Farmers' Knowledge, Effects of their Practices and Soil Amendments in the Management of Sweetpotato Pests in Southwestern Kenya

By

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DECLARATION

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This thesis is my original work and has not been presented for the award of a degree in any university or any other award.

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DEDICATION

For GT, my well beloved, for reasons best known to you and I. To my girls, Leslie and Latoya. Your laughter is like music in my ears, like sweet melody causing my heart to bubble with joy. In your way you make the world a brighter place, the best place to be with you beside.

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

ACT	Almanac Characterization Tool
CIP	International Potato Centre
FAO	Food and Agriculture Organization
GOK	Government of Kenya
MOA	Ministry of Agriculture, Kenya
NSFCIPM	National Science Foundation Centre for Integrated Pest Management
RUFORUM	Regional University Forum for Agriculture

ABSTRACT

Sweetpotato is a major food security crop grown in Kenya. Its production is however limited due to high prevalence of pests and diseases among other factors. Cultural control appears to be the most promising strategy in curbing this problem. However, the recommended cultural control practices are based on farming practices in Asia and United States of America that may not be appropriate for subsistence farmers found in Kenya. This study sought to establish farmers' knowledge on sweetpotato pests and their practices in the management of these pests in Southwestern Kenya; taking into account the sociocultural, socioeconomic and biophysical factors affecting sweetpotato production. It also sought to establish the effects of soil amendments on the diversity and abundance of soil-dwelling predatory arthropods which could be effective in the management of sweetpotato pests. Farmer based data was obtained using a semi structured questionnaire administered to a total of seventy five farmers. An experimental plot was set up in Rongo District with four treatments in four replications to establish the effects soil amendments on the diversity and abundance of ground dwelling predatory arthropods. The amendments included animal based manure, plant based manure, inorganic fertilizer and control. The outcome of the study indicated that farmers had limited knowledge on sweetpotato pests and did not carry out any methods of control against them. Sweetpotato production was basically left to women and the crop came second to maize. The major constraints to production included moles, hippos, hard labour, insect pests and diseases, costly transport, low selling prices and lack of storage mechanisms. Shannon Weiner diversity and species richness and evenness revealed that the greatest diversity and abundance of predatory arthropod species occurred in the control plot where no amendment was used. The control plot also recorded the highest percentage of both marketable and undamaged tubers though not significantly so. The least diversity and abundance of species was recorded in amendment with animal based manure whereas the least percentage of both marketable and undamaged tubers was recorded in amendment with inorganic fertilizer. This may imply that no amendments were actually required to enhance the diversity and abundance of ground dwelling predatory arthropods. Berger-parker dominance index indicated that species were more dominant in the amendments with inorganic fertilizer whereas Sorensen's similarity index revealed that the greatest similarity of species occurred between the amendments with plant based and animal based manure. The efficacy of the predatory arthropods in the management of sweetpotato pests could, however, not be established. The role of the amendments in enhancing the crop's resistance to sweetpotato pests could also not be ascertained within the scope of this study.

CHAPTER ONE

INTRODUCTION

1.1 Background

Sweetpotato, *Ipomoea batatas* (L.) Lam., is an important secondary food crop for many Kenyans whose staple diet is mainly based on cereals (Gakonyo, 1993). It is an important food security crop when maize is in short supply or in drought years (Mutuura *et al*., 1992). Its cultivation in many parts of Kenya is enhanced by its ability to adapt to a wide range of climatic conditions including marginal areas. Its ability to establish ground cover very fast enables suppression of weeds such as *Striga*, control of soil erosion and maintenance of soil fertility. This makes it an attractive crop for Kenya's subsistence farming systems.

Sweetpotato is grown on a total of 65,000 ha in Kenya, with an average yield of about 10 tons/ha, ranking third among roots and tubers, after Irish potatoes (90,396 ha) and cassava (79,170 ha) (MOA, 1991; FAO, 1997). Kenya is reported to have the highest sweetpotato growth rate in Sub-Saharan Africa, both in area and production (FAO, 1991). The former South Nyanza district in South Western Kenya is the principal sweetpotato growing district and accounts for 52% of the total area under sweetpotato production in the country (MOA, 1991). Average per capita consumption is about 24kg/year, with higher proportions consumed in Western parts of Kenya (Scott and Ewell, 1992). The varieties grown in the region include *Obera, Nyakabondo, Nyakathuri* and *Gikuyu* among others, with these names varying from locality to locality (FAO, 1998). In Kenya, and indeed the rest of East Africa, sweetpotato is mainly grown as a subsistence crop by resource poor female farmers who rarely use any inputs. Often, a few roots are dug up and sold to generate cash for household necessities. Production plots are usually small, rarely larger than 0.5 ha, although some large-scale production also exists. Farmers practice in-ground storage that guarantees fresh roots for a better part of the year but this increases susceptibility to pest infestation (Smit and Odongo, 1997).

The major constraints to sweetpotato production in the country include pests, diseases, prevalence of late maturing and low yielding varieties, limited forms of use, perishability, environmental factors, rodents and vermin, insufficient extension services and high marketing costs. Chemical and biological control have been used in the management of some of the pests and diseases. Cultural control has, however, been shown to be more effective and relevant for the subsistence farming conditions under which sweetpotato is grown. Several recommendations have been put in place for effective control.

1.2 Problem statement and justification

Up to 100% losses have been reported to occur from sweetpotato pests especially the sweetpotato weevil (Jansson and Raman, 1991). Studies have shown that infestation by sweetpotato pests can be reduced to some extent by various methods including host-plant resistance, biological, cultural and chemical control and behaviour influencing techniques such as pheromones, sticky traps and repellents (Smit and Odongo, 1997). However, cultural control is currently the most promising component of the Integrated Pest Management (IPM) strategy for sweetpotato under subsistence farming systems. Recommended cultural control practices that may help reduce the African sweetpotato weevil include crop rotation, field sanitation, use of clean planting material, planting away from weevil infested fields, hilling up to reduce soil cracking, adjusting planting time and timely harvesting (CIP, 1997). These recommendations are, however, based on production practices in the United States of America and Asia, which are different from those of tropical Africa. Thus, their applicability cannot be generalized since suitability of the methods appears to be site-specific, depending on agro ecological and socioeconomic conditions (Smit and Odongo, 1997). A study carried out in the former South Nyanza district of Kenya, to determine effects of farmers' cultural control practices on pest control noted that good field sanitation and avoidance of adjacent planting were most promising (Smit *et al*., 1994). This conclusion was, however, not backed by sufficient and subjective farmer-based data. Furthermore, the recommended cultural control practices completely ignored the role of other pests other than weevils. This study sought to establish farmers' practices that would be effective in the management of sweetpotato pests, thus enhancing sweetpotato production in the region.

Fertility management can have a lot of effects on plant quality and this can in turn affect diversity and abundance of soil dwelling predatory arthropods and insect pests. Such effects have however not been established on sweetpotato. This study sought to establish whether there are any pest management benefits emanating from soil fertility enhanced interventions in sweetpotato production. This understanding is likely to lead to a more holistic and scientifically rationalized cultural control approach in the management of sweetpotato pests.

1.3 Research questions

a. What knowledge do farmers have on sweetpotato pests and their management?
b. What are the effects of farmer practices on the management of sweetpotato pests?
c. What are the socio-cultural/socio-economic/biophysical factors affecting sweetpotato production and utilization in Southwestern Kenya?
d. What are the effects of soil amendments on the abundance and diversity of soil dwelling predatory arthropods?

1.4 Null hypotheses

a. Farmers do not have any knowledge on sweetpotato pests and their management.
b. Farmer practices have no effects on the management of sweetpotato pests.
c. Sweetpotato production and utilization is not affected by any socio-cultural/socio-economic/biophysical factors in Southwestern Kenya.
d. Soil amendments have no effects on the abundance and diversity of soil dwelling predatory arthropods.

1.5 Objectives

1.5.1 General objective

To establish effective and sustainable control practices that could be utilized in the management of sweetpotato pests.

1.5.2 Specific objectives

a. To assess farmers' knowledge on sweetpotato pests and their management.

b. To establish farmer practices and their effects on the management of sweetpotato pests.

c. To evaluate the effects of socio-cultural/socio-economic/biophysical factors on sweetpotato production and utilization in Southwestern Kenya.

d. To determine the effects of soil amendments on the diversity and abundance of soil dwelling predatory arthropods.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and distribution of sweetpotato

Sweetpotato originated in or near Northwestern South America around 8,000-6,000 BC (Austin, 1988). It is the seventh most important food crop worldwide and is now cultivated throughout tropical and warm temperate regions where there is sufficient water to support its growth (Jansson and Raman, 1991). According to FAO statistics, world production is 127 million tons, with the majority coming from China, which produces about 105 million tons (FAO, 2004). Per capita production is greatest in countries where it is a staple food for human consumption. Recent analysis by economists at the International Potato Center (CIP) indicates that in the near future, sweetpotato is likely to make a growing contribution to the global food system, as a source of vitamin A in Africa (CIP, 1999). Several varieties exist, differing in form and color as a result of varied contents of carotene and anthoxyanthins (Ezell and Wilcox, 1958; Ewell and Mutuura, 1994).

In Africa, production is concentrated in eastern, central and southern regions where it is generally grown for household food consumption with minimum use of inputs other than labour (CIP, 1996). Kenya is the fourth largest producer of sweetpotato after Uganda, Rwanda and Burundi (Wambugu *et al*., 1991).

In Kenya, sweetpotato production is mainly concentrated in western Kenya (including Kakamega, Bungoma, Busia, Homabay, Rachuonyo and Kisii districts). It is also grown to a small extent in Coast and Central provinces (FAO, 1998). It is the most widely distributed cash crop in Kenya (Wambugu *et al*., 1991) after maize, Irish potato and cassava (Ewell and Mutuura, 1994). The cultivated area under sweetpotato in Kenya has increased since 1996 from 65,000 hectares to 75,000 hectares in 1998 (FAO, 1998). About 75% of the total production is concentrated at mid altitudes 1000-1600 metres above sea level (Scott and Ewell, 1992). The production of this crop, however, differs by location due to differences in agro-climatic and socio-economic factors (MOA, 1992). In the arid and semi arid areas of the country, the crop is grown mainly under irrigation using water supplied by permanent or seasonal rivers (Ondiaka, 2007). The production areas are shown in the table below (Tab. 1)

Table 1: Average production of sweetpotato (tonnes) per ha in six provinces of Kenya from 1996-1998

PROVINCES	AREA (HECTARES)	PRODUCTION (TONNES)	PRODUCTION SHARE (%)
Nyanza	35,950	362,378	49.9
Western	17,953	180,971	24.9
Rift Valley	3675	32,485	4.5
Central	3558	31,449	4.3
Eastern	12,414	109,744	15.1
Coast	1117	9871	1.3
Total	74,667	726,893	100

Source: Ondiaka, 2007

2.2 Production systems

Most of the sweetpotato is grown in monoculture, but inter- and relay-cropping with maize, beans, cassava and a variety of other crops exists (Mutuura *et al*., 1992; Bashaasha *et al*., 1995; Kapinga *et al*., 1995). Production occurs on small plots rarely 0.5 ha, though some large scale commercial production also occurs (Mutuura *et al*., 1992, Smit and Matengo, 1995).

In Eastern Africa, sweetpotato producers are most often resource poor farmers and production is mainly dominated by women (Mutuura *et al*., 1992; Bashaasha *et al*., 1995). Often farmers choose relatively infertile soils, plant late after other more sensitive crops are safely in the ground, apply no fertilizer or manure and pay little attention to weeding (Smit, 1997). Farmers commonly plant different varieties in the same plot. Most of these varieties are selected by farmers on the basis of factors such as yield, time until first harvest, drought tolerance, palatability, root colour, size and shape, root quality, sweetness, storability in the ground, pests and disease tolerance or resistance, or marketability (Smit, 1997). Different varieties and cultivars are known by different names depending on the locality, making their identification by their local names imprecise (Ewell and Mutuura, 1994).

2.3 Uses of sweetpotato

Globally, sweetpotato is used as a staple food by many people due to its high nutritional value in respect to carotene, carbohydrates, vitamins A and C, and minerals such as iron and potassium (Watt and Merill, 1975; Food and Nutrition Board, 1980; Ewell and Kirby, 1991). It is also used as vegetable (fleshy roots, tender leaves and petioles), snack food, animal feed, industrial starch extraction and fermentation, for various processed products (Bouwkamp, 1985), and for prevention of soil erosion (Gregory, 1992). Its use for human consumption has however declined, whereas its use as an animal feed and raw material for manufacture of industrial products has increased (Gregory *et al*., 1990).

In Kenya, it is mainly used as a food security crop and has a low cultural status. It plays critical roles in rural diets in certain areas, in the hungry months when maize and other foods run short, and in years of drought and other catastrophes (Scott and Ewell, 1992). There is shortage of knowledge on its nutritional value and limited recipe for its preparation, making it a less preferred food (Jansson and Raman, 1991). The potential for diversification of its uses has also not been widely recognized by researchers and farmers (Carey *et al*., 1997). In Rangwe division of Homabay district in South Western Kenya, the *Kinda* Women group dry and grind sweetpotato which is then used for baking bread, cakes and preparation of other snacks. In spite of this the locals are yet to embrace the diverse uses of sweetpotato (Personal observation).

2.4 Marketing and storage of sweetpotato

In Eastern Africa, sweetpotato is mainly grown as a subsistence crop. However, many households utilize it as a supplementary source of income and sell at local markets (Smit, 1997). A few roots are dug up and sold to cover expenses for household necessities or school fees (Scotts and Ewell, 1992). It is also sold in urban markets, but its perishability and bulkiness cause losses and high marketing costs (Fowler and Stabrawa, 1992).

Commercial production also occurs in some areas (Mutuura *et al*., 1992). In Rachuonyo district of Southwestern Kenya, sweetpotato production is mainly commercial. Upon harvest, tubers are stacked in conjoined gunny bags and packed into trucks destined to major urban centers (Plate 1).

(Photo taken by Kababu, April 2007)

Plate 1: Packaging and loading of sweetpotato for transportation in Ringa, Rachuonyo District.

Fresh sweetpotato deteriorates rapidly under ordinary conditions due to their short shelf life. This has resulted to limited post harvest storage of sweetpotato in the region (Smit, 1997). In certain parts of Tanzania, however, storage of fresh roots take place in pits (Kapinga *et al*., 1995). In-ground storage of sweetpotato also occurs where the roots are left in the field (Ewell and Mutuura, 1994; Bashaasha *et al*., 1995). Storage of dried chips and flour occurs in areas with dry periods lasting 5 months or more (Ewell and Mutuura, 1994).

2.5 Constraints to sweetpotato production

The main constraints to sweetpotato production are pests and diseases. Talekar (1988) has recorded over 270 species of insects and 17 species of mites that feed on sweetpotato. The major pests include those that damage the storage roots, defoliators, vine borers and disease vectors.

