STUDIES ON SWEETPOTATO WEEVIL (*CYLAS SPP.*) WITH SPECIAL EMPHASIS ON EFFECTS OF CULTURAL PRACTISES ON WEEVIL DAMAGE AND YIELD OF SWEETPOTATOES (*IPOMOEA BATATAS (L) LAM*).

by

Joyce Nawire Baraza -Maling'a
Bsc. Agric. and Homec. (Egerton University)

A thesis
Submitted in partial fulfilment for the degree of Masters of science of Egerton University, Department of Agronomy, Crop production option.

August 2000

Eger234224

X

DECLARATION

I declare that this is my original work and it has not been previously presented in this or any other University for any other degree.

Name: Joyce Nawire Baraza-Maling'a

Signature.......Baraza.................. **Date** ...4/8/2000.........

This thesis is submitted with our approval as University supervisors.

Name: Dr. Alice Wangari Kamau

Signature...AW Kamau...... **Date** ...7/8/2000.........

Name: Dr. John Mburu Njoroge

Signature...JMNjoroge................... **Date** ...8/8/2000..........

COPYRIGHT

All rights reserved. No part of this thesis may be produced in any form or by any means, mechanical, including photocopying, recording, or any information storage and retrieval system, without the permission of the author or Egerton University on that behalf.

© Joyce Maling'a

DEDICATION

Dedicated to :

Husband, *James Maling'a*
Children, *David, Sally and Eric*
Parents, *Aineah and Salome Baraza*
Grandfather, *Ishmael Barasa, who died during my training.*

List of Acronyms

AVDRC	Asian Vegetable Development and Research Centre
ANOVA	Analysis of Variance
CIP	International Potato Centre
CV	Coefficient of Variation
IPM	Integrated Pest Management
KARI	Kenya Agricultural Research Institute
LM	Lower midlands
UM	Upper midlands
^0C	degrees centigrade
LSD	Least Significant Differences

ACKNOWLEDGEMENT

I thank my husband, James Maling'a to whom I owe this privilege to pursue this degree, and who has stood by me tirelessly throughout this period. I also thank Dr Njoroge for reading and correcting this thesis and Dr Nicole Smit for her counsel and provision of much of the literature cited. I extend my deep gratitude to Dr. Alice Kamau for her great kindness, constant patience, guidance and prayers and particularly for granting me full use of her office and computer during the critical period of writing this thesis. I would also like to thank Dr Orodho, Centre Director of Kakamega Regional Research Station, his deputy, Dr Odongo and his officer Mr Ndolo who were instrumental in assisting me to acquire this scholarship to study. I cannot forget that they supported my research work with funds taken from the Centre finances. I wish to thank the World Bank for awarding me the scholarship and the Director of Kenya Agricultural Research Institute for leave of absence to attend school to completion. Finally I give glory to God for the opportunity and grace to undertake this programme to completion.

Abstract

One of the major constraints to obtaining high sweetpotato (*Ipomoea batatas (L) Lam*) yields is damage by the sweetpotato weevil (*Cylas spp*) particularly during the dry periods and in dry areas when populations increase to high levels. High weevil population cannot be controlled by a single control method but require integrated pest management approach. Since there was limited information concerning Integrated pest management options, this study was initiated to quantify farmers crop losses due to weevils and to assess the effects of some of their crop management practises on yields, weevil population, infestation and severity of weevil damage. The objectives were achieved by conducting a survey on farmers' fields in Kabras division, Kakamega district, 1998 and an on station experiment at Kakamega and Busia in Western Kenya in 1998 and 1999.

The results of the survey showed that 81% of the fields surveyed were infested with sweetpotato weevil. The most commonly grown variety was Mwezitatu followed by Bungoma. Infestations in fields with Mwezitatu and Bungoma varieties were 86% and 57% respectively. The two planting methods used by the farmers were ridged seedbeds (52%) and flat seedbeds (48%). There were conflicting results on the effects of planting methods on the weevil infestation. There were no differences observed at two sites while more damage was recorded on ridged seedbeds at Namshya than Luvambo. There was generally long inground storage of roots (upto 11 months).

Incidence and severity of weevil damage was found to increase with age of crop in the field.

The results of the exploratory trial showed that Mwezitatu produced significantly more roots than Marooko in the short and long rains season at Kakamega and in the short rains season at Busia. However, Mwezitatu significantly out-yielded Marooko only at Kakamega in both seasons. Mwezitatu had significantly more roots infested with weevils resulting to significantly higher damage compared in Marooko except at Busia during the long rains season. There were significantly higher weevil population on Mwezitatu (19.2 and 30.6) than Marooko (1.6 and 15.7) during the short rains season at Kakamega and Busia respectively.

The use of insecticide did not significantly influence weevil population infestation and severity of damage on sweetpotato vines or roots. Sweetpotato planted on ridged seedbeds had significantly higher root numbers and yields than those on flat seedbeds in the short rains season at Busia. There were no significant differences on infestation levels between the two methods at both sites. There was generally no significant difference between planting times on yield, infestation and severity of weevil damage except at Busia in the short rains season. At this site, there was significantly lower yields, weevil densities, infestation and severity of damage on late planted than early planted crop.

- There was significant interaction between time and method of planting which showed significant reduction in yield of infested roots on sweetpotato planted early and on flat seedbeds (1.0 t/ha) than on ridged seedbeds (3.4 t/ha) in the short rains at Kakamega. There was no significant difference between the two planting methods on yield of infested roots; of crop planted late. Significant variety by method of planting interaction also showed that yield of infested roots significantly declined only when Mwezitatu was planted on flat seedbeds(0.2 t/ha) than on ridged seedbeds (3.2 t/ha) in the short and long rains season at Busia and Kakamega respectively. Significant Interaction between variety and planting time on weevil infestation showed that there was a significant decline of infestation on both Mwezitatu and Marooko but more pronounced on Mwezitatu, when the two varieties were planted late at Busia during the short rains season . During the long rains season at Kakamega, infestation was only significantly reduced when Mwezitatu was planted late.

TABLE OF CONTENTS

EGERTON UNIVERSITY LIBRARY

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Importance and uses of Sweetpotato

The sweetpotato (*Ipomoea batatas (L) Lam*) is an important food security crop for poor people across the world. It is mainly grown in developing countries (Horton, 1988). Ewell (1997) reported that approximately 1.5 million hectares mainly in the rural areas of sub-Saharan Africa are planted with sweetpotato. In this region, Kenya is the fourth most important producer after Uganda, Rwanda and Burundi (Ewell, 1997). FAO reports (1978, 1988 and 1998) show that sweetpotato acreage in Kenya has increased from 57,000 ha in 1975|1977 to 74,000 ha. in 1995|1997. Thirty percent of this production is in Western Province (Mutuura *et al.*, 1992).

Sweetpotato is a crop that is adaptable to a wide range of climatic and ecological conditions (Onueme and Charles, 1994). It has ability to yield well under low input management (Hahn, 1994). It is tolerant to drought and performs well under marginal soil conditions. Therefore, it becomes important in areas where maize the basic staple food crop of the Kenyan population regularly fails under drought conditions (Ewell, 1994). Mutuura et al. (1992) reported that 33% of rural households eat sweetpotato at least two to three times a week during the dry season. Smit (1997) reported that the crop has ability to store mature roots in the ground for 3 to 7 months. This is important to farmers in Kenya who practise piecemeal harvesting from 5 months of planting the crop (Smit, 1997). The surplus harvest is sold in local and urban markets and is significant source of cash for the poor who are mostly women (Mutuura *et al.*, 1992). According to Anon (1998) sweetpotato earned farmers of Western Province Ksh. 2.2 billion. Oyunga *et al.* (1997) has also reported the sweetpotato as one of the cheap source of beta-carotene that can combat vitamin A deficiency prevalent in parts of Western Kenya. The storage roots have been used to make bakery products by cottage industries (Carey *et al.*, 1994). Mutuura *et al.* (1992) also reported that vines of sweetpotato were an important forage particularly in the dry season in many parts of Kenya.

Despite its importance, the yields realised by farmers in Kenya are low. According to FAO reports (1978, 1988 and 1998) there exists a yield gap between Kenya's average yield of 9.8 metric tonnes per ha. and that of the world's 14 metric tonnes per ha. Reduction of this gap is necessary particularly in the view of the fact that sweetpotato production has fallen behind total population growth despite the critical role it plays in many parts of Kenya (Ewell, 1997). A review of markets in three main towns of Kenya, Nairobi, Mombasa and Nakuru showed that a 98 kg bag of sweetpotato was priced above Ksh. 1000/= between January and July, 1999, the price favourably compared to that of maize (The Daily Nation, January - July, 1999). Declining economic standards in Kenya are also forcing more people to depend on sweetpotato.

1.2 Production Constraints

The growing demand for sweetpotato can be met by expanding production into the marginal areas which form 83% of Kenya's land area (World Bank, 1989). Currently the crop is of major importance in the lower midland elevations of the Lake Basin and Eastern regions of Kenya (Mutuura *et al.,* 1992; Ngunjiiri *et al*, 1993). Sweetpotato production is however limited by poor agronomic practices, lack of improved planting materials, drought, diseases and insect pests (Ewell, 1994). One of the major insect pests significantly affecting sweetpotato production is sweetpotato weevil (*Cylas spp*) (Smit, 1997; Ames *at al*., 1997; Talekar *et al.,* 1989). The most important species according to Ames *et al.* (1997) are *Cylas brunneus*, *Cylas puncticollis* and *Cylas formicarius*. *C. brunneus* and *C. puncticollis* are the most important in Eastern Africa, being widespread in all the sweetpotato growing regions particularly in Western Kenya (Smit, 1997).

1.3 Sweetpotato weevils (Cylas spp) as constraints to sweetpotato production.

Sweetpotato weevils (*C. brunneus* and *C. puncticollis*) are serious pests of the sweetpotato crop grown under dry conditions. Diagnostic surveys conducted by Mutuura *et al.* (1992) and Ngunjiiri *et al.* (1993) found that farmers in dry lower midlands rated the sweetpotato weevils as their most serious production constraint affecting 90% of the crop. This limits one of Kenya Government's objectives in agricultural food policy which is to attain self sufficiency to feed the expanding population by increasing acreage under drought tolerant crops, like sweetpotatoes in the arid and semi-arid areas (Anon, 1997).

Mutuura *et al.* (1992) and Ngunjiiri *et al.* (1993) reported that at least fifty percent of farmers' crops at upper midlands elevations were also affected by *Cylas* weevils particularly during the dry season. A review of sweetpotato production trends in Kenya shows that more sweetpotato is grown during the short rainy season for consumption in the following dry season. However, higher consumption of sweetpotatoes during the dry season coincides with susceptibility to weevil attack in the field. The sweetpotato weevil reduces yields quantitatively and qualitatively by reducing the number of clean marketable tubers and qualitatively by causing infested tubers to develop a bitter taste and off-flavour that makes them inedible (Ames *et al.*, 1997). Sweetpotato is susceptible to sweetpotato weevil attack from the first month after plant establishment with infestation continuing in the store (Sutherland, 1986a).

Damage arises from the feeding activities of the larvae as it tunnels in the vine and root and deposits frass, leaving a bitter tasting and inedible root (Smit, 1997; Ames *et al*, 1997). Studies to quantify crop losses due to *Cylas* weevils which were conducted in Taiwan showed that losses of between 5 - 80 percent were incurred (Sutherland, 1986a; AVDRC, 1990) but similar studies are limited in Kenya. The only significant study which was conducted in Western Kenya showed that these weevils had already infested 17% of a young sweetpotato crop (KARI, 1990). Crop loss studies are an important aid in understanding the complex interactions between pest, crop and crop husbandry. This would help to establish the economic importance of the pest and identifying suitable control methods. A comprehensive crop loss assessment study on farmers fields was therefore deemed important to determine the distribution and importance of the sweetpotato weevil in Western Kenya.

Various methods that include: the use of host plant resistance, chemical, mechanical, biological and cultural have been used to control the sweetpotato weevil. The use of host plant resistance has received much study as it is considered the most sustainable control method. According to Thomas and Waage (1996) and II-Mok *et al.*(1994) to date there has been no successful development of a variety resistant to the sweetpotato weevil. Mechanical methods such as sex pheromone traps have been reported to reduce weevil population in Uganda and Taiwan, but their use has been limited by their unavailability (Smit ,1997 and Talekar, 1988). Odindo (1992) working in Western Kenya reported two entomopathogenic bacteria (*Beauveria bassiana* and *Metarhizium spp*) that significantly reduced weevils population but these have not been commercialised.

