande Naine par Kobenan (2000) et Traoré (2005).

Cette virulence de *P. coffeae* est une fois encore confirmée également par les travaux de Gnonhouri et Adiko en 2005 qui ont montré que dans les zones de production de la banane où *P. coffeae* était prédominant la durée des bananeraies était plus courtes (1 à 5 ans). Par contre dans les zones où *R. similis* était abondant et dominant, la durée des plantations était plus longue (6 à 15 ans).

Toutefois, pour les inoculations concomitantes, les dégâts des nématodes ont été relativement moins importants que le total cumulé de dégâts causés par chacune des espèces aux mêmes niveaux d'inoculum. Il est possible que les effets d'inhibition exercés par *P. coffeae* vis à vis *R. similis* et signalés plus haut, soient à l'origine de cette contre performance très souvent observée au cours des interactions entre nématodes endoparasites migrateurs (Griffin 1983 ; Obannon et *al,* 1976). L'activité pathogène des deux espèces de nématodes serait neutralisée mutuellement. Des observations similaires ont été faites par Estores et *al* (1972) entre *Meloidogyne incognita* et *Pratylenchus penetrans* sur la tomate et également par Ras et Seshadri (1981) entre *Meloidogyne incognita* et *Rotylenchulus reniformis* sur le raisin.

CONCLUSION

Cette étude a montré que *Radopholus similis* et *Pratylenchus Coffeae* ont eu des effets néfastes sur les paramètres agronomiques étudiés confirmant ainsi la sensibilité de la variété Cavendish aux nématodes des bananiers. Par contre *Pratylenchus Coffeae* parait plus virulent que *Radopholus similis*. Au niveau la relation nématodes- nématodes, il existe une interaction antagoniste entre les espèces .La présence de *Pratylenchus coffeae* a influence négative sur la multiplication de *Radopholus similis* en inhibant celle-ci. Au niveau de la relation plante hôte-pathogène, il existe une interaction négative dans la mesure où l'action conjuguée des deux espèces est inférieure au cumule des actions individuelles.

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Effect of six fungicides on *Lecanicillium (Verticillium) lecanii* (Zimm.) Zare & Gams

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ABSTRACT

The objective of the present work was to evaluate the effect of six fungicides on the entomopathogenic fungus *Lecanicillium (Verticillium) lecanii* (Zimm.) Zare & Gams), isolate Y–57. The assays were carried out *in vitro* with the following concentrations of the fungicides: 10, 100, 200, 500, 1000 and 2000 mg kg^{-1}. The inhibition of the growth of the fungal colony and the effect on spore production capacity and on the conidia germination was evaluated. Difenoconazol and tebuconazol belonging to the triazols group were more effective on *Lecanicillium lecanii,* both on the fungal growth and on the spore production and their germination. For that reason it was classified as toxic by the OILB scale and very toxic according to the compatibility scale using the T value. The fungicide cuprous oxide was lightly toxic for the OILB scale and toxic according to the compatibility scale, affecting the spore germination at lower concentrations than field dose. Metalaxyl of the acylalalnine group was lightly toxic for the OILB scale and compatible with *Lecanicillium lecanii*, not affecting spore germination at the studied doses. Mancozeb was inoffensive for *Lecanicillium lecanii* and moderately toxic according to the compatibility scale, though it affects the spore germination at all the studied concentrations, while zineb was lightly toxic according to the OILB scale and moderately toxic according to the compatibility scale, but spore germination was only affected at concentrations equal or higher than field doses.

Key words: Fungicide, entomopathogenic fungi, toxicity, *Lecanicillium lecanii*.

INTRODUCTION

Since 1994 there has been increased alternative production of fresh vegetables in Cuba through the Urban Agriculture program. This became a popular movement that contemplates 28 sub program, directed towards the main productions and some other collateral activities (Peña *et al.* 2004). As a support sub program, plant protection deals with insect pests and pathogens, including use of entomphagous and entomopathogens. Reproduction centres have been established that guarantee the supply of *Beauveria bassiana* (Bals.) Vuill., *Lecanicillium (Verticillium) lecanii* (Zimm.) Zare & Gams), *Metarhizium anisopliae* (Metsch) Sorok. and other beneficial organisms to the farmers, to carry out biological control of pests and diseases. This has reduced the use of chemical pesticides application.

In many other field crops in Cuba like tomato and pepper the use of *L. lecanii* for the control of *Bemicia tabacii* is recommended (Vazquez, 2003). These entomopathogenic fugus are also used for the control of *Thrips palmi* Karny in potato (Castellanos *et al.*, 2008).

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The growth of vegetables in organoponics and intensive orchards received an impulse in the Bolivariana Republic of Venezuela in the year 2003 with the support of the project UTF-VEN-008-VEN from the PESA-FAO. Ayala *et al.* (2007) recommended the use of *L. lecanii* for the control *of Bemisia* spp, *Aphis gossipii* Glover, *Myzus persicae* Sulzer, *Brevicorine brassicae* (L.) and *Lipaphis eryzimi* Kalteubach, in several crops sowed in organoponics and intensive orchards. Castellanos *et al.* (2005) reported 37 fungal borne diseases in the period 2004-2005 in the urban agriculture crops in 11 states of Venezuela. For the control of these diseases Ayala *et al.* (2007) recommend the fungicides: copper oxicloruro, mancozeb, zineb, azoxystrobin, matalaxyl and sulphur.
The objective of the present work was to evaluate the effect of six fungicides recommended for the control of crops diseases on the entomopathogenic fungus *L. lecanii.*

METHODOLOGY

Six fungicides of different chemical groups were selected, which are frequently used in horticultural crops like tomato, pepper and potato for the control of fungal diseases, according to recommendations of the National Centre of Plant Protection (CNSV, 2005), considering a final application volume of 400 litres per ha.

Fungicide	Chemical group	Field dose
Difenoconazol	Triazol	100 mg kg^{-1}
Tebuconazol	Triazol	200 mg kg^{-1}..
Cuprous oxide	Organic compound (cupric)	2000 mg kg^{-1}
Mancozeb	Ditiocarbamato	2000 mg kg^{-1}.
Metalaxyl	Acilalanina	200 mg kg^{-1}.
Zineb	Ditiocarbamato	2000 mg kg^{-1}

The assays were carried out in Petri dishes using the entomopathogenic fungus *L. lecanii,* isolate Y-57, obtained from the collection of the Provincial Plant Protection Laboratory of Cienfuegos. This isolate was conserved at 9°C in tubes on potato dextrose agar (PDA) culture medium.
To evaluate the inhibition of colony growth *in vitro*, the culture media (PDA) was treated with the following fungicide concentrations 10, 100, 200, 500, 1000 and 2000 mg kg^{-1} formulated from a stcok solution of 5000 mg kg^{-1}.
In the treated culture medium, 5 day old mycelial disks of 0,5 cm diameter of *L. lecanii* isolate Y- 57 was placed. A treatment was included with culture medium without adding fungicides as a control. Each treatment was replied five times, and arranged in a totally randomized design. The dishes were incubated at 27 °C in the darkness. On the 10^{th} day mycelial growth was evaluated, by measuring the colony diameter in mm. Percentage inhibition of the growth was calculated for each treatment by means of Abbot Formula (Ciba Geygi, 1981).

$$\%\,de\,inhibición = \frac{growth\ of\ colony(control) - growth\ of\ the\ colony\ at\ any\ concentration}{growth\ of\ the\ colony\ (control)} x100$$

Analysis of variance was carried out to determine the statistical differences between the fungicides with respect to the percentage of inhibition of the fungal mycelial growth at the different concentrations. The values in percentages were transformed by arcsine before analysis. Analysis was done using statistical package SPSS for Windows version 11.0. The means were compared by Duncan's multiple range test, with 5% of probability of error.

The DL-50 and DL-95 values were determined for each fungicide according to the curve dose/ percentage of the fungus growth inhibition 10 days after initiating the assay, at a probability level of 5%.

The toxicity of each fungicide was classified according to the values of percentage of inhibition of the fungus colony growth obtained on the 10^{th} day, using, using the scale of classification established by the International Organization of Biological Control (OILB) (Viñuela *et al.*, 1993): < 30% (Inofensive), 30–75% (Lightly toxic), 75–90% (Moderately toxic), > 90% (Toxic).

To measure the effect of each fungicide on the spore production capacity, the culture media were amended with different concentrations of fungicides as described above. The evaluation began from the third day and it end on the 10^{th} day. The parameter measured as indicator of the effect of the fungicide was conidia production intensity. To measure this, a disk of 0,5 cm diameter of the fungus was taken daily and placed in 2 ml of sterile distilled water with Tween 0,01%. The conidia suspension was agitated successively and later on the conidia were counted in the Neubauver camera and recorded as conidia/cm^2.

To define the compatibility of each fungicide with the entomopathogenic fungus, the T value, proposed by Alves *et al.* (1998) was calculated, using the two indicators evaluated previously, the percentage of inhibition of the fungus growth as well as the effect on the spore production capacity through the formula:

$$T = 20\,[CV] + 80\,[ESP] / 100$$

where:

T = corrected value for the classification of the product;
CV = percentage of vegetative growth with relationship to the control.
ESP = percentage of conidia production intensity with relationship to the control.

According to the T value calculated and the established scale, the fungicides were classified as: 0 -30 (Very toxic), 31 – 45 (Toxic), 46 – 60 (Moderately toxic), > 60 (Compatible).

The effect of the fungicides on the germination of *L. lecanii* conidia was determined. For that, slides were used on which 0,5 ml of the poisoned culture media of each product was placed with the concentrations being studied, to which was added 0,1 ml of a conidial suspension of 10^8 conidia ml^{-1} of the fungus. The mixture was incubated at 27 °C in the darkness. Five slides were used (replicates) for each treatment. The percentage of germination was determined 24 hours later by means of an optic microscope. One hundred conidia was evaluated for each replica.

RESULTS AND DISCUSSION

The inhibition of the mycelial growth of *L. lecanii* on the 10^{th} day reached 100% with difenoconazol and tebuconazol at all evaluated concentrations. This value differed statistically with the rest of the fungicides at all concentrations. The fungicide that was placed third was cuprous oxide, which almost always caused percentages of inhibition of the growth higher than metalaxyl, zineb and mancozeb, with difference from the statistical point of view with these at 10, 500, 1000 and 2000 mg kg^{-1} (Table 1). The fungicide that caused lesser inhibition of the fungus growth was mancozeb, with values between 6.2 and 34.3%, showing statistical difference for this parameter with the rest of the fungicides at all the concentrations, except to 10 mg kg^{-1}.

Table 1: Percentage of growth inhibition of *Lecanicillium lecanii* in the presence of six evaluated fungicides.

Fungicides	Concentrations					
	10 mg kg^{-1}	100 mg kg^{-1}	200 mg kg^{-1}	500 mg kg^{-1}	1000 mg kg^{-1}	2000 mg kg^{-1}
Difenoconazol	100 a	100 a	100 a	100 a	100 a	100 a
Tebuconazol	100 a	100 a	100 a	100 a	100 a	100 a
Cuprous oxide	27.7 b	33.3 c	41.6 b	47.2 b	66.6 b	69.4 b
Metalaxyl	25.0 c	30.6 d	42.2 b	41.6 c	41.6 d	52.7 c
Zineb	6.4 d	35.8 b	42.3 b	37.0 d	46.7 c	49.8 d
Mancozeb	6.2 d	18.7 e	12.5 c	25.0 e	31.2 e	34.3 e
E. Típico *	0.02	0.005	0.05	0.08	0.07	0.06
C.V. (%)	2.8	0.6	5.9	9.2	7.6	6.3

* Different letters following means along the columns indicate signfificant diefferenecs according to the Duncan multiple range test at $p \leq 0.05$.

The DL-50 and DL-95 of the difenoconazol and tebuconazol were below the concentrations studied. The DL-50 for the cuprous oxide was determined to be 325.47 mg kg^{-1}, for zineb 1136.68 mg kg^{-1}, for metalaxyl 2202.72 mg kg^{-1} and mancozeb a value over the 2000 $mg.L^{-1}$ (Table 2). These last three fungicides affected the mycelial growth of *L. lecanii* to a lesser extent than the others, mainly mancozeb.

Table 2: Values of DL-50 and DL-95 for numerous fungicides on the entomopathogenic fungus according to inhibition of the mycelial growth after 10 days.

Fungicides	Equation of regression	Coefficient of determination	DL-50 (mg kg^{-1})	DL–95 (mg kg^{-1})
Difenoconazol	_	_	<< 10 mg kg^{-1}	< 10 mg kg^{-1}
Tebuconazol	_	_	<< 10 mg kg^{-1}	< 10 mg kg^{-1}
Cuprous oxide	Y=0.5072+3.7256	0.8260	325.47 mg kg^{-1}	>2000 mg kg^{-1}
Mancozeb	Y=0.4951+2.9623	0.8992	> 2000 mg kg^{-1}	>>2000 mg kg^{-1}
Metalaxyl	Y=0.2574+4.1395	0.9292	2202.72 mg kg^{-1}	>>2000 mg kg^{-1}
Zineb	**Y=0.6198+3.1060**	**0.8336**	**1136.68 mg kg^{-1}**	>>2000 mg kg^{-1}

Difenoconazol and tebuconazol were classified as toxic by the OILB scale (100% of growth inhibition) (Table 3), while the cuprous oxide, metalaxyl, zineb and mancozeb, were lightly toxic for the OILB scale, to manifest inhibition values between 34.3 and 69.4%, showing mancozeb had the lowest value and cuprous oxide the highest one.

Table 3: Toxicity classification of the fungicides on *Lecanicillium lecanii* at field doses.

Fungicides	Toxicity (OILB)	
	Growth inhibition	**Classification**
Difenoconazol	100	Toxic
Tebuconazol	100	Toxic
Cuprous oxide	69.4	Lightly Toxic
Mancozeb	34.3	Lightly Toxic
Metalaxyl	42.2	Lightly Toxic
Zineb	**49.8**	Lightly Toxic

The present results correspondend with those of Muiño *et al*., (1998) who classified difenoconazol as toxic on *L. lecanii*, according to the OILB scale, and metalaxyl as lightly toxic. These results differed with regard to zineb and mancozeb, which were classified as moderately toxic by them. These investigators didn't study tebuconazol and cuprous oxide, the first one belonging to the same group as difenoconazol and which was also classified as very toxic in the present study. Regarding the second, they studied from the same group copper oxicloruro, which was also lightly toxic. It should be pointed out that in spite of having obtained the same classification of toxicity cuprous oxide caused bigger growth inhibition at the field dose than mancozeb, metalaxyl and zineb.

As a consequence of the non growth of *L. lecanii* when exposed to difenoconazol and tebuconazol the spore production was nil at all the concentrations (Table 4). The fungus spore production at different concentrations of cuprous oxide diminished from the control (from 7.3 X 10^7 conidia/cm^2) to 2.7x10^7 for the smallest concentration 10 mg kg^{-1} and up to 2.2 x10^7 to 1000 mg kg^{-1}. At 2000 mg kg^{-1} the fungus grew very little and it did not produce conidia.

The spore production *in vitro* by the fungus exposed to varying metalaxyl concentrations diminished with regard from the control (7.2 x 10^7conidia/cm^2) to 4.0 X 10^7 for 100 mg kg^{-1} and 2.7 x 10^7 for 2000 mg kg^{-1}, while with mancozeb it diminished from the control (from 7.5x10^7 conidia/cm^2) to 5.5x10^7 to 10 mg kg^{-1} and of 2.3 x10^7 to 2000 mg kg^{-1}.

Table 4: Spore production by *L. lecanii* under exposure to varying concentrations of six fungicides for 10 days.

Fungicides		Concentrations					
	Control	**10 mg kg^{-1}**	**100 mg kg^{-1}**	**200 mg kg^{-1}**	**500 mg kg^{-1}**	**1000 mg kg^{-1}**	**2000 mg kg^{-1}**
Difenoconazol	7.2 x 10^7	0	0	0	0	0	0
Tebuconazol	7.2 x 10^7	0	0	0	0	0	0
C. oxide	7.3 x 10^7	2.7 x 10^7	1.7 x 10^7	1.9 x 10^7	2.3 x 10^7	2.2 x 10^7	0
Metalaxyl	7.2 x 10^7	5.3 x 10^7	4.0 x 10^7	3.8 x 10^7	2.6 x 10^7	2.9 x 10^7	2.7 x 10^7
Mancozeb	7.5x10^7	5.5x10^7	2.9x10^7	3.5x10^7	3.0x10^7	2.5x10^7	2.3x10^7
Zineb	7.5x10^7	3.9x10^7	3.5x10^7	3.5x10^7	3.4x10^7	3.3x10^7	3.3x10^7

Difenoconazol and tebuconazol were classified as very toxic according to the scale of compatibility (T value =0) (Table 5). The copper derived fungicide, cuprous oxide, was also very toxic, reaching a T value of 6.12, while zineb, mancozeb, and the metalaxyl were moderately toxic, presenting T values between 45.44 and 53.16.

Laureiro *et al.* (2002) obtained T values = 0 for tebuconazol, mancozeb and metalaxil so they classified those as being very toxic on *L. Lecanii*. However, the present results are different for the two last, although it is necessary to specify that these investigators used a different fungal isolated denominated "JAB 02". On the other hand it should be kept in mind that Tanzini *et al.* (2002) observed response completely different for two isolates of *Metarhizium anisopliae* (Metsch.) Sorok. using three insecticides.

Table 5: Classification of the compatibility of the fungicides with *Lecanicillium lecanii* at field doses.

Fungicides	**Compatibility (Alves *et al.*,1998)**	
	T Value	**Classification**
Difenoconazol	0	Very toxic
Tebuconazol	0	Very toxic
Oxido cuproso	6.12	Very toxic
Mancozeb	45.44	Moderately toxic
Metalaxyl	53.16	Moderately toxic
Zineb	**46.24**	Moderately toxic

Germination of the fungus conidia exposed to different difenoconazol and difenoconazol concentrations were not observed, while in the control treatment they manifested 100 % germination 24 hours later (Table 6). With cuprous oxide the conidia of the fungus manifested 100 % germination in the treatment of 10 mg kg^{-1}, the same as in the control, but they were observed to be completely atrophied in the rest of the concentrations, while the exposure to metalaxyl slowed the germination of the conidia of *L. lecanii* lightly in all the concentrations with respect to the control at the 16 hours of initiating the assay, nevertheless at the 24 hours 100 % of germination was reached in all treated media.

The mancozeb effect on the germination of *L. lecanii* was total starting 16 hours from initiating the assay, within a period of 24 hours, 0 % of germination was observed in the treated media, and 100% in the control. However with zineb the conidia germination was affected totally at the same concentrations or higher than 500 mg kg^{-1} at the 24 hours of initiating the assay, while it was observed until 26,9% of germination of the conidia at concentrations of 10, 100 and 200 mg kg^{-1}, which showed lesser effect of the zineb.

Table 6: Percentage conidia germination of *Lecanicillium lecanii* at different fungicide concentrations at 24 hours.

Fungicides		**Concentrations**					
	Control	**10 mg kg^{-1}**	**100 mg kg^{-1}**	**200 mg kg^{-1}**	**500 mg kg^{-1}**	**1000 mg kg^{-1}**	**2000 mg kg^{-1}**
Difenoconazol	100	0	0	0	0	0	0
Tebuconazol	100	0	0	0	0	0	0
Cuprous oxide	100	100	0	0	0	0	0
Metalaxyl	100	100	100	100	100	100	100

Mancozeb	100	0	0	0	0	0	0
Zineb	100	25	27	26.9	0	0	0

All the studied chemical fungicides manifested some toxicity on *L. lecanii*, which indicates that extreme care should be taken when applying fungicides in crops where treatments with this entomopathogenic fungi are being applied considering triazoles the most dangerous, followed by cuprous oxide.