2.5.1. Root pests

Pests that damage storage roots include the sweetpotato weevils (Coleoptera: Curculionidae), wireworms (Coleoptera: Elateridae), flea beetles (Coleoptera: Chrysomelidae) and white grubs (Coleoptera: Scarabaeidae) (Jansson and Raman, 1991). Sweet potato weevils of the genus *Cylas* are considered to be the most destructive pests of sweetpotato in the world (Chalfant *et al*., 1990; Jasson and Raman, 1991). These have been reported to cause high yield losses of up to 90%, especially during dry spells (Alvarez *et al*., 1996). All the known or suspected pests species of this genus are found in Africa , *Cylas puncticollis* (Boheman) and *Cylas brunneus* (Fabricius) being the major ones (Wolfe, 1991) and *Cylas formicarius* (Fabricius) is found circumglobally outside Africa. Both *C. puncticollis* and *C. brunneus* were found to be of equal importance in South Nyanza, Kenya’s principal sweetpotato growing region (Magenya and Smit, 1991).

Principle damage by sweetpotato weevil (*Cylas spp*) is the mining of tubers by larvae (Sutherland, 1986; Jansson and Raman, 1991). The infested tuber is riddled with cavities, spongy in appearance, and dark in colour. They also cause indirect damage by facilitating entry of soil-borne pathogens. Feeding induces a chemical reaction that imparts a terpene odour to the tubers, rendering them unpalatable for human or even animal consumption (Sutherland, 1986). Feeding inside the vines causes malformation, thickening and cracking of the affected vine. Early infestation may lead to poor establishment of the planting material. Foliage may become pale in colour and the growth and vigor of the plants can be affected (Sherman and Tamashiro, 1954). The adult weevils may feed on tubers, creating numerous small holes (Sutherland, 1986; Jansson and Raman, 1991).

Wireworms bore fairly small irregularly shaped holes in the roots (Cuthbert, 1967; Davidson and William, 1987) while cucumber beetles eat small round holes through the skin of the roots and form irregularly shaped enlarged cavities just beneath the skin (Cuthbert, 1967; Davidson and William, 1987; Brill, 2005). White grubs damage roots by causing wide, tunnel-like gouges on the surface of the roots (Brill, 2005). Flea beetles are also known to cause winding tunnels just under the skin of the roots (Cuthbert, 1967; Davidson and William, 1987; Brill, 2005). Larvae of the rough sweetpotato weevil, *Blosyrus* spp. (Coleoptera: Curculionidae) damage roots by gouging deep grooves on the surface (Nsibande and McGeoch, 1999).

2.5.2 Defoliators

The defoliators include the sweetpotato butterfly *Acraea acerata* (Lepidoptera: Nymphalidae), cutworms, *Spodoptera litura* (Lepidoptera: Noctuidae), the sweetpotato hawk moth, *Agrius convolvuli* (Lepidoptera: Sphingidae) and the tortoise beetles, *Aspidomorpha* spp. (Coleoptera: Chrysomelidae) which greatly reduce the photosynthetic surfaces (Talekar, 1982; Nsibande and McGeoch, 1999). The large caterpillars of *A.*

c*onvolvuli* feed on leaf blades causing irregular holes. They may eat the entire blade leaving only the petiole. Both larvae and adults of tortoise beetles on the other hand eat large round holes on the leaves (Smit, 1997).

2.5.3. Vine borers

The vine borers include the clear wing moth *Synanthedon* spp (Lepidoptera: Sesiidae) and the stripped sweetpotato weevil *Alcidodes* spp (Coleoptera: Curculionidae), which cause considerable damage to the crown thus minimizing food translocation from the roots (Talekar, 1982). The larvae of clear wing moths burrow into vines and sometimes into roots. The vine base is characteristically swollen and is traversed by feeding galleries. The vines easily break off under heavy infestation. The larvae of *Alcidodes* spp bore into the vines, causing the vine base to swell up. Adult weevils girdle the vines, causing wilting (Smit, 1997).

2.5.4. Disease vectors and other constraints

The disease vectors include aphids and white flies that transmit the viral diseases affecting sweetpotatoes. Sweetpotato Virus Disease (SPVD) transmitted by white flies is the most widespread disease in the country (Wambugu *et al*., 1991). Nematodes and rodents have also been reported to cause considerable damage. (Jansson and Raman, 1991). Other constraints include storage methods, costs and losses, lack of processed products, transportation problems, high marketing costs, unstable supplies and prices, environmental factors and lack of improved cultivars and planting materials (Jansson and Raman, 1991).

2.6 Management of sweetpotato pests

2.6.1 Chemical control

Sweetpotato weevils have been controlled widely with chemical pesticides (Wheatley, 1961; Ingram, 1967; Kibata, 1977). Pre-planting insecticide applications have been used to manage weevils in planting materials (vine cuttings). Insecticides with adequate water solubility are presumably transported through the vine and kill the weevils within the vine. When combined with proper sanitation and other measures to prevent immigration of weevils from infested plants, this may result in satisfactory control of the weevil (Sherman, 1951; Ingram, 1967). Control achieved by post-plant applications appears to be due to mortality of weevil adults in search of feeding and oviposition sites (Jansson and Raman, 1991).

The commonly used insecticides include chlorpyrifos, endosulfan and phosmet which give varied levels of control of the major pests. These must, however, be applied at the appropriate time and in sufficient quantities for effective control (Brill, 2005). The onset of pesticide resistance and public concerns about environmental impact and safety of chemical applications, are driving research into alternatives including biological control (Smit, 1997).

2.6.2 Cultural control

This represents the most relevant pest and disease control option for subsistence farmers in Kenya. The method involves manipulating the environment to make it unsuitable for pests' survival, thus directly or indirectly reducing their populations. It includes crop rotation, intercropping, mulching, sanitation (removal of alternate hosts, use of clean cuttings and destruction of crop residues), manipulating both planting and harvesting dates, planting deep in the soil, use of deep rooted cultivars, use of resistant cultivars, weeding and ridging (Jansson and Raman, 1991; Smit and Odongo, 1997; Nsibande and McGeoch, 1999). These practices serve to protect crops from insect attack. Intercropping may reduce the accessibility of host plants to pests because the same crop species are more randomly distributed (Litsinger and Moody, 1976). Certain crops may also provide physical barriers for the movement of the pest insect (Talekar, 1988). Some of these practices such as hilling up, rotation and weeding have become so common among farmers for agronomic purposes that they are not recognized as control techniques (Smit and Odongo, 1997).

Farmers, for both social and economic reasons, have not implemented some of these control practices. Two practices with the most noticeable effect on weevil control (good field sanitation and planting away from weevil infested field) might require community effort in densely populated areas (Smit and Odongo, 1997). This is almost always the case in sweetpotato growing regions. Practices that would require more labour from farm families might be a constraint especially during peak periods of farm activities (Smit and Odongo, 1997). Besides, most of these recommendations are based on farming practices in Asia and United States of America where sweetpotato production is on a large scale. They are thus not easily adaptable to the subsistence farming conditions in tropical Africa.

2.6.3 Biological control

This involves the use of entomopathogenic fungi, entomophilic nematodes, parasitoids and predators in the management of pests. Predatory ants have been reported in the family Formicidae. The argentine ant, *Iridomyrex humilis* (Mayrs) and the big-headed ant, *Pheidole megacephala* (Fabricius) have been reported to attack *C. formicarius* in Louisiana (USA) and Cuba respectively, with the latter being more effective than chemical insecticides at managing weevil populations (Jansson and Raman, 1991). The spider, *Lycosa* sp., has also been implicated in the control of *C. formicarius* in Indonesia (Yaku, 1992). This is an indicator that several soil dwelling predatory arthropods may be effective in the management of sweet potato pests in the region. However, there are no reports of any predator groups in Kenya and their impact on sweet potato pests.

Six parasitoid species *Bracon, Macreupelmus, Cheilineurus, Eurytoma, Dinarmus* and *Menippus* var. *Africana* Nixon have been recorded by Jansson (1991) in East Africa while Allard and Rangi (1995) reported on several hymenopterans and dipterans as natural enemies of *C. puncticollis*. These are, however, not effective since the life stages of *Cylas* spp. are completed underground within the roots. This makes ground dwelling insect predators, entomopathogenic fungi, nematodes and bacteria, which are better suited to the underground conditions, have greater potential as biological control agents

(Ondiaka, 2007). Hyphomycetons fungi *Beauveria, Metarhizium, Paecilomyces* and *Verticillium* are among the most important genera that have potential for the control of curculionids, scarabs and lepidopterans (Ferron, 1981).

2.6.4 Soil fertility

Soil fertilization has been shown to affect all the three categories of resistance: antixenosis, antibiosis and tolerance. The obvious morphological responses of crops to fertilizers such as change in growth rates, accelerated or delayed maturity, size of plant parts and thickness and hardness of the cuticle also influence the success of many pest species utilizing the host (Altieri and Nicholls, 1990). Soil fertility management can have major effects on plant quality and this can in turn influence insect abundance and subsequent levels of plant damage. The reallocation of mineral amendments in crop plants can influence oviposition, growth rates, survival and reproduction in insects that use these hosts (Jones, 1976). Although more research is needed, preliminary evidence suggests that fertilization practices can influence the relative resistance of agricultural crops to insect pests (Phelan *et al.*, 1995). While there are records for many crops indicating that fertilization practices influence their relative resistance to various insect pests, none exists for sweet potato in Kenya.

2.6.5 Integrated Pest Management (IPM)

Integrated pest management is the coordinated use of pest and environmental information along with all available pest control methods to prevent unacceptable levels of pest damage in the most economical way, and with the least possible hazard to people, property and the environment (NSFCIPM, 1992). However, the pest management benefits of any developed IPM procedures may be mitigated by pest influx from the neighboring farms where they are not practiced. These procedures should therefore be practiced in all neighboring farms. This is not always possible, especially in developing countries where farmers lack education and extension services are poor or non-existent (Jansson and Raman, 1991).

A combination of tactics can provide effective control of the sweetpotato weevils and other pests damaging the tubers. With the exception of biological control in combination with post-plant application of insecticides, all the other control measures can be used together in the management of sweetpotato weevil (Talekar, 1988). In East Africa, the most promising components of IPM are cultural control and use of sex pheromones which require adaptation by farmers (Smit and Odongo, 1997).

Losses due to vine borers can be minimized by integrating various control tactics such as removing alternate wild *Ipomeas spp*. hosts, using resistant or tolerant sweetpotato cultivars, where such germplasm is available, and when economical, using chemical insecticides judiciously to minimize the exposure of natural enemies to toxicants. Potential sex pheromones may also be used (Jansson and Raman, 1991).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

The study was conducted in the South-western Kenya districts of Rongo, Rachuonyo and Suba. These sites are collectively described as belonging to the moist mid-altitude agro-ecological zone with altitudes ranging from 1170-2150 metres above sea level (Corbett *et al.*, 2001), with wide variations in climate. They have bimodal rainfall, which is sporadic and less reliable during the short rains along the lakeshore since the lowlands adjacent to Lake Victoria form a rain convectional shadow zone, with generally high temperatures. The soils are highly variable with some parts having rich volcanic soils; others have black cotton soil while other areas are described as marginal (parts of Rachuonyo and Suba).

In Suba, fishing is the main income generating activity and farming is minimal and mainly restricted to small plots along the lakeshore. Some of the plots in the riparian area are rocky and sandy hence not suitable for crop production. This being a very dry area, farmers fetch water from the lake to irrigate their crops. This is done manually without the use of pumps. In Rongo District individuals are mainly involved in sugarcane farming with sweetpotato playing a subsistence role, secondary to maize. In the upper zone of Rachuonyo district (mainly in Kabondo and Kasipul locations), sweetpotato is produced for commercial purposes (Appendix 1).

3.2 Farmer based data

A semi-structured questionnaire (Appendix 2) was used to collect farmer based data. This sought to establish farmers' knowledge and effects of their practices on sweetpotato pests and their management. Data collected included varieties of sweetpotato grown and reasons for growing them; specified/identified pest problems and their severity rating; estimated yield losses from each pest; farmers' control practices (if any) for each pest and estimated efficacy; other methods of control known but not practiced by the farmer and reasons for that, and other farm practices. Several socio economic factors affecting sweetpotato production in the region were also taken into consideration. These included the uses of sweetpotato produced and challenges faced in production, selling and storage.

It is estimated that about 50% of farmers practice some sort of cultural control practices against sweetpotato pests, and that this estimate is +/-20% accurate. To get a fair representation of the region, the study area was divided into three (Suba, Rongo and Rachuonyo districts). The sample size ***n*** within each district was then determined as follows:

$$\boldsymbol{n} = \frac{16\,P(1-P)}{C^2}$$ (Coe, 1996)

Where:

n = sample size,

P; Probability = (0.5)

C; Width of confidence interval = 2X0.2 = 0.4

Thus: ***n*** = 25

A total of seventy five farmers were thus interviewed in the study, twenty five from each of the districts. Sampling was purposive and questionnaires were administered to farmers as they were encountered and depending on their willingness to participate in the study.

3.3 Experimental design and plot lay out

To establish the effects of organic soil amendments on the diversity and abundance of ground dwelling predatory arthropods, an experimental plot was set up in a farmer's field in Awendo division, Rongo district. The plot was picked due to its large size, easy accessibility and willingness of the farmer to allow for his plot to be used in the study. This was set up in a random block design with four treatments in four replications on 5 x 5m plots. The treatments included (1) Animal-based manure; (2) Plant-based (sugar milling by-products) manure; (3) inorganic fertilizer (Diammonium Phosphate- DAP) and (4) control (no soil amendment). A buffer strip of two metres wide was left between the plots to reduce movement of ground arthropods from plot to plot. Both animal and plant based amendments were spread on the soil one week before planting at a rate of 15kg per plot, while inorganic fertilizer was applied a week after planting at the rate of 5g per plant.

The sweetpotato variety used in the entire experiment was *nyathi odiewo.* This was obtained from Kabondo in Rachuonyo district and the vine cuttings used were checked for any signs of pests' infestation before planting. This was to ensure that only clean planting material was used in the study. Planting was done on ridges and other agronomic practices followed appropriately within the desired time.

3.4 Pitfall trapping of ground dwelling arthropods

Ground dwelling arthropods were sampled by use of pitfall traps, which has long been an accepted and convenient method of sampling soil arthropods (Greenslade, 1964; Southwood, 1978). It is an effective and cheap way of quantitatively surveying the surface active arthropods and allows for comparison of assemblages in different habitats (Kamunya, 2002).

One litre plastic cups measuring about 11cm in diameter and 8cm high were half-filled with Ethyl glycol and placed in a hole sunk into the ground so that the mouth was level with the ground. Round mouth cups were used since they are not subjected to any directionality in sampling (Luff, 1975). These were roofed with lids supported on pegs to prevent entry of animals and precipitation from above (New, 1998).