There has been extensive work on chemical methods particularly by Sutherland (1986c) and Talekar (1987a) working in Asia, who found that the sweetpotato weevil has a concealed feeding habit and is therefore difficult to control conventionally. However dipping the planting material in diazinon or carbofuran was reported by Ames *et al* (1997) to offer protection from weevil attack for some months. Although this was possible, Sutherland (1987c) observed that it would be too expensive for sweetpotato production due to its low economic value.

Cultural control methods have been reported to manipulate and reduce weevil infestation and damage. Among these is the adjustment of time of planting which has been found to reduce weevils if the crop is planted earlier to enable it to mature faster and so escape weevil infestation. The planting of deep-rooted varieties has also been reported to reduce weevil damage (Ames et al, 1997). Weevils are not able to penetrate soil but access roots through cracks in the soil. Roots that grow deep in the soil therefore escape attack. Another potential but controversial cultural control method is the method of planting. Research work at the Coast and in Western Kenya (Munga *et al*., 1992; KARI, 1994; KARI, 1995) showed that flat seedbeds significantly reduced weevil damage to roots than ridges or mounds. Yet Smit (1997) reviewed work in Tanzania in which none of the three planting methods had any influence on weevil damage. However none of all possible methods when used singly was able to control sweetpotato weevil at high population (Ames *et al*., 1997).

There is therefore need to develop effective and economical Integrated Pest Management (IPM) options which can be recommended to the Kenyan farmers. Indeed extensive work on the ecology, biology and effect of farmers' practises on the *Cylas spp* in Western Kenya has been conducted by Smit (1997) but research on the integration of the control methods has not been undertaken.

1.4 Objectives

1. To conduct a survey on farmers' fields in Kakamega district in Western Province, Kenya in order to:

a) quantify crop losses due to sweetpotato weevil damage

b) determine the effect of farmers' crop management practises on weevil incidence, population density and severity of damage.

2. To determine the effect of variety, insecticide, time and method of planting on weevil population and yield of sweetpotato in Western Kenya.

3. To develop Integrated Pest Management options which can be recommended to farmers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Systematics, Importance And Distribution Of Sweetpotato Weevil.

The sweetpotato weevil is the common name given to *Cylas formicarius (Fabr.), Cylas brunneus (Fabr.*) and *Cylas puncticollis (Bohe*) (Coleoptera: Apionidae) (Pury, 1968; Collins *et al*., 1999). The adults of the sweetpotato weevil are elongate and similar to ants in appearance, but their species can be differentiated by size and colour (Smit, 1997). According to Smit (1997) the adults of *C. puncticollis* are completely black in colour and larger than both *C. formicarius* and *C. brunneus*. *C. formicarius* have bluish black abdomens and reddish brown thoraxes. *C. brunneus* are small (about 5 mm long) and are either black, brown or similar to *C. formicarius*. Those coloured like C. *formicarius* can be further differentiated by their male antennae. While the distal parts and basal parts are of equal size in *C. brunneus*, the distal parts of *C. formicarius* are larger than basal parts (CIP. 1991). The distal antenna segments also serve in sexing of the weevils, which in males are filiform and club-like in females (Sutherland, 1986a).

Infestations of *Cylas spp* have been reported in Venezuela, Mexico, Caribbean islands, South Pacific (Papua New Guinea, Samoa, Solomon Islands, Fiji), Eastern Australia, Asia (India, Bangladesh, Sri Lanka, South East Asia, China) and Africa (West, South and East Africa) (Ghosh *et al*., 1988). The distribution of the three species indicates that *C. formicarius* is circumglobal while both *C. puncticollis* and *C. brunneus* are specific to Africa (Collins *et al.,* 1999). Kenya and South Africa are the only countries in Africa that have reported the presence of *C. formicarius*, (Smit, 1997). The predominant species in Kenya are *C. brunneus* and *C. puncticollis*. Infestations of sweetpotato weevils have been reported in 65% of Kenyan sweetpotato farms. Of these, 88% are in the semi-arid elevations, 67% in the Central highlands, 66% in the Coastal region and 50% in the Lake Basin region comprising of Western Kenya (Mutuura *et al.*, 1992).

2.2 Biology

Sutherland (1986a) reviewed the life-cycle of the sweetpotato weevil and indicated that the female adults lay the eggs singly in a cavity in the vine or root and seals it off with a grey faecal plug. This plug preserves moisture, disguises location and protects the eggs from predacious ants. Eggs hatch within a week to white curved larvae which are the damaging stages of the weevil. They feed by tunnelling in the vine and tuberous roots as they develop for 2 - 4 weeks (Hill, 1983). Pupation occurs in a small chamber from which emerges the adult. Higher temperatures have been found to speed up weevil development (Sutherland, 1986a). Smit (1997) working under tropical conditions determined that *C. puncticollis* had a shorter lifecycle (20-28 days) than *C. brunneus* (32-41 days). The author further reported that adults of *C. puncticollis* lived for significantly more days (140) compared to 92 days for *C.*

brunneus. The latter had a fecundity of 100 eggs while the former had 103 eggs. Despite these differences, Magenya and Smit (1991) reported that the two species were of equal importance in Western Kenya.

2.3 Ecology

Work by Austin *et al*. (1991) has shown that the sweetpotato weevil is polyphagous and feeds on 35 species of convolvulaceae not restricted to the genus *Ipomoea*. In East Africa (Smit 1997) observed that the other species were not significant hosts because the debris of sweetpotato and standing crop was usually available for the survival of the weevils throughout the year. Sweetpotato grown in the dry seasons have been reported to have significantly more weevils than a rainy season crop (Hahn and Leuschner, 1982; Gaspasin, 1989).

In Kenya, Mutuura *et al* (1992) reported that 90% of farmers at lower midland elevations had sweetpotato crop infested with weevils compared to 50% in the upper midlands. Both *C. puncticollis* and *C. brunneus* are reported to be active at different times of the day. According to Smit (1997) the former are active in the evenings and at night while the latter are active during the day. This indicates that the sweetpotato crop is subjected to weevil pressure both in the day and night.

2.4 Infestation and dispersal of Sweetpotato weevil

Sweetpotato weevils infest both roots and woody sections of the vines of sweetpotato (AVDRC, 1990). The principal mechanism of infestation is by females gaining access to the tuberous root when it becomes exposed through soil cracks (Sutherland, 1986a). Hence planting methods that encourage soil erosion such as ridges and mounds result to the exposure of roots and promotes weevil infestation. Trials in Western Kenya and the Coast Province showed that weevil infestations were significantly higher in ridges and mounds than in flat seedbeds (Munga *et al.*, 1992; KARI, 1995).

Another important mechanism of infestation is via the vine cuttings used as planting material. AVDRC (1991) showed that woodier sections of the vine had significantly more larvae, pupae and adults than the tender tips, which frequently lacked any weevil. From these infested vines the weevils infest the roots. Talekar (1988) further noted that some cuttings actually carried adults hidden beneath the leaves of the vine cutting and later becoming sources of vine infestation.

Other important sources of infestation occur from sweetpotato debris left from a previous season's crop. Most farmers in Western Kenya do not practise field sanitation after harvesting but leave old crop or sweetpotato debris in the fields (Smit, 1997). Sutherland (1986a) and Talekar (1989) reported that the burning, burying or removal of old sweetpotato crop and debris was found to reduce weevil damage to roots in the following season.

Infestation also occurs when younger sweetpotato crop is planted adjacent to an older one as weevils simply migrate from the old crop. The adjacent crop is affected even when it is 100m away unless a high barrier such as a crop of sorghum lies between the two crops (Smit, 1997). The maximum dispersal distances for sweetpotato weevil either by crawling or flying, is 120 m and 80 m for *C. puncticollis* and *C. brunneus* respectively (Moriya, 1995; Smit 1997). A survey by Magenya and Smit (1991) reported that at least most farmers in western Kenya plant sweetpotato close to an old sweetpotato crop and this promotes weevil infestation.

2.5 Symptoms of damage

The larvae and adults of sweetpotato weevil are the destructive stages with the latter causing less damage. These feed on the epidermis of vines and leaves by scrapping oval patches. They further feed on the external surfaces of tuberous roots leaving tiny round holes that are deeper than the oviposition sites and lack a faecal plug (Sutherland, 1986a; CIP, 1994; Smit 1997). The larvae feed and develop within the vine and tuberous root depending on where they hatch. They make irregular tunnels in which they deposits frass (Sutherland, 1986b; Onueme and Charles, 1994; Ames *et al.,* 1997). The frass gives the root an off-flavour even when roots are cooked.

Furthermore damaged roots produce sesquisterpenes that make it bitter and inedible even at low concentrations and low levels of damage (Woolfe, 1991; Smit, 1997; Ames *et al.*, 1997). According to Sutherland (1986b) weevil damage to roots ranges between 5 - 80% and damage increases with the time the roots remain in the ground. Despite this, in-ground storage remains the principal method of storing fresh sweetpotatoes in the fields in Western Kenya (Smit and Matengo, 1995).

Symptoms of damage on the vine are characterised by long black patches (Ghosh *et al.*, 1988). These become malformed, thicken and crack if damage is extensive (Sutherland, 1986a). Some conflicting reports indicate that vine damage could reduce yields. Trials by Sutherland (1986b) showed that heavy infestation in the vines correlated highly with high damage levels in roots, reduction in total yields and tuber size. However a similar trial by AVDRC (1991) found no correlation at all.

2.6 Control methods

2.6.1. Chemical control methods

Insecticides have until recently been the quickest and most effective mode of pest control until concerns on environmental pollution and pest resurgence have reduced their use. Cuba which produces sweetpotato commercially had used insecticides at the rate of 10-12 sprayings per season to control the sweetpotato weevil. Yet even with chemicals, weevil damage levels were kept at 8% until 1991, when their source of chemicals the Soviet Union, collapsed as a nation (CIP, 1998). Without insecticides' weevil resurgence in farmers' fields increased to 50%, forcing researchers to look at alternative and integrated control methods that were not dependant on insecticides.

Work on insecticides dates back to 1936 by Cockerham and Dean who initiated chemical control trials of sweetpotato using DDT and calcium arsenate (Sutherland 1986a). Later in 1953, Sherman and Mitchell were able to prove that dipping of vines prior to planting combined with foliar spraying post planting reduced weevil damage (Sutherland, 1986a). Sutherland (1986c) reported on trials on 59 insecticides in which formorthion and fenthion were recommended for application fortnightly to keep weevil damage at 3%.

In developing countries where sweetpotato is mostly a subsistence crop, it is impractical to recommend foliar sprays. Apart from that, during the dry season, Gaspasin (1989) found that even with insecticide use weevil damage was 50%. Other studies however showed that merely dipping the planting material in a suitable systemic insecticide could reduce weevil damage (Ames *et al.*, 1997; Pillai *et al.*, 1993). Monocrotophos 0.5% (Pillai *et al.*, 1993), and diazinon 0.01-0.05% (Smit, 1997; Ames *et al.*, 1997) carbofuran or other organo phosphates and carbamates (Talekar, 1988) are recommended insecticides suitable as vine dips. The vine dips are thought to reduce weevil attack to vines for some months as well as killing all weevil stages in them (Talekar *et al.*, 1989). Vine dips have therefore become an important component of IPM packages for farmers in Taiwan. Vine dips have been used in Kenya only in experimental trials as they are thought to be uneconomical for most farmers (Smit, 1997) but this has not been verified. There is need to assess the efficacy of the dips under tropical conditions and to determine the economy of scale in farmers' practises.

2.6.2. The role of host plant resistance.

Cockerham and Dean (1947) initiated research to find resistant varieties and observed that cultivars with long and widely spaced roots prevented weevil attack. Indeed, six weevil resistant clones that produce roots 15 cm below the soil (a depth too deep for most weevils to attack) have been identified in Cuba (CIP, 1998). However, Collins *et al.*(1999) pointed out that successful development of resistant clones is not yet accomplished. Indeed the use of biotechnology has led to the development of protease inhibitors that inhibit the metabolism of sweetpotato weevils (CIP, 1998). However this approach is still being investigated. Accordingly control methods such as cultural practices have been thought to be the key strategy towards the management of the sweetpotato weevil (Sutherland, 1986b; Talekar, 1988; Ames *et al.*, 1997; Smit, 1997).