Difenoconazol and tebuconazol were classified as toxic with the OILB scale (maximum level of the scale with 100% of inhibition of the growth) and very toxic according to the scale of compatibility (T value =0). However cuprous oxide was lightly toxic for the OILB scale and very toxic according to the compatibility scale, this is because the T value considers the effect on fungus spore production capacity, which was very strong in the case of this fungicide. The other three fungicides were classified as lightly toxic for the OILB scale and moderately toxic according to the T value. The discrepancy for cuprous oxide reinforces the necessity to calculate the T value since the same effect level was not always observed in the inhibition of the mycelial growth as well as the spore production intensity. The T value has been used in recent years to evaluate the effect of chemical pesticides on the entomopathogenic fungi e.g. Cavalcanti *et al.* (2002), Loureiro *et al.* (2002), Tanzini *et al.* (2002) and Andaló *et al.* (2004). On the other hand, metalaxyl, zineb and mancozeb were classified as lightly toxics by the OILB scale and moderately toxics for the T value, but those showed differences with regard to the conidia effect, the first one didn't affect the germination of the conidia, zineb only affected it partially at concentrations below 500 mg kg^{-1}, while mancozeb affected the conidia at all concentrations, though it affected the mycelial growth lesser.

Thus, in spite of the advantages of the T Value, it doesn't include the effect of the pesticides on the inhibition of the germination of the conidia; it had different behaviour for some fungicides that had similar effect on mycelial growth and the spore production. It is evident it is necessary to evaluate the viability of the conidia in studies of pesticide toxicity on entomopathogenic fungi, previously suggested by Loureiro *et al.* (2002).

Although these results allowed classifying the fungicides for their toxic effect on the fungus, more trials should be carried out under field consitions to verify the effect observed in vitro.

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Current status of Brucellosis and helminthosis in cattle and goats in the southwestern rangeland zone of Uganda

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ABSTRACT
Between July 2008 and September 2009, a cross-sectional study was undertaken with the main aim of establishing the current status of Brucellosis and Helminthosis in cattle and goats in the nine districts comprising the Southwestern Rangeland Zone (SWRZ) of Uganda. In this study, blood and faecal samples were collected from a total of randomly selected 912 cattle and 530 goats in the nine districts of Sembabule, Kiruhura, Rakai, Lyantonde, Isingiro, Mbarara, Bushenyi, Ntungamo and Ibanda. Serum was subsequently prepared from the blood samples and antibody titres for Brucellosis were established using the Indirect Enzyme Linked Immuno-sorbant Assay (ELISA) procedure. All the faecal samples were examined for Strongyle eggs using the standardized procedure of Mac-master technique. This study established that Kiruhura and Isingiro districts had the highest prevalence of cattle Brucellosis with sero-prevalences of 41% and 34%, respectively; and Ntungamo district had the lowest sero-prevalence of 5%. The sero-prevalence of Brucellosis in goats was highest in Rakai and Isingiro districts with sero-prevalences of 46% and 27%, respectively; and Ntungamo district had a sero-prevalence of 1.9%. Cattle and goats which were more than 24 months old had the highest sero-prevalence of at least 50%. Trichostrongylus, Strongyloides and Haemonchus eggs were the most commonly indentified, making these worm species the commonest cause of helminthosis which could be due to lack of host specificity. These findings are quite useful in the improvement of the strategies for the control of Brucellosis and Helminthosis in cattle and goats in SWRZ of Uganda.
Key words: Brucellosis, Helminthosis, Cattle, Goats, Rangeland

INTRODUCTION
Brucellosis is a contagious and zoonotic disease caused by *Brucella abortus*, characterized by abortion, metritis, orchitis and epididymitis (Henry, 1989) leading to impaired fertility in cattle. In goats the disease is caused by *Brucella melitensis*. Brucellosis is of public health importance in Uganda (Kabagambe *et al*., 2001; Faye *et al*., 2005) as a milk borne zoonosis. Contact with infected animals when aborting, vaginal discharges, placentae, consumption of unpasteurized milk and poorly processed contaminated animal products increase transmission of Brucellosis to humans (McDermott and Arimi, 2002). Poor milk hygiene, lack of awareness and traditional lifestyle are

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associated with high sero-prevalences of Brucellosis (Oloffs *et al.*, 1998). Farmers, abattoir and animal health workers are at high risk of occupational exposure to Brucellosis (McDermott and Arimi, 2002). Keeping livestock and lack of awareness about the mode of transmission of Brucellosis are major risk factors that lead to increased incidence of human Brucellosis (Kunda *et al.*, 2007). In the Southwestern rangeland zone, cattle and goats are reared both intensively under fenced farms and extensively under pastoral farming systems. These systems are the two major sources of milk in Uganda.

Effective Brucellosis control programmes are currently non - existent in Uganda, partly because of the cost associated with vaccination that discourages cattle owners from implementing vaccination, and the lack of information to guide targeting of vaccination taking into account the differences between production systems and the age categories at greatest risk of Brucellosis.

Helminthosis in livestock may not be easily detectable by farmers due to the sub-clinical or chronic nature of the infection (Urquhart *et al.*, 1996). Yet these sub-clinical parasitic infections are responsible for significant economic losses: they hinder proper growth and weight gains, and reduce reproductive rates. And yet by the time the clinical disease is noticed in an animal, much economic loss in terms of animal productivity will have already occurred (Kaplan, 2006; Tibbo *et al.*, 2006). Parasitic nematodes of domestic ruminants therefore pose great disease problems in grazing livestock. Therefore, it is important to establish the type and level of parasitism in ruminant livestock routinely in order to be able to determine the significance of parasitic infections and to recommend the most beneficial and economically acceptable control measures.

During the 2007/2008 financial year, national priority setting under the National Agricultural Research Organisation (NARO) ranked cattle and goats as the most important livestock enterprises in the Southwestern rangeland zone of Uganda, while Brucellosis and helminthosis were the most important diseases affecting these livestock species (NARO, 2007). It is against that background that this study was undertaken to establish the current status of Brucellosis and helminthosis in cattle and goats in the nine districts comprising the Southwestern rangeland zone of Uganda.

RESEARCH APPROACH

The cross-sectional study was carried out in the SWRZ of Uganda covering the nine districts of Mbarara, Ibanda, Kiruhura, Bushenyi, Ntungamo, Isingiro, Lyantonde, Rakai and Sembabule. The commonest cattle breeds in the zone are the longhorn Ankole, Boran, Zebu breeds and Friesian crosses. The Mubende, Small East African and Boer goat crosses are the most common goat breeds in the zone. Cattle and goats are reared both on fenced farms and under extensive and open grazing systems. Cattle and goats commonly share grazing grounds with wild ruminants such as the impala, zebra, buffaloes, antelopes of Lake Mburo National Park (LMNP), especially during the dry seasons in the districts of Mbarara, Kiruhura, Isingiro and Rakai. Cattle and goats reared under the open grazing system in the district of Sembabule also commonly share grazing ground with wild ruminants. Cattle and goats were randomly selected from both fenced farms and communally grazed herds/flocks. Only herds/flocks with no recent history of Brucellosis vaccination were selected for this study.

While cattle blood and faecal samples were obtained from all the nine districts, the goat blood and faecal samples were collected from only six districts of Bushenyi, Isingiro, Mbarara, Kiruhura, Ntungamo and Rakai. Animals were bled from the jugular vein using non-heparinised vacutainers (Becton-Dickinson, Vacutainer System, UK). Blood samples were transported in a cool box to the laboratory where they were kept at 4°C overnight before separation of sera. For each animal sampled, its breed, age group, gender, location, grazing management system and owner's name were recorded. Cattle were sub-divided in the age categories of 0–6 months, 7–12 months, 13–24 months

and >24 months. The goats were subdivided in the age categories of 0-12 months, 13-24months, and > 24months. A standard ELISA test for brucellosis was carried out to detect anti Brucella spp IgG antibodies in animals

Faecal samples were collected from each animal presented by the farmers at designated sites in the selected villages. For each faecal sample collected, similar epidemiological data were recorded as in the case of the blood samples. Faecal samples were examined for nematode eggs using the McMaster method accurate to 50 eggs per gram of faeces as described by Hansen and Perry (1994).

The data of antibody titres and eggs per gram (epg) were entered and stored in Microsoft Excel USA (2007) spreadsheets. Later, the calculated antibody titre means and epg were compared to establish the significant difference. The bar charts were constructed using the Microsoft Excel office software package.

FINDINGS

Based on ELISA, the sero-prevalence of cattle Brucellosis (Figure 1) revealed that Kiruhura and Isingiro districts had the highest cattle Brucellosis of 41% and 34%, respectively; and Ntungamo district had the lowest prevalence of 5%. It was also revealed that cattle Brucellosis was highest among the old age group of 12 -24 months (Figure 2). The sero-prevalence of Brucellosis in goats was highest in Rakai and Isingiro districts with 46% and 27%, respectively; and was lowest in Ntungamo district at 1.9%. (Table 1). The highest prevalence of Brucellosis in goats was recorded among the older goats of more than 24 months and the lowest of 9% was recorded among the young goats of less than one year (Figure 3).

Results from the faecal analysis of cattle samples revealed that the district of Isingiro had the highest prevalence of helminth infestations of 47.3% while Rakai had the lowest prevalence of 1% (Table 2). Looking at the different age groups, the youngest age group of 0-6 months had a prevalence of 5% and the older cattle of more than 24 months had a prevalence of 40% (Fig. 4). Results from faecal analysis of goat samples indicated that Mbarara and Kiruhura districts had the highest helminth infestation of 71.2% and 49.1%, respectively, while the goats of Ntungamo district had the lowest helminth infestation of 26.6% (Table 3). The age group of 0-12 months had a prevalence of 20.4% while the older age group of more than 24 months old had a prevalence of 49.3% (fig.5).

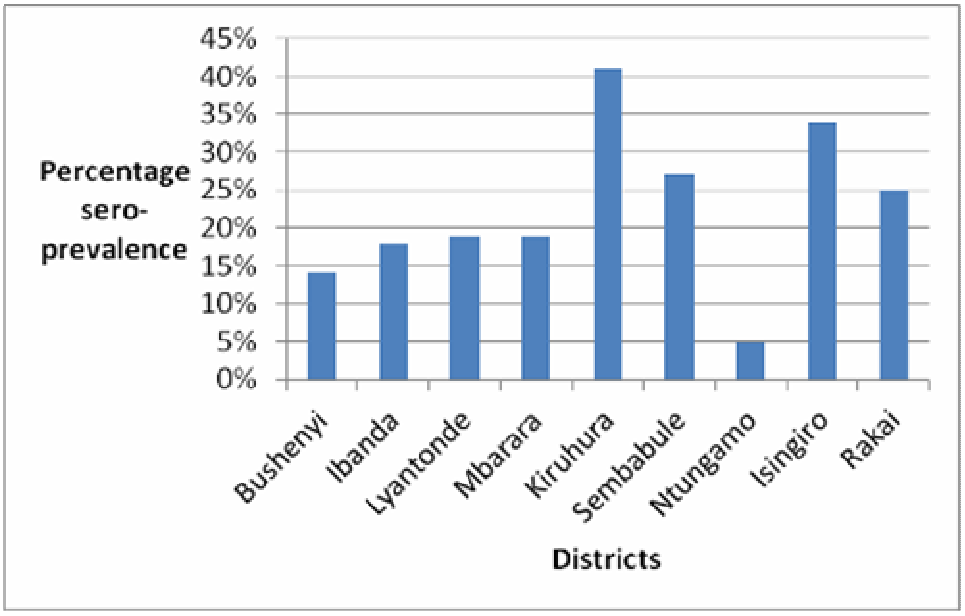

Figure 1: The percentage sero-prevalence of cattle Brucellosis in the nine districts of the South Western Rangeland Zone, Uganda.

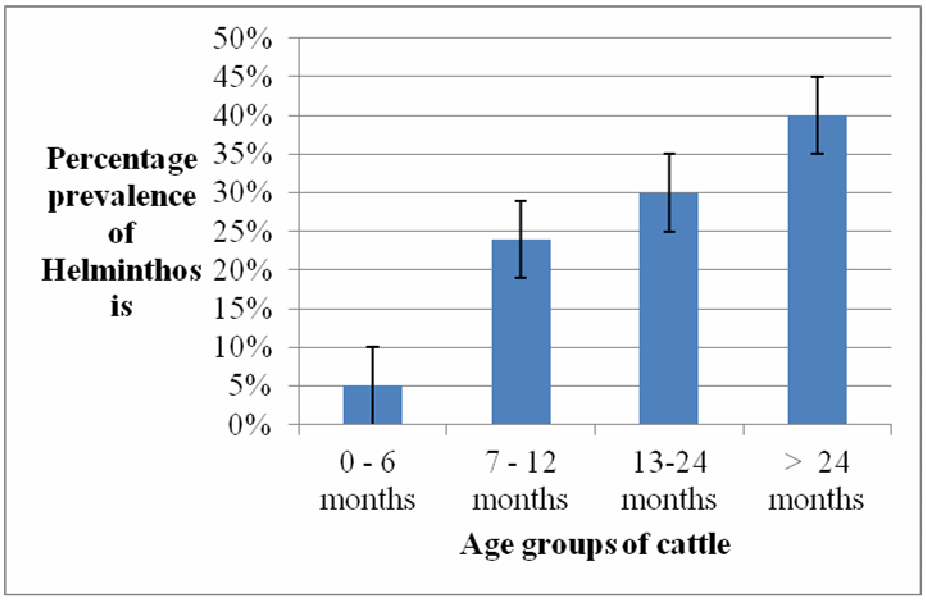

Figure 2: The prevalence of the cattle helminthosis among the different age groups.

Table 1: The sero-prevalence of goat Brucellosis in the South Western Rangeland Zone, Uganda.

Districts	Positives	Negatives	Total	Percentage sero-prevalence
Bushenyi	4	104	108	4
Isingiro	16	44	60	27
Mbarara	5	96	101	5
Kiruhura	8	89	97	8.2
Ntungamo	2	101	103	1.9
Rakai	47	55	102	46
Total	82	489	571	

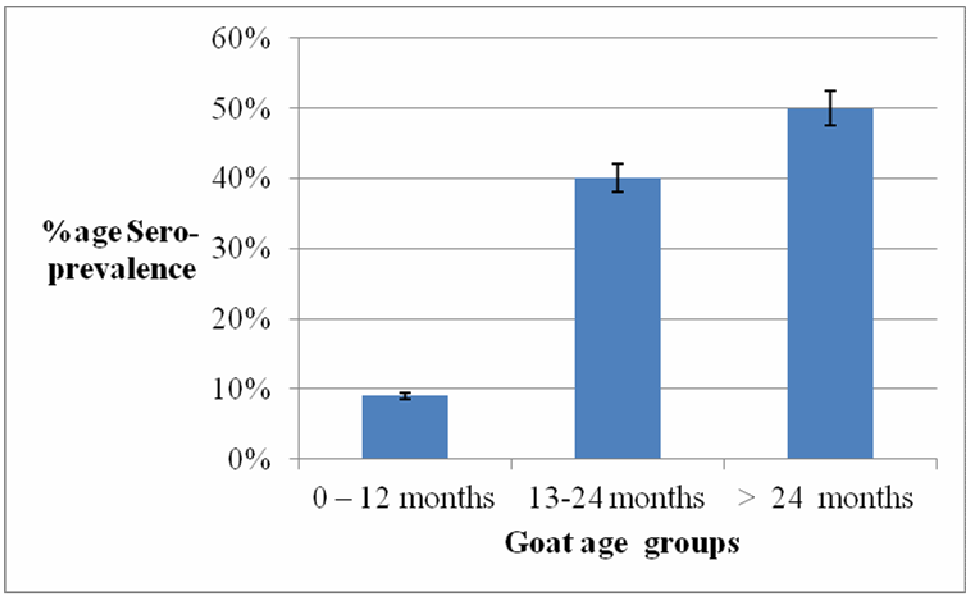

Figure 3: The Sero-prevalence of goat Brucellosis among the different age groups in the South Western Rangeland Zone, Uganda.

Table 2: The prevalence of cattle helminthosis in the South Western Rangeland Zone, Uganda.

Districts	Positive	Negative	Total	Percentage prevalence of helminthosis
Bushenyi	14	62	76	18.4
Ibanda	11	72	83	13.2
Lyantonde	2	54	56	3.5
Mbarara	5	93	98	5.1
Kiruhura	15	65	80	18.7
Sembabule	12	88	100	12
Ntungamo	8	67	75	10.6
Isingiro	44	49	93	47.3
Rakai	5	45	50	0.1
Total	116	595	711	

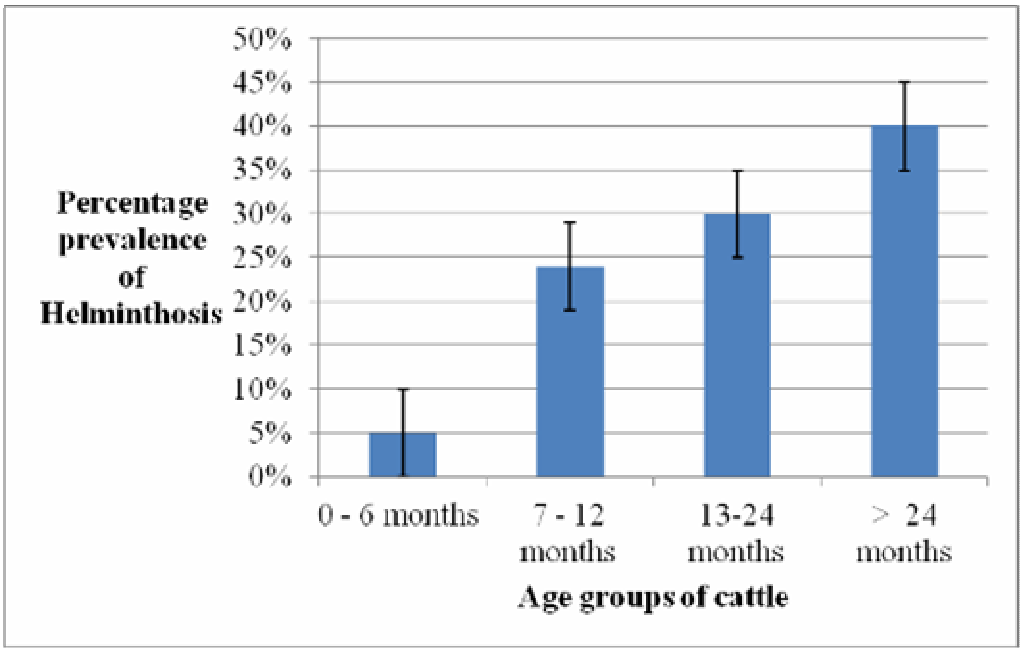

Figure 4: The prevalence of the cattle helminthosis among the different age groups.

Table 3: The prevalence of helminthosis in goats in the six districts of the South Western Rangeland Zone, Uganda.