One pitfall trap was set at the centre of each plot for a week after which they were removed by hand. The contents of each cup was collected by straining the preservative through a fine mesh and rinsing the contents of the strainer into a specimen bottle (vial) containing 70% alcohol and preserved for identification. Sampling commenced one month after planting and continued monthly for 5 months.

3.5 Identification of arthropods

Sorting and identification of all arthropods was done at the department of Zoological Sciences of Kenyatta University with the help of qualified staff. Except for a few cases, all arthropods collected were identified to species level. Special attention was, however, paid to predatory arthropods which were targeted in this study.

3.6 Damage assessment

Foliar and yield assessment was done at harvest. This took into account the length and number of vines, weight and number of tubers and all damage inflicted on the tubers. To do this, ten plants were randomly selected from each plot. The length of vines was measured with the aid of a tape measure and the number of vines per plant recorded. The number of tubers from these plants was recorded and their weight taken. The tubers were then cleaned thoroughly to reveal any damage inflicted by pests then separated in terms of marketable and non marketable produce. The damage assessment evaluation included number punctured, number tunneled or with blemishes on the skin and the unaffected.

3.7 Data management and analysis

Questionnaire based data was coded then analyzed using descriptive statistics. Frequencies were expressed as percentages and represented in form of graphs and pie charts.

Data obtained from pitfalls were pooled for each of the treatments. The following species indices were then calculated using methods by Krebs (1989):

- S – species richness, the total number of species present;
- Shannon-Weiner diversity index, expressed as

$$\mathbf{H}' = \sum pi\ (\log pi.),$$

Where pi is the proportion of the i^{th} species in the sample

- Evenness, a measure of relative abundance, expressed as;

  J=H'log S

  Where S is the species richness and H' is the Shannon Weiner diversity index

- Dominance

  $$d = \frac{\text{total number of individuals}}{\text{Total number of individuals of all species}}$$

- Sørensen's similarity coefficient

  QS= 2C/A+ B

  where A and B are the species numbers in sample A and B, respectively, and C is the number of species shared by the two samples

Data testing treatment effects was analyzed using Analysis of Variance (ANOVA). Shapiro Wilkes test revealed strong evidence against normality in all parameters of the study. All the count data was thus transformed {log (x + 1)} before ANOVA then back transformed after analysis. Differences between means were then separated using student Neuman Keuls's test (SNK).

CHAPTER FOUR
RESULTS

4.1 Demographic information of the respondents

Majority of the respondents were females (73.3%), most having dropped out of school at primary level (Fig. 1). Most of the respondents were in their prime age and had their household heads aged between 20-40 years (50%) (Fig. 2). They were mainly involved in subsistence farming and sold some of their farm produce in nearby markets to generate income for other household necessities. Other occupations mentioned were teaching, masonry, accounting and technical work. Others reported that they had no other sources of income. The male respondents indicated that they delegated the duty of looking after the farm and selling of produce to their spouses, giving the impression of sweetpotato being a woman's crop.

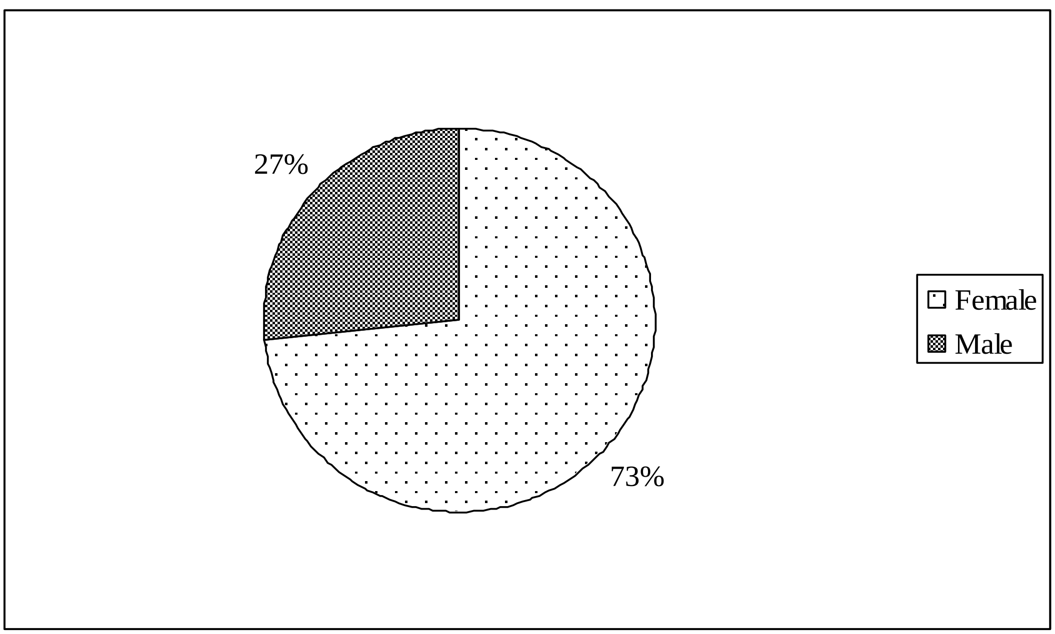

Figure 1: Sex of respondents

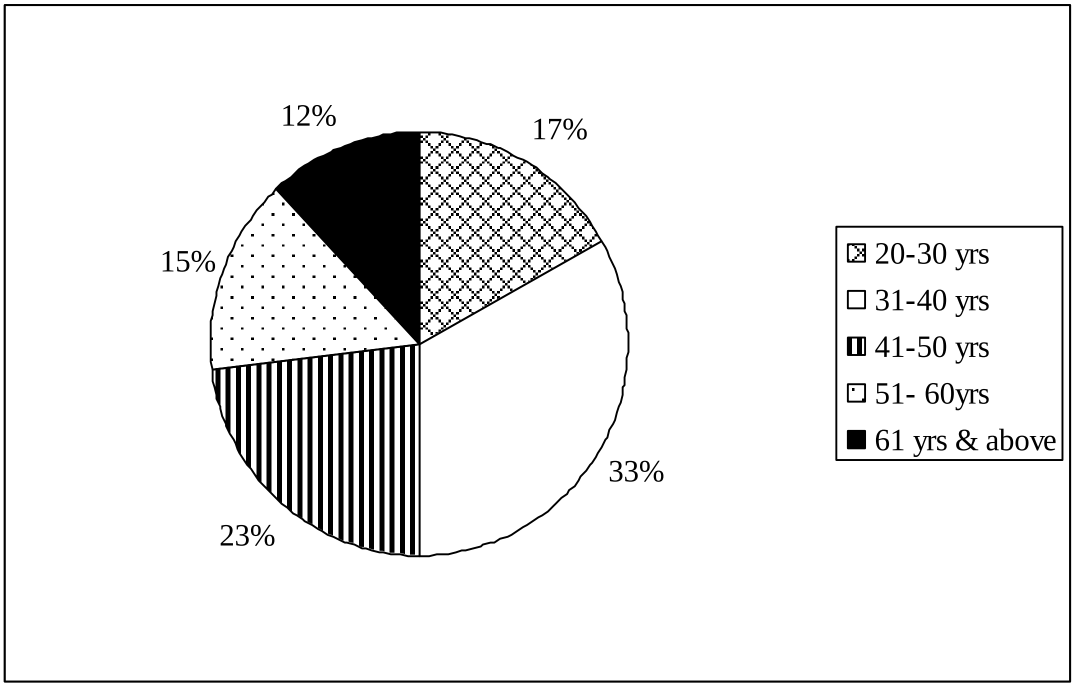

Figure 2: Age of household heads

4.2 Farmers' knowledge on sweetpotato pests and their management

Farmers' knowledge on sweetpotato pests was generally sparse in the region. However, most of them were aware of the sweetpotato weevil. Out of the seventy five individuals interviewed, 85.3 % were aware of the presence of root feeders. The remaining 14.7%, mainly from Rongo and Suba districts were ignorant of the presence of root feeders (Fig. 3). In Suba, some respondents mistook damage by pests as scorching from the sun. This was due to withering of foliage resulting from tuber damage. In most cases when the plants were uprooted, it was noted that damage was massive at the base of the vines which formed entry points for the root feeders causing plants to wither (Plate 2).

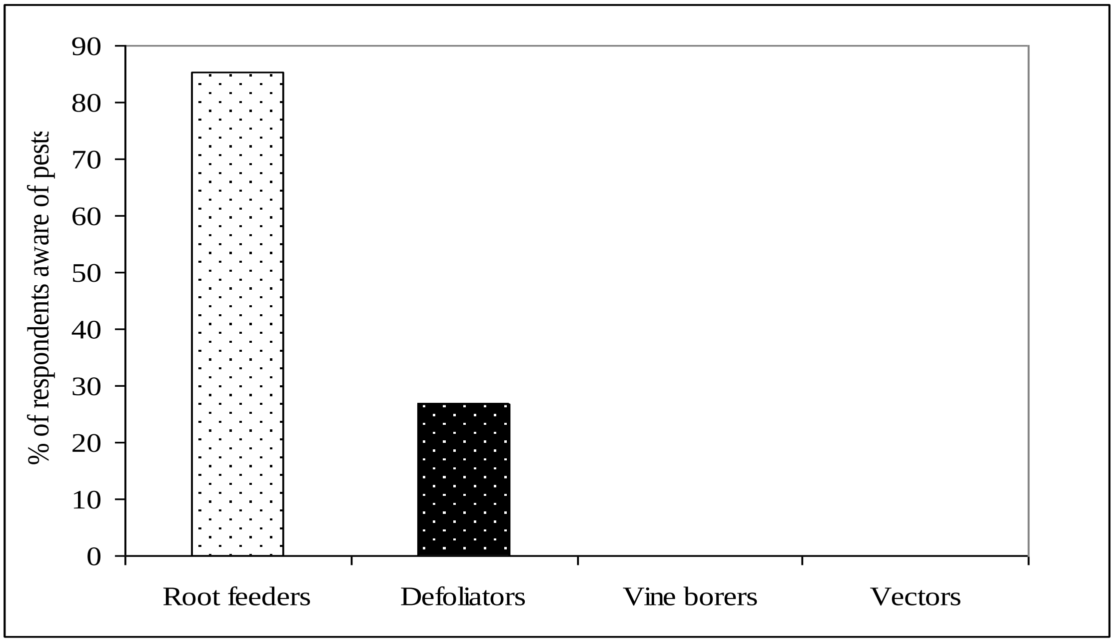

Figure 3: Farmers' knowledge on sweetpotato pests in southwestern Kenya (n=75)

Plate 2: Swelling and malformation of vines due to infestation by root feeders, resulting to withering of plants in Suba District

Some of the individuals (27%) who had knowledge on the presence of root feeders did not however, know the identity of the pests damaging the tubers (Fig. 4).

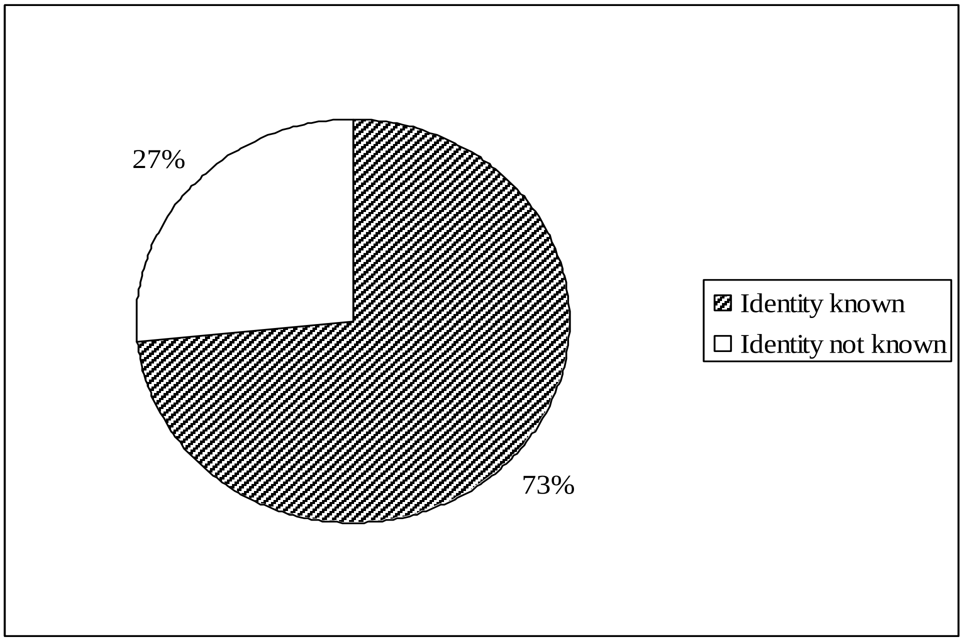

Figure 4: Ability to identify root feeders as reported by farmers

The respondents reported various damages resulting from root feeders (Plate 3). The most common damage observed by respondents was rotting of tubers with larvae present (38.7%). About 22.7% of the respondents reported tunneling of tubers with blemishes on their skin. Some other 4.0% reported boring of holes and some 5.2% reported four other different types of damage which include deformed tubers, tubers having a characteristic smell, tubers containing water and tubers drying up. The remaining 29.3% were not aware of the damages caused hence did not indicate any (Table 2). The most common damage reported in Suba and Rachuonyo districts was rotting of tubers with larvae present. In Rongo, however, tunneling of tubers with blemishes on the skin was the most common damage (Table 2).

Table 2: Percentage of farmers by district reporting various types of damage caused by root feeders

Damage caused by root feeders	Frequency of respondents reporting on damages by root feeders in the districts			
	Suba	Rachuonyo	Rongo	Total
Rotting of tubers with larvae present	14 (56%)	12 (48%)	3 (12%)	29 (38.7%)
Tunneling of tubers/blemishes on the skin	3 (12%)	6 (24%)	8 (32%)	17 (22.7%)
Boring of holes	1(4%)	_	2 (8%)	3 (4%)
Tubers with a characteristic smell	_	_	1(4%)	1 (1.3%)
Tubers soggy	_	_	1(4%)	1 (1.3%)
Tubers deformed	1(4%)	_	_	1 (1.3%)
Tubers drying up	1(4%)	_		1 (1.3%)
Not known	5 (20%)	7 (28%)	10 (40%)	22 (29.3%)
Total	25 (100%)	25 (100%)	25 (100%)	75 (100%)

a **b**

c **d**

Plate 3: Damages caused by root feeders (a) tunneling of tubers with blemishes on the skin (b) rotting of tubers with larvae present (c) boring of holes (d) gouging of tubers and boring of holes.

Forty four percent of the respondents indicated that root feeders posed a serious problem while 13% indicated that the problem was not serious. The remaining (43%) individuals did not rate the severity of damage caused (Fig. 5).