2.6.3 Cultural control methods

Cultural control methods use the modification of crop management practises directly or indirectly to suppress pests. The cultural practises that have been reported to reduce weevil infestation in sweetpotato are: crop rotation of sweetpotato within five years of planting, avoidance of planting sweetpotato for two successive years, the use of sweetpotato cuttings from a weevil free source, the destruction of crop residue left in the field after harvest, prevention of soil cracking which exposes roots to weevil infestation by hilling the area around the plant or irrigating frequently, deep planting of cuttings, using deep-rooted cultivars, harvesting the crop as soon as roots mature and selecting a new planting area away from an infested site (Talekar, 1988). In addition, the use of vine tips, early planting and planting on flat seedbeds were later recommended (Ames *et al.,* 1997; Smit 1997)

Deep-rooted varieties have been reported by Cockerham and Dean (1947) and Ames *et al.* (1997) to escape weevil attack because of deep placement in the soil. This is a form of pseudo-resistance, a false form of resistance based on escape mechanism exhibited in the sweetpotato in which the roots are inaccessible to the weevils so that they are not attacked (Thomas and Waage 1996). According to Smit (1997) weevils are not able to penetrate beyond 1 cm of soil but rather gain access to roots when they become exposed on the surface or by passing in cracks of the soil. A variety that is deep-rooted and long maturing which is commonly grown in Western Kenya is

Marooko although it has not been screened for weevil resistance (Ndolo, personal communication, 1998).

Another cultural practice reported by Ames *et al.* (1997) to reduce weevil damage to roots is early planting. However, Odongo and Smit (1997) working in Uganda observed that weevil damage to roots were lowest when planting was carried out two months after onset of rains. Yet farmers' planting calendar for sweetpotato crop runs throughout the year (Mutuura *et al.*, 1992; Ngunjiiri *et al.*, 1993). There is a need to determine further the effects of time of planting as a component of IPM package and its effects on weevil damage to roots. What is certain is that damage levels are higher in the dry season than in the wet season (Gaspasin, 1989; Mutuura *et al.*, 1992; Ngunjiiri *et al.*, 1993; Smit, 1997).

The planting method used has been reported to also reduce weevil damage although there is controversy over this fact. KARI (1990), Magenya and Smit (1992) and KARI (1995) all working in Kenya found that weevil damage was significantly lower in flat seedbeds compared with ridged and mounded beds. Soil erosion was thought to account for high weevil damage on ridges and mounds. Yet Smit (1997) reviewing work in Tanzania found no differences in weevil damage to sweetpotato roots using different planting methods. There is need for further work to verify the importance of seedbed types in weevil management. This is important especially as Mutuura *et al.*

(1992) reported that in Kenya 46 % farmers use flat seedbeds while 54% use either ridges and mounds. Despite using different planting methods most farmers in Western Kenya will subsequently earth up roots once or twice during weeding (Mutuura *et al.*, 1992, Smit and Matengo (1995). Earthing up has been reported to reduce weevil damage by covering soil cracks and exposed roots hence limiting weevils access to roots (Sutherland, 1986a; Smit, 1997).

The type of planting material used could also influence weevil incidence in the sweetpotato crop. Apical cuttings of 30cm long of sweetpotato vines have been reported to be free from weevils and could be considered clean (AVDRC, 1991). Lower vine sections that are woody have been found to be preferred by weevils as oviposition sites (Smit, 1997). Smit and Matengo (1995) reported that most farmers in Western Kenya use vine tips as planting material and only in the dry season will a few farmers infrequently use the woodier sections when planting material becomes scarce. Clean planting material can also be achieved by dipping planting material in diazinon 0.01% - 0.05% ai.(Smit, 1997).

2.7 Integrated Pest Management

Talekar (1988), Ames *et al.* (1997) and Smit 1997) noted that the different control methods can individually control weevils when the populations are low but not during long dry periods when weevil populations rise to damaging levels. Integrated Pest

Management (IPM) approach may be the only alternative that can control the sweetpotato weevils especially at high pest population (Talekar *et al.*, 1989; AVDRC, 1989; Ames *et al.*, 1997; Smit, 1997). However, there is scanty information available on IPM options to control this pest.

An on-farm IPM study using sex pheromone traps, hilling up, uprooting of all volunteer Ipomoea plants, crop rotation, dipping planting material in carbofuran 0.05% for 30 minutes and post application of carbofuran monthly up-to harvest was conducted in Taiwan (AVDRC, 1989 and Talekar *et al.*, 1989). Their results showed that fields where cuttings were dipped in insecticide and Ipomoea weeds controlled with monthly application of carbofuran granules were free of sweetpotato weevils. While those in which planting material was not dipped in insecticide solution but Ipomoea weeds were controlled with post application of carbofuran granules did not get complete control of sweetpotato weevil while the monthly post application of carbofuran was effective in controlling sweetpotato weevil, it is however too expensive for subsistent farmers in Kenya. Therefore there is a need to develop cheaper IPM options which can be recommended to resource poor farmers.

In India, Pillai *et al.*(1993) also showed that dipping planting material in monocrotophos 0.05% for 10 minute, use of sex pheromones and re-ridging the crop twice reduced weevil damage from 30 to 10 percent. As sex pheromones seem to offer a long-term and environmental friendly solution both Pillai *et al.* (1993) and later Smit (1997) recommended that it could be used as a a part of an IPM programme. However, the availability of these sex pheromones may still be limited world-wide and hence it may not possibly be the most appropriate component to include in an IPM package. Cultural practises are preferred as they often involve activities farmers already carry out and that can be manipulated to control weevils. The use of ridged seedbeds, a common practice in Kenya would be a more suitable inclusion in an IPM study for Kenyan farmers. More recently, and in Cuba IPM pilot trial combined the use of predatory ants, fungus *Beauveria bassiana*, mass capture of males using sex pheromones and planting of short season cultivars was conducted. The results of this trial showed that weevil damage fell from 50% to 2 % (CIP, 1998). In Kenya, there has been some scanty work on biocontrol of the pest by Odindo (1992) which is still under study. Planting of short season cultivars may not be an option for Kenyan farmers who seem to like long maturing varieties that store long in the ground. As Smit (1997) pointed that out IPM approaches cannot be translated from one place to another but its options must be developed for each specific place. In Kenya, there have been very limited comprehensive IPM studies, although extensive work on the components has been documented by Smit (1997). Therefore there is need to develop and evaluate IPM options for their efficacy and economic feasibility before testing them with farmers.

EGERTON UNIVERSITY LIBRARY

CHAPTER THREE

3.0 On Farm Crop Loss Assessment Caused By Sweetpotato Weevil (*Cylas Spp.*) In Kabras Division, Kakamega District, Western Province Of Kenya.

3.1 Introduction

There is limited information available in Kenya on the extent of crop losses caused by sweetpotato weevils and their relative importance in limiting production in Kabras division, Kakamega district, Western Kenya. This area produces a significant proportion of sweetpotato in Western Province (Anon, 1993) which accounts for 30% of Kenya's sweetpotato production. Although there have been widespread reports by farmers of occurrence of sweetpotato crop damage due to sweetpotato weevil, especially during the dry season (Ngunjiiri *et al.*, 1993; Mutuura *et al.*, 1992; Smit, 1997), comprehensive information on crop losses is lacking. This study was thus conducted to assess the on-farm losses due to sweetpotato weevil and crop management factors influencing these losses in Kabras division. The information generated from the study would aid in quantifying crop losses and in designing of appropriate control strategies for sweetpotato weevil.

The sweetpotato weevil is a serious pest of the sweetpotato crop grown under hot and dry conditions (Smit, 1997). Therefore, a crop loss assessment was conducted at the end of the dry season from 2nd to 5th February, 1998 in Kabras division, Kakamega district. Kabras division is mostly located across lower midland marginal sugarcane agro-ecological zone (LM 2) (Jaetzold and Schmidt, 1982).

3.2 Materials And Methods

3.2.1 Study area

The area has a bimodal type of rainfall pattern divided into long and short rain seasons. The long rains start between end of February and early March while the short rains start between end of August and early September. The annual rainfall varies between 1200-1500 mm per year with the dry periods beginning in November and peaking in January and February. The average annual temperature is about 21.6°C, the minimum and maximum monthly is 20.9°C and 22.3 °C respectively.

The soils in the area vary from ferrasols in some places to cambisols in others (Jaetzold and Smith, 1982). Ferrasols are well drained, moderately deep to deep, dark friable clays. Cambisols are well drained, deep reddish brown to brown friable sandy clay loams to clays with very thick acid humic topsoil (Jaetzold and Smith, 1982).

3.2.2 Methods

3.2.2.1 On farmers field survey on methods of planting sweetpotatoes and weevil infestation levels on two common varieties in Kabras division.

Forty-two sweetpotato fields were randomly selected from five villages (Luambo, Namshya, Makucho, Vihiga and Matsakha) in two sub-locations Chekulo and Kivaywa which are major producers of sweetpotatoes in Kabras division. This was done by walking through a representative cross section of each village. In every field visited the farmer was interviewed and the following records were taken.

1. Month of planting sweetpotato
2. Sweetpotato planting method
3. Month of initial harvest
4. Month of final harvest
5. Acreage of sweetpotato crop
6. Variety grown
7. Farmers knowledge on control of sweetpotato weevil

3.2.2.2 Effect of crop management practises on sweetpotato weevil population density, incidence and severity of damage.

After the interviews, five sweetpotato plants per field were randomly selected and harvested using destructive sampling technique, and the following data was taken.

1. Yield of roots was determined by counting the roots and weighing them.
2. The percentage incidence of weevils in roots was determined by examining roots for weevil infestation, counting, weighing infested roots and the data was subjected to the formula below:

$$\frac{\text{Number of weevil infested roots from 5 plants}}{\text{Total number of roots harvested per 5 plants}} \times 100$$

3. a) Severity of external damage due to weevils on roots was determined on three roots randomly selected per sample per field. Each root was visually assessed and scored on a scale of (1 - 5): (1= no damage, 2= upto 25% damage, 3 = 25-50% damage, 4 = 51- 75% damage, 5= 76-100%). The weighted average score of the three roots was recorded.

   b) Severity of internal damage in roots was then determined by cutting longitudinal half sections and visually scoring each root using the same scale (1 - 5) as above. Similarly the weighted average score of internal damage of three roots was recorded.

4. Weevil population density emerging from 1 kg infested roots of each variety were stored according to their time of planting in plastic buckets

covered with netted material. The weevils emerging within 8 weeks of the harvest were counted.

5. The identification of weevils found in the roots using Smit (1997) guide was done.

6. Similarly, percentage incidence of weevils on crowns was determined by cutting off 15cm length of crown from the crown base and examining it for weevil infestation. Percentage incidence was then determined as follows:

$$\frac{\text{Number of weevil infested crowns from 5 plants X 100}}{\text{No of crowns}}$$

3.2.3 Data analysis

Data analysis was done using descriptive analysis.

3. 3 RESULTS AND DISCUSSION

3.3.1 Survey Results

The survey showed that sweetpotato is an important food and cash crop in Kabras division, Kakamega district. Sweetpotato is mainly grown as a monocrop in fields ranging between 0.04 to 0.75 ha (2.4 acres = 1 ha), most of which are 1 acre. Sixty percent of the fields were managed and the produce owned by women. The sweetpotatoes were continuously planted throughout the year but most fields (72%) of fields were planted between July and October. Most sweetpotato fields were planted adjacent to each other particularly in Chekulo sub-location where the highest concentration of sweetpotato fields were found.

The two main methods of planting sweetpotato in the area were planting on ridged seedbeds and on flat seedbeds. Ridged seedbeds were prepared by ploughing the land using oxen then earthing up the soil to make ridges prior to planting of sweetpotato vines on them. Similarly, the flat seedbeds, were first ploughed with oxen but furrows were then opened in which the vines were planted. Fifty-two percent of the fields surveyed were planted on ridged seedbeds (Table 1). In both planting methods, subsequent earthing up was carried out usually during weeding at least 1-2 times before harvest.

Several varieties of sweetpotato were grown by farmers and included Mwezitatu, Bungoma, Loise, Mshoka and Lumola. However, Mwezitatu and Bungoma were the most common varieties grown in significant hectarage, while other varieties were planted in a few rows. Mwezitatu was grown on 83% of the fields surveyed while 17 % had Bungoma variety (Table 1). Eighty-six percent of the fields planted with Mwezitatu variety were infested with weevils compared to 57% of fields planted with Bungoma. Eighty-one percent of all the fields surveyed were infested with sweetpotato weevils (Table 1).

Most farmers were able to identify the sweetpotato weevil (locally known as "tsinglukusi") as the pest damaging their sweetpotato crops. They reported that weevil damage peaked in the latter part of the dry season. However, most of them did not know of any control methods although a few farmers reported that subsequent earthing up during weeding helped reduce weevil damage. A few farmers seemed to be aware of the importance of using vine tips as clean planting material in the control of sweetpotato weevils. However most of the fields were planted with cuttings taken from all sections of the vines other than vine tips. Vine tips have been reported to be relatively free of weevils (AVDRC, 1991, Ames *et al.* 1997). Therefore the high weevil incidence can partly be attributed to the use of infested vines harvested from the previous crops. Most farmers also practised inground storage of mature roots and some kept the crop in the field for as long as 11 months.