Districts	Positive	Negative	Total	% prevalence of helminthosis
Bushenyi	39	53	92	42%
Isingiro	21	39	60	35%
Mbarara	77	31	108	71.2%
Kiruhura	59	61	120	49.1%
Ntungamo	32	88	120	26.6%
Rakai	55	65	120	45.8%
Total	**283**	**337**	**620**	

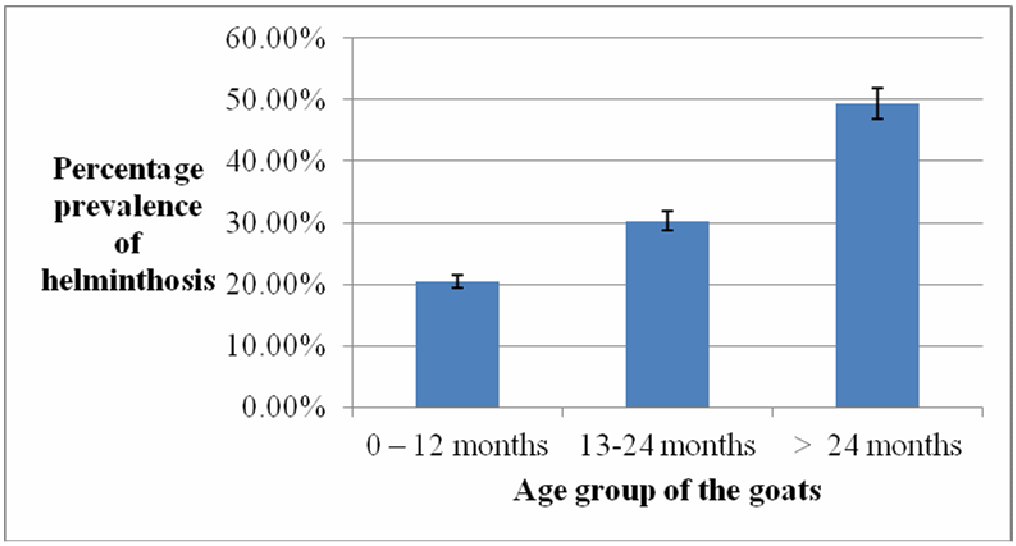

Figure 5: The percentage prevalence of goat helminthosis among the different age groups, Uganda.

DISCUSSION

The sero-prevalence of cattle Brucellosis (Figure 1) were highest in the districts of Kiruhura and Isingiro with 41% and 34%, respectively; and the lowest prevalence was in Ntungamo district at 5%. Kiruhura and Isingiro districts border Lake Mburo National Park, which is home to several ruminants and yet during the dry season domestic cattle commonly share grazing pasture. Isingiro further borders northern part of Tanzania which is also a game reserve. The source of infection is in most cases the contaminated pastures with infected afterbirths and dead foetuses. The results also revealed that cattle Brucellosis was highest among the old age group of 13 -24 months (Figure 2).

The prevalence of Brucellosis is seen to increase with the age, this is probably due to the reason that the older livestock move longer distances in search of pastures, thus increasing chances of contracting the disease from contaminated pastures. The older goats and cattle may also contract the disease during breeding with infected communally grazed males. The sero-prevalence of Brucellosis in goats was highest in Rakai and Isingiro districts with 46% and 27%, respectively; and lowest in Ntungamo with 1.9% (Table 1).

The prevalence of goat Brucellosis in Rakai is mainly due to the reason that the goats are more likely to feed on contaminated pastures due to open grazing system practised. Several farmers have been encouraged to start commercialized goat farming, but the source of new stock is never tested for Brucellosis before purchase. This may result in purchase of infected new stock onto the farm. The results have indicated that the prevalence of Brucellosis was highest among the older goats of more than 24 months old (Figure 3) whose source of infection is mainly consumption of contaminated pastures and from mating with communally-shared bucks.

Results of the analysis of faecal samples from cattle, indicated that Isingiro district had the highest prevalence of helminth infestations of 47.3% while Rakai had the lowest prevalence of 1% (Table 2). This is probably because the cattle are managed under the communal grazing system and continuously share grazing pastures with wild ruminants from the national park in Uganda and northern Tanzania. While in the different age groups, the youngest age group of 0-6 months had a prevalence of 5% and the older cattle of more than 24 months had a prevalence of 40% (Figure 4).

Results from the analysis of faecal samples from goats indicated that Mbarara and Kiruhura districts had the highest helminth infestation of 71.2% and 49.1%, respectively (Table 3). This is probably because goats are housed under a semi-intensive management system in these two districts. This may result into a high build up of worm burden due to poor hygienic conditions which favour the survival of the larvae. The age group of 0-12 months had a prevalence of 20.4% while the older age

group of more than 24 months old had a prevalence of 49.3% (Figure 5). This is mainly due to the fact the older goats are more likely to get infected as compared to the young age group (Magona and Musisi, 2002) as they move longer distances in search for grazing pastures.

Trichostrongylus, Strongyloides and Haemonchus eggs were the most commonly indentified, making these worms the commonest cause of helminthosis. This is because these parasitic helminths have a very wide host range and have a good ability to survive unfavourable conditions compared to other genera (Anderson and Levine, 1968).

CONCLUSIONS AND RECOMMENDATIONS

- Attempts to control Brucellosis and helminthosis should target young stock**.** While older cattle and goats more than 24 months old should be culled since they are capable of releasing the brucella organisms at parturition and abortion.
- Farmers should be advised to avoid purchasing cattle and goats more than 24 months old, since these are usually chronic carriers.
- Farmers should be encouraged to always carry out Rose Bengal tests on new stock to avoid importing the disease into their farm or herd.
- Good stocking rates and provision of adequate pasture should be observed.
- Proper and hygienic disposal of afterbirths and aborted calves should be strictly adhered to.
- Efforts should be made to protect livestock by reducing contact especially in grazing with the potential wild game by good fencing and paddocking practices.
- Supplying wild game with antihelmintic treatment incorporated in mineral blocks distributed at water points should be encouraged.

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Ethnobotanical survey and propagation of some endangered medicinal plants from South Nandi district of Kenya

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ABSTRACT

Studies were conducted at Maseno University, Kenya to investigate the ethnobotanical and chemical characterization of selected medicinal plants growing in South Nandi District in the year 2004 and 2005. Subsequently, propagation studies were carried out on the identified endangered medicinal plants. Local communities who use medicinal plants were interviewed. Ethnobotanical data on families, plant species, botanical name, local name, part(s) used, popular ethnobotanical medicinal use, forms of preparation and applications of the herbal remedies were collected. Plants were collected, pressed, dried, preserved, mounted and identified through available literature and voucher specimens at the University of Nairobi and National Museum Laboratories. From the surveys carried out it was observed that the endangered plants were *Asystasia schimperi, Carissa edulis, Toddalia asiatica*. These were propagated using stem cuttings subjected to different concentrations of auxin in a polypropagator in a compeletely randomised design experiment. It was found that as auxin concentration increased from 100 to 500 ppm, there was increase in rooting and growth in the decreasing order of *Asystasia schimperi, Carissa edulis and T. asiastica*. The treated cuttings were planted in polythene pots which were placed in a non-mist propagator. The duration of the experiment on propagation was four months and the data taken were number of rooted plants, plant height, and number of leaves. The data on propagation was subjected to analysis of variance and Least Significant Difference (LSD) at $P \leq 0.05$ used for separation of means. The results showed that hormone concentration, species and date of sampling significantly ($P \leq 0.05$) affected the number of leaves, plant height and number of rooted cuttings. *A. schimperi* had the best rooting and subsequent growth followed by *Carissa edulis* and lastly *Toddalia asiastica*.It is concluded that *Asystasia schimperi* and *C. edulis* can be easily propagated by stem cuttings hence has good opportunities of being introduced to the farmers of South Nandi District.

KEY WORDS:

Ethnobotanical, Endangered, Medicinal, Vegetative Propagation, Auxin.

INTRODUCTION

[12] In: Contributions of agricultural sciences towards achieving the Millenium Development Goals. F*a*CT Publishing, Nairobi. 175 pp. Mwangi, M. (Ed.) ISBN: 978 9966 7415 2 6. Published online at http://www.m.elewa.org

Man uses plants in many different ways to meet his basic needs. These include food, clothing and shelter. Wild plants supply medicine, crafts and cosmetics to rural and urban areas. In addition, they are sources of income and employment to the rural areas (Balick *et al.,* 1996; Karori, 2003; Olembo *et al.,* 1995; Kokwaro, 1976 and 1993). Important herbal products are spices, herbal teas, functional food ingredients, medicinal raw materials, aromatic plants, essential oils, flavouring, fragrant products and dietary supplements. Plants have also been used as medicine for thousands of years by people all over the world. WHO estimates indicate that 80% of the population (mostly in developing countries still relies on plant-based medicines for primary care.

In Kenya the role of plants as sources of herbal products has been recognized and as scientific knowledge on the medicinal values of indigenous plants increases (Rukangira, 2001), there is a proportional increase in demand for herbal products both locally and internationally. The demand for herbal products is caused by population increase, poverty, increasing awareness of herbal products, high cost of modern medicine and limited access to trained doctors. It is estimated that about 80% of the rural dwellers get treatment from traditional healers according to the 1978 World Health Organization report. About 80% of the African populations rely on traditional medicine for primary health care (Karori, 2003). Further, during periods of food scarcity in the dry areas of Kenya or during famines the poor rural communities harvest wild plants, including fruits and leaves for food (Elizabetsky, 1991). The type of plants and parts removed vary from one locality to another and their use depends on the local indigenous knowledge and experience accumulated over countries.

Due to high human population growth in South Nandi District (G.O.K., 2002) demand for indigenous tree products is increasing and some of the important plants have been over-harvested reducing the inventory of those wild resources (G.O.K., 1993). Deforestation caused by the need for human settlement and allied infrastructure development and cultural expansion, charcoal production, timber sales and overgrazing have further caused the shortage of herbal plants (Biketi, 2001). Deforestation directly reduces the biodiversity of wild plant resources and indirectly so through the loss of the habitat areas as well as other organisms important for ecosystem function (Repetto, 1989).

Demand for herbal products however, is on the increase, exerting a lot of pressure on the remaining indigenous medicinal plants. This calls for the need to devise strategies to increase the supply of these resources as well as protecting the source habitats. This could be achieved through practicing sustainable harvesting techniques and also by raising selected plant species either i*n situ* or *ex situ. In situ* conservation through encouraging natural regeneration or enrichment planting has the advantage that plants are already adapted to the environment (Cunningham, 1997, UNESCO, 1997). However, it may not be possible to raise sufficient materials *in situ* and domestication of indigenous plants *ex situ* has not been widely practiced for various reasons including the assumption that supply from the wild would be insufficient and therefore no incentive to domesticate (Cunningham, 1990, 1993). As the exploitation pressure mounts and the potential for earning high prices from the wild herbal resources increase the need for domestication is urgent hence the purpose of the present study on propagation techniques to increase the supply of medicinal herbal products.

Although many studies concerning the use of medicinal plants in Kenya have been carried out targeting the different groups / tribes and localities (Heriz, 1962, Masinde, 1996, Njoroge, 2006 and 1994, Johns, 1990, Stiles *et al*, 1999, Omino *et al*., 1991, Maundu *et al*, 1991) the ethnobotany of South Nandi is scarcely known and so are the propagation techniques to be used to ensure sustainable production of the endangered medicinal plants. Thus the main objective of this study was to carry out an ethnobotanical survey and propagation of some endangered medicinal plants used in South Nandi district, Kenya.

RESEARCH APPROACH

A total of 60 practitioners were interviewed who depend on wild plants as sources of medicine. Some 50% of the participants were renowned herbalists (30 years and above). They were selected using purposive random sampling and interviewed using semi-structured questionnaire. The plants cited were collected, identified at the Department of Botany University of Nairobi and authenticated at East Africa Herbaria and the voucher specimens were deposited in the Botanical Garden herbarium of Maseno University.

The endangered plants namely: *Carrisa edulis* (M_1), *Asystasia schimperi* (M_2) and *Toddalia asiatica* (M_3) were propagated at the Botanic Garden of Maseno University, Kenya in a non-mist polypropagator and later transplanted for *ex situ* conservation and eventual dissemination to the local communities, at the same place. Juvenile stem cuttings were harvested from different medicinal plant species from the wild in South Nandi district and transported to Maseno University where they were kept in a refrigerator. One to four node cuttings were used depending on species (about 50 - 60mm long) to facilitate handling and with a leaf area of about $50cm^2$. In large leaved species, leaf areas were reduced by trimming prior to severance to reduce water loss and to allow photosynthesis to take place. The basal end of the cuttings were cut at right angles and treated with different hormone concentrations before being planted into the media. It was dipped 12 hours in root hormone – S solutions (0.3% IBA) to a depth of about 2.5mm before they were planted in a non-mist propagator. The IBA formulation was prepared in liquid form using one litre of distilled water and standard chemical methods used to calculate the different hormone concentrations to be used for the study. To minimize stress, the cuttings were inserted in the non-mist polypropagator as soon as they were dry.

The plant cuttings were then planted in polythene tubes (17cm by 16cm) filled with a mixture of sterilized forests and sandy soils (50:50). An American electric pressure steam sterilizer (Model No. 25) was used at 250^0F. The media was removed and spread to cool for two hours then transported to the experimental site where the cuttings were planted erect. After planting, the cuttings were watered using a watering can and subsequently twice a day (morning and evening).

A biweekly assessment was carried out on the cuttings starting two weeks after planting. At each assessment, the number of leaves and heights were recorded on a tagged plant until the end of the experiment. Also the number of plants rooted in each pot was recorded. Temperatures and humidity values were also taken twice a day (morning and evening) using a wet and dry thermometer. In all instances the propagator temperature was between 22 – 27^0C. Three plant species with growth hormones at different concentration level (0ppm, 100ppm, 200ppm, 300ppm, 400ppm, 500pp) were used in a completely randomized design (CRD) with factorial arrangement. The treatments were replicated three times.

The non-mist propagator used is based on that of Howland (1975), modified by Leakey and Longman (1988) and modified further so that it does not require daily watering. It comprises a wooden frame enclosed in clear polythene so that the base is water tight (Leakey, 1989). The frame also provides support for the enclosed volume of water. The polythene base of the propagator is covered in a thin layer of sand to prevent the polythene from being punctured by the large stones (6 – 10cm), which are placed to a depth of 10 – 15cm to a total depth of 20cm. The gravel provides support for the rooting medium, which is the upper most layers, while the spaces between the stones are filled with water (Leakey, 1990). The rest of the frame is covered tightly with a single piece of clear polythene and a closely fitting lid is attached.

RESULTS AND DISCUSSIONS

Information was obtained on therapeutic uses of 152 plant species in 57 families (Table 1). The commonly utilized taxonomic families for herbal medicine are Compositae (12.5%), Leguminosae

(7%), Lebiatae (6.5%), Acanthaceae (5.2%), Euphobiacease (5.9%), Solanaceae (3.2%) and Rabiaceae (3.2%) (Table 1 and table 2). This may be a reflection of the high number of species found in these families worldwide; Asteraceae 19, 085, Papilionaceae 12,615, Lamiaceae 6,970 and Solanaceae 2, 900 (Masinde, 1996). This implies that they are the most widely available plants in the biodiversity and it is indicative of the richness of medicinal flora. This supports the need for further exploitation of the area in this regard.

Table 2: Diversity of medicinal plant species in South Nandi District, Kenya**.**

Plant Families	Number of medicinal plant species	Percentage of total species mentioned as medicine.
Acanthaceae	8	5.2
Amaranthaceae	4	2.6
Anacardiaceae	2	1.3
Aloaceae/Liliaceae	1	0.6
Araceae	1	0.6
Araliaceae	1	0.6
Asclepiadaceae	**2**	1.3
Aspiadiaceae	1	0.6
Apocynaceae	4	2.6
Asparagaceae/Liliaceae	1	0.6
Basellaceae	1	0.6
Bignonaceae	2	1.3
Boraginaceae	1	0.6
Campanulaceae	1	0.6
Cyperaceae	1	0.6
Canellaceae	1	0.6
Compositae/Asteraceae	19	12.5
Capparadiceae/Capparaceae	2	1.3
Crassulaceae	1	0.6
Cucurbitaceae	5	3.2
Verbenaceae	1	0.6
Euphorbiaceae	9	5.9
Flacourtiaceae	4	2.6
Gramineae	3	1.9
Guttiferae	1	0.6
Labiatae/Lamiaceae	10	6.5
Leguminosae subfam. Papilionoideae	5	3.2
Leguminosae subfam. Caesalpinioideae	1	0.6
Leguminosae subfam. Mimosoideae	5	3.2
Myrtaceae	1	0.6
Meliaceae	2	1.3

Myrsinaceae	2	1.3
Moraceae	3	1.9
Musaceae	1	0.6
Table 2: continued		
Plant Families	Number of medicinal plant species	Percentage of total species mentioned as medicine.
Malvaceae	5	3.2
Melianthaceae	1	0.6
Melastomataceae	1	0.6
Menispermaceae	1	0.6
Oleaceae	1	0.6
Oxalidaceae	2	1.3
Polygonaceae	2	1.3
Phytolacaceae	1	0.6
Passifloraceae	1	0.6
Proteaceae	1	0.6
Rutaceae	**3**	1.9
Ranunculaceae	**1**	0.6
Rhamnaceae	1	0.6
Rosaceae	3	1.9
Rubiaceae	**5**	3.2
Solanaceae	5	3.2
Sapotaceae	1	0.6
Sterculiaceae	1	0.6
Tiliaceae	1	0.6
Umbelliferae	2	1.3
Urticaceae	2	1.3
Vitaceae	1	0.6
Verbenaceae	4	2.6
TOTAL = 57	**152**	**100**

Table 3: Plant parts utilized in herbal medicines in south Nandi, Kenya.

PART UTILIZED	FREQUENCY	PERCENTAGE (%)
Roots	38	25.00
Leaves	32	21.05
Root/ leaves	31	20.39
Root /bark	14	9.21
Bark	10	6.58
Seeds	8	5.26
Whole plant	7	4.61

Bark/leave	3	1.97
Flowers	3	1.97
Fruit	2	1.32
Bulb	2	1.32
Sap/latex	2	1.32
Total	**152**	**100**

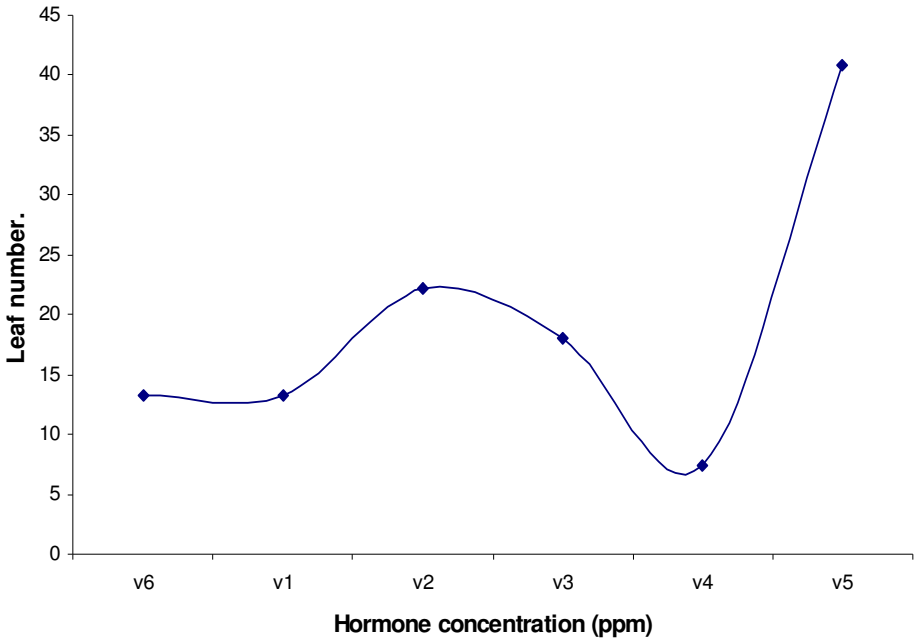

Fig: Effect of hormone concentration on number of leaves.