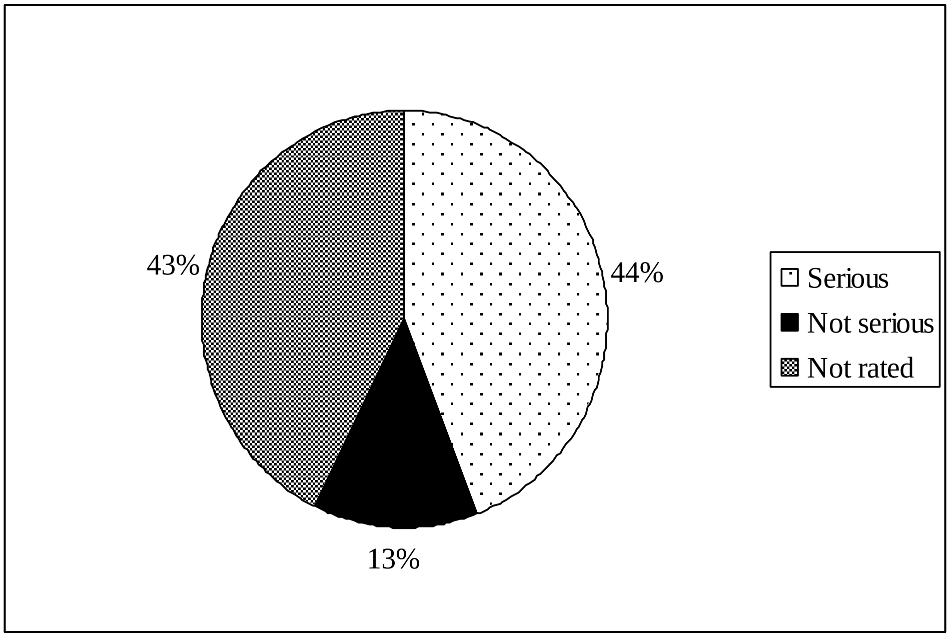

Figure 5: Severity of damage caused by root feeders as reported by farmers

Knowledge on defoliators was sparse in the entire region. Only 26.7% of the respondents were aware of the presence of defoliators and recognized them as pests though they could not identify them (Fig. 3). The types of damages reported included meshing, windowing and folding (Fig. 6; Plates 4). Windowing was the most common damage reported in the Suba and Rachuonyo districts. However, individuals from Rongo district did not report on any form of damage by defoliators and therefore did not rate the severity of damage caused. Apart from root feeders and defoliators, farmers did not mention other pests affecting sweetpotato.

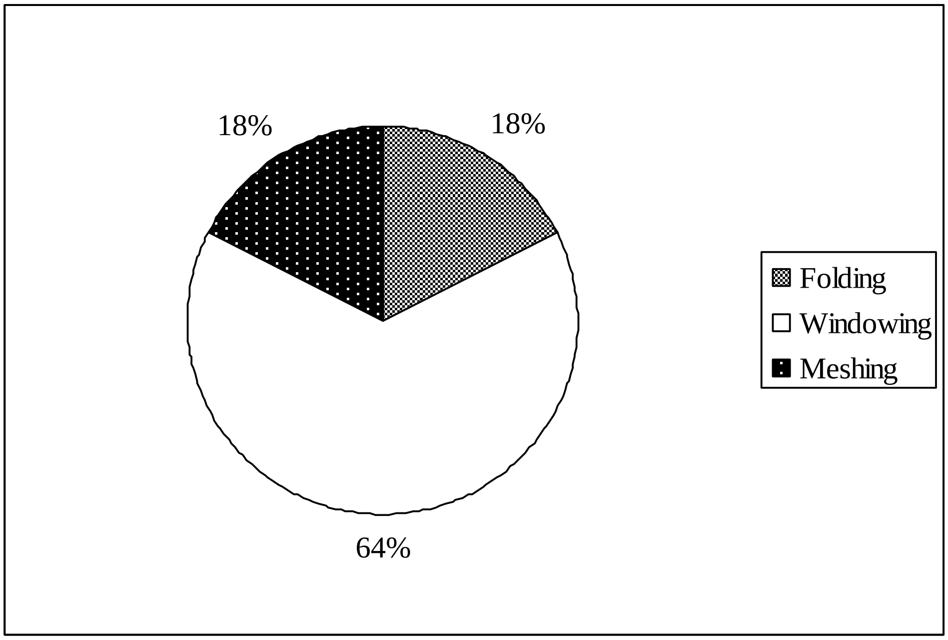

Figure 6: Damages caused by defoliators as reported by farmers

a **b**

Plate 4: Damages caused by defoliators (a) folding of leaves (b) windowing

4.3 Farmers' practices and their effects on the management of sweetpotato pests

Majority of the respondents (94.8%) reported that they did not practice any method of control against sweetpotato pests (Fig. 7). They also indicated that they were not aware of the practices that could help reduce pests' infestation. The other 5.2% of the respondents were aware of four different methods of control which they did not implement. These included early harvesting, ridging, removal of infested tubers and rotation. The respondents did not report on the efficacy of these practices in the management of pests.

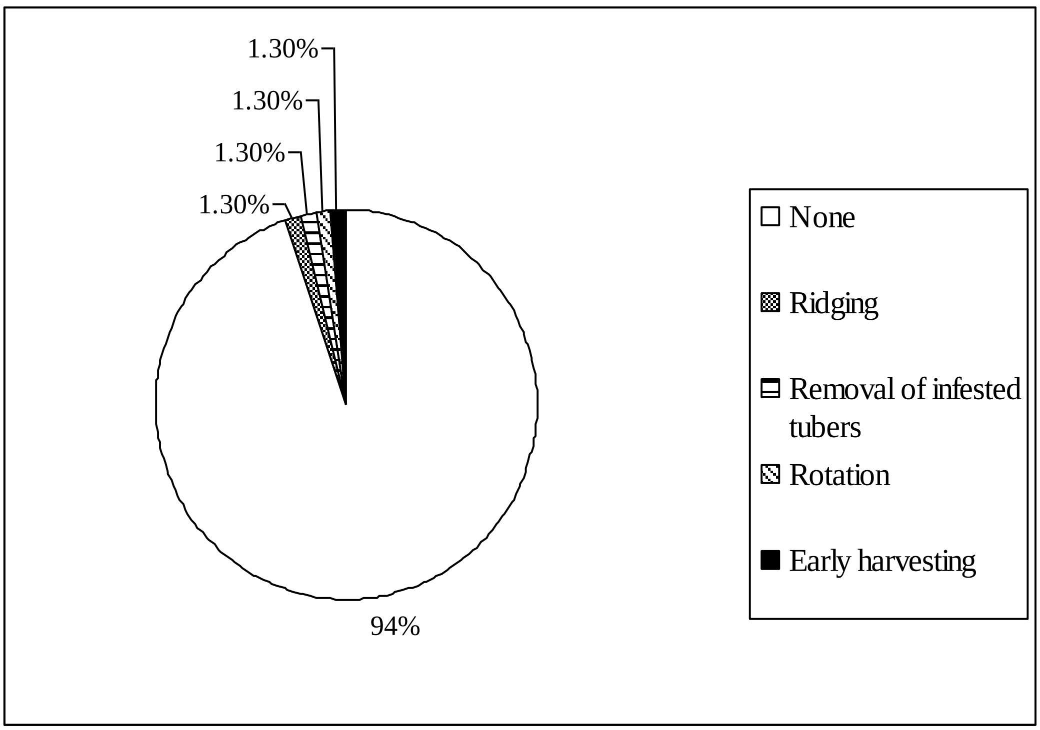

Figure 7: Farmers' knowledge on methods of controlling sweetpotato pests

4.3.1 Varieties of the grown sweetpotato

Different varieties of sweetpotato were grown in the region. The major varieties of sweetpotato grown included *Ombeko leso*, *Nyathi odiewo* and *Oduoko* in Suba, Rachuonyo and Rongo districts respectively. Other varieties were also grown but different names appear to have been given to similar varieties in different localities. Most of the varieties were grown due to their ability to produce many tubers (30%), availability (27%), ability to mature fast (25%) and sweetness (11%) (Fig. 8). Other reasons for growing different varieties included drought tolerance, ability to sell fast and the better performance of maize after sweetpotato.

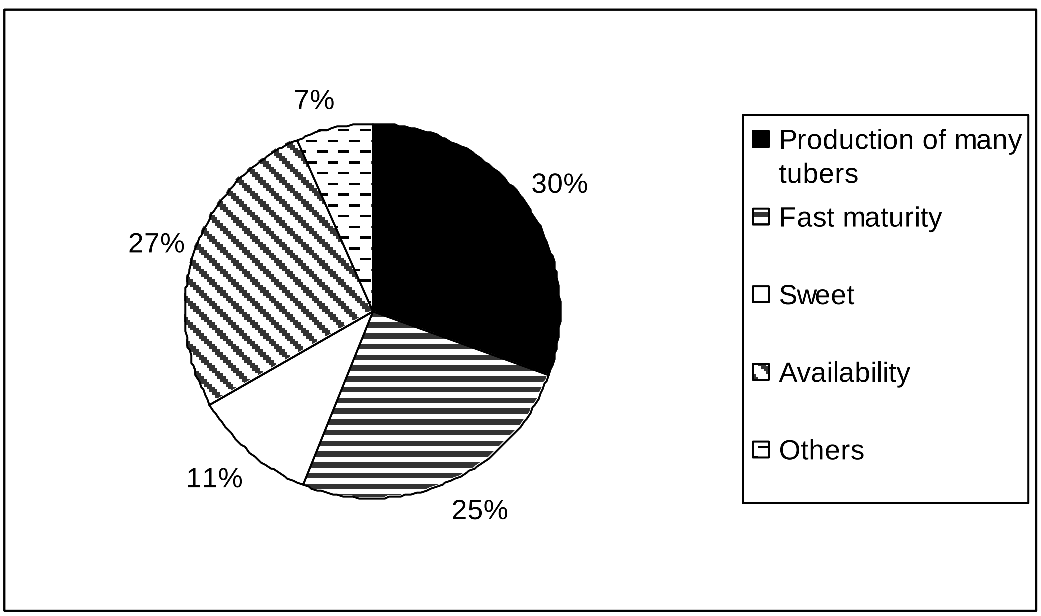

Figure 8: Reasons for growing different varieties of sweetpotato as reported by farmers

4.4 Socio-economic, biophysical and socio-cultural factors affecting sweetpotato production in Southwestern Kenya

4.4.1 Major crops grown by respondents

Overall, majority of the respondents (50.7%) reported maize to be a major crop with sweetpotato (20.0%) coming second in the entire region (Table 3).

Table 3: Major crops grown by respondents in the selected districts in Southwestern Kenya

Major crop grown	Percentage of respondents growing different crops in the three districts			
	Suba	Rachuonyo	Rongo	Total
Maize	8 (32%)	13 (62%)	17 (68%)	38 (50.7%)
Sweetpotato	3 (12%)	12 (48%)	_	15 (20.0%)
Sugarcane	_	_	7 (28%)	7 (9.3%)
Millet/sorghum	4 (16%)	_	_	4 (5.3%)
Mangoes	3 (12%)	_	_	3 (4%)
Kales	3 (12%)	_	_	3 (4%)
Bananas	2 (8%)	_	_	2 (2.7%)
Arrow roots	1 (4%)	_	_	1 (1.3%)
Groundnuts	1 (4%)	_	1(4%)	2 (2.7%)
Total	25 (100%)	25 (100%)	25 (100%)	75 (100%)

In Rachuonyo District, sweetpotato (48%) was secondary to maize (62%) in production. However, the scenario was different in Suba and Rongo Districts. In Suba, sweetpotato (12%) came third after maize (32%) and millet (16%) whereas none of the respondents from Rongo District grew sweetpotato as a major crop. The respondents mainly concentrated on maize (68%) and sugarcane (28%) production.

4.4.2 Size of farms owned by respondents

Majority (41.3%) of the respondents owned between 0.5ha to 1ha of land (Table 4). It was also noted that the majority grew maize as a major crop irrespective of the size of their farms (Table 5). Majority (54%) of the respondents who grew sweetpotato as a major crop owned between 0.5-1 ha of land (Fig. 9).

Table 4: Size of farms (ha) owned by respondents in the region

Size of farm	Percentage of respondents owning various sizes of farm in the three districts			
	Suba	Rachuonyo	Rongo	Total
< ½ ha	8 (32.0%)	2 (8.0%)	12 (48.0%)	22 (29.3%)
½-1 ha	9 (36.0%)	13 (52.0%)	9 (36.0%)	31 (41.3%)
>1 ha	8 (32.0%)	10 (40.0%)	4 (16.0%)	22 (29.3%)
Total	25 (100%)	25 (100%)	25 (100%)	75 (100%)

Table 5: Major crops grown on different sizes of farm owned by respondents

Major crop grown	Frequency of respondents growing different major crops on different sizes of farms (ha) owned			
	< ½ ha	½-1 ha	>1 ha	Total
Maize	12 (54.5%)	16 (51.6%)	10 (45.5%)	38 (50.7%)
Sweetpotato	2 (9.1%)	8 (25.8%)	5 (22.7%)	15 (20.0%)
Sugarcane	3 (13.6%)	1 (3.2%)	3 (13.6%)	7 (9.3%)
Millet/sorghum	2 (9.1%)	2 (6.5%)	0 (0%)	4 (5.3%)
Others	3 (13.6%)	4 (12.9%)	4 (18.2%)	11 (14.7%)
Total	22 (100%)	31 (100%)	22 (100%)	75 (100%)

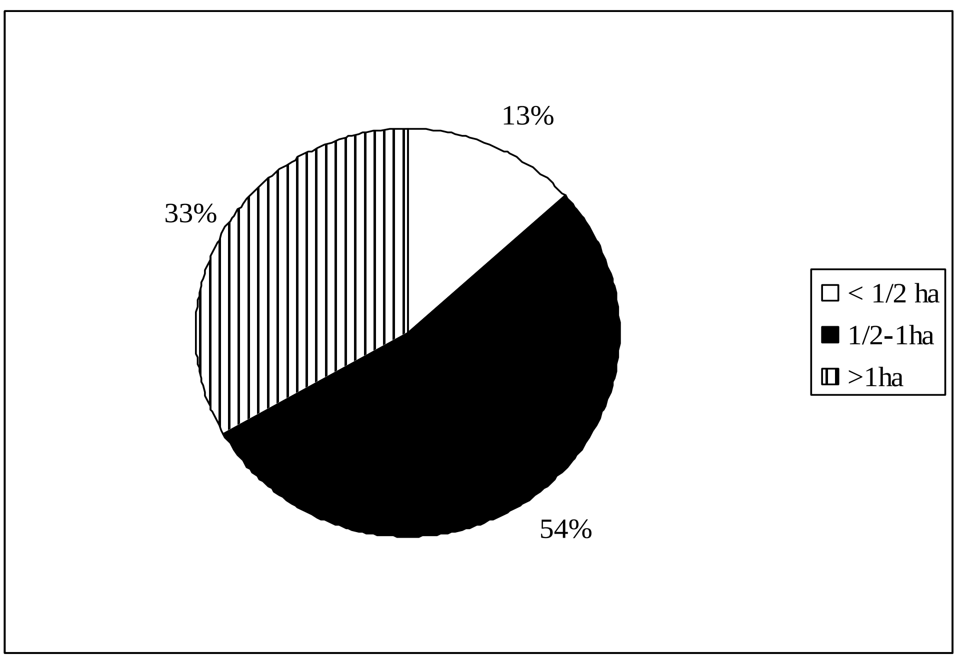

Figure 9: Size of farm owned by respondents growing sweetpotato as a major crop

4.4.3 Uses of sweetpotato produced

Sweetpotato in the region was grown for both commercial and subsistence purposes. Most of the respondents (53.3%) produced sweetpotato for subsistence purpose whereas the remaining ones (46.7%) were involved in commercial production (Fig. 10). Selling was mostly done in the farms or nearby markets. In Rachuonyo, tubers were collected by buyers from the farms. In Rongo most of the tubers were consumed whereas in Suba they were sold locally from the farm or nearby markets.