Table 1 Method of planting sweetpotatoes and sweetpotato weevil infestation levels on two common varieties on farmers' fields in Kabras division, Western Kenya.

S/location/ village	No of fields surveyed	No of fields per seedbed method		No of fields per variety grown		No of infested fields per variety		Total infested
		Ridged	Flat	Mwezitatu	Bungoma	Mwezitatu	Bungoma	fields
Kivaywa								
Vihiga	9	4	5	5	4	4	3	7
Matsaskha	5	1	4	5	0	4	0	4
Chekulo								
Luvambo	8	4	4	6	2	6	1	7
Namshya	18	12	6	17	1	15	0	15
Makucho	2	1	1	2	0	1	0	1
Total No of fields	42	22	20	35	7	30	4	34
Percentages (%)	100	52	48	83	17	86	57	81

3.3.2. Effect of crop management practises on sweetpotato weevil population density, incidence and severity of damage.

The results of the effect of time of planting, duration of in-ground storage and planting method on sweetpotato weevil density, incidence and severity of damage are shown in Tables 2 and 3. The highest weevil incidence on crowns was recorded in March followed in descending order by sweetpotatoes planted in October, August and September with lowest incidence (20%) recorded in June (Table 2). The high weevil incidence on March crop was attributed to long in-ground storage period (11 months) which exposed the crop to weevil attack and population build-up. Secondly, the crop was planted at the onset of the rains and high population of weevils in the old crop caused by the preceding dry seasons might have migrated to the newly established crop. On the other hand, the young October crop was planted at the end of the short rains season prior to the onset of the long dry season hence was subjected to high weevil pressure throughout its growth (Appendix 1). The low incidence observed on crowns of the June crop could be attributed to the plant growing under cool temperatures and high soil moisture not compatible with rapid weevil development. The rest of the months show moderate incidence levels on crowns. This could be attributed to the fact that being planted in the middle of the rainy period were able to grow under low weevil pressure for sometime before the drier and warmer months set in. The importance of incidence to crown damage lies in the fact that most farmers will use these same infested vines as planting material in the next season.

The percent incidence of weevil damage on roots was highest on crop planted in May (78%) followed by March and August (71%) with the least recorded in October (22%) (Table 2). Percentage incidence of weevil damage on roots generally increased with time of inground storage (except for August, 71%) with incidence declining thereafter on crops planted in June and July. The reason for this decline may be due to high rainfall during the formation of storage roots thus creating unfavourable conditions for weevil population build-up. Similar results were reported in Uganda by Smit (unpublished) and Odongo and Smit (1997).

Both external and internal root damage increased with time of inground storage. Therefore it is important to advise the farmers not to store the roots for a very long period.

The count of weevils showed that both *Cylas puncticollis* and *C. brunneus* were found to occur in the roots. These results agree with those of Smit (1997) who reported similar findings South Nyanza. The mean weevil density per kg of root was highest on May crop followed by August crop. It was lowest on March crop and October crop. The low weevil density on March crop can be attributed to the fact that the weevils were infesting younger crops with well-formed roots. The October crop was not mature and was just being infested, thus explaining the low weevil density observed.

Table 3 shows that percentage incidence of weevil damage on roots was generally high on both ridged seedbeds and flat seedbeds in all areas surveyed. The percentage weevil incidence on roots at Vihiga and Matsakha did not differ between the planting methods. Similar results were reported by (Smit 1997). The lack of difference between planting methods may be due to the earthing up of soil onto exposed roots during weeding. However, there were slightly higher incidences on flat seedbeds (75%) than on ridged seedbeds (37%) at Luvambo. A reverse trend was observed at Namshya, with slightly higher incidence recorded on ridged seedbeds (54%) than on flat seedbeds (40%). These results contradict that of KARI (1995) that recorded more weevil incidence on roots planted on ridges and mounds. These conflicting results observed on planting methods indicate that this area needs further comprehensive study.

Table 2 Effect of planting time and inground storage on incidence on crowns and roots, weevil density and severity of damage on roots of sweetpotato of Mwezitatu variety assessed in Kabras Division, Kakamega District In February, 1998.

Planting time	months stored inground	% incidence crowns	% incidence roots	Root damage (scale 1-5) external	Root damage (scale 1-5) internal	mean no of weevils / kg
October	4	75	22	1.4	1.1	0.3
September	5	53	41	1.8	1.6	0.7
August	6	63	71	2.5	2.2	1.3
July	7	45	53	2.6	2.0	0.7
June	8	20	65	2.7	2.7	0.6
May	9	50	78	3.0	2.8	2.0
March	11	80	71	3.0	3.0	0.3

Key Scale 1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%

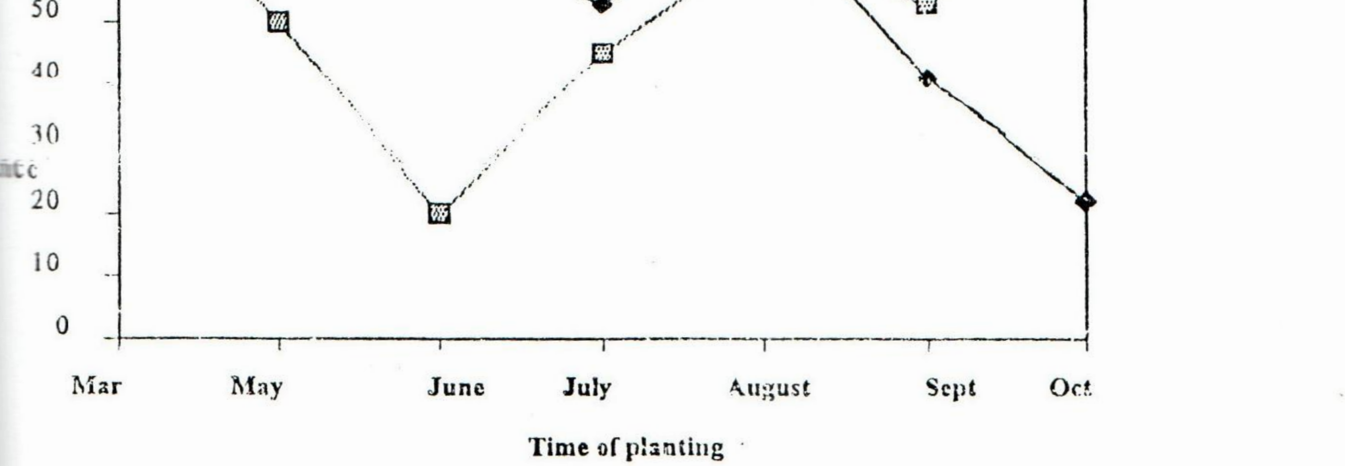

Figure 1. Effect of Time cf planting on incidence of crowns and roots in farmers, fields at Kabras division, in February, 1999

Table 3. Effect of planting method on incidence and severity of weevil damage on roots in four areas of Kabras division, Kakamega district in February, 1998.

Area Planting method	% weevil incidence on roots	Severity of damage on roots (scale 1-5) External damage	 Internal damage
Vihiga			
Ridged seedbeds	67	3.0	3.0
Flat seedbeds	67	2.7	2.0
Matsakha			
Ridged seedbeds	50	3.0	2.0
Flat seedbeds	50	2.2	1.7
Luvambo			
Ridged seedbeds	37	3.0	2.3
Flat seedbeds	75	3.0	2.2
Namshya			
Ridged seedbeds	54	2.3	2.0
Flat seedbeds	40	3.2	3.2

Key Scale 1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%

CHAPTER FOUR

4.0 Effect of variety, insecticide, time and method of planting on sweetpotato weevil (Cylas spp.) damage, population density and its effect on the yield of sweetpotatoes.

4.1 Introduction

The sweetpotato weevil (*Cylas spp.*) is a serious pest of sweetpotato in dry seasons and dry areas. The insect damages the crop by boring and tunnelling in the vines and the edible roots. Damaged roots are bitter and inedible and susceptible to rotting resulting to yield losses. Conventional control methods applied singly have been reported not to effectively control weevils at high populations which occur during dry periods (Ames *et al*., 1997; Talekar *et al*., 1990). Information from literature shows that the pest can be managed when methods are combined in various ways (Smit, 1997; Ames *et al*., 1997 and Collins *et al*., 1998). The approach also known as Integrated Pest Management (IPM) has been found to reduce weevil damage on roots (AVDRC, 1990; Talekar *et al*., 1989 and Pillai *et al*., 1993). However there is limited information on sweetpotato weevil IPM in East Africa. Therefore, there was a need to carry out comprehensive research to identify effective but economical IPM options which can be recommended to the farmers.

4.2 Materials and Methods

4.2.1 Study area

The experiment was conducted at the Regional Research Centre, Kakamega and Alupe Agricultural Sub-centre, Busia during the short rains(September to November, 1998) and long rains(April to July, 1999) seasons (Appendix 2). Kakamega (0' 20" N, 34' 46"E) is located in the upper midland coffee/ tea zones (UM1) at 1520m above sealevel (a.s.l.) and has a mean temperature of 20.7 oC with annual mean rainfall of 1513 mm over two seasons. The soils are dystro mollic nitisols: dusky red to dark red and dark reddish brown clay loams. Alupe (0"30"N, 34' 8"E) is located in the lower midland sugar zone (LM1) at 1170 m a.s.l. and has a mean temperature of 22.2 oC and annual rainfall of 1460 mm over two seasons (Jaetzold and Schmidt, 1982). The soils are ferralo chromic acrisols: an association of acrisols that are well drained, dark yellow brown to strong brown, friable sandy clay loam to clays that are moderately deep to deep, in some places. Prior to the planting of the trial upto its harvest, monthly temperature and rainfall data were obtained from KARI-Kakamega and Busia FTC meteorological station during the cropping season (Appendix 3 - 5).

4.2.2 Materials

The experimental design was a randomised complete block design in a split plot arrangement with replicated three times. Four crop management factors were investigated: variety, insecticide, method and time of planting each at two levels as described below.

Variety

1) Mwezitatu, an early maturing common variety in Western Kenya but highly susceptible to weevils.
2) Marooko, a late maturing variety grown in some areas during the dry season and has been reported by farmers to have low susceptibility to weevils.

Insecticides

1) None
2) Diazinon 60% EC @ the rate of 30 ml in 20 litres of water, in which planting material was dipped for 30 minutes prior planting.

Planting method

1) Ridged - planting on ridged seedbeds measuring 30 cm high and wide
2) Flat - planting on flat seedbeds.

Planting time

1) Plant at onset of rains
2) Plant 1 month after onset of rains.