Rooting percentage, number of leaves and plant height varied according to species, hormone concentration and tiem of assessment (data not shown).

As would be expected, medicinal plant species in this region is dominated by shrubs, contributing 35.526% (54 species), while herbs contribute 33.553 %(51 species), trees 19.737 %(30 species) and lianas 11.184% (17 species) (Table 1). This may be attributed to the high levels of destruction of trees for timber and due to over-grazing and over exploitation of the forests trees resulting in the low numbers of trees and lianas.

Although most plant parts were utilized for the preparation of herbal remedies in this area, majority of the medicines were obtained from the roots (25%) followed by leaves and bark (Table 3). Except where the drugs are obtained from leaves, the use of bark, roots or uprooting the whole plant of a given species was found to be a destructive way of obtaining the herbal remedies. These unfavorable extraction methods contribute to the loss of the forest trees.

Most methods of extraction of the active ingredients require crushing of the plant tissue and homogenizing with water and boiled in water to improve extraction. Application of crushed plant tissue without water is used but is not common.

Comparison of the folk phytotherapeutical data in our study with data from other research has revealed the new medicinal uses of known medicinal plants. For example, *Datura stramonium* was reported for the first time in the treatment of madness. In addition, new medicinal uses of *Ehretia*

cymosia and *Conyza subscaposa* species have also been reported in this study. It has also concurred with many previous researches about the medicinal uses of several species for instance *Carissa edulis, Toddalia asiatica and Prunus africana* (Kokwaro, 1976; Begum *et al*, 2000). *Trimeria grandifolia, Fuerstia africana* and *Pentas longiflora* were reported to be used as antimalarials and antiseptics.

The most frequently used preparation for drug methods were concoction and decoction. Use of concoctions suggests that the drugs may only be active in combination, due to synergistic effects of several compounds that are active singly (Gessler *et al*., 1994). It is possible that some of the compounds that are active *in vitro* could exhibit activity in *vivo* due to enzyme catalysed transformation into potent derivatives and therefore are playing the role of prodrugs. This phenomenon has been demonstrated for *A. indica* extracts (Parida *et al., 2002*). The use of more than one plant especially for the bitter remedies may be to neutralize any poison (antidote). Most herbalists claimed to administer remedies for malaria, cough and cold, pneumonia and other respiratory diseases (Table 1). These were reported as the most prevalent diseases, which have high morbidity rates, and this concurs with previous report (GoK, 1997- 2001). The disease incidence may be due to cold temperatures because of high rainfall and consumption of untreated water. Other diseases mentioned to be common include; skin diseases, intestinal worms, rheumatism and HIV/Aids.

The herbal remedies preparations were evidently prepared by different methods. These included decoctions, infusion, poultices, roasting, concoctions, paste, pomades, ointment of ghee and powder (ash). Preparation of compounds from dry parts of one plant or several plant drugs and ashes was done using grinding stones. Burning, chewing, heating/roasting, pounding, and boiling or soaking in hot or cold water and milk and various other solvents is common like honey and this way, orally administered. This may be because the mode is convenient. Preparations for application to the skin such as ointments, liniments, foam to lotion, and baths, etc was also encountered. Application is frequently precutanaeous, by rubbing or covering (including poultices, by washing or baths, occasionally complimented by massage.

Most methods of extraction of the active ingredients require crushing of the plant tissue and homogenising with water. Tissues are also boiled in water to improve extraction. Application of crushed plant juice without water is used but not common. Chewing plant tissue directly is one of the methods not commonly used.

The results of the present studies show that auxin promote the rooting of stem cuttings of the three medicinal plant species tested. Several workers have reported promotion of rooting by auxins in other plant species (Hartmann, *et al*., 2001; Leakey *et a*l., 1982; Hartmann *et al*., 1990, Aminah *et al*., 1995, Tchoundjeu and Leakey, 1996; Haissing and Davies, 1994; Copes and Mandel, 2000). The results also indicate that species M_1, M_2 and M_3 have different ranges of effective auxin concentration with the latter two having broader ranges than M_1. This agrees with Leakey (1990) who reported that increase in auxin concentration increases rooting as in this study and that auxin or IBA has a broad range of activity. The results indicate a need for research to determine the specific requirements of each plant species.

CONCLUSION

The ethnobotanical survey revealed 152 medicinal species in 57 families. Two new medicinal species and three new uses of already recorded medicinal species were recorded for the first time. This reinforces the importance of these types of ethnobotanic surveys. On propagation it can be concluded that Indole Butyric Acid (IBA) can be used to root the stem cuttings of the plant species at concentration from 100ppm to 400ppm. It can also be concluded that the non-mist polypropagator is a suitable technology that can be used to propagate medicinal plant species because it promotes good rooting and it can be constructed from available and affordable materials.

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Table 1. Medicinal plants used in Aldai Division of South Nandi District, Kenya

LOCAL NAME	SPECIFIC NAME	FAMILY	HABIT	PARTS USED	PREPARATIONS	AILMENTS TREATED/ USES
Chemurguiwet	*Asystasia schimperi* T.Anders	Acanthaceae	Herb	Leaf	Infusion (internal)	Cough, skin diseases
Chemurguiwetab Suswek	*Dyschoriste radicans* Nees	Acanthaceae	Herb	Leaves	Infusion (internal & external)	Skin diseases, wounds, eye infections
Nyamdutiet	*Lepidagathis scariosa* Nees.	Acanthaceae	Herb	Leave	Infusion (internal)	Antidiarrhoea, wounds, `mireiwek', oedema, foot &mouth in livestock, pneumonia
Cheperenet	*Barleria grandicalyx* Lindau	Acanthaceae	Herb	Leaves	Paste (external)	Snake bites
Cheptereret	*Thunbergia alata* Sims	Acanthaceae	Herb	Leaves	Infusion (internal & external)	Cough,`mireiwek',fopetus placement in the womb, backache
Kipkesio	*Justicia betonica* L	Acanthaceae	Herb	Leaves, flower	Ash (internal)	Cough, anti-diarrhoea, orchitis
Ndakariat	*Acanthus pubescens* (Oliv.) Engl	Acanthaceae	Shrub	Leaves	Ash (internal)	Dry cough, pneumonia, chronic asthma, cancer, tonsils, flu,`mireiwek'
Rokorabchepkimis/ Chepyochoit	*Justicia flava* Vahl	Acanthaceae	Herb	Leave	Ash (infusion)	Soccery, charms, ulcers, pneumonia
Tangaratwet	*Aloe kedongensis* Reynolds	Aloeaceae	Shrub	Leaves, roots	Infusion (internal & external)	Typhoid, skin diseases, malaria, colds, ear problems, wounds, coccidiosis
Chesirimiot/Chesirimto	*Achyranthes aspera* L.	Amaranthaceae	Herb	Root	Ash (internal)	Cough
Mbogiat	*Amaranthus graecizans* L	Amaranthaceae	Herb	Leaves	Paste (external)	Cancer, boils
Namgwet	*Cyathula schimperiana* non Moq	Amaranthaceae	Herb	Leaves, roots	Decoction (internal)	Malaria, antidiarrhoea, fungal infections
Ng'atumyat	*Cyathula cylindrica* Moq	Amaranthaceae	Herb	Root	Decoction (internal)	Malaria, purgative, emetic
Kipng'etingwet	*Lannea schimperi* (A. Rich.) Engl.	Anacardiaceae	Tree	Bark	Decoction (internal)	Diarrhoea, pain stomach, chest problems
Siriat	*Rhus natalensis* Krauss	Anacardiaceae	Tree	Roots	Decoction (internal)	Venereal diseases, heartburn, abdominal pains, cold, cough, antidiarrhoea
Keliot	*Acokanthera*	Apocynaceae	Shrub	Roots	Decoction (internal)	Venereal diseases (syphilis)

	schimperi (A.DC.) Schweinf.					
LEGETETIOT/Tamuryekiat	*Carissa edulis.* (Forsk.) Vahl.	Apocynaceae	Shrub	Roots	Decoction (internal)	Venereal diseases, epilepsy, malaria, heartburns, arthritis, sorcery, cancer,
						Typhoid, pneumonia, cough, ulcers, antidiarrhoea
Mabondet	*Tabernaemontana stapfiana* Britten	Apocynaceae	Tree	Roots, bark	Decoction (internal)	Pneumonia, chest problems, aids in delivery
Nyakinchwet	*Landolphia buchananii*	Apocynaceae	Shrub	Leaves	Infusion (external)	Wounds, gonorrhoea, molluscides
Chepnamobon/Kipnamobon	*Culcasia falcifolia* Engl.	Araceae	Liana/climber	Leaves	Ash (internal)	Dry cough, ECF, oedema, epilepsy
Soiyet	*Polyscias fulva* (Hiern) Harms	Araliaceae	Tree	Bark	Decoction (internal)	Obesity
Simatwet	*Curroria volubilis* (Schltr.) Bullock	Asclepiadaceae	Liana/climber	Bark	Decoction (internal)	aid in delivery, malaria
Sinendet	*Periploca linearifolia* Dill. & Rich	Asclepiadaceae	Liana/climber	Roots, milky latex	Decoction (internal) & exudates (external)	Venereal diseases, warts, rituals, pneumonia, cancer, antidiarrhoea, fertility
Tilalwet	*Pteridium aquilinum* (L.) Kuhn Bracken	Aspidiaceae	Shrub	Leave shoots	Infusion (external)	Skin diseases
Nderemiat	*Basella alba* L.	Basellaceae	Liana/climber	Root, leaves	Decoction (internal)	Removal of after birth, vegetable, stomach pains, increase milk production
Ratinuet	*Kigelia africana* (Lam.) Benth.	Bignoniaceae	Tree	Bark, seed, root	Decoction (internal)	Skin diseases, ulcers, diabetes, purgative, diarrhoea
Sebetaiyat	*Spathodea campanulata* P. Beauv	Bignoniaceae	Tree	Sap	Infusion (internal)	Colds in children
Mororwet	*Ehretia cymosa* Thonn	Boraginaceae	Shrub	Leaves, roots	Infusion (internal)	Venereal diseases, pneumonia, epilepsy, dry cough, malaria, ECF, tonsils, mental problems, withcraft, asthma, typhoid, wounds, aphrodisiac
Senetwet	*Cassia didymobotrya* Fres.	Caesalpinioideae	Shrub	Leaves, roots	Infusion (internal)	Cancer purgative, skin diseases, malaria, gonorrhea, ring worms, emetic, eccess bile
Masiririet	*Plantago palmate*	Campanulaceae	Herb	Roots	Decoction (internal)	Tonsils, pneumonia, eye problems,

	Hoof.					venereal diseases, typhoid, antidiarrhorea
Soget	*Warburgia ugandensis* Sprague	Canellaceae	Tree	Bark	Decoction (internal)	Pneumonia, tonsils, uvala problems, stomachache, constipation, fever
Isakiat	*Cleome gynandra* L	Capparidaceae	Herb	Leaves, roots	Decoction (internal)	Vegetable, malaria, facilitates &removes afterbirth, stomach congestion
Chebara/ Chebartet	*Sonchus aspera* (L.) Hill	Compositae	Herb	Bulb	Juice (internal)	Tonsils, cough, `mireiwek'
Chemamaiyat	*Senecio discifolius* Oliv.	Compositae	Herb	Leaves	Infusion (internal)	Chronic asthma, eye infection, ring worm
Chepilibiliotab Oinet	*Chrysanthemum americanum* (L.) Vatke	Compositae	Herb	Whole plant	Ash infusion (internal)	Dry cough
Chepkurbet	*Solanecio mannii* (Hoof.f.) C.Jeffrey	Compositae	Tree	Roots	Decoction (internal)	Cancer, pneumonia, cough, epilepsy, typhoid
Chepng'ombet	*Conyza subscaposa* O.Hoffm.	Compositae	Herb	Root, leaves	Decoction (internal)	Obesity, breast cancer, tonsils
Chepnyosoret	*Tagetes minuta* L	Compositae	Herb	Leaves	Ash (external)	Insecticide, wounds, ulcers
Katabelelyat	*Berkheya spekeana* Oliv.	Compositae	Shrub	Leaves, flower	Ash (internal)	Chest problems, chronic asthma, cough/cold, pneumonia, edema
Kimogit	*Sonchus oleraceus* L.	Compositae	Herb	Leave	Infusion (internal)	Prolong virility of gentlemen, impotency
Kimogit	*Sonchus luxurians* (R.E.Fries) C.Jeffrey	Compositae	Herb	Root	Decoction (internal)	Tonsils, stomach upsets, fever
Kipkoleitet	*Bidens pilosa* L	Compositae	Herb	Roots, leaves	Infusion (internal)	Epilepsy, spinal cord, ear and eye problems, wounds, stomach-ache, heart burns
Namkechir	*Ageratum conyzoides* L	Compositae	Herb	Bark, leaves	Ash (external)	Wounds, stops bleeding in cuts
Ng'osng'osiat	*Conyza stricta* H.B.K	Compositae	Herb	Leaves, roots	Infusion (internal)	Dry cough, tonsils, uvala problems, toothache, sore throat
Pilipiliotab Oinet	*Gutenbergia cordifolia* Oliv.	Compositae	Herb	Seeds	Decoction (internal)	Stomachache
Putputik	*Spilanthes mauritiana* (A. Rich.) DC	Compositae	Herb	Flower, leave	Infusion (internal)	Venereal diseases, cough, mouth problems, antidiarrhoea, toothache,

						ear ailments, insect repelant
Rirmosok / Nanwaket	*Microglossa pyrifolia* (Lam.) O.Kuntze	Compositae	Shrub	Roots, root	Decoction (internal)	Arthritis, skin diseases, cough, cancer, malaria
Sergutiet	*Vernonia hymenolepis* A. Rich	Compositae	Shrub	Leave, flower	Paste (external)	Wounds
Chepchego	*Piloselloides hirsuta* (Forsk.) C.jeffry	Compositae	Herb	Bark, roots	Decoction (internal)	Typhoid, cancer
Tabkwei	*Dichrocephala integrifolia* O.Kuntze	Compositae	Herb	Leaves	Decoction (external0	Skin rashes
Tebeng'wet	*Vernonia auriculifera* (Welw.)Hiern	Compositae	Shrub	Root, leaves	Decoction (internal)	Pneumonia, cough, tonsils, pregnancy, anti-diarrhoea, footrot in people, fever
Kuserwet/Chebibi	*Kalanchoe lanceolata* (Forsk.)Pers.	Crassulaceae	Herb	Leaves	Infusion (internal)	Rheumatism, stiff joints
Chebololet	*Cucurbita maxima* Duchesne ex Lam	Cucurbitaceae	Liana/climber	Seeds	Decoction (internal)	Deworming
Sumet	*Cucumis ficifolius* A. Rich	Cucurbitaceae	Liana/climber	Whole plant	Paste (external)	Ring worms, bruises, sprains
Cheptenderet	*Momordica foetida* Schumach	Cucurbitaceae	Liana/climber	Leaves, roots	Decoction (internal)	Chronic asthma, ear problems, soccery, athritis, burns, stomachache, fever, cuts, measles, intestinal worms, poultry fever, malaria
Manereriat/Kimanererit	*Zehneria minutiflora (Cogn.) C.Jeffrey*	Cucurbitaceae	Liana/climber	Roots, leaves	Decoction (internal)	Malaria, eye and ear problems, dry cough, ECF
Silakwet	*Lagenaria siceraria* (Molina) Stanley	Cucurbitaceae	Liana/climber	Seed	Decoction (internal)	Purgative
Burburetiet	*Kyllinga erecta* Schum.	Cyperraceae	Herb	Root	Decoction (internal)	Fungal infection (-ring worms)
Usuet	*Euclea divinorum* Hiern	Ebenaceae	Tree	Roots, bark	Decoction (internal), tooth brush	Deworming, malaria, chest pains, purgative, toothache, stomachache, purgative
Chemelet	*Tragia brevipes* Pax	Euphorbiaceae	Liana/climber	Leaves, roots	Ash (internal)	Dry cough, obesity, enhance virility, rituals, rheumatism, purgative
Imaniat	*Ricinus communis* L	Euphorbiaceae	Shrub	Roots, seeds	Decoction (internal)	Venereal diseases, enhances fertility, contraceptives, typhoid, malaria
Kulelwet	*Croton dichogamus* Pax.	Euphorbiaceae	Shrub	Whole plant	Decoction (internal)	Chest problems, malaria, typhoid, pneumonia, toothache, arthritis

KURMENYAT/ Turmenyat	*Clutia abyssinica* Jaub. & Spach	Euphorbiaceae	Shrub	Roots, leaves	Decoction (internal)	Venereal and skin diseases, chest problems, cancer, fertility in both humans
						And cattle, pneumonia, witchcraft, cough, jaundice, malaria cancer, athritis
Masineitet	*Croton megalocarpus* Hutch.	Euphorbiaceae	Tree	Bark	Decoction (internal)	Arthritis, whooping cough, intesinal worms
Tebeswet	*Croton macrostachyus* Del.	Euphorbiaceae	Tree	Roots, leaves	Decoction (internal)	Pneumonia, backache, cancer, dry cough, obesity, malaria, skin diseases,
						E.C.F, typhoid, sorcery, purgative
Chemagaldet	*Bridelia micrantha* (Hochst.)Baill.	Eurphorbiaceae	Tree	Bark	Decoction (internal)	E.C.F, joint ailments, stomachache, STD, tapeworms.
Chepsakaina	*Erythrococca atrovirens* (Pax) Prain.	Eurphorbiaceae	Shrub	Roots	Decoction (internal)	Arthritis, cancer
Chepkererlong	*Trimeria grandifolia* (Hochst.) Warb	Flacourtiaceae	Shrub	Roots	Decoction (internal)	Malaria, typhoid, cuts/burns, enhances sterility in men
Kapchobiniot	*Dovyalis macrocalyx* (Oliv.) Warb	Flacourtiaceae	Shrub	Roots, leaves	Decoction (internal)	Pneumonia, arthritis, cancer, Oedema, typhoid, migraines, indigestion, epilepsy
Segetetiet	*Phyllanthus fischeri* Pax.	Euphorbiaceae	Shrub	Fruit	Ash (internal)	Cough
Nukchat/Nokok	*Dovyalis abyssinica* (A. Rich.) Warb	Flacourtiaceae	Shrub	Leaves, roots	Decoction (internal)	Cancer, pneumonia, athritis, tonsils, mental problems, fertility in cows, malaria, oedema, typhoid, gonorrheae, stomach-ache, fever, molluscides, malaria
Tungururwet	*Chaetacmi aristata* (Burm.f.)Merrill.	Flacourtiaceae	Shrub	Root, bark	Decoction (internal)	Pneumonia, typhoid, venereal, liver cirrhosis
Bunyeriat	*Imperata ssp*	Gramineae	Herb	Leaves	Ash (internal)	Cough
Kipsongik	*Eleusine coracana* ***Gaertn.***	Gramineae	Herb	Seeds	Powder (internal)	Anti-diarrhea
Mosongik	*Sorghum bicolor*	Gramineae	Herb	Seed	Powder (internal)	Anti-diarrhea
Nderiot	*Garcinia buchananii* Bak.	Guttiferae	Tree	Roots	Decoction (internal)	Venereal diseases
Chelelgatiat	*Ajuga remota*	Labiatae	Herb	Leaves,	Decoction (internal)	Malaria, tonsil, antidiarrhoea, treat