Majority of respondents (42.5%) involved in subsistence production of sweetpotato had less than 0.5 ha of land whereas most (45.7%) of those involved in commercial production had between 0.5 and 1ha of land (Table 6).

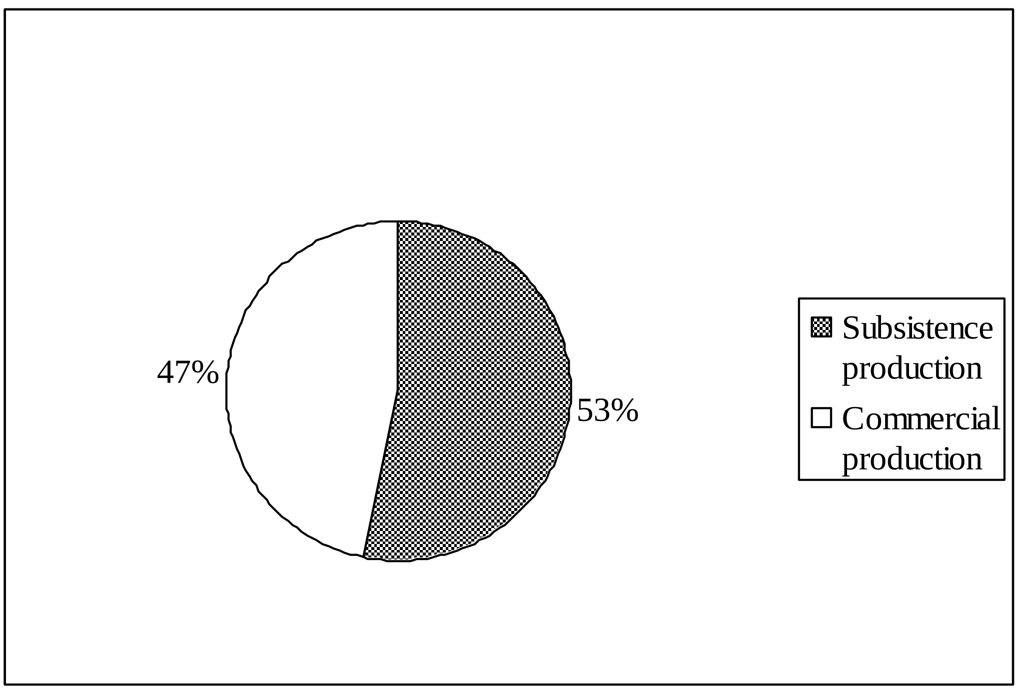

Figure 10: Uses of sweetpotato produced as reported by respondents

Table 6: Size of farm (ha) owned by respondents producing sweetpotato for different purposes (n=75)

Size of farm	Frequency of respondents with different sizes of farm reporting on uses of sweetpotato produced	
	Subsistence	Commercial
< ½ ha	17 (42.5%)	5 (14.3%)
½-1 ha	15 (37.5%)	16 (45.7%)
>1 ha	8 (20.0%)	14 (40.0%)
Total	40 (100%)	35 (100%)

4.4.4 Challenges faced in the production of sweetpotato

The major constraints to production of sweetpotato in the region included moles (20.4%), hippos (16.3%), poor performance of crops (16.7%), hard labour (11.1%), insect pests and diseases (10.0%), lack of space (8.9%), and financial constraints (7.8%). Other challenges included feeding on crops by farm animals and lack of planting materials (Fig. 11). In Rongo District, moles (63.6%) were reported as the major threat to the production of sweetpotato (Fig. 12). Other challenges included poor performance of crops (13.6%), removal of tubers by monkeys (13.6%) and lack of space (9.2%).

In Rachuonyo District, respondents reported poor performance of crops (22.9%) and the prevalence of pests and diseases (20.0%) as the main constraints to production (Fig 13). Financial constraints (17.1%), removal of tubers by moles (14.3%) and hard labour

(11.4%) were also reported as challenges to production. Other (14.3%) challenges reported included lack of space and lack of planting material.

In Suba District, however, the main challenge to production was destruction of crops by hippos (41.7%) (Fig.14). Hard labour (16.7%) and lack of space (13.9%), poor performance of crops (11.1%) and prevalence of pests and diseases (5.5%) were also reported as constraints to production. Other (11.1%) constraints reported included lack of planting material, financial constraints and destruction of crops by livestock.

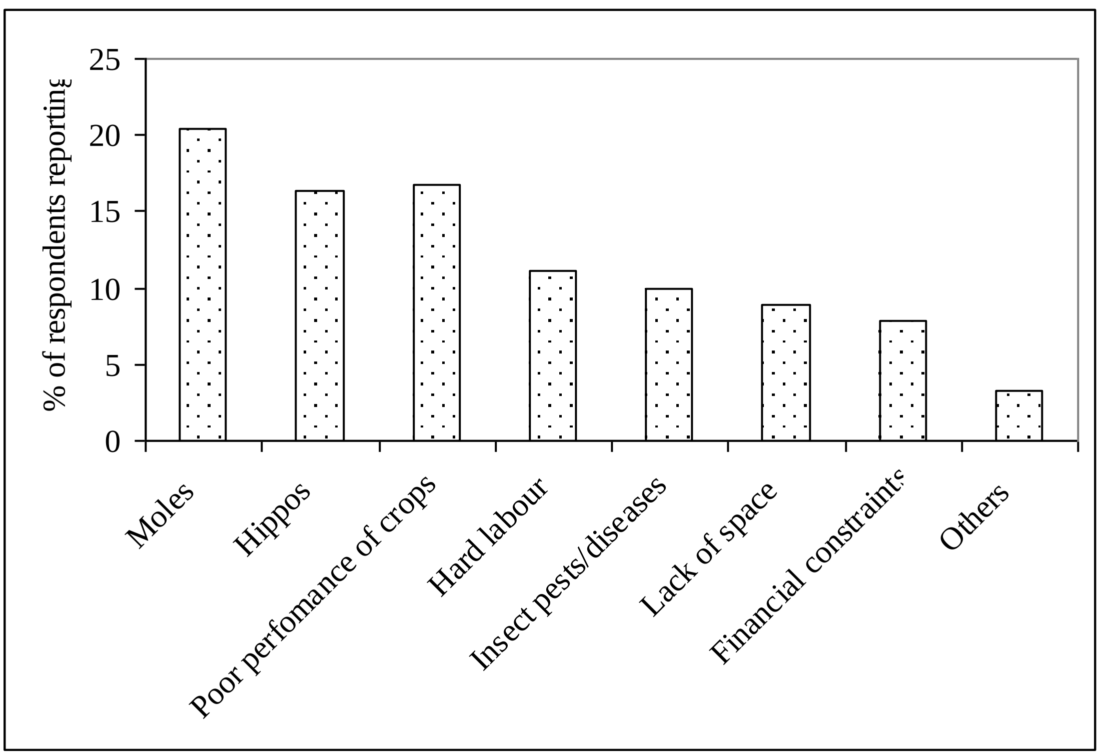

Figure 11: Challenges faced in the production of sweetpotato as reported by respondents in the region

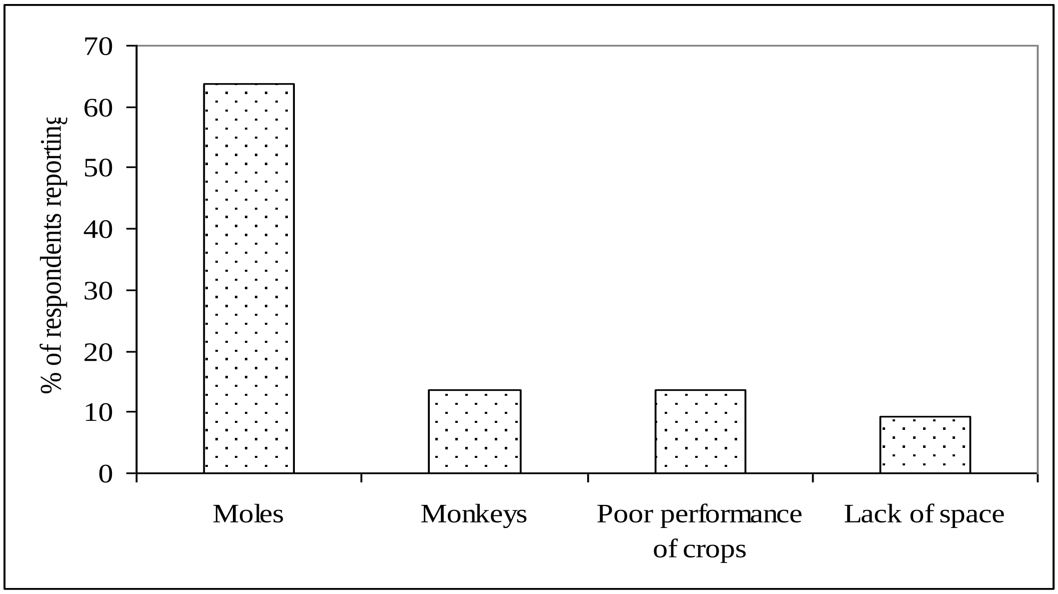

Figure 12: Challenges faced in the production of sweetpotato as reported by respondents in Rongo District

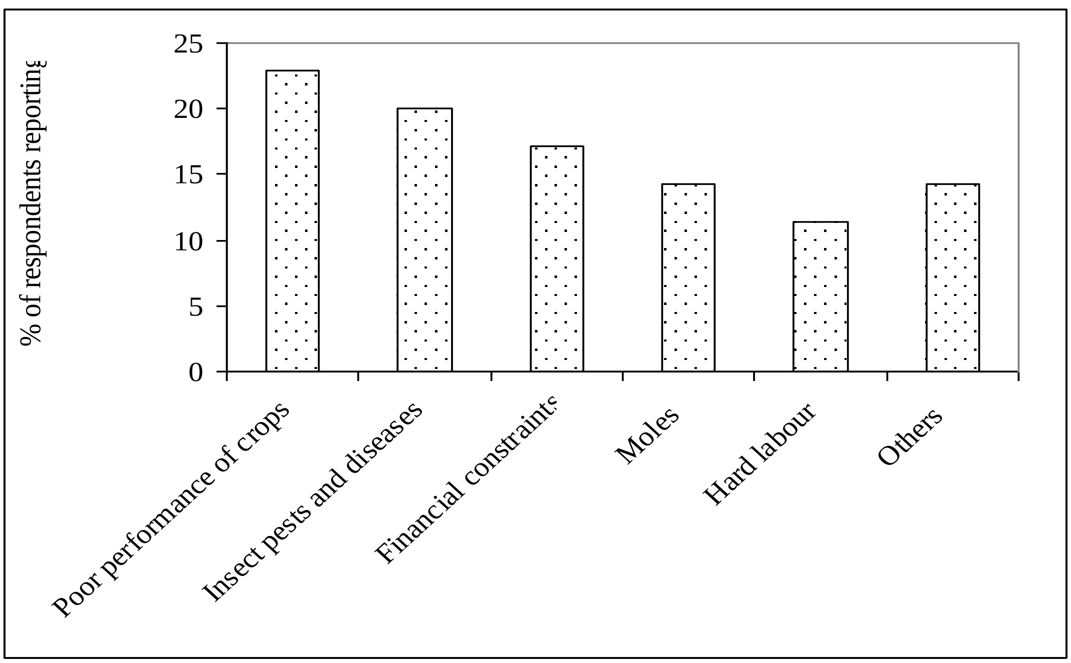

Figure 13: Challenges faced in the production of sweetpotato as reported by respondents in Rachuonyo District

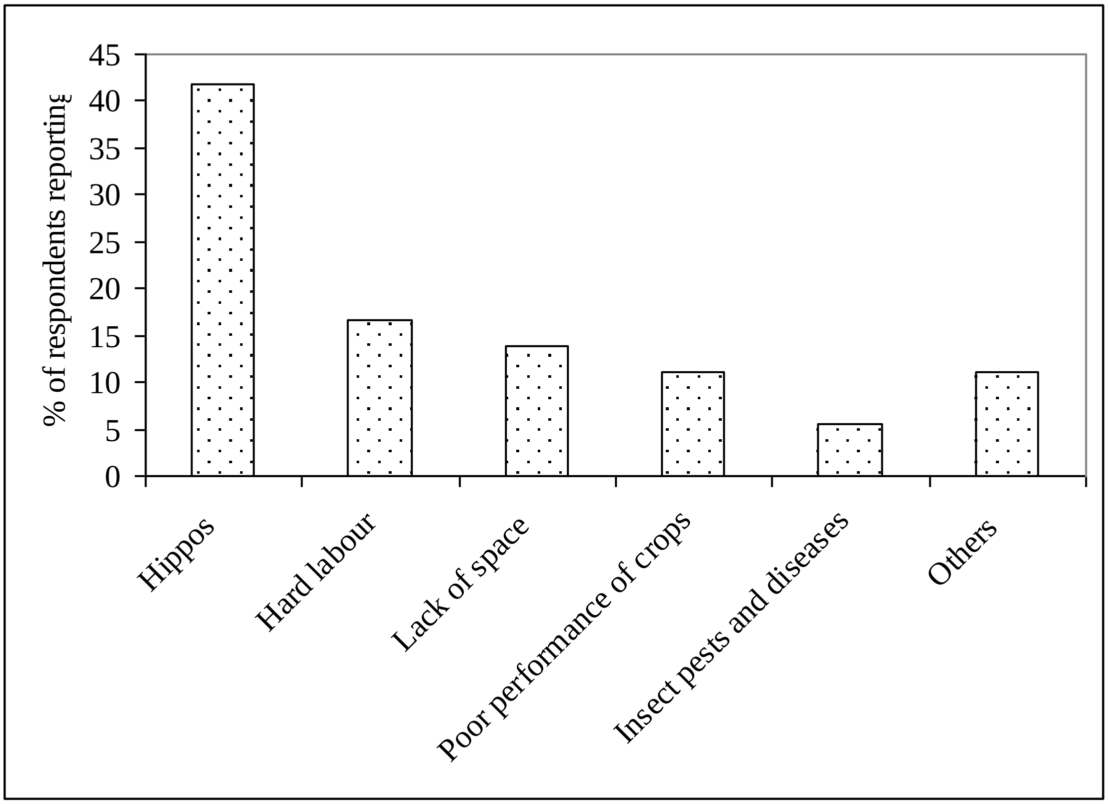

Figure 14: Challenges faced in production of sweetpotato as reported by respondents in Suba District

4.4.5 Challenges faced in the storage of sweetpotato

Sweetpotato is a perishable crop and its storage was generally out of question in the region. Most of the respondents indicated that they carried out piecemeal harvesting of tubers. This enabled tubers to remain in the soil for long periods of time. In Rachuonyo District, however, harvesting was done once and respondents indicated that perishability of produce (46%) and lack of storage mechanisms (54%) posed the major threat to storage of the produce (Fig. 15).