Plate l. Sweetpotato variety, Mwezitatu in field plot

Plate 2. Sweetpotato variety, Marooko in field plot

Plate 3: Ridged seedbeds in trial plot

Plate 4: Flat seedbeds in trial plot

Plate 5: Early and Late planted crop

Plate 6: Cross section of infested roots

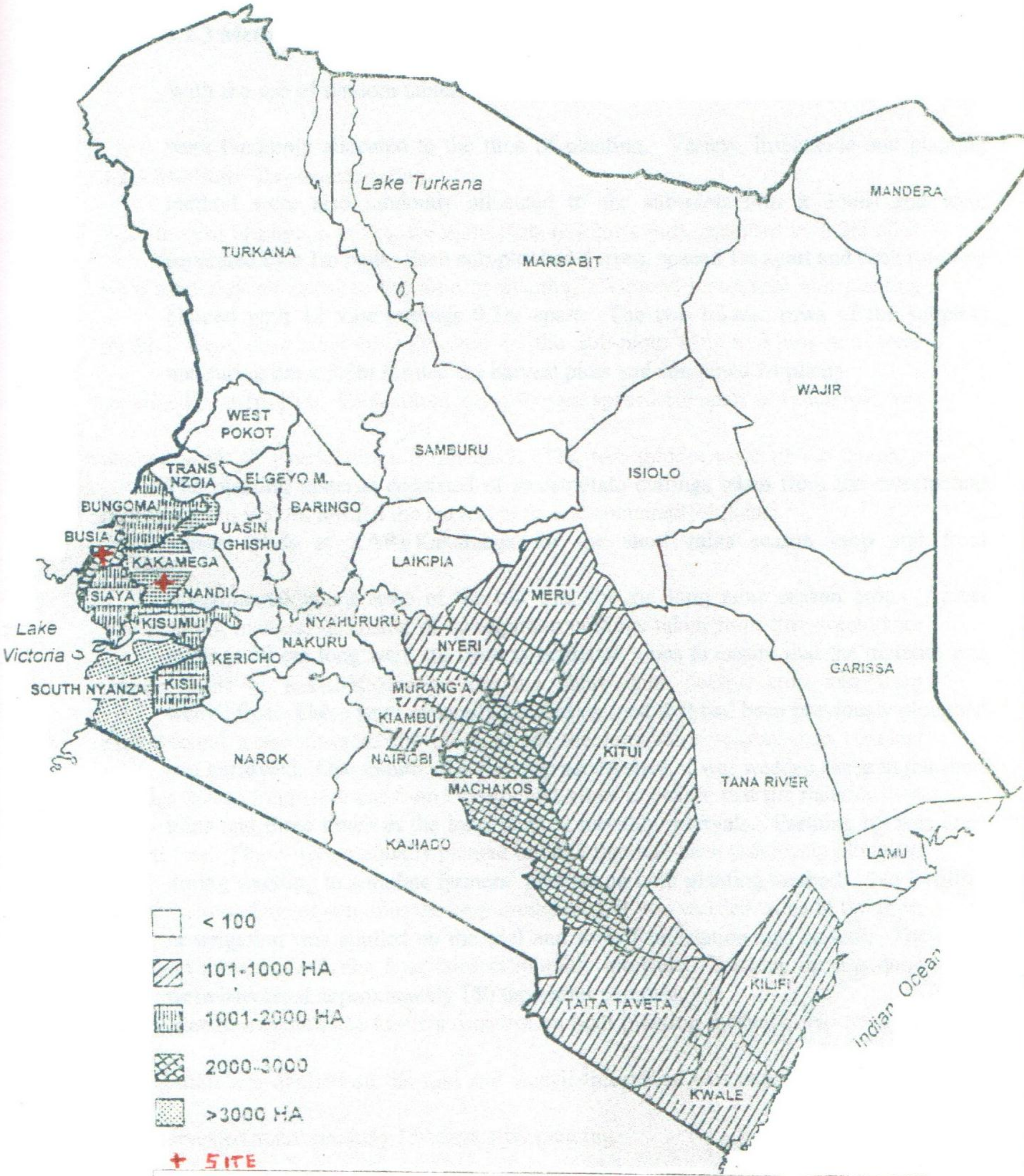

Plate 7: Map 1: Sweetpotato producing areas in Kenya.
Source. Ministry of Agriculture and Livestock Development Annual Report, 1989 and 1991

4.2.3 Methods/ Experimentation

With the use of random tables, the main plots (39.2m x 4m) separated by a 2m alley were randomly allocated to the time of planting. Variety, insecticide and planting method were also randomly allocated to the sub-plots (4m x 3.9m) and were separated by a 1m path. Each sub-plot had 4 rows, spaced 1m apart and each row was planted with 12 vine cuttings 0.3m apart. The two middle rows of the subplots measuring 2m x 3.9m formed the harvest plots and contained 24 plants.

The planting material consisted of sweetpotato cuttings taken from the sweetpotato nursery beds at KARI-Kakamega for the short rains season crop and from experimental guard rows of the old trial for the long rains season crop. Apical cuttings 30 cm long were cut from sweetpotato vines to ensure that the material was weevil free. These were manually planted on land that had been previously ploughed and harrowed. One month after the crop established, it was weeded twice in the short rains and three times in the long rains at monthly intervals. Earthing up was done during weeding to simulate farmers' practise on both planting methods. No fertiliser or irrigation was applied on the trial and weevil infestation was natural. The crops were harvested approximately 150 days after planting.

4.2.4 Parameters Measured

1. The stand count of established sweetpotato plants which was taken at four weeks and at harvest to determine the number of plants surviving during the crop growth period.

1. The yield of storage roots of the harvest plot were determined by harvesting all storage roots and separating them from foliage. Roots were then counted and weighed.

2. The yield of weevil infested roots was determined by examining all storage roots from the harvest plot for weevil damage and these were counted and weighed.

3. Severity of external and internal root damage caused by weevils to roots was evaluated by randomly selecting five infested roots which were first externally examined and scored on a scale of 1 - 5 as follows, (1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%). Later, the roots were cut longitudinally into half sections and scored for internal damage on the same scale. The weighted mean damage of both external and internal damage on sweetpotato roots was then calculated using the formula below;

$$\frac{\text{(no of roots in each damage class X score of the damage class)}}{\text{Total no of roots}}$$

4. The weight of inedible portion of weevil damaged roots for each harvest plot was

determined by carefully examining all infested roots and cutting off the infested parts and weighing them.

5. The weevil density in cut infested parts of the five marked roots were further split into cross-sections quarters 1/2 cm thick, and the count of larvae, pupae and adults of weevils taken.
6. The external and internal weevil damage to crowns of sweetpotato vines was determined by random selection of five crowns, cut from the crown up the vine, 15cm long. These were visually scored by examining the extent of the severity of external damage on a scale of 1-5, (1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%) then split lengthwise and weevil tunnels measured and scored for internal damage on the same scale. Weighted mean damage of external and internal damage was then calculated for the five crowns.
7. The weevil density in the crowns were determined by counting all the larvae, pupae and adults within and their species determined according to Smit (1997).

4.2.5 Data Analysis

Data on the means of numbers and weights of total, infested, inedible roots and weevil density of roots and crowns were transformed using square root (x + 1) to homogenise and stabilise the variance (Steele and Torrie, 1980). Analysis of Variance (ANOVA) was done using a computer (MSTAT-C) sourced from Michigan State University (1985) statistical programme at ($p<0.05$). Least Significant Difference (LSD) test was used in separating the treatment means.

4.3. RESULTS AND DISCUSSIONS

4.3.1 Results on the effect of weevil infestation on total number of sweetpotato roots and yield.

Results on the effect of variety, insecticide, planting method and time of planting on total number and yield of roots harvested and infested by sweetpotato weevil during the short (1998) and long (1999) rains seasons at Kakamega and Busia are reported in Tables 4 - 7. Analysis of variance showed that there were significantly ($p = 0.05$) higher number of roots recorded on Mwezitatu variety than on Marooko variety in both the short and long rains season at Kakamega and the short rains season at Busia (Tables 4 - 6). The differences were attributed to the fact that Mwezitatu was early maturing unlike Marooko, a late maturing variety with most roots not yet physiologically mature at the time of harvest. Despite the significantly higher root numbers, the yields of Mwezitatu were only significantly ($p = 0.05$) higher at Kakamega in both seasons (Tables 4 and 6). The difference was attributed to more large roots which were formed on Mwezitatu variety than on Marooko variety in both seasons at Kakamega. High yields have been associated with high number of large roots (Bartolini, 1982).

There was no significant difference observed between the number and yields of roots on the two varieties in the long rains season at Busia (Table 7). The lack of significant differences at Busia was possibly because of delayed harvesting (three weeks late) which allowed more roots of Marooko to attain physiological maturity and thus resulting to increased yields.

There were significantly higher yields of Mwezitatu on short season crop than long season crop at Kakamega. These findings agree with those of Zera *et al*. (1982) who also reported finding higher yields in the dry season crops than in the wet season crop, attributing the differences in yields to weather effects. Zera *et al.* (1982) indicated that waterlogged conditions in the wet season crop, suppressed tuber formation and promoted formation of fibrous roots. However on Marooko variety, the yields were appreciably higher during the long rains than in the short rains season and particularly at Busia where the crop was harvested late. (Tables 4 - 7). It is possible that Marooko requires higher rainfall amounts to exploit its full genetic yield potential.

The number (incidence) and yields of infested roots were significantly ($p=0.05$) higher on Mwezitatu than on Marooko variety, except at Busia during the long rains season (Table 4-7). These differences were partly attributed to the root placement of the two varieties. Mwezitatu being a shallow rooted variety unlike Marooko variety which is deep-rooted was more exposed to weevil infestation through soil cracks formed in the dry period. Deep-rooted varieties have been reported to escape weevil damage due to their depth in the soil (Ames *et al.* 1997; CIP 1998). Despite being deep-rooted, Marooko suffered appreciably high weevil infestation during the short rains season at Busia. This was possibly due to presence of clay soils found in Busia. Brady (1990) reported that such soils develop deep cracks during the dry season thus could expose even deep-rooted varieties. It is thought that soils especially clay based crack more in the dry season and hence allow weevils to access roots for infestation. In addition weevil population has been found to decrease with elevation and low temperatures (Ghosh *et al.*, 1988). This may partly explain the comparatively higher incidence and severity of weevil damage on Marooko during the short rains season at Busia. Therefore the use of deep-rooted varieties at Busia could be augmented with other control methods.

The yield of infested inedible roots was significantly ($p= 0.05$) higher on Mwezitatu (1.8 and 1.3 t / ha) than on Marooko (0 and 0.4 t/ha) variety at both Kakamega and Busia respectively, during the short rains season in 1998 (Tables 4 and 5). The differences were attributed to high weevil infestation on Mwezitatu variety. However there was no significant difference observed between the yields of the two varieties at both sites during the long rains season (Table 6 and 7). This was possibly due to low weevil infestation caused by the high rainfall over this period (Appendices 3 and 5). These results indicate that Marooko is less affected by weevils and would be a good variety for the short rains season. However, for farmers with a preference for Mwezitatu variety, integrated control methods aimed at suppressing weevil population would be required.

Dipping planting vines in diazinon did not significantly influence either weevil incidence, and severity of damage in both the short and long rains season at Kakamega and Busia (Table 4-7). The lack of significant differences were possibly because vines free from weevils (clean) were used in the study. In addition, Sutherland (1986a) showed that weevil populations quickly established in newly planted crops hence a dip could only be expected to kill the adults that were present or emerging from the vines used for planting. However weevils would not be prevented from breeding within the new vine growth and subsequently infesting roots once diazinon ceased to be effective. Diazinon has been reported by Smit (1997) to control weevils for at least one month but efficacy of contact insecticides has been reported by AVDRC (1989) to be reduced under high temperatures or rainfall. High rainfall present in the early part of both seasons possibly accounted for lack of differences. Nevertheless further work on farmers fields is required to confirm these results. This is important as farmers do use infested planting material especially when it is inadequate and the study would particularly benefit commercial sweetpotato farmers.

Sweetpotatoes planted on ridged seedbeds produced significantly ($p = 0.05$) more roots and higher yields than those planted on flat seedbeds during the short rains season at Kakamega and Busia (Tables 4 and 5). Similar findings have been reported by Munga *et al.* (1992), KARI (1992, 1995) working in Mombasa and Smit *et al.* (1992) working in South Nyanza. However, there was no significant difference between the two planting methods with respect to weevil incidence and severity of damage. These findings agree with work done in Tanzania and reviewed by Smit (1997) but differ with that reported by KARI (1992) and (1995) who reported significantly higher damage on ridged beds than on flat seedbeds. Soil types might have caused differences in these results with those of KARI (1992, 1995). Both reported trials were grown on sandy soils, which differed from the loam to clay soils at Busia and Kakamega. Ridged seedbeds made in sandy soils tend to undergo heavy erosion, which could have exposed sweetpotato roots.

There were significantly ($p = 0.05$) higher yields but also significantly higher incidence and severity of weevil damaged roots on sweetpotato planted early at the onset of rains than one month later at Busia, during the short rains season (1998). (Table 5). The difference was possibly due to the particularly high soil temperatures at Busia and adequate moisture both, which declined with a delay in planting time. High soil temperatures have been found by (Spence and Humphries, 1972) to promote starch deposition to roots but to also promote weevil build-up (Smit, 1997). Hence this resulted in the formation of more large sized roots with high weevil infestation on sweetpotato crop planted early at the onset of rains at Busia. However, there was no significant difference with respect to time of planting on the yields, incidence and severity of damage at Kakamega in the short rains season and at both sites in the long rains season (Table 4, 6 and 7). This was possibly due to the fairly cool conditions under which the crops were grown.

Table 4. Effect of variety, insecticide, method and time of planting on number and yield of harvested sweetpotato roots, infested and inedible roots due to *Cylas spp.* during the short rains season, at Kakamega, Kenya in 1998.