	Benth.			roots		after birth pains, fever, toothache, dysentry, high blood pressure, tape worms
Chepkari	*Leucas martinicensis* (Jacq.) Ait.f.	Labiatae	Herb	Flowers, leaves	Infusion (internal)	Chronic asthma, eye problems, oedema, fever, stops vomiting due to fever
Chepsakitiet	*Satureia biflora* (D.Don) Benth.	Labiatae	Herb	Leave	Infusion (internal)	Anti-diarrhoea, skin diseases, cough/cold, migraines
CHEREKERIOT, Chepchai	*Ocimum kilimandscharicum* Guerke	Labiatae	Shrub	Roots, leaves	Decoction (internal)	Cancer, athritis, fertility in cattle, venerial diseases, oedema, abdominal pains
CHERORONIT/Cherungut	*Hoslundia opposita* Vahl.	Labiatae	Shrub	Whole plant	Decoction (internal)	Antidiarrhoea, wounds,`mireiwek',oedema,evil teeth,fever,stomach pains, wounds
Chuchuniat	*Leonotis mollissima* Guerke	Labiatae	Shrub	Root, leaves	Decoction (internal)	`Mireiwek, venereal diseases, stomache, wounds, oedema, malaria
Irakwet	*Plectranthus barbatus* Andr.	Labiatae	Shrub	Leaves, roots	Decoction & infusion (internal)	Cuts, skin diseases,`mireiwek',amoebic dysentry,gastrointestinal problems
NG'ARIAB SAWE/ Birirwobsot	*Fuerstia africana* T.C.E.Fr.	Labiatae	Shrub	Leaves	Infusion (internal)	Eye problems, skin diseases, `mireiwek', stomach ulcers, tongue infection
Ng'ejepchiat	*Leucas calostachys* Oliv.	Labiatae	Shrub	Leaves, roots	Decoction (internal)	Wounds, dry cough, amoeba, heartburns, muscle pull, waterborne diseases, cough, kidney problems, pneumonia, malaria, stomach-ache
Sisiyat	*Ocimum lamiifolium* Benth.	Labiatae	Shrub	Roots	Decoction (internal)	Malaria, enhances delivery, cough
Kapkutuet	*Entada abyssinica* Steud.	Leguminosae	Tree	Roots, Bark	Decoction (internal)	Arthritis, venereal diseases, epilepsy, cough
Mitiat	*Crotalaria brevidens* Benth.	Leguminosae	Herb	Leaves	Decoction (internal)	Pneumonia, stomach pains & swellings
Seet	*Albizzia gummifera* (J.F.Gmel.)	Leguminosae	Tree	Root, bark	Decoction (internal)	Stomachache, skin diseases, malaria
Tilatiliet	*Acacia hockii* De Wild.	Leguminosae	Shrub	Leaf	Infusion (internal)	Skin diseases, anti-fungal, hydatis, venereal,joint ailment
Chebitet	*Acacia gerrardii* Benth.	Leguminosae	Tree	Roots	Decoction (internal)	Epilepsy
Chemulmitia	*Crotalaria*	Leguminosae	Herb	Leaves,	Decoction (internal)	Arthritis

	laburnifolia L			roots		
Cheperenet	*Glycine wightii* (Wight & Arn.) Verdc.	Leguminosae	Liana/climber	Roots, leaves	Decoction (internal)	Pneumonia, spider bites
Kakaruet	*Erythrina abyssinica* DC.	Leguminosae	Tree	Bark, roots	Decoction (internal)	Malaria, enhances delivery, pneumonia, venereal diseases, cough, trachoma, chest problems, typhoid, liver cirrosis, diarrhoea, mumps, uvala problems
Chesibaiyat	*Asparagus racemosus* Willd.	Liliaceae	Shrub	Roots	Decoction (internal)	`Mieriwek', athritis, venereal diseases, cancer, asthma, pneumonia, cough, sore throat, purgative, proper pregnancy, stomach up-sets, fertility in women
Chemulmeswo	*Urena lobata* L	Malvaceae	Herb	Root, leaves	Decoction (internal)	Aids in delivery
Korkoriet/Chepkorkoriet	*Sida cuneifolia* Roxb.	Malvaceae	Shrub	Root	Decoction (internal)	Skin rashes, venereal diseases
Menjeiwet	*Sida cordifolia* L	Malvaceae	Shrub	Leaves	Infusion (internal)	Ear problems, malaria
Chemanjililiet/Chepsabuni	*Pavonia kilimandscharica* Gurke	Malvaceae	Herb	Roots	Decoction (internal)	Malaria, enhances delivery, pneumonia, arthritis, pregnancy, cough, epilepsy
Mondililietab Saos	*Dissotis canescens* Taub.	Malvaceae	Herb	Leaves	Infusion (internal)	Worms
Mandililiet/ Chebsebwet	*Tristemma incompletum* R.Br.	Melastomataceae	Shrub	Leaves	Infusion (internal)	Tonsils, stomach up-sets
Mwarubaini	*Melia azedarach* L	Meliaceae	Tree	Leaves, barks	Decoction (internal)	Malaria, skin rashes, any other disease
Teldet	*Ekebergia capensis* Sparrm.	Meliaceae	Tree	Bark, roots	Decoction (internal)	Venereal diseases, pneumonia, cancer, typhoid, chest problem, skin rashes
Kibuimetiet	*Bersama abyssinica* Fres.	Melianthaceae	Tree	Bark	Decoction (internal)	Toothache, kidney problems, muscle cramps, malaria
Tabarariet/Borowa	*Stephania abyssinica* (Dillon & A. Rich.) Walp.	Menispermaceae	Liana/climber	Roots	Infusion (internal)	Witchcraft in children`` migraine"
Musengertet	*Albizia coriaria* Oliv.	Mimosoideae	Tree	Whole plant	Decoction (internal)	Menorrhagia, threatened abortion, venereal diseases, sore eyes, ECF
Chilgatuet	*Ficus glumosa* Vahl.	Moraceae	Shrub	Root	Decoction (internal)	Epilepsy, cancer

Chomisiat	*Ficus exasperata* Vahl.	Moraceae	Tree	Bark	Decoction (internal)	Hiccups
Mogoiwet	*Ficus sycomorus* L	Moraceae	Tree	Root	Decoction (internal)	Venereal diseases
Sasuriet	*Ensete ventricosum* (Welw.) Chessman	Musaceae	Herb	Roots	Decoction (internal)	Enhances reproduction in men, colds in children, anhances delivery
Kibabustanyiet	*Maesa lanceolata* Forssk	Myrsinaceae	Shrub	Root	Decoction (internal)	Epilepsy, dry cough, malaria, cancer, typhoid, `bad eyes', jaundice
Kibong'ong'inik	*Embelia schimperi* Vatke	Myrsinaceae	Tree	Seed	Decoction (internal)	Deworming, malaria
Lamaiyuet	*Syzygium guinneense* (Willd.) DC	Myrtaceae	Tree	Bark	Infusion (internal)	Chest problems, painful menstruation
Kapikeriet	*Schrebera alata* (Hochst.) Welw	Oleacea	Tree	Leave	Infusion (internal)	Cough, soccery/charms
Nyonyoek	*Oxalis corniculata* L	Oxalidaceae	Herb	Whole plant	Infusion (internal)	Eye problems, arthritis, fever, mouth freshener
Nyonyoekab Suswek	*Oxalis obliguifolia* A. Rich	Oxalidaceae	Herb	Leaves	Infusion (internal)	Blood disorders, mouth sores, sore throat
Tilyamook	*Rhynchosia hirta* (Andrews) Meikle & Verdc.	Papilionaceae	Liana/climber	Root	Decoction (internal)	Ulcers, cancer, malaria
Chepnyalildet	*Adenia gummifera* (Harv.) Harms.	Passifloraceae	Liana/climber	Roots, leave	Ash (internal)	Venereal, diarrhoea in children, urinary problems, virility, typhoid, coccidiosis, wounds, enhances fertility in women
Chepkorotit	*Polygonum salicifolium* Willd.	Polygonaceae	Herb	Roots, leaves	Ash (internal)	Athritis, mental problems, nasal and eye problems, tonsils, cough, soccery
Mandawet	*Rumex usambarensis* (Dammer) Dammer	Polygonaceae	Shrub	Root	Decoction (internal)	Cough, scabies
Batkawet	*Phytolacca dodecandra* L Hiern	Phytolaccaceae	Liana/climber	Leaves	Ash (internal)	Chronic, asthma, pneumonia, backache, cough, ring worms, jaundice
Sumeiyot	*Protea gaguedi* J.F.Gmel.	Proteaceae	Shrub	Leaves	Paste (external)	Wounds
Sassiat	*Clematis hirsuta* (Perr. & Guill.)	Ranunculaceae	Shrub	Whole plant	Infusion (internal)	Chronic asthma, mental problems, nosal problems, pneumonia, burns, diarrhoea, purgative, cancer, soccery
Kosisitiet	*Rhamnus prinioides*	Rhamnaceae	Shrub	Roots	Decoction (internal)	Cancer,,pneumonia,malaria,child

	L. Her					delivery,urinaryand chest problems
Momoniat	*Rubus steudneri* Scweinf.	Rosaceae	Shrub	Roots	Decoction (internal)	Impotency in men
Momoniat	*Rubus pinnatus* Willd.	Rosaceae	Shrub	Roots	Decoction (internal)	Athritis, cure impotency in men, cancer
Tendwet	*Prunus africana* (Hook.f) Scweinf.	Rosaceae	Tree	Bark, leave	Decoction (internal)	Prostate cancer, Ulcers, ECF, malaria, stomachache, liver, coccidiosis, pneumonia, indigestion
Chemurguiywet	*Spermacoce princeae* (K.Schum.)Verdc.	Rubiaceae	Herb	Roots, leaves	Decoction (internal) & paste (external)	Chronic asthma, cancer, wounds, eye problems, mastitis in cows, venereal, skin diseases, pneumonia, typhoid, catapillar bites, antidiarrhoea
Chepkurwet	*Tarenna graveolens* (S.Moore) Brem	Rubiaceae	Shrub	Roots	Decoction (internal)	Pneumonia
Chepsaleitet	*Rubia cordifolia* L.	Rubiaceae	Liana/climber	Roots, leaves	Ash (internal)	Venereal, pneumonia, cough/cold, tonsils, uvula problems, asthma, purgative, ``mireiwek", nose bleeding, ulcers, athritis, kidney, hypertension, diarrhea
Cheroriet	*Pentas longiflora* Oliv.	Rubiaceae	Herb	Leaves, roots	Decoction (internal) & paste (external)	Skin diseases, malaria, cancer, urinary problems, cough,`mireiwek', sore eyes
Kimoluet	*Vangueria volkensii* K.Schum	Rubiaceae	Shrub	Roots	Decoction (internal)	Venereal diseases
Kipkoskosit	*Toddalia asiatica* (L.) Lam.	Rutaceae	Shrub	Roots, leaves	Decoction (internal)	Cancer, chest and urinary problems, chronic asthma, cough/cold, pneumonia
						Typhoid tonsilitis, athritis malaria
Noiywet	*Fagaropsis angolensis* (Eng.) H.M.Gardner	Rutaceae	Tree	Roots	Decoction (internal)	Cancer, malaria
Sagawatiet	*Zanthoxylum gilletii* (De.Wild) Waterman	Rutaceae	Tree	Bark, roots	Decoction (internal)	Venereal, pneumonia, cough/cold, tonsils, uvala problems, toothache,
						Waterborne diseases, athritis, cancer, malaria, snake bites,
Lolwet	*Mimusops bagshawei* S.Moore.	Sapotaceae	Tree	Bark, roots	Decoction (internal)	Athritis, cirrosis

Chebo Kimagun	*Datura stramonium* L.	Solanaceae	Shrub	Seeds, leaves	Ash (internal)	Toothache, ear problem, nervous system, madness
Labotwet	*Solanum incanum* L.	Solanaceae	Herb	Leaves	Ash (internal)	Cough/cold, chest problems, removal of after birth, venereal diseases
Pilipiliot	*Capiscum annuum* L.	Solanaceae	Shrub	Seed	Ash (external)	Pneumonia, coccidiosis, kills aphids in plants, acaricide
Sigowet	*Solanum micranthum* Schltdl	Solanaceae	Shrub	Root, seed	Decoction (internal)	Pneumonia, Arthritis, Cancer, chronic asthma, oedema, ECF, epilepsy, udder problems in cattle, antidiarrhoea in children, ulcers
Isochot	*Solanum nigrum* L.	Solanaceae	Herb	Fruits		Pneumonia, aching teeth, stomache-ache, tonsilitis, tonic, ring worms
Silipchet	*Dombeya torrida* (J.F.Gmel) P.Bamps	Sterculiacea	Shrub	Root	Paste (external)	Cuts, burns
Meswot	*Triumfetta macrophylla* K.Schum	Tiliaceae	Shrub	Root	Decoction (internal)	Pregnancy, musle pull
MUGUNGETAB BELIOT - Ne Chabai	*Hydrocotyle mannii* Hook.f.	Umbelliferae	Herb	Leave	Infusion (internal)	Ear problems, antidiarrhoea, headache, abdominal pain
MUNGETAB BELIOT -Ne Sing, Ortot	*Centella asiatica* (L.) Urb.	Umbelliferae	Herb	Leave	Paste (external)	Wounds, skin diseases, abdominal pain
Kipsotiet	*Urera hypselodendron* (A. Rich) Wedd.	Urticaceae	Liana/climber	Roots	Decoction (internal)	Enhances reproduction in men, urinary problems, expels placenta
Siwot	*Urtica massaica* Mildbr.	Urticaceae	Herb	Leaves	Infusion (internal)	Foot and mouth disease, enhance virility, arthritis
Abetiot/Kabetiot	*Clerodendrum myricoides* (Hochst.) Vatke	Verbenaceae	Shrub	Roots	Decoction (internal)	Epilepsy, athritis, malaria, diabetes, typhoid, cough/cold, eye problems, proper positiong of fetus, tonsillitis, rheumatism, gonorrhoea, ECF,
Baiwab Tarit	*Lantana trifolia* L.	Verbenaceae	Shrub	Roots	Decoction (internal)	Chest problems, chronic asthma, cancer, tonsils, pneumonia, indigestion
Mwokiot	*Lippia javanica* (Burm.f.) Spreng	Verbenaceae	Shrub	Leave	Infusion (internal)	Cough, nosal congestion, chest congestion, termite repellant
Singoruet	*Clerodendrum johnstonii* Oliv	Verbenaceae	Shrub	Leaves	Infusion (internal)	Tonsils, malaria
Torotwet	*Rhoicissus tridentata* (L.f) Willd Drum.	Vitaceae	Shrub	Bulbs	Juice (internal0	Diabetes, malaria, fertility in cattle, epilepsy

Rapid Multiplication of Pineapple: Effects of length and method of stem shoot cuttings

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ABSTRACT
Trials were carried out to improve pineapple production by increasing planting materials through the use of rapid multiplication method in order to determine the best length and method of propagation. The treatments included three lengths of stem shoot cuttings; 5cm, 7.5cm and 10cm, having both sliced and unsliced stem shoot cutting methods. These sliced and unsliced stem shoot cutting of different sizes were planted on a sawdust: poultry manure (1:1) mixture and watered fortnightly. Plant height and number of leaves of sprouted plant at transplanting were significantly affected by all the treatments and their various combinations. Number of sprouted plants was significantly ($P \leq 0.05$) influenced by lengths, methods and length and method combined effect at each sampling occasions. The sett size of 7.5cm with sliced stem shoot cutting method gave the best growth parameters and more sprouted plants than the other cutting sizes. Therefore, 7.5cm sliced stem shoot cutting which produced more planting materials and better percent plant survival in the field can be recommended as rapid multiplication methods for pineapple.

Key words: *Ananas comosus*, stem shoot, cutting length, cutting method, sprouted plant, growth.

INTRODUCTION
Pineapple (*Ananas comosus*), is the leading edible member of the family Bromeliacea which consists of about 2,000 species, mostly epiphatic and many strikingly ornamental (Morton *et al*, 1987). Pineapples are grown all year round in the warmer climates. Its origin has been traced to Brazil and Paraguay in the Amazonic basin where the fruit was domesticated (Collins, 1949; Drew, 1980).
Nearly 70% of the pineapple is consumed as fresh fruit in producing countries, commercial production is normally geared towards processing. The main products are canned fruit slices and chunks, juices, jams and dried candid pineapples. By-products such as vinegar, citric acid, enzymes and wine are also produced. The pineapple plant and fruit are also used as ornamentals; they contain vitamins A and C (Collins, 1960; Dull, 1971). Pineapple, serves various purposes, it is of great importance to humans. It is also medicinal. Pineapple produces Bromelain which is an enzyme. It helps the body's digestive system and it also has anti-inflammatory properties. It has been used to treat a number of medicinal problems, including heart diseases, arthrithis and upper respiratory infections. This remarkable enzyme is found in all types of pineapples (Morton *et al*, 1987). Fruits generally are highly nutritious; they supply nutrients to human body when consumed (Dull, 1971). The fruit quality is determined by size (finger length and thickness), evenness of ripening, freedom from blemishes and defects and the arrangement of the clusters.

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Pineapple contains micro-nutrients that experts believe protects against cancer and these micro-nutrients also break up blood clots and are beneficial to the heart. The ripe pineapple has diuretic properties. Its juice also kills intestinal worms, it also relieves intestinal disorders and soothes the bile. Pineapple juice contains chemicals that stimulates the kidney and aids in removing toxic element from the body (Morton *et al*, 1987). Pineapples are sometimes important to livestock, the crowns are fed to horses if not needed for planting. Final pineapple waste from the processing factories may be dehydrated as "bran" and fed to cattle, pigs and chickens (Morton, 1987). The pineapple fruit with crowns intact is often used as a decoration and there are variegated forms of the plant universally grown for their beauty (Julia, 1987).

Pineapple is second after bananas, contributing to over 20% of the world production of tropical fruits (Coveca, 2002). Pineapple dominates the world trade of tropical fruits, although other fruits have gained. Market share statistics from year 2000 indicate that pineapple trade took 51% from a total of 2.1million tons of the whole fruit market with mangoes taking the second place, with 21.7% (FAO, 2002). Pineapple is the best positioned fruit since its trade is oriented to developed countries as Japan, the USA and European Community (Coveca, 2002). Consequently, during the past decade world production of pineapple has increased at a rate of 1.9% per year, despite the occurrence of unfavourable weather and economic situation (FAO, 2002).

Pineapple is propagated in vegetative form using the crown or the suckers or stem shoots of healthy and productive plant. These materials must be properly selected by size to assure crop uniformity (Py, 1969).Vegetative propagation is classified according to the position at which the culturing material is reproduced with respect to the plant such as suckers, stem shoots and slips (Collins, 1960; Coveca, 2002). On the other hand, a periodical renewal of cultures is required in order to keep fruit quality in commercial plantations. Most of large production fields allow plants to produce only two or three harvest. Lack of renovation produces decreased fruit size and lack of uniformity (Oirsa, 1999).

In Nigeria, despite the favourable weather conditions that favours pineapple production and the fact that it is one of the preferred fruits consumed by many tribes, the production is low and does not the demand. The duration at which pineapple matures is one of the major constraints in production. Therefore, rapid means of multiplying pineapple using planting materials from their parent plants, which is more economical, is desirable.

The objectives of the study were to improve pineapple production by increasing planting materials through the use of rapid multiplication methods, and to determine the best cutting method and size of planting materials for the rapid multiplication of pineapple.

RESEARCH APPROACH

The experiment was carried out at the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, Nigeria.The experiment was of two phases. The first phase was done on the nursery site, where the plantlets were raised from the stumps or stem shoots while the second phase involved establishment of plantlets on the field.