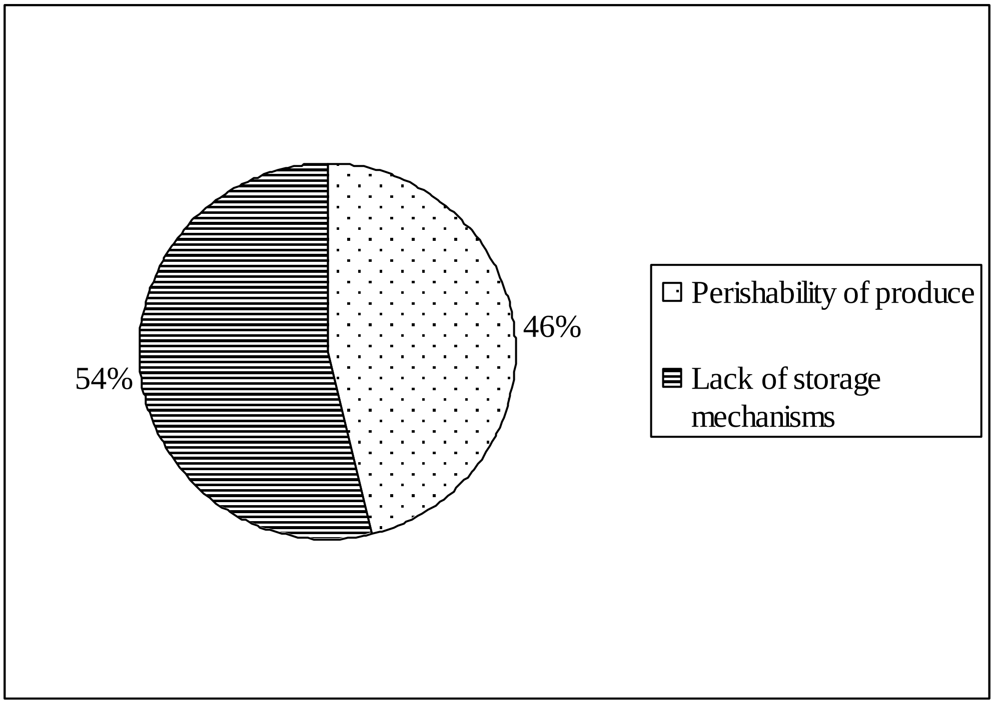

Figure 15: Challenges faced in the storage of sweetpotato as reported by respondents

4.4.6 Challenges faced in marketing sweetpotato

The constraints faced by respondents in marketing sweetpotato included low selling prices (40%), exploitation by buyers (28%), costly transport (20%) and unreliability of buyers (8%) (Table 7). In Suba, costly transport (75%) and low selling prices (25%) were reported as challenges. In Rachuonyo where sweetpotato production was mainly commercial, the constraints reported by farmers included low selling prices (45%), exploitation by buyers (35%), costly transport (10%) and unreliability of buyers (10%). Rejection of infested tubers was the only challenge reported in Rongo District.

Table 7: Challenges faced in marketing sweetpotato as reported by respondents

Challenge faced in marketing sweetpotato	Frequency of respondents reporting on challenges faced in marketing sweetpotato in the three districts			
	Suba	Rachuonyo	Rongo	Total
Low selling prices	1 (25%)	9 (45%)	_	10 (40%)
Costly transport	3 (75%)	2 (10%)	_	5 (20%)
Exploitation by buyers	_	7 (35%)	_	7 (28%)
Unreliability of buyers	_	2 (10%)	_	2 (8%)
Rejection of infested tubers	_	_	1 (100%)	1 (4%)
Total	4 (100%)	20 (100%)	1 (100%)	25 (100%)

4.5 Foliar and yield/damage assessment

4.5.1 Assessment of foliar growth

During the long rains, foliar growth was massive, with long vines recorded in all the treatments (Table 8). Treatment with inorganic fertilizer registered the longest vines (346 cm). This was followed by treatments with animal-based manure (322.20 cm) then the control plot (318.25 cm). Treatment with plant based manure recorded the shortest vines (280.50cm). A significant difference was revealed between treatments in this season ($F_{3, 156} = 3.06$; $P< 0.05$). Treatment with inorganic fertilizer had significantly longer vines compared to treatment with plant based manure (SNK test). However, there was no significant difference between treatments with inorganic fertilizer, animal based manure and the control and between animal-based manure, plant based manure and the control.

During the short rains, the lengths of vines recorded were much shorter in all the treatments (Table 9) compared to those recorded during the long rains (Table 8). The longest vines were recorded in the control plot (192.50cm). This was followed by treatments with animal-based manure (186.75cm) then inorganic fertilizer (177.25cm). Treatments with the plant-based manure had the shortest vines (176.25cm). There was, however, no significant difference between treatments within the season ($F_{3,\ 156} = 1.37$; $P > 0.05$). The trend taken by vine length among treatments was not uniform across the seasons. In both cases, however, the shortest vines were recorded in treatment with plant based manure.

The mean number of vines differed significantly ($F_{3,\ 156} = 2.86$; $P < 0.05$) between treatments during the long rains (Table 8). The highest number of vines was recorded in the treatments with the animal based manure (2.88±0.13). This was followed by treatments with plant based manure (2.65±0.15), the control (2.58±0.13) then inorganic fertilizer (2.35±0.10). The treatment with inorganic fertilizer registered significantly fewer vines than treatment with the animal based manure. There was, however, no significant difference between the treatments with inorganic fertilizer, plant based manure and the control; and the between animal based manure, inorganic fertilizer and the control.

During the short rains there was no significant difference (($F_{3,\ 156} = 1.37$; $P > 0.05$) recorded in the mean number of vines between the treatments (Table 9). The treatment with plant based manure recorded the highest number of vines (1.30±0.09). This was followed by treatments with animal based manure (1.18±0.09) then inorganic fertilizer (1.15±0.06). The control plot had the least number of vines (1.10±0.05). The mean number of vines in different treatments did not follow the same trend in the long and short rain seasons

Table 8: Effect of different soil treatments on foliar growth during the long rains of 2007

Treatment	Vegetative parameters	
	Mean no of vines/treatment	Mean length of vines (cm)/treatment
Animal based manure	2.88±0.13a	322.20±17.17ab
Plant based manure	2.65±0.15ab	280.50±12.09b
Inorganic fertilizer	2.35±0.10b	346.00±17.89a
Control	2.58±0.13ab	318.25±14.11ab
$F_{3,156}$	2.86	3.06
P	0.039	0.031

Means (±SE) followed by the same letter in the same column are not significantly different (P=0.05, SNK)

Table 9: Effect of different soil treatments on foliar growth during the short rains of 2007

Treatment	Vegetative parameters	
	Mean no of vines/treatment	Mean length of vines (cm) /treatment
Animal based manure	1.18±0.09	186.75±9.87
Plant based manure	1.30±0.09	176.25±9.98
Inorganic fertilizer	1.15±0.06	177.25±11.42
Control	1.10±0.05	192.50±11.44
$F_{3,156}$	1.37	0.53
P	0.2528	0.6611

4.5.2 Yield/damage assessment

During the long rains (Table 10), the treatment with inorganic fertilizer recorded the highest mean weight of tubers (15.75 kg). This was followed by treatment with the animal based manure (15.50 kg) then the control (13.75 kg). Treatment with the plant based manure recorded the least weight (12.25 kg). There was, however, no significant difference between the weight of tubers among the treatments ($F_{3, 12} = 0.46$; $P > 0.05$). In the short rains season (Table 11), the weights were much lower compared to those of the long rains. Treatment with the plant based manure recorded the highest weight (8.5 kg). This was followed by the animal based manure (8.25 kg), then inorganic fertilizer (6.25 kg). The control plot recorded the least weight of tubers (3.75 kg). A significant difference was observed between the treatments within this season ($F_{3, 12} = 3.97$; $P < 0.05$).

Treatment with the animal based manure recorded significantly greater weight compared to the control. There was, however, no significant difference between treatments with the animal based manure, plant based manure and inorganic fertilizer; and between the inorganic fertilizer and control.

During the long rains (Table 10), the animal based manure recorded the highest number of tubers (34.25±4.48). This was followed by treatments with the inorganic fertilizer (31.50±5.68) then the control (27.50±6.54). The plant based manure had the least number of tubers (22.50±1.66). There was no significant difference recorded between the treatments ($F_{3, 12}$ = 0.98; P>0.05). A similar trend was observed during the short rains (Table 11). The animal based manure recorded the highest number of tubers (35.25±5.76). This was followed by the treatments with inorganic fertilizer (33.75±4.92) then the control (24.75±5.20). The plant based manure had the least number of tubers (22.25±1.49) and there was no significant difference recorded between these treatments ($F_{3, 12}$ = 1.88; P> 0.05).

In the long rains season (Table 10), treatments with the plant based manure recorded the highest percentage tubers punctured (20%) compared to the other treatments. This was followed by the treatment with inorganic fertilizer (17%) and the control (17%). Treatment with the animal based manure had the least percentage of tubers punctured (15%). There was no significant difference in the number of tubers punctured between these treatments ($F_{3, 12}$ = 0.14; P>0.05). In the short rains season (Table 11), all the tubers in all the treatments were punctured.

In the long rains season (Table 10), the highest percentage of tunneled tubers was recorded in the treatment with the animal based manure (31%). This was followed by treatments with plant based manure (30%) then inorganic fertilizer (28%). The control plot recorded the least percentage of tubers tunneled (18%). There was, however, no significant difference in the number of tubers tunneled between the treatments within this season ($F_{3, 12} = 0.28$; $P>0.05$). In the short rains season (Table 11), all the tubers in all the treatments were tunneled.

In the long rains season (Table 10), the greatest percentage of the undamaged tubers was recorded in the control (67%). This was followed by treatment with the plant based manure (64%) then the animal based manure (58%). The least percentage of undamaged tubers was recorded in the treatment with inorganic fertilizer (52%). Difference between the number of undamaged tubers between the treatments within this season was, however, not significant ($F_{3, 12} = 0.48$; $P>0.05$). All tubers were damaged in all the treatments within the short rains season (Table 11). There was no difference indicated between treatments within this season.

In the long rains season (Table 11), the percentage of marketable and non marketable tubers varied between the treatments. However, there was no significant difference recorded in the number of marketable ($F_{3, 12} = 0.62$; $P>0.05$) and non marketable ($F_{3, 12} = 1.26$; $P>0.05$) tubers between treatments within the season. The control plot recorded the highest percentage of marketable tubers (83%) and the least percentage of the non marketable tubers (17%). This was followed by the plant based manure (77%) then the animal based manure (73%). Treatment with the inorganic fertilizer recorded the least percentage of marketable (71%) and the highest percentage of the non marketable (29%) tubers. All the tubers in all the treatments were greatly damaged and were thus non marketable during the short rains.

Table 10: Effects of different soil treatments on yield and quality of tubers during the long rains season of 2007

Treatment	Yield and quality parameters						
	Mean wt of tubers/ treatment (kg)	Mean no of tubers/ treatment	Mean no of tubers punctured/ treatment	Mean no of tubers tunneled/ treatment	Mean no of tubers undamaged/ treatment	Mean no of tubers marketable/ treatment	Mean no of tubers non-marketable/ treatment
Animal based manure	15.50±1.55	34.25±4.48	5.25±0.63 (15%)	10.75±4.09 (31%)	19.75±3.82 (58%)	22.50±3.28 (73%)	9.25±3.17 (27%)
Plant based manure	12.25±1.49	22.50±1.66	4.50±0.87 (20%)	6.75±0.75 (30%)	14.50±0.65 (64%)	17.25±0.85 (77%)	5.25±0.85 (23%)
Inorganic fertilizer	15.75±2.59	31.50±5.68	5.25±1.65 (17%)	8.75±1.11 (28%)	16.25±1.49 (52%)	24.75±4.87 (71%)	9.25±1.31 (29%)
Control	13.75±3.30	27.50±6.54	4.75±0.75 (17%)	5.00±2.35 (18%)	18.5±5.30 (67%)	22.75±5.45 (83%)	4.75±1.89 (17%)
$F_{3,12}$	0.46	0.98	0.14	0.28	0.48	0.62	1.26
P	0.717	0.433	0.935	0.838	0.701	0.614	0.333

Table 11: Effects of different soil treatments on yield and quality of tubers during the short rains season of 2007

Treatment	Yield and quality parameters				
	Mean wt of tubers/ treatment (Kg)	Mean no of tubers/ treatment	Mean no of tubers punctured/ treatment	Mean no of tubers tunneled/ treatment	Mean no of tubers non-marketable/ treatment
Animal based manure	8.25±0.63a	35.25±5.76	35.25±5.76	35.25±5.76	35.25±5.76
Plant based manure	8.5±1.66a	22.25±1.49	22.25±1.49	22.25±1.49	22.25±1.49
Inorganic fertilizer	6.25±1.31ab	33.75±4.92	33.75±4.92	33.75±4.92	33.75±4.92
Control	3.75±0.63b	24.75±5.20	24.75±5.20	24.75±5.20	24.75±5.20
$F_{3,12}$	3.97	1.88	1.88	1.88	1.88
P	0.035	0.187	0.187	0.187	0.187

Means (±SE) followed by the same letter in the same column are not significantly different (P=0.05, SNK)

4.6 Diversity and abundance of ground-dwelling predatory arthropods

The highest number of species was recorded in the control plot (14). This was followed by treatments with the plant based manure (12) and the inorganic fertilizer (12) which had a similar number of species. The least number of species was recorded in the treatment with the animal based manure (9). Species were more evenly distributed in the control plot (1.148). This was followed by treatments with the plant based manure (1.067) then inorganic fertilizer (0.944). Treatment with the animal based manure (0.723) had the least even distribution of species (Table 12). Since abundance is determined by species richness and evenness, species were more abundant in the control plot. This was followed by treatment with the plant based manure then the inorganic fertilizer. The animal based manure had the least abundance of species.