Factor	Mean no of roots(x 10^3)		Mean yield of roots t/ha		
	harvested	infested	harvested	infested	inedible
Variety					
Mwezitatu	7.0 (49.2)	3.2 (13.2)	3.3 (10.4)	2.1 (3.8)	1.6 (1.8)
Marooko	5.3 (28.4)	1.2 (0.5)	2.1 (3.7)	1.0 (0.0)	1.0 (0.0)
LSD	0.5	0.4	0.2	0.3	0.1
Diazinon (30 ml/ 20 litres water)					
0	6.3 (40.7)	2.4 (7.0)	1.5 (1.9)	3.5 (17.6)	1.3 (0.9)
30	6.0 (37.0)	2.4 (6.7)	1.6 (2.0)	3.6 (11.3)	1.3 (1.0)
LSD	ns	ns	ns	ns	ns
Planting method					
Ridged beds	6.5 (42.0)	2.6 (8.2)	2.9 (7.9)	1.7 (2.5)	1.4 (1.1)
Flat beds	5.9 (35.7)	2.1 (5.6)	2.6 (6.3)	1.4 (1.1)	1.3 (0.7)
LSD	0.5	ns	0.2	ns	ns
Time of planting					
Early	6.0 (36.2)	2.2 (6.0)	2.9 (7.8)	1.6 (2.2)	1.4 (1.1)
Late	6.4 (41.5)	2.5 (7.8)	2.6 (6.4)	1.5 (1.6)	1.3 (0.7)
LSD	0.1	ns	ns	ns	ns
CV (%)	14.0	36.1	13.9	22.4	16.7

Figures in parenthesis are means of original values

Table 5. Effect of variety, insecticide, method and time of planting on number and yield of harvested sweetpotato roots, infested and inedible roots due to *Cylas spp.* during the short rains season at Alupe, Busia, Kenya in 1998.

Factor	Mean no of roots x 10^3)		Mean yield of roots t/ha		
	harvested	infested	harvested	infested	inedible
Variety					
Mwezitatu	6.7 (45.6)	4.1 (19.3)	2.5 (5.5)	1.8 (2.6)	1.4 (1.3)
Marooko	5.4 (29.6)	2.0 (4.5)	2.2 (4.0)	1.3 (0.8)	1.2 (0.4)
LSD	0.6	0.5	ns	0.2	0.1
Diazinon 60 EC (30 ml/ 20 litres water)					
0	6.1 (37.5)	3.1 (12.2)	2.4 (4.9)	1.5 (1.7)	1.3 (0.8)
30	6.1 (33.7)	3.0 (11.5)	2.3 (4.7)	1.5 (1.7)	1.3 (0.9)
LSD	ns	ns	ns	ns	ns
Planting method					
Ridged bed	6.2 (45.6)	3.3 (13.4)	2.5 (5.7)	1.6 (1.9)	1.4 (1.1)
Flat bed	5.5 (29.6)	2.9 (10.4)	2.1 (3.8)	1.5 (1.5)	1.2 (0.6)
LSD	0.5	ns	0.3	ns	ns
Time of planting					
Early	6.4 (41.5)	4.2 (19.6)	2.5 (5.9)	1.9 (3.1)	1.5 (1.6)
Late	5.8 (33.7)	1.9 (4.1)	2.1 (3.7)	1.1 (0.4)	1.1 (0.2)
LSD	0.1	0.6	0.3	0.1	0.2
CV (%)	17.5	34.5	20.7	21.0	17.8

Figures in parenthesis are means of original values

Table 6. Effect of variety, insecticide, method and time of planting on number and yield of harvested sweetpotato roots, infested and inedible roots due to *Cylas spp* during the long rains' season, at Kakamega, Kenya in 1999.

Factor	**Mean no of roots($x10^3$)**		**Mean yield of roots (t/ha)**		
	harvested	**infested**	**harvested**	**infested**	**inedible**
Variety					
Mwezitatu	5.9 (37.2)	1.6 (1.8)	2.7 (7.4)	1.3 (0.7)	1.1 (0.2)
Marooko	4.3 (21.1)	1.2 (0.4)	2.1 (4.5)	1.1 (0.2)	1.0 (0.1)
LSD	0.9	0.2	0.5	0.1	0.1
Diazinon 60 EC (30 ml/ 20 litres water)					
0	5.1 (28.4)	1.4 (1.2)	2.5 (5.9)	1.1 (0.3)	1.1 (0.1)
30	5.1 (29.9)	1.3 (1.0)	2.4 (6.0)	1.1 (0.3)	1.0 (0.1)
LSD	ns	ns	ns	ns	ns
Planting method					
Ridged beds	4.96 (28.0)	1.3 (1.0)	2.4 (5.6)	1.2 (0.4)	1.0 (0.0)
Flat beds	4.14 (30.3)	1.4 (1.2)	2.5 (6.2)	1.2 (0.4)	1.1 (0.2)
LSD	ns	ns	ns	ns	ns
Time of planting					
Early	5.1 (29.0)	1.5 (1.6)	2.4 (5.7)	1.2 (0.6)	1.0 (0.0)
Late	5.1 (29.3)	1.2 (0.6)	2.5 (6.2)	1.1 (0.3)	1.1 (0.2)
LSD	ns	ns	ns	ns	ns
CV (%)	35.1	29.33	38.6	19.8	11.7

Figures in parenthesis are means of original values

Table 7. Effect of variety, insecticide, method and time of planting on number and yield of harvested sweetpotato roots, infested and inedible roots due to *Cylas spp* during the long rains' season, at Alupe, Busia, Kenya in 1999.

Factor	Mean no of roots($x10^3$)		Mean yield of roots (t/ha)		
	harvested	infested	harvested	infested	inedible
Variety					
Mwezitatu	6.1 (38.0)	1.5 (1.7)	2.6 (6.5)	1.1 (0.4)	1.0 (0.6)
Marooko	6.0 (37.0)	1.2 (0.8)	2.9 (8.3)	1.1 (0.3)	1.0 (0.1)
LSD	ns	ns	ns	ns	ns
Diazinon 60 EC (30 ml / 20 litres water)					
0	6.1 (38.3)	1.4 (1.6)	2.7 (7.2)	1.2 (0.4)	1.1 (0.1)
30	6.0 (37.3)	1.3 (0.8)	2.8 (7.5)	1.1 (0.2)	1.0 (0.0)
LSD	ns	ns	ns	ns	ns
Planting method					
Ridged beds	6.2 (39.6)	1.5 (1.8)	2.8 (7.5)	1.1 (0.4)	1.0 (0.0)
Flat beds	5.9 (36.0)	1.2 (0.7)	2.7 (7.2)	1.1 (0.3)	1.0 (0.0)
LSD	ns	ns	ns	ns	ns
Time of planting					
Early	6.3 (39.7)	1.5 (1.4)	3.3 (10.3)	1.1 (0.3)	1.0 (0.1)
Late	5.8 (35.9)	1.3 (1.1)	2.2 (4.4)	1.1 (0.4)	1.0 (0.2)
LSD	ns	ns	ns	ns	ns
CV(%)	20.1	38.2	21.8	22.7	4.1

Figures in parenthesis are means of original values

4.3.2. Results on weevil density and severity of damage in roots and crowns of sweetpotato.

Results on the effect of variety, insecticide, method and time of planting on weevil densities and severity of damage on crown and roots in Kakamega and Busia during the short rains season are shown in Table 8 and 9. Analysis of variance showed that the mean number of weevils recovered from roots were significantly ($p = 0.05$) higher in Mwezitatu (19.2 and 30.6) than Marooko (1.6 and 15.7) at Kakamega and Busia respectively during the short rains season (Tables 8 and 9). The differences were possibly because Mwezitatu being shallow rooted was more easily infested by weevils.

The external and internal root damage were significantly ($p=0.05$) higher on Mwezitatu than Marooko at Kakamega and Busia (Tables 8 and 9). This was attributed to the high weevil densities present in roots of Mwezitatu.

The use of insecticides did not affect incidence, population densities nor severity of damage on either roots or crowns during the short rains, at both sites. This has been attributed by Sutherland (1986a) to the concealed feeding habit of weevils.

There were significantly (p=0.05) higher weevil densities in roots of sweetpotato planted on ridged seedbeds at Busia in the short rains season, but this had no effect on the severity of damage in the roots (Tables 9). The difference in weevil densities were attributed to the erosion which could have occurred on ridged seedbeds and so exposed roots to weevils. The planting method did not significantly influence weevil densities, and severity of damage on crowns at Kakamega and Busia.

Significantly (p = 0.05) higher weevil densities were observed on roots of crop planted early (44.5) than late planted (1.7) during the short rains season at Busia (Table 9). This resulted in significantly higher severity of external and internal root damage. Differences were due to the root placement, which allowed the shallow rooted Mwezitatu to be highly infested when subjected to high weevil pressure unlike the deep-rooted Marooko.

Table 8. Effect of variety, insecticide, planting method and time of planting on weevil population and severity damage to roots and crown infested by sweetpotato weevil in the short rains seasons at Kakamega in 1998.

Factor	Weevils per 5 roots	Severity of damage in roots (score 1-5)		Weevils per 5 crowns	Severity of damage in crowns (score 1-5)	
		External	Internal		External	Interna
Variety						
Mwezitatu	3.4 (19.2)	2.3	1.9	1.3 (0.8)	2.0	2.1
Marooko	1.3 (1.6)	1.3	1.3	1.3 (0.7)	1.8	2.0
LSD	1.1	0.2	0.3	ns	ns	ns
Diazinon (30ml/ 20 litres water)						
0	2.3 (11.3)	1.8	1.6	1.3 (0.7)	1.8	2.1
30	2.3 (9.5)	1.8	1.6	1.3 (0.8)	2.0	2.0
LSD	ns	ns	ns	ns	ns	ns
Planting method						
Ridged beds	2.8 (16.0)	1.9	1.6	1.3 (0.9)	2.0	2.1
Flat beds	1.8 (4.8)	1.7	1.5	1.2 (0.7)	1.9	2.0
LSD	ns	ns	ns	ns	ns	ns
Time of planting						
Early	2.5 (12.8)	1.6	1.4	1.3 (0.8)	1.8	1.9
Late	2.1 (8.0)	2.0	1.7	1.3 (0.7)	2.0	2.1
LSD	ns	ns	ns	ns	ns	ns
CV(%)	95.3	22.8	30.1	29.1	30.5	30.9

Figures in parenthesis are means of original values

Table 9. Effect of variety, insecticide, method of planting and time of planting on weevil population and severity of damage to roots and crowns infested by *Cylas* weevil in the short rains season at Busia in 1998.

Factor	Weevils per 5 roots	Severity of damage in roots (score 1-5)		Weevils per 5 crowns	Severity of damage in crowns (score 1-5)	
		External	Internal		External	Interna
Variety						
Mwezitatu	4.5 (30.6)	2.9	2.5	2.9 (10.1)	3.2	3.3
Marooko	3.1 (15.7)	2.1	1.6	2.2 (4.4)	2.7	2.6
LSD	0.6	0.4	0.3	ns	ns	ns
Diazinon (60 EC 30ml / 20 litres water)						
0	3.6 (19.7)	2.7	2.0	2.5 (6.7)	2.9	2.9
30	4.1 (26.5)	2.4	2.1	2.7 (7.8)	3.1	3.1
LSD	ns	ns	ns	ns	ns	ns
Planting method						
Ridged beds	4.2 (25.5)	2.5	2.2	2.5 (6.0)	3.1	3.1
Flat beds	3.5 (20.8)	2.6	1.9	2.6 (8.6)	2.8	2.9
LSD	0.6	ns	ns	ns	ns	ns
Time of planting						
Early	6.3 (44.5)	3.5	2.4	3.2 (11.4)	3.0	2.8
Late	1.4 (1.7)	1.6	1.6	2.0 (3.2)	3.0	3.2
LSD	0.4	0.2	0.3	ns	ns	ns
CV (%)	39.6	29.5	27.6	44.7	15.1	14.7

Figures in parenthesis are means of original values

4.3.3. Results on significant interaction effects between various treatments on weevil infestation and numbers of sweetpotato roots.

Analysis of variance showed that there was significant (p=0.05) time of planting by method of planting interaction effects on the yields of infested roots during the short rains season, 1998, at Kakamega (Table 10). The yields of infested roots on crop planted early and on ridged seedbeds were significantly higher than that planted on flat seedbeds. However, there was no significant difference when late planted crop was grown on either seedbed. Differences on early planted crop were possibly due to erosion on ridged seedbeds that was caused by high rainfall intensity in the early part of the season and so exposed roots to weevils. It is recommended that farmers who wish to plant early in the short rains season at Kakamega would be advised to plant on flat seedbeds. However, if the farmers plant late, they could use either of the planting methods but preferably ridged seedbeds because they have been reported to increase the yields of sweetpotatoes (KARI 1995; Smit *et al*, 1992).

Significant (p = 0.05) variety by planting method interaction effects were detected on yields of infested roots during the short rains season (1998) at Kakamega and the long rains season (1999) at Busia (Tables 11 and 12 and Fig 1 and 2). The yield of infested roots was significantly (p = 0.05) higher on Mwezitatu variety planted on ridged seedbeds in both seasons while no significant differences were observed for Marooko planted on either seedbeds.

The differences observed on Mwezitatu were possibly because the variety is shallow rooted and so it was exposed more when ridged beds were eroded. It is suggested that planting Mwezitatu on flat seedbeds could keep infestation low and may be recommended (KARI, 1995).