The experimental nursery site was cleared and 18 sunken beds were made on the 15th of January, 2007. There were three replicates and each replicate consisted of six beds. Each bed measured 2m x 1m with a 1m spacing in between beds for easy movement during cultural operations. Each sunken bed was filled with growth media consisting of a mixture of sawdust and poultry manure in a ratio 2:1.

Pineapple stumps were obtained from the pineapple plot of the Agronomy Department, LAUTECH, Ogbomoso. The stumps or stem shoot were cut into three sizes or lengths; 5cm, 7.5cm and 10cm, each having sliced and unsliced cutting methods. The resulting combination gave six treatments, namely: 5cm unsliced, 5cm sliced, 7.5cm unsliced, 7.5cm sliced, 10cm sliced and 10cm

unsliced. These were randomly assigned into beds within each replicate. The 2x3 factorial experiments were arranged in a randomized complete block design with three replications.
The planting materials (sliced and unsliced stumps) were treated with 5ml furadan diluted with 10litres of water overnight, to prevent diseases and pests infestations in the field. Twenty planting materials were planted on each bed irrespective of the treatment combinations. After planting, the beds were mulched with dry grasses to conserve moisture. Insect pests were controlled by spraying neem seed extract. Regular weeding was done manually to control weeds on the plots.
The permanent site was clear felled and ridges were made. The sprouted plants from each bed were transplanted to the permanent field at 18 weeks after planting. Watering and mulching of the transplants were carried out immediately after transplanting. Also, soil was amended with 4 t. ha^{-1} of cassava peel compost for proper plants establishment.
Prior to transplanting, the number of sprouted stumps produced from each bed were counted and recorded at two weeks interval. Also, growth parameters such as number of leaves and height of plant were determined by counting and measuring with metre ruler and recorded, respectively at two weeks interval. Data were also collected from the plants on the field 6 weeks after transplanting to assess rate of establishment and survival of the plants. The parameters assessed were: number of leaves, height of plant and percent plant survival. Data collected were subjected to analysis of variance and means compared by the least significant difference (LSD) at 0.05% probability levels.

RESULTS AND DISCUSSION

Number of sprouted plants was significantly ($P \leq 0.05$) influenced by the cutting length, cutting method and cutting length and method combined effect at the various sampling occasions except at 6 and 8 WAP for methods of cuttings (Table 1). The 7.5cm sliced stumps produced more plants at 16 weeks after planting, followed by 5cm and 10cm sliced whereas the least plantlets were recorded from 10cm unsliced cuttings. Cutting methods also had effect on the sprouting rate of pineapple stumps, with sliced stem shoot cuttings irrespective of length sprouted rapidly and producing more plantlets than unsliced stem shoot cutting.
The use of sliced stumps or stem shoot cuttings in the rapid multiplication of pineapple yielded higher plantlets than unsliced stump. The rapid sprouting and more sucker production from the sliced cuttings may be attributed to its ability to break dormancy faster as compared to the unsliced stem shoot cuttings irrespective of cutting length. It also showed that uniform suckers can be obtained in appreciable number by the stimulation of the dorminant axillary buds on the old stump. The highest plantlets obtained from the sliced stem shoot cuttings is contrary to the findings of Simone (1999), who recommended unsliced stem shoot cuttings for multiplying pineapple suckers. This is probably because the sliced stem shoot cuttings can break dormancy faster and have a direct access to water and nutrients from the organic growth medium.
Growth parameters and weight of sprouted plants at transplanting were significantly affected by all the treatments and their combinations (Table 2). The highest number of leaves and plant height of the sprouted plants at transplanting (16WAP) were obtained from while the least values were recorded from 5cm unsliced cuttings. The number of leaves and plant height of the sprouted plants increased as the cutting length increased up to 7cm, then declined thereafter at 10cm.
The results revealed that 7cm is the longest stem shoot cutting length in the rapid multiplication of pineapple, where vigorous and better plantlets can be developed. The better performance recorded from the sliced stem shoot cuttings might be due to their ability to form roots early and easy accessibility to the growth medium as compared to the unsliced stem shoot cuttings.
After transplanting, it was observed that number of leaves, plant height and leaf area were significantly influenced by the length, method, and length and method combined effect of stem

shoot cuttings. The highest growth parameters were obtained from 7.5cm sliced plants on the field whereas 5cm unsliced gave the least performance.

The vigorous growth of suckers observed from 7.5cm sliced and from all the sliced stem shoot cuttings in this study might be due to the direct access of the cut surfaces to water and nutrient elements from the surrounding growth medium before transplanting. Variability in number of leaves, height of plant and leaf area shows that the plants responded to various treatments on the nursery beds.

Percentage of plants survived on the field was significantly influenced by length, method and length and method combined effects of cuttings. It was observed that all lengths and methods of stem shoot cuttings had satisfactory percentage of plant survival except 5cm unsliced which had the least survival of less than 50%.

The general better performance in terms of vigorous growth and plants establishment on the field of suckers derived from 7.5cm sliced stem shoot cuttings under this study corroborated the work of Simone (1999) who recommended sliced stump cuttings of between 6.3 and 7.5cm for banana. The 7.5cm sliced cutting obtained in this work for rapid multiplication and plant establishment is in contrary to 5cm stump cutting recommended for pineapple by Simone (1999). This probably might be due to the more 'eyes' (buds) found on 7.5cm than on 5cm cutting, from which the new suckers emanate.

In conclusion, the growth parameters assessed under this study and plants establishment on the field were significantly ($P \leq 0.05$) influenced by the various treatments. The planting materials with 7.5cm in length and sliced methods of stem shoot cuttings were able to produce more plantlets with vigorous growth rate than other sizes and cutting methods. Therefore, it can be recommended that 7.5cm sliced cutting is a good rapid multiplication method for pineapple suckers.

Table 1: Mean number of sprouted plants in the nursery.

Treatments	WEEKS AFTER PLANTING					
	6	8	10	12	14	16
5cm unsliced	2.0	4.5	5.0	6.0	6.5	7.0
5cm sliced	3.0	4.5	5.0	5.0	7.0	7.5
7.5cm unsliced	4.5	7.0	5,0	5.5	6.0	6.0
7.5cm sliced	6.0	8.0	8.0	8.0	9.0	9.0
10cm unsliced	1.5	3.5	3.5	4.0	4.0	4.0
10cm sliced	2.0	5.5	6.0	6.0	7.5	7.5
LSD (0.05):						
Length	1.29	0.08	0.56	1.31	1.07	1.10
Method	Ns	Ns	0.46	1.07	0.88	0.91
L x M	Ns	0.88	0.26	1.40	0.94	1.01

Table 2: Growth parameters and weight of sprouted plants at transplanting (16 WAP).

Treatments	Number of leaves	Plant height (cm)	Plant weight (g)
5cm unsliced	15.4	7.0	40.0
5cm sliced	17.1	9.0	56.0

7.5 unsliced	16.6	10.3	60.0
7.5cm sliced	18.4	10.6	70.0
10cm unsliced	15.6	7. 2	50.0
10cm sliced	16.1	8.4	63.4
LSD (0.05):			
Length	0.79	0.82	6.81
Method	0.64	ns	Ns
L x M	0.50	0.82	6.81

Table 3: Growth parameters and percent plant survival of plants on the field at 12WAP.

Treatments	**Number of leaves**	**Plant height (cm)**	**Leaf Area (cm^2)**	**Plant survival (%)**
5cm unsliced	9.00	21.14	43.76	47.0
5cm sliced	16.50	26.00	67.93	88.9
7.5cm unsliced	16.17	30.83	94.03	92.3
7.5cm sliced	18.17	30.30	104.56	94.1
10cm unsliced	9.86	20.29	44.48	71.4
10cm sliced	12.83	24.00	65.28	69.20
LSD (0.05):				
Length	0.48	5.61	0.36	1.21
Method	0.39	ns	0.29	0.99
L x M	0.19	5.61	0.10	1.20

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Characteristics of fresh (ware) potato traders in Nairobi and Nakuru towns, Kenya

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ABSTRACT
The potato is an important food crop in Kenya employing over 2.5 million people along its value chain thereby contributing to food security and poverty alleviation. The fresh (ware) potato market is an integral part of this chain. The potato market in Kenya has been assumed to have no defined structure and having various limitations that require urgent redress. In this study a total of 169 potato sellers were interviewed in Nairobi and Nakuru town markets. About 25 % of the respondents were located in Nakuru town while 75 % were located in Nairobi. A large number (70 %) of respondents traded in potatoes as the only source of income while 30 % traded in other fresh produce in addition to fresh potatoes. The average daily sales in terms of quantity were 200 kg while sales volume in monetary value ranged from KSH. 5, 000 – 31, 500; 1USD = KSh. 75). Demand by customers varied highly (99 %) with seasons, being low between January and March which coincide with harvesting seasons but improves between April and June to 24 % when glut reduces and reaches a peak in July-August (79 %) when most stocks of fresh potatoes have run out of season. The demand for fresh potatoes was significantly ($P \leq 0.05$) correlated ($r = -0.96$) to the supply. The main buyers of the fresh potatoes were individuals who bought the produce for home consumption; wholesalers and traders (23 %); outside caterers (21 %) while kiosks and supermarkets were the least buyers at 0 - 3 % . The potato varieties sold by most sellers were Cangi (42 %) and Tigoni (34 %) while Nyayo and Meru were the least traded (4 %). Most traders (48 %) depended on the farmers and fellow traders (41 %) as sources of information compared to Ministry of Agriculture (7 %) and other researchers (4 %). Approximately 56 % of the respondents stored fresh potatoes for between 1-3 weeks in gunny bags at their premises with reported losses mainly due to rotting (69 %) and greening (31 %). Traders lacked proper skills in handling and storage of fresh potatoes required to prevent these losses. Many Kenyans depend on fresh (ware) potato trading as a source of income. The demand, however, varies with seasons. The information obtained from the study is vital for improving the quality of potato for processing since these markets are the major sources of raw potatoes for the many small-scale crisps processors in Kenya. . There is general lack of skills and capacity for handling and storing potatoes, which can be bridged through appropriate training of the traders.

Key words: Ware Potato, handling, trade, varieties.

INTRODUCTION

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Roots and tubers, notably potatoes, cassava, sweet potato and yam are among the most important primary crops. They play a critical role in the global food system, particularly in the developing world, where they rank among the top ten food crops. In sub-Saharan Africa, they are a major source of sustenance, accounting for 20% of calories consumed (Rosegrant et al. 2000; Ochieng', 2007). In Kenya, potato is ranked second after maize in terms of utilization (MoA, 2008).

The potato being an important food crop in Kenya employs over 2.5 million people along it value chain thereby contributing to food security and poverty alleviation (Songa, 2010). The value of the crop is more than KSh. 1.5 billion per year (Maingi, 2010). The potato market in Kenya has been known to lack a well defined structure with various limitations that require urgent redress. Fresh potato packaging for instance is an issue that needs immediate redress especially regulating the amount of kilograms in a bag. The adoption of 110 kg standard bag has been recommended instead of the current extended bags which often reach up to 200 kg (Wang'ombe, 2008; Mutunga, 2010). However, even the 110 kg standard needs to be reduced to 50 kg in order to be in line with the International Standards and Labour Laws of the International Labour Organization (ILO), which Kenya has pledged to observe.

The potato crop in Nakuru District was categorized as socio-economically important to both commercial and smallholder farmers. Resource-poor farmers prefer growing potatoes because the crop has a short maturity period and can be grown throughout the year. When compared to other staples, beans were by far more expensive, while potato was cheaper than maize in the better part of the year (Kabira, 2002).

Potatoes are mainly consumed when boiled, fried or mashed. Urban inhabitants are the major potato consumers, stimulating demand for ware potatoes and processed products such as chips and crisps. Potato is also important as a cash crop, making a significant contribution to economic growth. Being labour-intensive, the crop generates employment in production, marketing and processing sectors (NPTFR, 2009). For the approximately 500,000 potato growers in the country, annual production of the crop is worth about Ksh. 5 billion at farm gate prices. Beyond the farm, the industry employs thousands as market agents, transporters, processors, vendors and exporters and the value of the crop at consumer prices is more than KSh.10 billion per year. The fresh potato market is the major source of raw materials for processors, especially the small-scale crisps processors in Kenya.

Constraints that have posed great challenge to potato marketing include poor road infrastructure, hence high costs of transportation, poor dissemination of market information, lack of improved storage, price instability, lack of enforcement of standardized grading, packaging and weights, multiple taxation and poor markets infrastructure and services (NPTFR, 2009; Wang'ombe, 2008; Walingo *et al.*, 2004a).

RESEARCH APPROACH

This study was carried out between March and April 2010. Nairobi and Nakuru towns were purposively selected due to the large number of markets that sold potatoes intended for processing. The sellers' sample size was determined according to Nassiuma (2004). A total of 169 potato sellers were surveyed. Data was collected using a structured questionnaire which had previously been pre-tested. Data was collected on location, volume of sale, customer base, sources of information, variety most traded, demand and supply variations and produce handling practices by the traders.Data from potato crisps processors were analyzed using Statistical Package for Social Scientists (SPSS) version 11.5. Chi-squire analysis was performed to check for any hidden relationships.

RESULTS AND DISCUSSION

A total of 169 potato sellers were surveyed. Twenty five perecent (25 %) of the respondents were located in Nakuru town while 75 % were located in Nairobi, mainly in the city centre markets of Muthurwa and Wakulima. About 37 % of the respondents were male while females constituted the largest group at 63 %. A large number (75 %) of respondents traded in potatoes as the only source of income while 25 % traded in other fresh produce in addition to potatoes. The other fresh produce included tomatoes (6 %), onions (8 %), fruits (6 %), maize and cabbage (2 %), and bananas (1 %). The potato was however highly ranked by the sellers. It is a common practice for many traders to have a main product and other additional minor products as a form of diversification and to cushion them against any risk that may befall the business.

The number of years the sellers have been trading in fresh potato among the respondents was 8 years on the average. The duration, however, ranged from 1 to 41 years. The observation that some respondents had traded in fresh (ware) potatoes for a long time indicates that it is a dependable business.

Approximately 70 % of the respondents depended on fresh potato trade as the only source of income compared to 30 % who also had additional sources of income. The average daily sales in terms of quantity were 200 kg while sales volume in monetary value ranged from Ksh. 5000-31500. The number of years one had been trading did not, however, significantly ($P \geq 0.05$) determine the sales volume. Packaging of fresh potatoes was almost exclusively in gunny bags except in the cases where potatoes were sold for home consumption in smaller units in which case small plastic bags were used (Figure 1).

Traders acquired fresh (ware) potatoes either directly from farmers or brokers in 110 kg bags at an average price of KSHs. 1, 650 which varied from KSHs. 800 in high supply seasons to KSHs. 4500 during the low supply seasons. However, the use of extended bags weighing between 120-180 kg was a common purchasing unit with prices ranging from KSHs. 1, 000 to KSHs. 6, 000. The traders then sold the fresh potatoes in the same units or repackaged them into smaller units depending on the needs of the consumers. The unit sale and average costs of fresh (ware) potatoes are shown in Table 1. There were wide variations in minimum and maximum prices that can be explained by the fact that potato demand and supply depended on seasons. Prices are significantly ($P \leq 0.05$) low during high supply (harvesting) seasons and extremely high during low supply seasons.

Table 1: Variations in sale weights and prices of fresh (ware) potatoes in the markets.

Unit sale weight (Kg)	Average price (KSHs) ± Sd	Range (KSHs)
0.5	13 ± 5	10.0-20
1	21 ± 3	20-30
2	36 ± 16	20-100
4	80 ± 32	40-150
8	80 ± 0	0
10	173 ± 52	80-300
17	226 ± 56	150-400
110	3000 ± 100	1500-4500

According to the respondents surveyed, demand by customers varied highly (99 %) with seasons being low between January and March which coincides with the harvesting seasons. The demand improved between April and June to 24 % when the glut reduces but reaches a peak in July-August

(79 %) when most stocks of potatoes have run out (Figure 2). The demand for fresh potatoes was significantly ($P \leq 0.05$) correlated negatively ($r = -0.96$) to the supply. The results are in agreement with the observations of Walingo *et al.* (2004a).

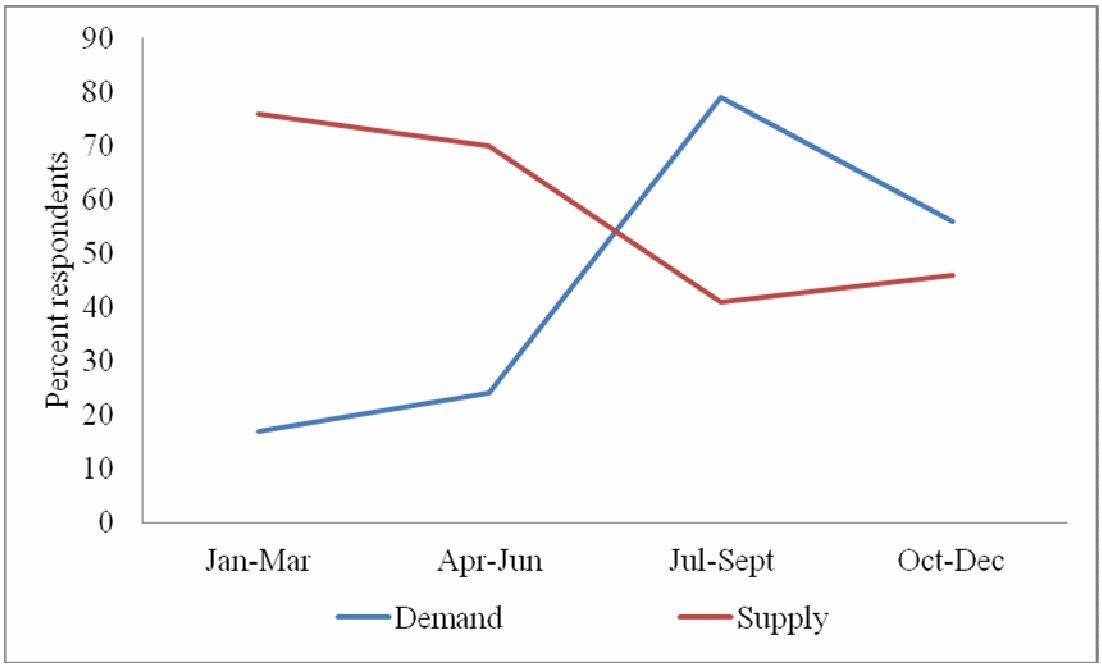

Figure 2: Seasonal variation of fresh potato demand and supply.

The main customers of the fresh potatoes were individuals who bought the produce for home consumption, wholesalers and small-scale processors (23 %) and outside catering (21 %), while kiosks and supermarkets were the least buyers at 0 - 3 % . The traders are important since they are the major suppliers of raw materials to processors, especially small-scale crisps processors. To most potato sellers (49 %), the market had changed for the worse within the last 2 - 5 years. It had, however, improved for 17 % and remained the same for 22 %. Table 2 shows the major varieties of potatoes currently traded in markets in Nairobi and Nakuru.

Table 2: Major varieties of potatoes currently traded in markets in Nairobi and Nakuru.