According to the Shannon index, the highest diversity of species was recorded in the control plot (1.002). This was followed by treatments with the plant-based manure (0.989) then inorganic fertilizer (0.875). Treatment with the animal-based manure (0.758) recorded the least diversity of species (Table 12).

The Berger-Parker Dominance revealed that treatment with the animal-based manure (38.636) had the most dominant species. This was followed by treatment with inorganic fertilizer (28.205) then the control (27.778). Treatment with the plant-based manure (18.919) had the least dominant species (Table 12).

According to the Sorensen's similarity matrix (Table 13), the greatest similarity of species occurred between treatments with the animal-based manure and the plant-based manure (0.55). This was followed by treatments with the animal-based manure and the control (0.5), then the inorganic fertilizer and the control (0.46). The least similarity of species occurred between treatment with the plant-based manure and the control (0.31). This was followed by treatments with the plant based manure and inorganic fertilizer (0.33).

Table 12: Composition and diversity of ground dwelling predators

Species	Treatment			
	Animal manure	Plant manure	Fertilizer	Control
Acilius sulcatus				2
Agelena sp	1	2	2	3
Aurilaria sp			1	
Calosoma auropunctata		3	8	3
Cychrus caraboides	8	3		
Chelidurella acanthopy			3	
Dysdera crocota				1
Dolomedes fimbriatus				1
Drassodes lapidocus			1	2
Lycosa narbonensis			1	
Labidura riparia				1
Linyphia triangularis		2		
Marava arachides				1
Myrmica rubra	8	5	8	5
Messor sp	17	7	11	10
Monomorium sp	1	7	1	4
Necrodes littoralis		2		
Nala lividipes		1	1	
Paederus littoralis			1	
Pseudochelidura	1			
Pterostichus		1		
Silpha atrata	2			1
Salticus senicus				1
Segestria senoculata	2		1	
Steatodea		1		
Tegenaria gigantea	4	3		1
Total Individuals (*n*)	44	37	39	36
Total Species (*S*)	9	12	12	14
Species evenness (J)	0.723	1.067	0.944	1.148
Alpha (α)	3.423	6.166	5.921	8.415
Shannon H' Log Base 10.	0.758	0.989	0.875	1.002
Berger-Parker Dominance (d%)	38.636	18.919	28.205	27.778

Table 13: Sorensen's similarity matrix

	Animal manure	Plant manure	Inorganic fertilizer	Control
Animal based manure	-	0.55	0.36	0.50
Plant based manure			0.33	0.31
Inorganic fertilizer				0.46
Control				

CHAPTER FIVE

DISCUSSION

5.1 Farmers' knowledge on sweetpotato pests

Knowledge on sweetpotato pests was generally sparse in Southwestern Kenya. This was contrary to findings by Smit (1997) who reported that farmers were able to identify different pests affecting sweetpotato in the region. Majority of the respondents were aware of the presence of root feeders though some did not know their identity. The most commonly known root feeder was the sweetpotato weevil. The respondents reported that they found larval stages of insect pests within tubers; the tubers had a characteristic smell and were unpalatable. The larval stages of the sweetpotato weevil are known to mine tubers and facilitate entry of soil borne pathogens (Sutherland, 1986; Jansson and Raman, 1991). Their feeding induces a chemical reaction that imparts a terpene odour to the tubers, rendering them unpalatable for human or even animal consumption (Sutherland, 1986).

In Rachuonyo District, all the respondents were aware of the presence of root feeders. They reported to have found tubers that were riddled with cavities; some were tunneled and had blemishes on their skin while others had numerous holes. Sutherland (1986) reported that tubers infested by the sweetpotato weevils are riddled with cavities and feeding by adults lead to formation of numerous small holes. White grubs have been reported to damage roots by causing wide, tunnel-like gouges on the surface of the roots (Brill, 2005). The rough sweetpotato weevil is also known to damage roots by gouging deep grooves on the surface (Nsibande and McGeoch, 1999). These findings indicate that the damages reported may have resulted from several root feeders. The respondents however, associated all the damages caused with the sweetpotato weevil.

Most respondents from Suba and Rongo Districts were completely ignorant of the presence of root feeders. They reported to have seen the damages caused but did associate these with the presence of insect pests. In Suba District, several respondents indicated that their crops withered due to the effect of the sun and probably due to the poor nature of soils. Farmers also indicated that plants were cut off at the base of the soil while others had swollen and deformed vines. When the affected plants were cut open during the field study larvae and frass were found. Sherman and Tamashiro (1954) indicated that feeding inside the vines by the sweetpotato weevils cause malformation, thickening and cracking of the infested vine. They also indicated that early infestation may lead to poor establishment of the planting material, foliage may become pale in colour and the growth and vigour of the plant can be affected. Smit (1997) on the other had reported that larvae of clear wing moths burrow into vines and sometimes into roots. The base of an infested vine is characteristically swollen and is traversed by feeding galleries. Such vines easily break off under heavy infestation. The larvae of *Alcidodes* species have also been reported to bore into the vines, causing the vine base to swell up whereas adult weevils girdle the vines, causing wilting (Smit, 1997). According to these findings, various insect pests damaging both tubers and vines may have been present in the region. However, the respondents did not associate the symptoms with pest incidence.

The level of pests' infestation was observed to be high especially in Suba though, the respondents were completely unaware of this. This district was much drier compared to Rachuonyo and Rongo Districts. Up to 90% yield losses have been reported to occur due to sweetpotato weevils during dry spells (Alvarez *et al*., 1996). Bourke (1985) remarked that economic damage occurs in areas with a marked dry season or in unseasonally dry years. This implies that high level of pests may occur in dry areas, leading to such massive damage. Harvesting was also done on piecemeal basis, causing the crops to stay longer in the farms; this may have led to the build up of insect pests. The increase in damage has been reported to occur with time and delayed harvesting (Sherman and Tamashiro, 1954; Sutherland, 1986). Piecemeal harvesting has also been reported to provide a continuum for sweetpotato weevils (O'Hair, 1991). Smit (1997), however, argues that this is a direct control method since mature, enlarged tubers are removed when they are at the greatest risk of weevil attack.

The most common damage reported was rotting of tubers, with larvae present. Tubers were tunneled, with numerous holes and others had blemishes on their skin. Such damages were among those resulting from feeding by root feeders (Sutherland, 1986; Jansson and Raman, 1991). The farmers reported that they did not know any method of controlling these pests.

Most of the respondents did not consider defoliators as pests although their effect was apparent in almost all the farms visited. The few individuals who were aware of the presence of defoliators could not identify them. This could be due to the fact that little attention is paid to sweetpotato foliage since its use is yet to be exploited in the region. The most common damage observed was windowing. Meshing and folding of leaves was also observed. Some of the damages were similar to those caused by the tortoise beetles and sweetpotato hornworms. Adults and larvae of the tortoise beetles have been reported to eat large round holes on leaves while the large caterpillars of sweetpotato hornworm feed on the leaf blades, causing irregular holes (Smit, 1997).

5.2 Farmers' practices and their effects in the management of sweetpotato pests

Several agronomic practices carried out by the farmers were among the cultural control measures effective in the management of sweetpotato pests. The farmers were, however, ignorant of this and reported that they did not carry out any methods of control. This concurred with the findings by Smit and Odongo (1997) who reported that some practices such as hilling up, rotation and weeding have become so common among farmers for agronomic purposes that they are not recognized as control techniques. Hilling up is a direct weevil control method, soil cracks are filled and exposed tubers covered blocking the way for weevils (Smit, 1997). Weeding ensures the removal of alternate hosts which may serve as reservoir for pests (Jansson and Raman, 1991). Rotation, on the other hand, has been reported to suppress insects, weeds and diseases by effectively breaking the life cycles of pests (Altieri and Nicholls, 2004). Other control measures mentioned were ridging and removal of infested tubers which were, however, not implemented by the respondents.

Since this study required farmer subjective data, it was thus assumed that farmers did not carry out any practices to manage sweetpotato pests in the region. Efficacy of these practices could also not be established.

5.3 Varieties of the grown sweetpotato

Different varieties of sweetpotato were grown in the region; however, none was grown for its ability to evade pest damage. Reasons for growing the varieties included production of many tubers, availability, fast maturity, sweetness and drought resistance among others. These are among the factors implicated by Smit (1997) for growing different varieties. Identification of the varieties by their local names was rather difficult since a variety could be given different names depending on where it was first obtained, size of tubers or colour of tubers. Ewell and Mutuura (1994) indicated that different varieties and cultivars are known by different names depending on the locality thus making their identification by their local names imprecise.

5.4 Socio-economic and biophysical factors affecting sweetpotato production

5.4.1 Major crops grown by respondents

The outcome of this study revealed that sweetpotato production in the region was secondary to maize. Gakonyo (1993) indicated that it is an important secondary food crop for many Kenyans whose staple diet is based on cereals. Ewell and Mutuura (1994) on the other hand indicated that it is the fourth most widely distributed cash crop in the country after maize, Irish potato and cassava. In Rachuonyo district where sweetpotato production was mainly commercial, sweetpotato came second to maize while in Suba it was third after maize and millet/sorghum among the major crops grown. In Rongo production was mainly subsistence and none of the respondents grew sweetpotato as a major crop. The respondents were mainly involved in sugarcane production, which was secondary to maize among the major crops grown in the district.

5.4.2 Size of farms owned by respondents

The majority of respondents growing sweetpotato as a major crop owned less than one hectare of land. Findings by Mutuura *et al*. (1992) and Smit and Matengo (1994) indicated that production of sweetpotato occurs on small plots rarely more than half hectare, though some large-scale commercial production also occurs.

5.4.3 Uses of the produced sweetpotato

Sweetpotato production in the region was both commercial and subsistence. Majority of the respondents from Suba and Rongo districts were mainly involved in subsistence production of sweetpotato. A few roots were, however, dug out and sold in the nearby markets or from the farms to generate income for other household use (Scott and Ewell, 1992; Smit, 1997).

In Rachuonyo district, production was mainly commercial and involved large stretches of land. Harvesting was done once and selling done in lump sum to available buyers who often negotiated prices before the crop was removed from the field. This process was rigorous and harvesting was done using ploughs before the tubers were collected. The tubers were cleaned then packed into conjoined 100kg gunny bags then loaded onto trucks destined to major urban centres. Small scale selling of sweetpotato also took place in the local markets.

It was interesting to note that all the individuals from Rachuonyo district involved in commercial production of sweetpotato were aware of the presence of root feeders and the damages they inflicted. This could be due to reduction of market value of the infested tubers that were more than often rejected by buyers.

5.4.4 Challenges faced in the production of sweetpotato

The major constraints to sweetpotato production in the region included moles, hippos, poor performance of crops, hard labour, insect pests/diseases and lack of space. Other challenges included financial constraints, destruction of crops by domestic animals and lack of planting material or poor varieties. Smit (1997), however, established that moles and sweetpotato weevils topped the list of constraints. The challenges faced differed greatly between the districts. Mutuura *et al*. (1992) indicated that problems vary between agroecological zones. Moles were the major problem in wet zones at higher elevations whereas in drier low elevation regions, sweetpotato weevils, drought and lack of planting materials posed the major threat.

In Suba, hippos posed the major threat to production. Farming was mainly along the lakeshore and hippos fed on sweetpotato foliage causing massive destruction on plots. Fencing of plots or digging of trenches had to be done regularly to help keep them off. However, this strategy was not effective in some cases. This process was rigorous and required hard labour. Apart from this, the area was generally dry with sparse rainfall and farmers had to draw water from the lake to irrigate their plots. This was done manually without the use of pipes or pumps, making it tedious and time consuming. Since farming was restricted to the shore, farmers complained of lack of space. Most of the plots were limited in size whereas others were rocky and had loose soil which was not suitable for crop production. The nature of soils allowed for high levels of pest infestation especially those damaging the tubers. This led to poor performance of crops which farmers associated with the effects of the sun due to wilting of crops. A closer observation, however, revealed massive insect pest damage at the base of vines, leading to crop failure. Other challenges included lack of planting material, financial constraints and destruction of crops by domestic animals. Farmers used the readily available planting material, some of which they reported to perform poorly. They indicated that they lacked finances to enhance sweetpotato production and occasionally domestic animals fed on sweetpotato vines.

In Rachuonyo district, poor performance of crops was reported as the major threat to production. Production was mainly commercial and farmers expected massive output for high profit margins. Pests and diseases also posed a major threat to production. These inflicted damage on tubers, thus lowering their quality and market value, leading to great losses. More often than not the infested tubers were rejected by buyers. Financial constraints, hard labour, limited space and lack of planting material were also mentioned as hindrances to production. The respondents reported that they lacked finances to enhance sweetpotato production. Agronomic practices involved in large scale production of sweetpotato required hard labour and finances when labourers were employed to help out. Respondents complained of lack of planting material and lack of space since more income was obtained when the produce was plenty. This was, however, determined by the size of farm and variety grown.

In Rongo district, moles posed a major threat to production. Respondents reported that these dug out whole tubers and caused massive destruction on farms. The respondents also indicated that they did not know how best to manage this problem since the most effective method of control appeared to be use of poison which they considered expensive and unsafe. Poor performance of crops and lack of space were also implicated as factors affecting production. Monkeys were also reported to dig out tubers and had to be scared away from the farm. The respondents were oblivious of insect pests and did not mention them as a challenge to production. This could be due to the fact that production was mainly subsistence and respondents concentrated more on sugarcane production. Little attention was thus paid to sweetpotato and besides, damages caused might have been inconspicuous or less severe.

5.4.5 Constraints to storage and marketing of sweetpotato

Storage of fresh roots was basically out of question in the study area. Smit (1997) reported that fresh sweetpotato tubers have a very short shelf life and tend to deteriorate rapidly under ordinary conditions. A few respondents, however, mentioned perishability and lack of storage mechanisms as limitations to storage. In most cases in ground storage was practiced since harvesting was done on piece meal basis (Ewell and Mutuura, 1994; Bashaasha *et al*., 1995). However, this was not mentioned as a storage mechanism by respondents.

Challenges faced in marketing sweetpotato in the region included low selling prices, exploitation by buyers, costly transport and unreliability of buyers. In 1998, unstable sweetpotato supplies and prices, and lack of suitable processed products were reported as the major post harvest constraints to production (Smit, 1997). Lack of transport and high labour costs have also been reported to impede production (Bashaasha *et al*., 1995; Low, 1996). Perishability and bulkiness of the produce have also been implicated in contributing to losses and high marketing costs (Fowler and Strabawa, 1992).