There was a significant ($p=0.05$) variety by time of planting interaction on the number and yield of infested and inedible roots, at Busia during the short rains season in 1998 (Table 13). The number and yields of infested roots were significantly ($p = 0.05$) reduced on both varieties when they were planted late, with effects being more pronounced on Mwezitatu. The yields of infested inedible roots were however only significantly reduced on Mwezitatu planted late.

During the long rains season, 1999, at Kakamega a similar significant ($p=0.05$) variety by time of planting interaction was observed on total number of harvested roots, the number and yields of infested roots. There was a significant decrease in the number of roots harvested on Mwezitatu variety planted late while the reverse was true on Marooko variety. Similarly, incidence and severity of damage significantly declined on Mwezitatu planted late (Table 14). The reduction in the level of infestation on late planted crop and particularly on Mwezitatu was possibly caused by low weevil population. Therefore, farmers who would prefer to plant late, would be advised to plant either of the varieties. However, should they wish to plant early, then Marooko which is less affected by weevils would be a better choice. Before these recommendations can be made, there would be a need to verify these findings by conducting on farm trials for at least two more seasons.

Table 10 Planting By Planting Method Interaction On Mean Yields Of Sweetpotato Roots Infested By Weevils In The Short Rains Season At Kakamega. In 1998.

Yield of infested roots (t/ha)

Planting method	Time of planting	
	Early	Late
Ridged beds	1.9 (3.4)	1.5 (1.5)
Flat seedbeds	1.4 (1.0)	1.5 (1.8)
LSD	0.3	

Table 11. Effects of variety by planting method interaction on yields (t/ha) of sweetpotato roots infested by weevils in the short rains season at Kakamega in 1998.

Planting method		Variety	
Ridged beds	2.3 (4.8)		1.0 (0.1)
Flat seedbeds	1.8 (2.7)		1.0 (0.1)
LSD		0.3	
C.V. (%)		22.4	

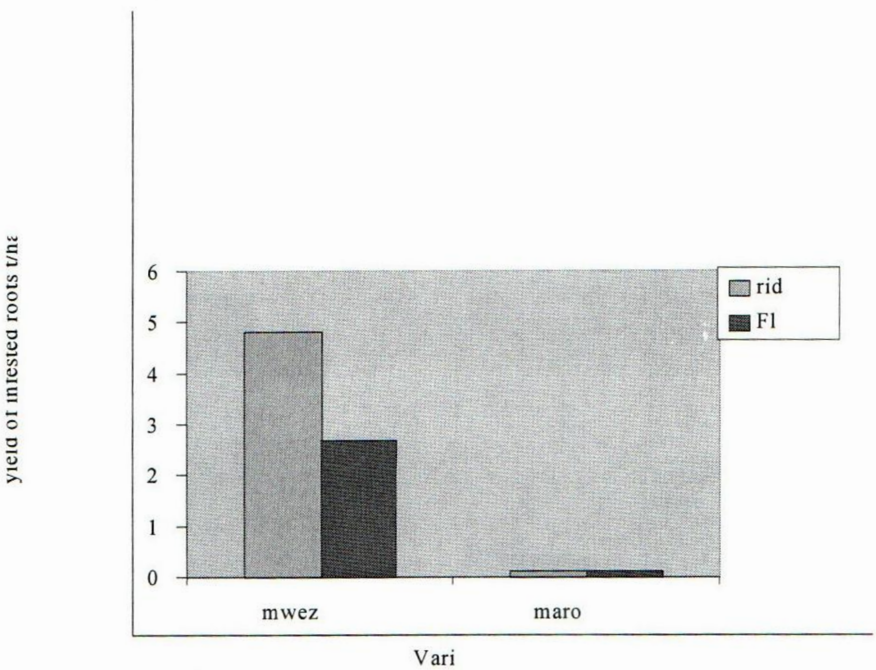

Fig. 2. Effects of variety by planting method interaction on yields (t/ha) of sweetpotato roots infested by weevils in the short rains season at Kakamega in 1998

Table 11 Effects of variety by planting method interaction on yield (t/ha) of sweetpotato roots infested by weevils in the long rains season at Busia in 1999.

Planting Method	Time of planting	
	Early	Late
Ridged beds	1.9 (3.2)	1.1 (0.4)
Flat seedbeds	1.1 (0.2)	1.4 (1.2)
LSD	0.4	
C.V. (%)	38.2	

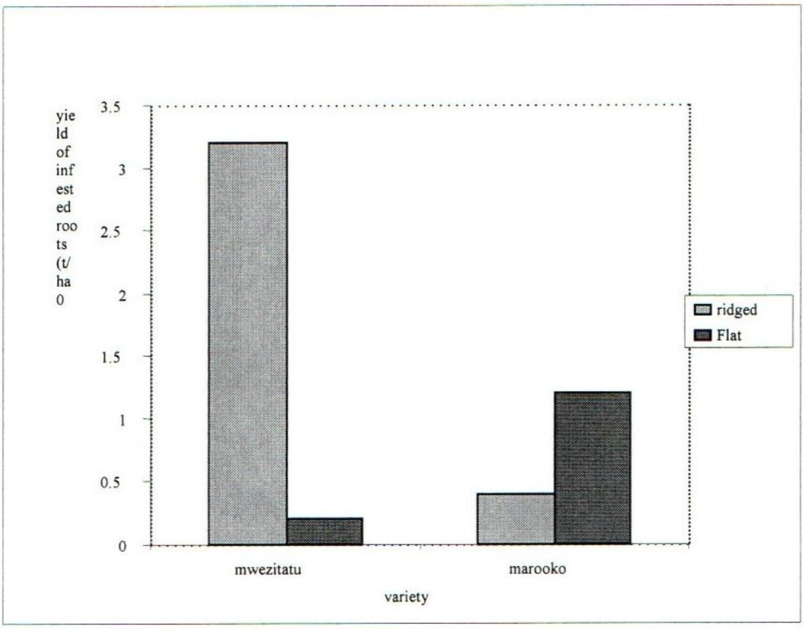

Fig 3.Effects of variety by planting method interaction on yield (t/ha) of sweetpotato roots infested by weevils in the long rains season at Busia in 1999

Table 11 Effects of variety by planting method interaction on yield (t/ha) of sweetpotato roots infested by weevils in the long rains season at Busia in 1999.

Planting Method	Time of planting		
	Early		Late
Ridged beds	1.9 (3.2)		1.1 (0.4)
Flat seedbeds	1.1 (0.2)		1.4 (1.2)
LSD		0.4	
C.V. (%)		38.2	

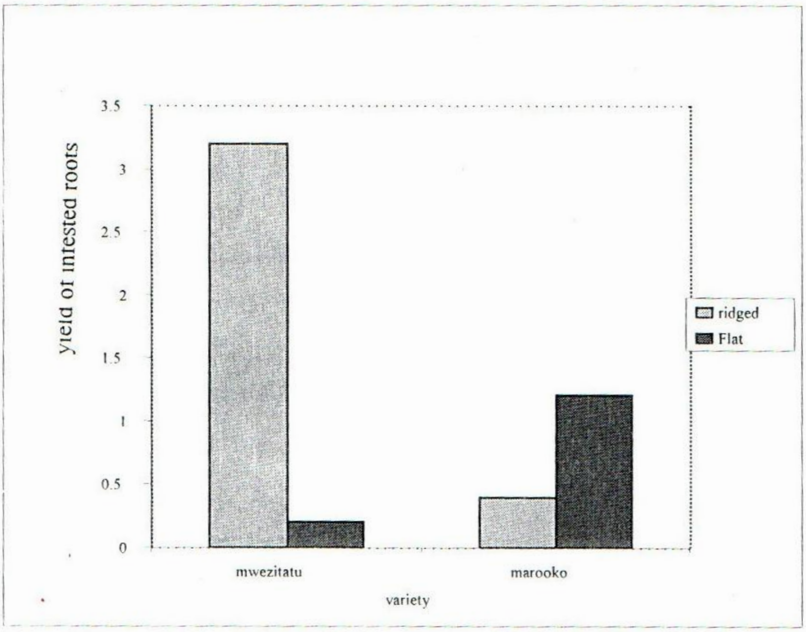

Fig 3.Effects of variety by planting method interaction on yield (t/ha) of sweetpotato roots infested by weevils in the long rains season at Busia in 1999

Table 13. Effect of variety by planting time interactions on number and yields of roots infested and rendered inedible by the Cylas weevil in the short rains season, at Busia in 1998.

Planting	Variety					
Time	No of infested roots ($10\ x^3$)		Yield of infested roots (t/ha)		Yield of inedible roots (t/ha)	
	Mwezitatu	Marooko	Mwezitatu	Marooko	Mwezitatu	Marooko
Early	5.6 (31.1)	2.8 (8.3)	2.3 (4.7)	1.5 (1.5)	1.8 (2.2)	1.3 (0.8)
Late	2.7 (7.6)	1.2 (0.6)	1.3 (0.6)	1.0 (0.1)	1.1 (0.3)	1.1 (0.0)
LSD	0.6		0.3		0.2	
CV(%)	34.5		21.0		17.8	

Figures in parenthesis are means of original values

Table 14. Effects of variety by planting time interaction on mean number of sweetpotato roots harvested and mean number and yields of roots infested by *Cylas* weevil at Kakamega in the long rains season in 1999.

Planting Time	**Variety**					
	No of harvested roots ($10 x^3$)		**No of infested roots ($10 x^3$)**		**Yield of infested roots (t/ ha)**	
	Mwezitatu	**Marooko**	**Mwezitatu**	**Marooko**	**Mwezitatu**	**Marooko**
Early	6.8 (46.6)	3.4 (11.4)	1.8 (2.9)	1.1 (0.3)	1.3 (0.8)	1.0 (0.1)
Late	5.1 (27.9)	5.2 (30.8)	1.1 (0.7)	1.2 (0.5)	1.0 (0.1)	1.1 (0.3)
LSD	1.4		0.2		0.2	
CV(%)	35.1		28.9		19.9	

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

The field survey showed the sweetpotato weevil infested majority of sweetpotatoes grown in this division particularly on Mwezitatu variety which was the dominant variety grown. Another common variety grown in the area was Bungoma and was found to be less infested. This indicates that there is need to introduce other varieties that are high yielding and acceptable to farmers but tolerant to sweetpotato weevils.

The practise of using planting material from all sections of the vines accounted for higher weevil infestation particularly during the dry season. There is need to sensitise farmers on the importance of using vine tips in reducing weevil infestation. Some farmers were aware of this importance but were handicapped by lack of adequate planting material especially in the dry season. There is a need for extension agents and researchers to bulk more clean planting material and to also train farmers or group of farmers on how to establish individual bulking plots for their own use.

The practise of continuous and adjacent cropping of sweetpotato fields contributed to build-up of weevils. There is need to sensitise farmers on the dangers attributed to this practise and encourage crop rotation where possible, of at least two seasons. This is quite practical in Kabras division where farms are relatively large.

Farmers also practised inground storage of roots for long periods which promoted weevil build-up and damage. There is need to determine the maximum duration of inground storage in relation to time of planting that would not result to economic losses due to weevil infestation.

There were contradictory results on the effect of planting methods on weevil infestation on the sweetpotato crop. More research work is required in this area to verify these results.

The results of the exploratory experiment to determine the effect of variety, insecticide, method and time of planting showed that Mwezitatu was significantly high yielding than Marooko but significantly more susceptible to weevil damage particularly in the short rains season. Therefore Marooko can be grown in the short rains season when weevil population is high because it is less susceptible. This is desirable because results of the study have also shown that if harvesting is delayed for one month , Marooko could out-yield Mwezitatu. There is limited research work on the evaluation of improved and local varieties on their susceptibility to weevil damage. Detailed and comprehensive work in this area is required especially to cover the lower Midland agro-ecological zones. Marooko performed well during the long rains and particularly when harvesting was delayed by three weeks, hence if given a longer period in the field it could outyield Mwezitatu. There is some limited work on improved varieties on yield, agronomic performance and susceptibility to weevil damage. There is need for further work which should include local varieties.

During the short rains season at Busia when there was high weevil pressure, late planted crop had significantly low incidence and severity of damage. There was also a significant variety by time of planting interaction which showed that delaying planting sweetpotato by one month after onset of rains resulted to decreased weevil infestation on both varieties being more pronounced on Mwezitatu variety. This indicates that it is good to delay planting after the onset of rains as it exposes roots to low weevil infestation.

The trial also showed that there was no significant differences when insecticide dip was applied. This indicates that insecticides may not be recommended for use for subsistence farmers as it has an additional cost.