Variety	Skin colour	Shape	Reasons liked	Reasons disliked	Percent respondent
Nyayo	white	oval	good for chips	short storage life	3.93
Cangi	Red	round/oval	can be used for chips or crisps	short storage life	41.57
Dutch Robjyn	Red	Round	Best for crisps and mashing	Expensive	7.87
Roslin Tana	cream/yellow	long oval	best for chips	expensive	8.43
Tigoni	cream/white	round	best for chips/crisps	none	34.27
Meru	white	round/oval	used for chips	none	3.93

The potato variety traded by most sellers was Cangi (42 %) followed by Tigoni (27 %) while Nyayo and Meru were the least traded (4 %). The variety Cangi is grown in most potato regions and is an early maturing variety with adequate yields. Tigoni which is a native Kenyan variety is high yielding and grown by a large number of farmers. It is, however, used mostly by restaurants and processors who acquire it directly from the farmers to make chips, hence the lower representation compared to cv. Cangi in the surveyed market. A small portion of Dutch Robjyn (8 %) was traded in the open air markets since it is acquired by most crisps processors at the farm gate (Walingo et al., 2004b).
Most of the potato sold in Nairobi and Nakuru originate from Nairobi and its environs, Bomet, areas around Nakuru town, Mau Narok, Molo, Narok and Kinangop. Sources of information for the traders concerning new and improved technologies and varieties available in the market were found to be varied (Figure 3). Most traders (48 %) depended on the farmers and fellow traders (41 %) for market information compared to Ministry of Agriculture (7 %) and other researchers (4 %). This kind of information flow arrangement may be attributed to the fact that traders interact more often with the farmers and fellow traders frequently. Researchers and ministry officials mostly deal with farmers and rarely with traders. These results indicate a need for researchers to improve their relationship with traders especially where issues dealing with post-harvest handling and storage of fresh potatoes are of concerned.

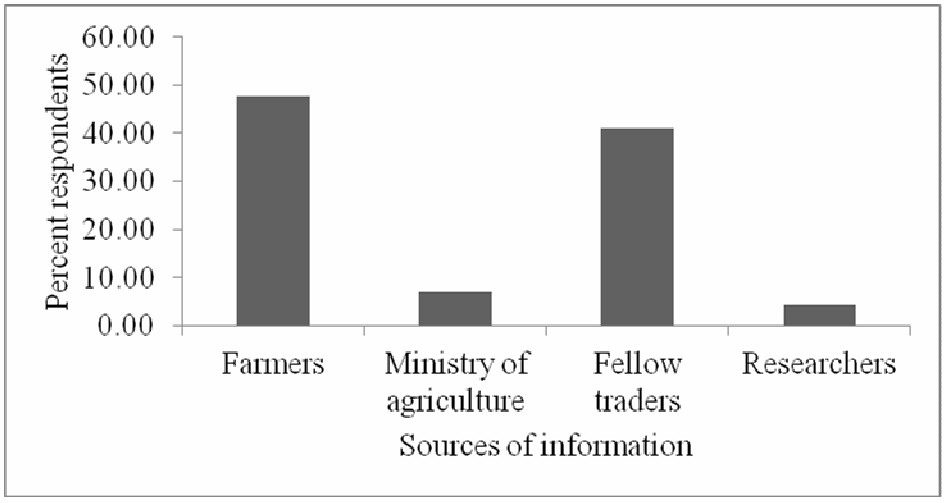

Figure 3: Sources of information for fresh potato traders in Nairobi and Nakuru markets.

Approximately 60 % of the respondents stored fresh (ware) potatoes for between 1-3 weeks in gunny bags at their premises. However, some respondents (40 %) traded in small quantities enough to be sold within one week. It was noted that most of the traders exposed potatoes to sunlight oblivious of the danger posed by greening of the produce. They had no knowledge of lurking danger such as of solanine development on exposure of fresh potatoes to sunlight. Most traders (89 %) reported losses in stored potatoes compared to 11 % who reported no loss. The reported losses were mainly due to rotting (69 %) and greening (31 %). The traders lacked proper skills of handling and storage of fresh potatoes that are needed to prevent these losses. Steroid alkaloid (solanine) is generally present in fresh potato tubers at a concentration of 2-10 mg/100 g. However, exposing tubers to sunlight leads to increased accumulation of solanine. Tubers with solanine concentration of 20 mg/100 g and above are considered toxic and unfit for human consumption (Burton, 1989). Care is therefore needed on selecting potatoes and the green ones that have more of these antinutrients ought to be avoided (Kabira and Lemaga, 2006).

CONCLUSIONS AND RECOMMENDATIONS

More fresh potato sellers were located in Nairobi than in Nakuru. A large number of respondents traded in potatoes as the only source of income while just a few traded in other fresh produce in addition to potatoes. The fresh potato market has significant contribution to the economy, especially to the small-scale traders. Demand for fresh potatoes by customers is highly dependent on seasons, being low in harvesting seasons. The potato varieties traded by most sellers included Cangi, Tigoni, Nyayo and Meru. Most traders depended on farmers and fellow traders compared to Ministry of Agriculture and other researchers. Most respondents stored fresh potatoes for short periods in gunny bags at their premises with reported losses being mainly due to rotting and greening. Traders lacked proper skills of handling and storage of fresh potatoes which are needed to prevent these losses. This information is vital for purposes of improving quality of potato processing since these markets are the major sources of raw potatoes for the many small-scale crisps processors in Kenya. The gap in potato handling and storage skills could be bridged through appropriate training of the traders.

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Cassava production and limitation of propagation through tissue culture

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ABSTRACT
With the unrelenting increase in human population it is important that concerted efforts be made to increase crop productivity so as to match the expected increase in food demand. The gravity of this problem is well appreciated considering the fact that the increasing human population is occurring on a planet with constrained and diminishing natural resources. It is therefore important to respond to this challenge by developing and disseminating technologies that increase productivity per unit area, conserve the natural resource base and impact on many rural-based communities. Droughts have played a significant role in food shortages. As a result farmers are being encouraged to grow food crops which are relatively drought tolerant and take a shorter time to mature, such as cassava. Lack of quality planting material of farmer-preferred varieties, produced locally and at a low-cost is, however, a major constraint to cassava production. Tissue culture technology whereby plant cells and tissues are multiplied in vitro under aseptic conditions, offers a feasible solution to this. Tissue culture techniques have been employed to complement and/or aid conventional methods of plant breeding. It has been used as a tool for multiplication of superior clones, *ex-situ* conservation of valuable germplasm and production of pathogen-free plants. However, the technology is capital, labor and energy intensive hence out of reach for resource poor farmers. Hence, it is necessary to have low cost options for propagation of important plant species.

INTRODUCTION
Cassava (*Manihot esculenta* Crantz) belongs to the genus *Manihot* in the family Euphorbiceae, subfamily Crotonoideae and tribe Manihotae. It is the only cultivated species in this genus producing tuberous roots (Chiwona-Karltun, 2001). It is a perennial woody shrub with an edible root, which grows in tropical and subtropical areas of the world. It is probably the only crop whose production cuts across all ecological zones. It is also called yuca (in Spanish countries), manioc (in French-speaking Africa), and mandioca (in Brazil, Paraguay and Argentina). Cassava has the ability to grow on marginal lands where cereals and other crops do not grow well; it can tolerate drought and can grow in low-nutrient soils. Because cassava roots can be stored in the ground for up to 24 months, and some varieties for up to 36 months, harvest may be delayed until market, processing, or other conditions are favorable.
Cassava has massive leaf production which drops to form organic matter thus recycling soil nutrients; it requires little or no fertilization and yet will maintain a steady production trend over a long period of time in a continuous farming system. It has ability to suppress weeds. Improved

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varieties develop many branches forming a canopy that shed weeds from solar radiation. This reduces weeding operation drastically.

Africa produces more than half of the world's cassava. However; the continent's average yield of 10 tonnes per hectare is quite low in comparison to other cassava growing regions, such as India, which produces 26 tonnes of cassava per hectare. One of the reasons for Africa's low cassava yields is a limited market for the crop. Without sufficient demand farmers are not willing to invest in new technologies that can increase productivity and production. Similarly, there is little investment in post-harvest processing to add value to the crop and/or reduce losses.

However, the future appears bright for cassava in Africa. The global food crisis and demand for cheaper fuel have renewed interest in the crop, which has a high potential to serve as a buffer against hunger for millions and provide raw materials for ethanol. The African Union's New Partnership for Africa's Development (NEPAD) has identified cassava as a poverty fighter and developed a market-oriented strategy to develop it (Whingwiri, 2004). At the same time, the United Nations Industrial Development Organization (UNIDO) is promoting the development of a biofuel industry in Africa in collaboration with AU and the Brazilian Government.

Even individual countries have put in place new policies to support cassava production and processing. In Nigeria, for instance, the government has launched a presidential initiative that encourages millers to add 10% cassava flour to wheat flour for making bread. The countries private sector is also investing heavily in cassava-based ethanol production. The potential large-scale uses of cassava require a large number of small-scale cassava processing units. The existing capacity for processing cassava in Africa is low and, unless upgraded, cassava farmers and entrepreneurs will be unable to benefit from the new market opportunities.

Cassava toxicity: Cassava contains toxic compounds known as cyanogenic glucosides. If present in sufficient quantities, these compounds can cause acute cyanide poisoning and death in man and animals. The amount of these compounds varies according to cultivars and growing conditions. There are many types of cassava based on the amount of cyanide content of the tubers: sweet cassava contains 40 - 130 ppm (parts per million) cyanide; non-bitter cassava,30 - 180 ppm; bitter cassava, 80 - 412 ppm; and very bitter cassava, 280-490 ppm. At concentrations less than 50 ppm, cassava products are considered harmless. Consumption of cassava containing non-toxic levels of cyanide over long periods of time results in chronic cyanide toxicity. Cassava toxicity is also associated with malnutrition. In societies where the diet is lacking in protein, ingestion of under-processed bitter cassava can result in poisoning. High dietary cyanide in cassava leads to a neurological disorder known as konzo (Diasolua, 2006). This leads to spastic paralysis of the legs.

Many traditional methods exist to reduce the concentration of cyanide. Various processing methods, such as grating, sun drying, and fermenting, are used to reduce the cyanide content. The cyanide content of the sweet cassava tubers is mainly located in the skin, therefore, sweet cassava only require peeling and boiling to reduce the cyanide content to non-toxic levels. The bitter varieties are usually grated or chopped finely and allowed to soak in water where fermentation occurs, converting the cyanogenic glucosides into cyanide which is released in the environment. Drying (for storage purpose) and boiling will further detoxify the tubers. Only young leaves of the cassava plant are eaten and they require boiling prior to consumption.

Uses of cassava: Cassava is one of the leading food and feed plants of the world. It ranks fourth among staple crops, with a global production of about 160 million tons per year. Most of this is grown in three regions: West Africa and the adjoining Congo basin, tropical South America and south and Southeast Asia (Lincoln and John, 2003). The young tender leaves are used as a potherb, containing high levels of protein and vitamins C and A. The leaves are prepared in a similar manner

as spinach, while eliminating toxic compounds during the cooking process.It is mainly used for human consumption, less for animal consumption and for industrial purposes, though this may vary by country. The roots are rarely eaten fresh but are usually cooked, steamed, fried or roasted when fresh or after drying or fermenting. It offers the cheapest source of food calories and the highest yield per unit area. With minimum maintenance, farmers can dig up the starchy root of cassava and eat it 6 months to 3 years after planting. In some parts of Africa (Affran, 1968), people also eat the leaves of the cassava as a green vegetable, which provide a cheap and rich source of protein and vitamins A and B. In Southeast Asia and Latin America, cassava has also taken on an economic role. Various industries use it as a binding agent, because it is an inexpensive source of starch. Its flour is used to make cookies, quick breads, loaf breads, pancakes, doughnuts, dumplings, muffins, bagels. Cassava extracted juice is fermented into a strong liquor in some communities. The peeled roots of the sweet variety are usually eaten cooked or baked. The juice can be concentrated and sweetened until it becomes dark viscous syrup which has antiseptic properties and is used for flavoring.

Cassava leaves and stem meal are used for feeding dairy cattle. Both fresh and dried cassava roots are consumed by ruminants in different forms (chopped, sliced, or ground). Cassava bushes three to four months old are harvested as foliage for cattle and other ruminants. Its starch is also used in the production of paper, textiles, and as monosodium glutamate (MSG), an important flavoring agent in Asian cooking.

However, cassava is a perishable commodity with a post-harvest shelf-life of less than three days. This has important implications for example, marketing systems for fresh roots have to be well integrated with production, and it also means that processing is far more important than for other commodities. More than 40% of cassava is currently processed, mainly into traditional food products, which increases the crop's post-harvest shelf-life, adds value at the local level, and reduces the bulk to be marketed.

Challenges in cassava production: In Africa cassava production is faced by a number of constraints which include pests like the cassava green mite, the cassava mealybug, and the variegated grasshopper. The main diseases affecting cassava are cassava mosaic disease, cassava bacterial blight, cassava anthracnose disease, cassava brown streak disease and root rot. In Kenya, the most economically important disease affecting cassava production are the cassava mosaic disease and cassava brown streak virus disease (Theodore and Balezi, 2001; Calvet and Thresh, 2002). Pests and diseases, together with poor cultural practices, combine to cause yield losses that may be as high as 50%.The production of cassava is dependent on a supply of quality stem cuttings (seedlings are produced from seeds only for breeding purposes). The multiplication rate of these vegetative planting materials is very low compared to grain crops, which are propagated by true seeds. In addition, cassava stem cuttings are bulky and highly perishable as they dry up within a few days.As a root crop, cassava requires considerable labor to harvest. Because they are highly perishable, roots must be processed into a storable form soon after harvest.

Cassava diseases

a) Leaf and stem diseases: Common leaf and stem diseases of cassava are cassava mosaic disease, cassava bacterial blight, cassava anthracnose disease, cassava bud necrosis, and brown streak disease.

i) Cassava mosaic disease: Cassava mosaic disease is caused by a virus which occurs inside cassava leaves and stems. The leaves of diseased plants are chlorotic. The chlorotic patches can be confused with cassava green mite feeding damage .Severe attack leads to very small, distorted leaves and stunted plant growth. The disease symptoms are more pronounced on younger plants usually under 6 months.Cassava mosaic virus is transmitted mainly by

whiteflies *(Bemisia tabaci)*. The virus occurs in the saliva of the whitefly. The insect transmits the virus into cassava leaves during feeding. The virus then multiplies within the leaves and the stem.

ii)Cassava bacterial blight: Cassava bacterial blight is caused by a bacterium which occurs inside cassava leaves and stems. Initially, damage by cassava bacterial blight appears as water-soaked dead spots (lesions). The lesions occur between leaf veins and are most evident on the lower surfaces of the leaves. The lesions are small, not completely round in shape, and have a few angles at their edges. These angular lesions later join together into larger patches killing the leaf blade as they enlarge. The leaf blade turns brown with the water soaked area at the leading edge of the brown patch. This symptom is known as leaf blighting. Severely blighted leaves wilt, die, and fall causing defoliation and shoot tip die-back or complete death of the shoot. Leaf blighting starts from the leaf blade and moves towards the petiole. The petiole retains a horizontal position before leaf fall .This is unlike cassava anthracnose-damaged leaves whose petioles droop before leaf fall. Drops of brownish gum may occur on the leaves, petioles, and stems of plants infected with cassava bacterial blight. The damage symptoms of cassava bacterial blight are more evident in the wet than in the dry season. The disease is more severe in young plants than in older ones.

The main sources of the bacterium are cassava plants with the disease. The bacterium enters cassava plants through wounds and scratches on the stems and leaves. It multiplies and occurs in large numbers in the leaves and stems. Cassava bacterial blight is therefore spread by planting stem cuttings from plants with the disease symptoms. Dead cassava stems and leaves with the bacterium also serve as sources of the disease if they are not destroyed after root harvest.

The disease is spread naturally by raindrops which splash the bacterium from infected plants to healthy plants. Insects, for example, grasshoppers become contaminated with the bacterium and spread it to healthy cassava plants. Farm tools that are used to cut infected cassava plants should be cleaned after use to prevent the bacterium on them from spreading to other plants.

iii) Cassava anthracnose disease: Cassava anthracnose disease is caused by a fungus which occurs on the surface of cassava stems and leaves. The disease appears as cankers ("sores") on the stems and bases of leaf petioles. Cankers weaken the petioles so that the leaf droops downwards and wilts. The wilted leaves die and fall causing defoliation and shoot tip die-back or complete death of the shoot. Soft parts of cassava stems become twisted under severe attack by the disease. The disease usually starts at the beginning of the rains and worsens as the wet season progresses.

The main sources of the fungus causing the disease are cassava plants with the disease. The fungus spreads by wind carrying spores from cankers on the stems, or by planting stem cuttings with cankers. The fungus enters cassava plants through wounds and feeding punctures made by the bug *Pseudotheraptus devastans*. Dead cassava stems and leaves with the fungus also serve as sources of the disease if they are not destroyed after root harvest.The fungus also attacks other crops such as coffee, pepper, and pawpaw.

iv) Cassava bud necrosis: Cassava bud necrosis is caused by a fungus which occurs on the surface of cassava stems and leaves. The disease appears as patches of brown or grey fungal matter covering the stem. The fungal matter sometimes covers buds ("eyes") on cassava stem cuttings. The affected buds die, which reduces the sprouting ability of stem cuttings.

The main sources of the fungus are cassava plants with the disease. Dead cassava stems and leaves with the fungus also serve as sources of the disease if they are not destroyed after root harvest. The fungus spreads by wind, however, planting of infected stem cuttings is the main

method by which the disease spreads. Apart from cassava the fungus also causes leaf spots on a variety of plants including grasses, cereal crops, banana, and mango.

v) Leaf spot diseases: Cassava leaf spot diseases are caused by fungi. There are three different types, namely white leaf spot, brown leaf spot, and leaf blight. Cassava white leaf spot disease appears as circular white or brownish-yellow spots on the upper leaf surfaces. The spots sometimes have purplish borders around them. Cassava brown leaf spot disease appears as small brown spots with dark borders on the upper leaf surfaces. The brown spots occur between leaf veins, and their sizes and shapes are limited by the distance between these veins. The dead tissue in the center of brown spots may fall to give the leaf surface a "shot hole" appearance. Under severe attack the infected leaves become yellow, dry, and die prematurely. Cassava leaf blight disease appears as light brown lesions on the upper surfaces of the leaves. The lesions are not limited by veins, therefore they are usually larger than brown leaf spots. The lesions may enlarge to cover most of the leaf surface and cause leaf blighting. The blighted leaves lack water soaked areas, which are typical of leaf damage by cassava bacterial blight. Leaf blight lesions also lack the dark borders of brown leaf spots and they do not develop into "shot holes" on the leaf surface.

The main sources of the fungi are infected cassava leaves on the plant or those fallen on the ground. The fungi spread to new plants from these sources by wind or rain splashes, Leaf spot fungi can occur on weeds which then serve as sources for spread of the diseases

b) Stem and root diseases

i) Cassava brown streak disease: Cassava brown streak disease is caused by a virus. Presently the disease is reported only from cassava-growing regions in East and Southern Africa. Damage symptoms of the disease appear on the leaves, stems, and storage roots. On the leaves, the disease appears as patches of yellow areas mixed with normal green color. The yellow patches are more prominent on mature leaves than on young leaves. The damaged leaves do not become distorted in shape as occurs with leaves damaged by cassava mosaic disease. On the stems, the disease appears as dark brown "streaks" with dead spots on leaf scars. These streaks are most prominent on upper, green portions of the stems. The diseased plants may show shoot tip die-back. The shape of the storage roots is distorted. This may have cracks and discoloration.