In Suba, transport posed the main threat. Transporting tubers from the lakeshore to the markets proved cumbersome and the selling prices were reported to be too low. In

Rachuonyo district, low selling prices posed a major threat. Two 100kg sacs (gunny bags) were sewn together and tubers neatly arranged within them. This was then sold for Ksh.700 to agents. Occasionally prices were negotiated before harvesting. The respondents considered this a high level of exploitation but were obliged to sell for ready cash. Besides, it was costly to gain access to markets where they assumed prices were better. Perishability and bulkiness of the produce also forced them to sell at such low prices to avoid further loss. In Rongo district on the other hand, only one farmer reported rejection of infested tubers by buyers as a challenge to selling.

5.5 Socio-cultural factors affecting sweetpotato production

The outcome of this study revealed that sweetpotato production in the region was mainly dominated by women most of whom derived their income from farming and small businesses. This was true even in Rachuonyo district where sweetpotato was majorly grown for commercial purposes. Previous studies by Mutuura *et al*. (1992) and Bashaasha *et al*. (1995) obtained similar findings, implicating sweetpotato as a woman's crop mostly grown by resource poor farmers. Researchers have cited the inferior status of sweetpotato as a "poor man's", a "famine" or "fall back" food as a significant constraint to increased sweetpotato production and consumption (Tsou and Villareal, 1982). This, together with its low social status where cereals are the preferred food (Smit, 1997), could explain why sweetpotato production was mainly left to women and its consumption less preferred. In cases where men were involved, they delegated the farm activities to their spouses who looked after the farms and sold the produce.

5.6 Foliar growth and yield assessment

In this study, foliar growth was massive within the first season (long rains 2007) of planting with high lengths and number of vines recorded in all the treatments. Insect damage on tubers and foliage was also minimal. In the second season (short rains 2007), however, the exact opposite was observed. Foliar growth was poor with shorter and fewer number of vines recorded in all the treatments. Damage on foliage was massive and total yield loss was recorded in all the treatments.

Rainfall has been shown to influence sweetpotato weevil incidence and damage levels in some countries (Sutherland, 1986), in other countries however the reverse has been shown (Powell *et al*., 2001). The outcome of this study revealed massive tuber damage during the short rains compared to the long rains. Smit (1997) argues that high rainfall precludes cracks formation in the soil, which prevents or reduces root accessibility to the ovipositing sweetpotato weevils. Bourke (1985) on the other hand indicated that weevils cause economic damage in areas with a marked dry season or in unseasonally dry years. The massive damage in the short rains season may have resulted from easy access of tubers by weevils due to crack formation in the soil. The continuous crop of sweetpotato may have also resulted in a cumulative build up of pest populations which the crop could not evade during the short rains. Apart from this, the presence of old vine material, near or within the plots after harvesting in the long rainy season may have acted as a source of pests' infestation during the short rains (Powell *et al*., 2001). This highlights the need for crop rotation, fallow or effective sanitation to break the pests' life cycles (Talekar, 1983). Rotation has been reported to suppress insects, weeds and diseases by effectively breaking the lifecycle of pests (Altieri and Nicholls, 2004). Fallow vegetation on the other hand influence soil fertility levels and can potentially reduce pests' incidence by disrupting their life cycle either through a break in crop rotation or by the release of allellopathic chemicals (Powell *et al*., 2001). The levels of triterpenoids have been reported to increase in sweetpotato in dry seasons (Gershenzon, 1991). These act as ovulation stimulants for the sweetpotato weevil, thus increasing the susceptibility of the crop to weevils (Powell *et al*., 2001). This may have accounted for the high level of infestation and tuber damage during the short rains.

The control plot which had no amendment recorded the highest percentage of both undamaged and marketable tubers whereas the treatment with inorganic fertilizer recorded the least percentage of both undamaged and marketable tubers. Increasingly, research is showing that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to the optimal physical, chemical and especially biological properties of soil (Altieri and Nicholls, 2004). There is increasing evidence that crops grown in organic-rich and biologically active soils are less susceptible to pest attack (Altieri and Nicholls, 2004). On the other hand, farming practices such as high applications of nitrogen fertilizer can cause nutrition imbalances and render crops susceptible to diseases such as *Phytophora* and *Fusarium* and stimulate outbreaks of Homopteran insects such as aphids and leafhoppers (Campbell, 1989). The use of nitrogen fertilizer may have increased the susceptibility of the crop leading to the high percentage of both damaged and unmarketable tubers recorded where inorganic fertilizer was used. However, the highest percentage of marketable and undamaged tubers were recorded where no amendment was used compared to where organic amendments were used. Nitrogen has also been reported to increase the protein and starch content of sweetpotato (Bartolini, 1982; Li, 1982) and influence the levels of triterpenoids in other plants (Gershenzon, 1991). Protein and starch are important nutritional requirements of insects, whilst triterpenoids are known to influence ovipository behaviour of sweetpotato weevils increasing the susceptibity of the crop to weevil attack (Nottingham *et al*., 1998).

5.7 Diversity and abundance of ground dwelling predatory arthropods

Organic- rich soils have been reported to exhibit good soil fertility as well as complex food webs and beneficial organisms that prevent infections by disease causing organisms such as *Phythium* and *Rhizoctonia* (Hendrix *et al*., 1990). According to the outcome of this study, the greatest diversity and abundance of species occurred in the control plot where no amendments were used. This was followed by amendments with the plant based manure in both diversity and abundance of species. Amendment with inorganic fertilizer, however, registered a higher diversity and abundance of species compared to treatment with the animal based manure. The two treatments recorded more dominant species compared to the control plot and the plant based manure. More similar species were obtained where organic amendments were used.

Total yield loss was recorded during the second season of the study. Tubers were heavily infested by pests in all the amendments and were non marketable. This could only indicate that the predatory arthropods collected from the field were not effective against the sweetpotato pests possibly because they were too few to combat the pests. Phelan *et al.* (1995) indicated that fertilization practices can influence the relative resistance of agricultural crops to insect pests. This could not be ascertained in this study probably due to high level of pest infestation that could not be countered by plant resistance.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

This study revealed that farmers had limited knowledge on sweetpotato pests and their management. Most farmers were only aware of the sweetpotato weevil as the pest affecting their crops; they thus assumed that all damage to the tubers was associated with the weevil. Defoliators were not considered pests in spite of evidence of severe defoliation; there was no mention of vine borers and disease vectors. The respondents indicated that they were not aware of ways of curbing the pests.

Several agronomic practices which were carried out by farmers included effective cultural control practices used in the management of sweetpotato pests. The farmers were, however, ignorant of this and indicated that they did not practice any method of control against sweetpotato pests. Since the study required farmer subjective data, it was assumed that the farmers did not carry out any control practices against sweetpotato pests. The efficacy of their practices against sweetpotato pests could thus not be determined.

Socio economic and biophysical factors affecting sweetpotato production in the region included hard labour, lack of space, financial constraints, moles, hippos, poor performance of crops, insect pests and diseases and lack of planting material. Constraints to marketing of produce included low selling prices, unreliability of buyers, exploitation by buyers, and costly transport. Perishability and lack of storage mechanisms posed a major threat to storage of the produce. In the entire region sweetpotato came second to maize and its production was left to women. It was mostly grown on small plots with no inputs after maize was already set in the fields.

The greatest diversity and abundance of ground dwelling predatory arthropods was recorded in the control plot where no amendment was used. The least diversity and abundance on the other hand was found where the animal based manure was used. This could indicate that no amendments were actually required to enhance diversity and abundance of ground dwelling predatory arthropods. The efficacy of the ground dwelling predatory arthropods against the sweetpotato pests could, however, not be determined within the scope of this study.

6.2. Recommendations

To come up with an IPM strategy that would be effective against sweetpotato pests and to enhance sweetpotato production in the region, the following factors should be taken into consideration:

a. Extension services should be offered to farmers to enlighten them on sweetpotato pests and their management. This would enable them to acknowledge and carry out practices aimed at reducing pest incidences which will in turn reduce the level of insect pest infestation.
b. Farmers should form cooperatives to help them collectively bargain for good prices to avoid exploitation by buyers. This would encourage more individuals to venture into sweetpotato production and may help lift its face so that it is not considered a poor man's crop. Farmers should also be educated on the nutritive values of sweetpotato so that it is not set aside for hungry months.

Suggestions for further research

a. This being a preliminary study, further work should be done to determine the role of soil amendments in enhancing the diversity and abundance of soil dwelling predatory arthropods and to establish if it does enhance sweetpotato resistance to pests. This should be replicated in different agro ecological zones to see if similar results will be obtained before a generalization is made.

b. The efficacy of each of the predatory arthropods species obtained should be established in the management of sweetpotato pests. This should be done in a controlled environment to rule out the effects of microclimate.

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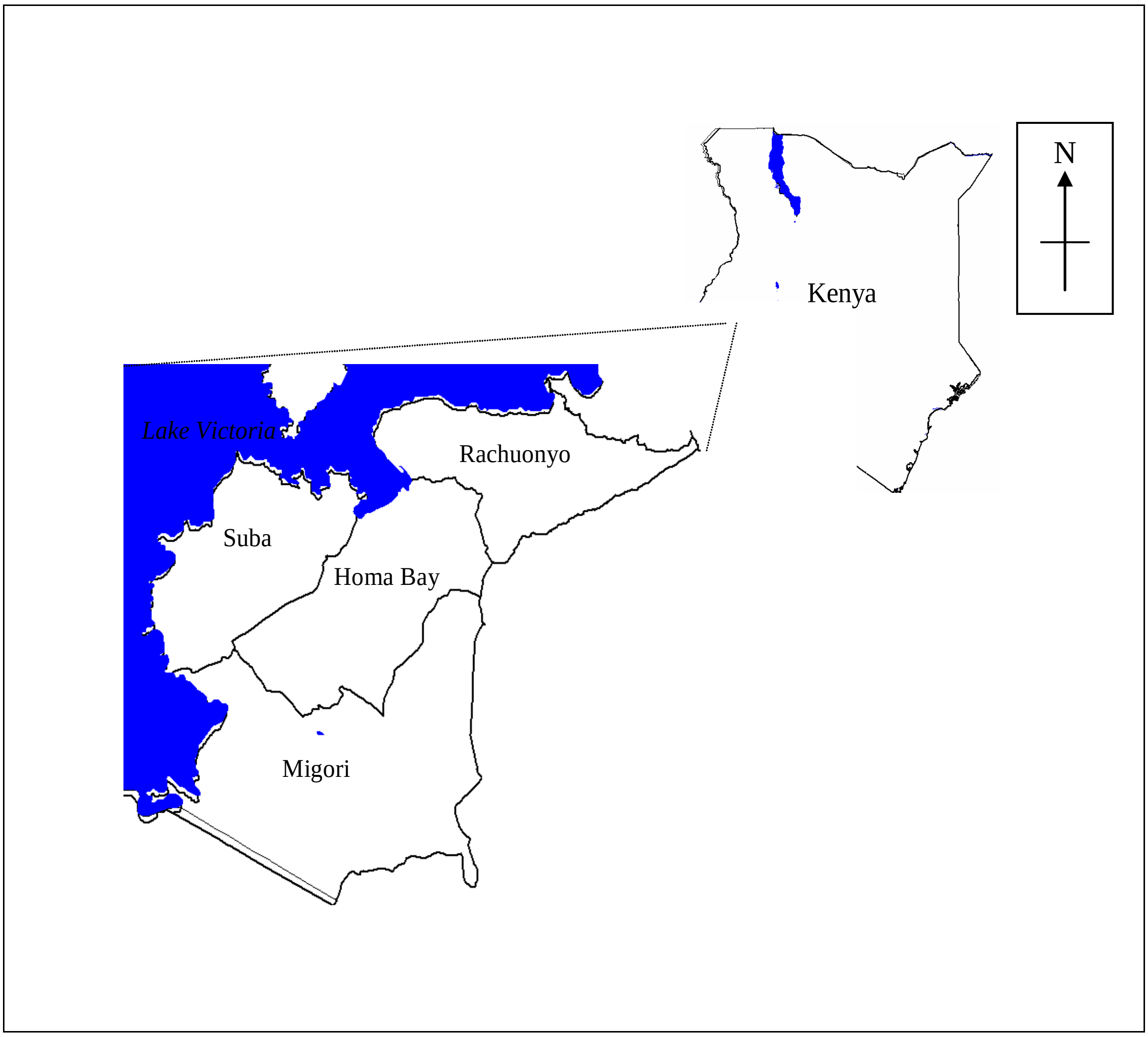
APPENDICES

Appendix 1: Map of the study area



Appendix 2: Questionnaire

Farmers' knowledge level, impact of their practices in the management of sweetpotato pests and socio-economic factors affecting sweetpotato production, and utilization in Southwestern Kenya.

Questionnaire number………

Zone (Low/medium/high altitude): …………………….

SECTION A: PERSONAL INFORMATION

1.1 Respondent's identity………………………….

1.2 Sex: Male………………….   Female…………………..

1.3 Age of head of household ……………………………..

1.4 Occupation……………………….

1.5 Level of education………………………

1.6 Size of household: …………………………………..

1.7 Farmer's sources of income
…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

SECTION B: FARM CHARACTERISTICS

2.1. What is the size of your farm?
………………………………………………………………………..

2.2. List the crops you grow in the order of their importance
…………………………   …………………………   ……………………………
…………………………   …………………………   …………………………...
…………………………   …………………………   …………………………...

2.3. Who allocates plots for growing crops?
…………………………………………………………………………………
…………………………………………………………………………………

2.4. Who determines when to plant the crops?

2.5. What varieties of sweetpotato do you grow?

Variety grown	Reason

2.6. Who looks after the farm?
…………………………………………………………………………………………
…………………………………………………………………………………………

2.7. How do you use the sweetpotato produced?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

2.8. Do you sell any?

Yes………………….. No…………………….

2.9. Where do you sell them?………………………….

2.10 Who does the selling?..

2.11 How far is the nearest market from your homestead (in terms of hrs/min)?

…………………………………………………………………………………………

2.12. What means do you use to get to the market?

2.12.1 On foot……………..

2.12.2 Bicycle……………..

2.12.3 Matatu………………..

2.13. What challenges do you face?

2.13.1 In production of sweetpotatoes
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

2.13.2 In storage of sweetpotatoes

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

2.13.3 In marketing of sweetpotatoes

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…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

2.13.4 Other challenges on sweetpotato production

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

SECTION C: SWEETPOTATO PESTS AND THEIR MANAGEMENT

3.1 Which pests affect your crops?

Pest	**Seriousness** 1=serious 2=not serious	**Damage**	**Control**	**Time of Implementation of Control** 1=before infestation 2=after infestation	**Efficacy Of Control** 1=effective 2=not effective
Root feeders					
Defoliators					
Vine borers					
Others					

3.2. Do you use chemicals to control sweetpotato pests?

Yes………………. No………………………..

3.2.1. If yes

Chemical used	Time of application (before/after damage occurs)

3.3. What other methods of controlling sweetpotato pests do you know but don’t practice?

Method	Reason