The main sources of the virus are cassava plants with the disease. The disease is spread through the planting of stem cuttings from diseased plants. The virus is also believed to be spread from plant to plant by insects.

ii) Cassava root rot diseases: Cassava root rot diseases are caused by various kinds of fungi living on or in the soil. The fungi occur mainly in soils that do not drain properly and in forest fallow land that has been recently cleared. The leaves on affected plants turn brown, wilt, and the plant appears scorched. The leaves may or may not remain attached to the plant, but the plant loses a lot of water and dies. Root rot diseases kill both feeder and storage roots of cassava. The storage roots may swell unusually and develop light brown coloration .The roots may give out a bad odor as they rot.

The important sources of cassava root rot fungi are soils and cassava root and stem debris contaminated with the fungi. The fungi enter cassava plants through wounds caused by pests or farming tools or by piercing the roots by themselves. Tools used in cassava farms with the disease should be cleaned after use to prevent the fungi on them from spreading to other areas. Similarly, cassava plant debris in farms with the disease serve as sources of root rot fungi and should be destroyed by burning. Cassava root rot fungi attack a wide range of other crops including maize, soybean, sunflower, and coffee.

Significance of cassava diseases

Yield loss: The diseases reduce yield from the crop. Root rot and cassava brown streak diseases attack storage roots and cause immediate and direct losses. By damaging leaves and stems, cassava diseases generally interfere with the way by which the plant makes food for storage in the roots. This will reduce the growth of the plants, the number of storage roots they can form, and the ability of the storage roots to store food and mature for harvest. However, most cassava varieties can lose a lot of leaves before the root yield is reduced

Loss of planting material: Many cassava diseases contaminate cassava stems with viruses, bacteria, and fungi. This makes stem cuttings unhealthy and unsuitable for planting. Certain cassava diseases, for example, cassava bacterial blight, cassava anthracnose, and cassava brown streak diseases, reduce the quantity and quality of planting material by causing shoot tip die-back. Cankers of cassava anthracnose disease cause cassava stems to break easily. Fungal infection kills the buds ("eyes") on stems and reduces the ability of stem cuttings to sprout.

Loss of leaves: In areas where cassava leaves are used as food, leaf diseases "rob" farmers and other consumers directly of the leafy vegetables. For example, cassava bacterial blight and cassava anthracnose disease defoliate cassava plants; cassava mosaic disease and cassava brown streak discolor the leaves, and cassava mosaic disease distorts the leaf shape and size. These kinds of damage will also reduce the ability of cassava plants to make sufficient food for storage in the roots.

Increase in weeds and erosion: Diseases that defoliate and kill cassava shoot tips encourage weed growth in farms because the cassava plants are no longer able to block sunlight from reaching the weeds growing underneath. Where loose soils occur, defoliation of cassava plants will expose the soil to erosion.

Cassava breeding

Although cassava is a major food crop, its breeding began only recently compared to other crops. Significant progress has been achieved, particularly in Asia where cassava is used mainly for industrial processes and no major biotic constraints affect its productivity (Ceballos *et al.*, 2004). Cassava breeding faces several limitations that need to be addressed. The heterozygous nature of the crop and parental lines used to generate new segregating progenies makes it difficult to identify parents with good breeding values. Heterozygosity, polyploidy, the complex genetic structure of the species, absence of flowering in some genotypes and low production of seeds, often associated with irregular germination, hinder breeding efforts (Mussio *et al.*, 1998).

TISSUE CULTURE

Tissue culture (TC) refers to growing and multiplication of cells, tissues and organs on defined media under aseptic and controlled environmental conditions. The technology is used for the production of doubled haploids, cryopreservation, propagating new plant varieties, conserving rare and endangered plants, difficult-to-propagate plants, and to produce secondary metabolites and transgenic plants (Ahloowalia *et al., 2002*). The production of high quality planting material of crop plants and fruit trees, propagated from vegetative parts, has created new opportunities in global trading, benefited growers, farmers, and nursery owners, and improved rural employment. However, there are still major opportunities to produce and distribute high quality planting material, e.g. crops like banana, date palm, cassava, pineapple, plantain, potato, sugarcane, sweet potato, yams, ornamentals, fruit and forest trees.

The main advantage of tissue culture technology lies in the production of high quality and uniform planting material that can be multiplied on a year-round basis under disease-free conditions anywhere irrespective of the season and weather. However, the technology is capital, labor and

energy intensive. Although labor is cheap in many developing countries, the resources of trained personnel and equipment are often not readily available. In addition, energy, particularly electricity, and clean water are costly. The energy requirements for tissue culture technology depend on day temperature, day-length and relative humidity, and they have to be controlled during the process of propagation. Individual plant species also differ in their growth requirements. Hence, it is necessary to have low cost options for weaning, hardening of micropropagated plants and finally growing them in the field.

NEED FOR LOW COST OPTIONS FOR CASSAVA TISSUE CULTURE

Propagation by stem cuttings is the conventional means of planting cassava. This mode of propagation exposes the crop to a wide range of pests and diseases. This association of cassava pests and diseases with conventional vegetative propagation affects production. It is also a major constraint for the maintenance of germplasm collections and for regional and international movement of cassava clones. Most of cassava tissue culture work has thus been oriented toward the recovery of healthy clones from diseased varieties by meristem and shoot tip culture methods.

Tissue culture methodologies can be used to produce high quality vegetative planting material, which ensures high productivity. This technology is being used to generate disease-free planting material, and has been developed and applied to a wide range of crops, and forest and fruit trees. However, in many cases, the cost of micropropagule production precludes its adoption for large-scale commercial propagation. To attain desirable impact, a cheap and simplified method for micropropagation is required (Santana *et al*., 2009). To achieve this, there is need to develop low cost media from locally available materials. This will in turn reduce the unit price of tissue-cultured cassava plantlets. Low-cost tissue culture technology is the adoption of practices and use of equipment to reduce the unit cost of micropropagule production. There are reports on tissue culture of other plant species, wherein the components of tissue culture media have been modified or replaced with low cost substitutes such as sucrose with table sugar (Kaur *et al*., 2005), omission of agar (Mehrotra *et al*., 2007) and use of sunlight and tubular skylight (Kodym and Francisco, 2004). Moses and Grace (2004) reported that cassava flour can be a substitute of agar. The design of plant culture media as a low-cost strategy to produce planting material must guarantee high quality and well developed plants that can easily be adapted to green house and field conditions.

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Comparative performance of indigenous chicken ecotypes and Bovans Brown crosses

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ABSTRACT
Work previously done at Serere Agricultural and Animal Production Research Institute in Uganda showed that crossbreeding Bovans Brown cocks and indigenous hens significantly increased growth rate, number of eggs per clutch and mean live weight at 20 weeks of age. While those findings could have been attributed to heterosis it was not possible to delineate genetic and environmental (feeding) contributions. In order to study the genetic and feeding contributions, new eggs (1-4 days old) of local chickens were purchased from households in Soroti, Sironko, Jinja, Masaka, Sembabule and Mbarara districts in Uganda. In addition, new eggs of the same age of crossbred chickens (Bovans Brown x Local) were purchased from Soroti and Mukono districts. All eggs were hatched at the same time using a commercial hatchery at Mukono Agricultural Research and Development Centre. Hatchability was recorded and Local eggs from Sironko district had the highest hatchability (90.0%) followed by those from Sembabule district (87.0%) and the crossbred eggs (75% cross) from Soroti the lowest hatchability (70.0%). Chicks from Sembabule local eggs were heaviest (30.53gm) on average at day 1 followed by the crossbred chicks (75% cross) from Soroti which had average weight of 28.88gm at day 1. The smallest chicks (26.46gm) at day 1 were from the local eggs collected in Soroti district. All day 1 chicks were later transferred to Serere Institute where they were managed in the same way and fed *ad libitum*. Weights from day 1 to day 180 were recorded. Between day 1 and day 30, all chicks grew almost at the same pace but after day 60, the chicks from Masaka (local) grew fastest followed by those from Soroti district. Those from Sembabule were the slowest growers on average. The rest were between these two ecotypes. The highest increase in body weights was recorded between day 60 and day 150. At day 180 (6 months) the weights of all ecotypes converged towards the same mean weight of 1636gm with no signs of further growth. It was noted that some indigenous chicken ecotypes had better growth than the crossbred chickens and that among the indigenous chicken ecotypes there were significant differences in growth reflecting a certain level of genetic variability. If the feeding was standardized at *ad libitum* and management was uniform, the differences observed in growth could be attributed to differences in genes or differences in feed conversion.
Key words: Hatchability, Growth, Indigenous chickens, Bovans Brown, *Ad libitum*

INTRODUCTION
Indigenous (local) chickens dominate the chicken industry in developing countries. It has been estimated that more than 70% of rural households in developing countries keep local chickens (Aini, 1990; MOAC, 1997; MAAIF, 2008). Uganda has about 32 million chickens (MAAIF, 2008) and of these 90% are indigenous chickens managed mainly under free-range scavenging system while the rest are in commercial modern management system. Indigenous chickens play a significant role in

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rural livelihoods. They are a readily available animal genetic resource, do not need much land, have a short generation interval, are a source of protein and income, and hence an easy entry point for poverty reduction efforts.The distribution of indigenous chickens in Uganda varies with the different agro-ecologies. Although efforts have been made to describe them phenotypically (Ssewannyana *et al.*2003a; 2003d; 2005), they are largely non-descript types. They vary widely in body size, conformation, plumage colour and other phenotypic characteristics (Ssewannyana *et al.*2003a, 2003d, 2005). The productivity of these chickens under the rural production system in Uganda is very low, expressed in terms of slow growth, low egg production, small sized eggs and high mortality of chicks (Ssewannyana *et al.*2003d). This study was initiated to further examine the possible contributions of genetics and feeding to the previously observed improved performance.

MATERIALS AND METHODS

Study areas*:* Six districts in different agro-ecologies were selected for this study, i.e. Soroti (Teso system), Sironko (Mountainous system), Jinja (Busoga system), Masaka (Banana/Coffee system), Sembabule (agro-pastoral system) and Mbarara (pastoral system). The 6 districts gave rise to the 6 indigenous chicken ecotypes.

Egg collection and production of chicks*:* Fertile eggs produced by indigenous chickens were purchased from households in the villages of the selected study districts. Households were randomly picked. For each hen identified for the study, all already-laid eggs were marked to differentiate them from the new ones to be laid. New eggs (1-4 days old) were collected from the selected households on the same day. In addition, new eggs of the same age of crossbred chickens (Bovans Brown x Local) were purchased from Soroti and Mukono districts for comparison purposes. All eggs were hatched at the same time using a commercial hatchery at Mukono Agricultural Research and Development Centre. After 21 days, hatchability and day 1 weight were recorded.

Management of chicks: After hatching and recording day-1 weights, all chicks were vaccinated against New Castle disease, Fowl typhoid and Marek's disease. Then, they were transported to Serere Institute and the different chicken ecotypes were kept in different pens. The chicks were offered a commercial starter ration for a period of 8 weeks (brooding period) and then a commercial growers ration for an additional period of 16 weeks ad libitum. Monthly body weights were recorded until week 24 (180 days). Data was analyzed using GLM of SAS version 9 (2004).

RESULTS AND DISCUSSION

Egg codes used, number of eggs collected per district, number set, hatchability percentage and mean day-1 chick weights are presented in Table 1.

Table 1: Egg collection and hatchability

District	Egg Code	No. of Eggs Collected	No. of Eggs Set	Egg Hatchability (%)	Mean Day-One chick Weights (gm)
SOROTI	SRT	63	63	86.8[a]	26.46[a]
SIRONKO	SRK	60	56	90.0[a]	28.80
JINJA	JNJ	60	57	80.0	28.82
MASAKA	MSK	68	68	71.8[b]	26.96
SEMBABULE	SBL	62	62	87.0[a]	30.53[b]
MBARARA	MBR	60	59	77.5	27.90
F_1(MUKONO)	F_1	60	60	82.9[a]	28.10
F_2(SOROTI)	F_2	60	60	70.0[b]	28.88
AVERAGE		61.6	60.6	81.1	28.31

[ab] –Means with different superscripts in a column are significantly different ($p<0.05$)

Local eggs from Sironko district had the highest hatchability (90.0%) followed by those from Sembabule district (87.0%) and the crossbred eggs (75% cross) from Soroti the lowest hatchability (70.0%). Chicks from Sembabule local eggs were heaviest (30.53gm) on average at day 1 followed by the crossbred chicks (75% cross) from Soroti which had average weight of 28.88gm at day 1. The smallest chicks (26.46gm) at day 1 were from the local eggs collected in Soroti district. Overall, hatchability for all types of eggs was 81.10%. The good hatchability observed confirms that the eggs were fertile and fresh (1-4 days old). The differences in hatchability percentage across the different indigenous ecotypes could be due to differences in their genetics or due to the management systems in the different villages or even households. However, hatchability differences between the indigenous ecotypes and the crossbred chickens, particularly the 75% crosses from Soroti district were genetic differences. The observation that the 50% crosses had impressive hatchability (82.9%) means that the trait of broodiness is highly maintained in the first crosses. As heterosis reduced and possibly genetic drift also set in, the hatchability reduced in the 75% crosses. This phenomenon had been observed earlier by (Ssewannyana *et al.*, 2001; 2003b; 2003c).

Indigenous chicks at day 1 had variations in their weights and the differences between those from Soroti and those from Sembabule were significant ($P<0.05$). It would have been good if egg weights had been taken before hatching so that hatchability and day 1 weights could be correlated or related.

Table 2 gives the mean monthly weight recordings of the 6 indigenous chicken ecotypes and the 2 genotypes of the crossbred chickens.

Table 2: Mean monthly weight recordings of the 6 ecotypes of indigenous chickens and the 2 genotypes of crossbred chickens

DISTRICT	AVERAGE CHICK WEIGHTS (gm)						
	Day One	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
SOROTI	26.46	199.91	585.14	1027.42^{a}	1340.53^{a}	1677.44^{a}	1654.61^{a}
SIRONKO	28.80	213.95	587.43	940.54	1235.24^{c}	1463.13	1640.30
JINJA	28.82	196.68	577.00	944.31	1308.04	1548.07	1726.48^{b}
MASAKA	26.96	187.26	635.35	1083.65^{b}	1406.04^{b}	1611.91^{a}	1688.86^{a}
SEMBABULE	30.53	194.74	526.03	888.37^{c}	1188.13^{c}	1460.25^{b}	1641.00
MBARARA	27.90	202.36	526.93	978.04	1291.11	1422.64	1654.39
AVERAGE	28.25	199.15	572.98	977.06	1294.85	1530.57	1667.60
F_1(MUKONO)	28.10	205.74	558.03	944.32	1386.00	1613.65	1701.65^{b}
F_2(SOROTI)	28.88	159.88	534.72	922.96	1257.46	1476.63^{b}	1509.75^{c}
AVERAGE	28.49	182.81	546.38	933.64	1321.73	1545.14	1605.70

^{abc} –Means with different superscripts in a column are significantly different ($p<0.05$)

Figure 1 presents the growth curves of the 6 indigenous chicken ecotypes compared with the 50% and 75% Bovans Brown crossbred chickens. Figure 2 looks at the comparison in growth among the 6 indigenous chicken ecotypes. Between day 1 and day 30, all chicks grew almost at the same pace but after day 30, chicks from Masaka grew the fastest and those from Sembabule were the slowest growers on average. The rest were between these two ecotypes. The trend observed indicated that the chicks had a lot of compensatory growth particularly those from Soroti district and that, at that time, the increases in mean body weights had no relationship with the mean weights of the chicks day 1. The aspect of compensatory growth or faster growth could be a result of genetics but could also be confounded with feed conversion efficiency.

The biggest increases in body weights were recorded between day 60 and day 150. At day 180 (6 months) the weights of all ecotypes converged towards the same mean weight of 1636gm with no signs of further growth. It was i noted that some indigenous chicken ecotypes had better growth

than the crossbred chickens. Among the indigenous chicken ecotypes there were significant differences in growth reflecting a certain level of genetic variability. Studies carried out in Northwest Ethiopia on growth performance of native chicken ecotypes and exotic chickens revealed significant body weight differences within the native, between native and exotic chicken populations (Hassen *et al.,* 2006).

As the feeding was standardized at *ad libitum* and management was uniform, the differences observed in growth could be attributed to differences in genes or differences in feed conversion. Feed conversion ratio (feed: gain) is a complex process and a highly aggregate trait which is the result of the interaction of behavior, level of production, appetite and other factors. Hence, it is very difficult to delineate it properly.

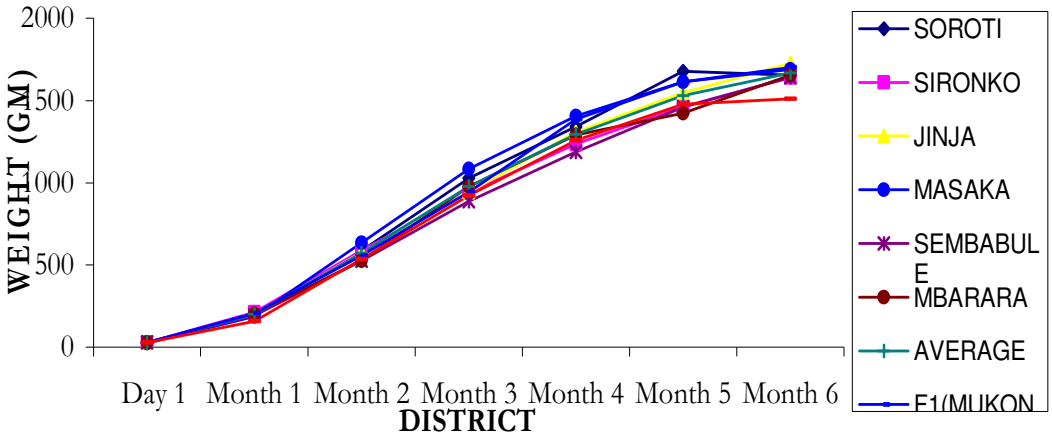

Figure 1: Growth of six indigenous chicken ecotypes compared with 50% and 75 % crossbred chickens

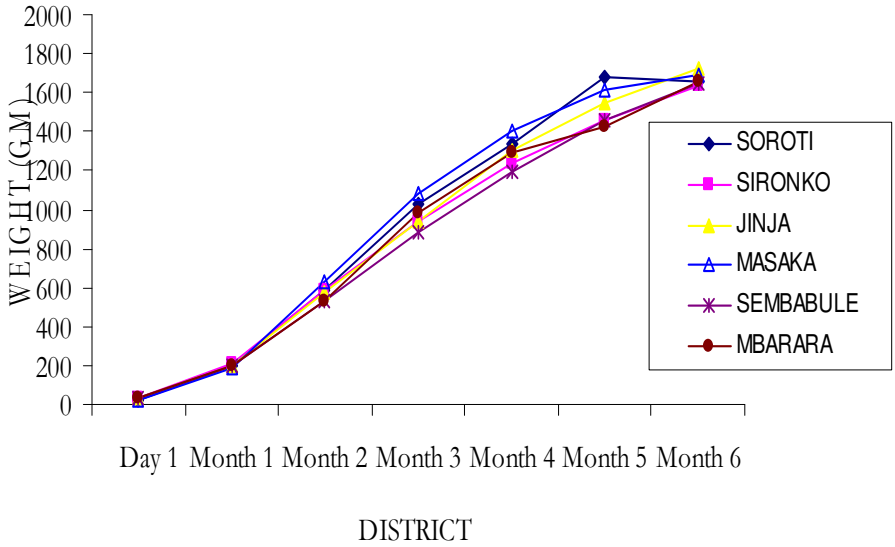

Figure 2: Growth of six indigenous chicken ecotypes

CONCLUSION

Bearing in mind the complexity of feed conversion at individual level, the mean findings presented here could be more attributed to genetics rather than to feeding.

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