Neither ridged nor flat seedbeds had any significant influence on weevil infestation. However ridged seedbeds appear to significantly improve the yields and number of storage roots of sweetpotatoes especially in the short rains season. Therefore ridging should be encouraged during this period.

A significant interaction between time and method of planting showed that there was significantly low severity of damaged roots when planting on ridged seedbeds was delayed after onset of rains. Similarly, low damage was recorded on crop planted at the onset of rains and on flat seedbeds. A further significant difference was observed between variety and planting method in which Mwezitatu planted on flat seedbeds had significantly lower yield of damaged roots. If farmers want to plant early they would be advised to plant on flat seedbeds. However, if they delay planting it would be beneficial to plant on ridged seedbeds as this has an advantage of increasing yields. An important question to be answered, is how long should we delay planting without sacrificing yields. There is need for further study, that would allow for optimum yield and minimum weevil infestation.

In conclusion, crop management practises such as the time of planting and correct selection of variety, depending on the agroecological zone in which sweetpotato is grown could play a major role in the management of sweetpotato weevils. Therefore there is a need to train extension workers on the various sweetpotato crop management practises important in the control and management of sweetpotato weevils. Their training should facilitate them to sensitise farmers on the harmful effects of some of the practises they persist in and to build-up on good crop management practises. The present study has been exploratory to determine the major control options which can be combined to form the basis for future comprehensive on-farm research to develop effective and economical IPM options.

References

Anonymous. 1998. *Ministry of Agriculture annual report. Western Province, 1997* Republic of Kenya.

Anonymous. 1997. *Eighth National Development Plan for 1994 -1996*. Republic of Kenya, 1997. 113-120.

Anonymous. 1993. *Ministry of Agriculture annual report. 1992* Republic of Kenya. (Nairobi: Ministry of Agriculture).

Ames, T., N. E. J. M, Smit; A. R. Braun, J. N. Sullivan, and L. Skoglund. 1997. *Sweetpotato major pests, diseases and nutritional disorders*. International Potato Center (CIP). 4-7.

Austin, D. F., R. K. Janson and G. W. Woolfe. 1991. Convolvulaceae and Cylas : a proposed hypothesis on the origins of this plant-insect relationship. *Tropical Agriculture.* 65(2):162-190.

AVDRC. 1989. *Progress report, 1989*. Asian Vegetable Research and Development. Publication (89-310). 32 - 41.

AVDRC. 1990. *Progress report, 1989*. Asian Vegetable Research and Development. Publication (90-329). 149-155.

AVDRC. 1991. *Progress report, 1980*. Asian Vegetable Research and Development. Publication (91-338): 112-118.

Bartolini, P.V. 1982. Timing and frequency of topping sweetpotato at varying levels of Nitrogen. In: Villareal R. L. and Griggs J. D. (eds.). 1982. *Sweetpotato. Proceedings of the first International Symposium* .AVDRC Publication No. 82-172. 209-214.

Brady N. C. 1990. *The nature and properties of soils*. 10 th edition. 207 -211.

Braun, A. R. and E. O. De Fleivert. 1999. Impact of sweetpotato weevil (Cylas formicarius) and the effectiveness of Cylas sex pheromones traps at farm level in Indonesia. *International Journal of Pest Management*. 45(2): 101-110

Carey, E., S. Gichuki, Onyango M, Maling'a J, and Ndolo P. 1994. Sweetpotato cultivars for processing in developing countries. *Subproject Annual Progress Report.* CIP, Nairobi, Kenya. 1-4.

CIP. 1991. CIP course. Integrated Pest Management. August 1991.

CIP, 1994. CIP in 1993. *International Potato Center annual report*. Lima, Peru. 14

CIP. 1998. CIP in 1997. *International Potato Center annual report*. Lima, Peru. 26-27.

Cockerham, K. L. and O.T., Deen. 1947. Resisitance of new sweetpotato seedlings and varieties to attack by the sweetpotato weevil. *Journal of Economic Entmology* 40(3) :439-441.

Collins W.W., E. E. Carey, I. Mok,. P. Thompson and Z. D. Peng 1999. Utilisation of sweetpotato genetic resources to develop Insect resistance. In: Clement, S. L. and S. S. Quisenberry (eds). *Global plant genetic resources for Insect-Resistant Crops. Sweetpotato weevil resistance*. CRC Press LLC. 193- 205.

Daily Nation. 1999. Market prices between January to July.

Ewell P. T. 1994. The sweetpotato in Eastern and Southern Africa, CIP's collaboration with NARS. *In sweetpotato situation and priority in West and Central Africa*. Proceedings of the workshop held at Duoala, Cameroun. July 27-29. 1992. 123-134.

Ewell P. T. 1997. International cooperation for the improvement of potato and sweetpotato in subsaharan Africa. In : *Proceedings of the fourth Triennial Congress of the African Potato Association*; Pretoria South Africa, 23-27 Feb. 1997. 157-164.

FAO. 1978. *FAO Production year book 1977*. FAO statistics series no 135. Food and Agriculture Organization of the United Nations vol. 31:

FAO. 1988. *FAO Production year book 1987*. FAO statistics series no 135. Food and Agriculture Organization of the United Nations vol. 41

FAO. 1998. *FAO Production year book 1997*. FAO statistics series no 135. Food and Agriculture Organization of the United Nations vol. 51:

Gaspasin, R. M. 1989. Studies on major diseases and insect pests of sweetpotato at VISCA, Philippines. In Mackay K.T., M. K., Palmer and R. T. Sanic (eds.). *Sweetpotato research and Development for small farmers*. 151-168.

Ghosh, S. P., T. Ramanujam, L. S. Jois, S. N. Moorthy and R. G. Nair. 1988. *Tuber Crops*. Oxford and IBI Publishing Co. PVT Ltd. New Delhi. 149 - 288.

Hahn, S. K. 1994. Root crops for food security in Africa. In (Akoroda M. O. (ed). *Proceedings of the fifth triennial Symposuim of the International Society for tropical food crops*. Africa Branch. 16-21.

Hahn S. K. and K. Leuschner. 1982. Breeding sweetpotato for weevil resistance. In: Villareal R. L. and Griggs J. D. (eds.). 1982. *Sweetpotato. Proceedings of the first International Symposium* .AVDRC Publication No. 82-172. 331-336.

Hill, D. S., 1983. *Agricultural Insect Pests of the tropics and their control*. Second edition. Cambridge University Press. 469-472.

Horton, D. 1988. *Underground crops: Long-term trends in production of roots and tubers*. Morrilton: Winrock : Winrock International. 1-14.

II-Mok G., E. E. Carey and G. J. Scot. 1994. Sweetpotato for the developing world. In Rasco Jnr. E. T. and V. dr Amante (eds). *Sweetpotato variety evaluation vol 2. Background papers and sapprad country reports*. 42-57.

Jaetzold R. and Schmidt, H. 1982. *Farm management handbook of Kenya. Vol. 11/A Western and Nyanza Provinces*. Ministry of Agriculture, Nairobi, Kenya. 397 pages.

KARI. 1990. *1990 Annual report*. Kenya Agricultural Research Institute. 180-183.

KARI. 1992. *1991 Annual report*. Kenya Agricultural Research Institute. 36-37

KARI. 1995. *KARI. 1994 Annual report/ Kenya*. In : Fungoh P. O. and J. A.

Ochieng (eds.). Kenya agricultural Research Institute. 67-68.

KARI. 1997. *KARI. 1995. Annual report/Kenya*. Kenya Agricultural Research Institute. 133-134

Kays S. J., K. E. Magnuson and Y. Fares. 1982. Assimilation patterns of C in developing sweetpotato using 11C and 14C In : Villareal R. L. and Griggs J. D. (eds.). 1982. Sweetpotato. *Proceedings of the first International Symposium* . AVDRC Publication No. 82-172. 95-118.

Magenya O. and N. E. J. M. Smit. 1991. Preliminary note on sweetpotato pests and local control practices in South western Kenya. In: Alvarez M. W. and R. Asiedu (eds.). *The role of root crops in Regional Food security and sustainable agriculture*. Proceedings of the fourth Eastern and Southern Africa. Regional workshop on root and tuber crops., Mansa, Zambia. 29 Oct. - 2nd Nov. 1990. IITA. 130 -138.

Michigan State University (1985) . MSTATC Source

Moriya, S. 1995. A preliminary study on the flight ability of the sweetpotato weevil, *Cylas formicarius (Fabricius)* (Coleoptera: Apionidae) using a flight mill. Applied Entomology Zoology. 30: 244-246.

Munga T. l. , A Abubakar and C. Carli. 1992. Effect of different growing methods on the yield of sweetpotato. Preliminaries results. In Kabira J. and P. Ewell. *Current Research for the improvement of potato and sweetpotato in Kenya*. KARI/ CIP. 86-87.

Mutuura , J. N., P. T., Ewell., A. Abubakar, T Muga, S. Ajanga, J. Irungu, F. Omari and S. Maobe. 1992. Sweetpotatoes in the food systems of Kenya: results of a socioeconomic survey. In J. N. Kabira and P. T. Ewell (eds) *Current research for the Improvement of Potatoes and sweetpotatoes in Kenya*. Proceedings of a KARI/ CIP technical workshop on colloborative research, Nairobi, November 1991 (Nairobi: CIP) : 51-66.

Ndolo, P. J. National Sweetpotato programme Co-ordinator leader from 1995 to date.

Ngunjiri M., A. Abubakar, A. O. Oketch and P. T. Ewell. 1993. *Sweetpotato in the food systems of four regions of Kenya.* A collaborative survey by the Kenya Agricultural Research Institute, the International Potato Centre and the collaborative study of cassava in Africa (COSCA/ IITA) . 14 pages.

Odindo, M. O. 1992. Future prospects for application of insect pathogens on a compact of integrated pest management in tropical root crops. In: *Biocontrol science and technology*. 2(3): 179-191.

Odongo B. and N. E. J M. Smit. 1997. The influence of planting time on infestation of sweetpotato by *Cylas spp.* (Coleoptera: Apionidae) in Uganda. In : *Proceedings of the fourth Triennial Congress of the African Potato* Association; Pretoria South Africa, 23-27 Feb. 1997: 135- 140.

Onueme, I. C. and W. B. Charles. 1994. *Tropical root and tuber crops. Production, perspectives and future prospects*. FAO 126: 127-130.

Oyunga , M. A, J. Low, V. Hagenemana, R. K. Kinyae, J. N. Kabene and S. M. Njoroge. 1997. A strategy for combating vitamin A defiency through the use of beta- carotene Rich sweetpotato Kenya: a woman centred approach. *Proceedings of the fourth Triennial Congress of the African Potato Association*; Pretoria South Africa, 23-27 Feb. 1997: 234-251.

Pillai K. S. , P. Rajamma and M. S. Palarniswami. 1993. New techniques in the control of sweetpotato weevil using synthetic sex pheromones in India. *International Journal of Pest Management*. 39: 84-89.

Pury, J. M. S. 1968. *Crop Pests of East Africa.* Oxford University Pres. 150-163.

Sherman M. and W. C., Mitchell. 1953. Control of sweetpotato insects in Hawaii. *Journal of Economic Entomology* 44(5): 652-656.

Smit, N. E. J. M., O. Magenya and G. Maisiba. 1992. Integrated Pest Management in Western Kenya. In Kabira J. and P. Ewell. *Current Research for the improvement of potato and sweetpotato in Kenya*. KARI/ CIP. 86-87.

Smit, N. E. J. M., O. Magenya and B. L. Parker. 1994. Biology and pheromone studies with sweetpotato weevils, *Cylas puncticollis* and *C. brunneus*. in

Ofori and S. K. Hahn (eds.). *Tropical root crops in a developing Economy.* Proceedings of the ninth conference of the International Society for Tropical Root crops 20-26 October. , 1991. Accra Ghana. IITA. Nigeria. 399-405

Smit , N. E. J. M. and L. O. Matengo. 1995. Farmers cultural practices and their effects on pest control in sweetpotato in South Nyanza, Kenya. *International Journal of Pest Management*. 41(1): 2-7

Smit, N. E. J. M. 1997. *Integrated Pest Management for sweetpotato in Eastern Africa*. Ph.D. Thesis. Curafisch Service Centrum Van Gilb B. V., Wagenigan.

Spence J. A. and E. C. Humphries. 1972. Effect of moisture supply, root temperature and growth regulators on photosynthesis of isolated rooted leaves of sweetpotato (*Ipomoea batatas*).*Annual Botany*. 36 : 115-121.

Steele, R.G.D. and J.H.Torrie. 1980. *Principles and procedures of statistics*. Mcgraw-Hill. New York.

Sutherland, J. A. 1986a. A review of the biology and control of sweetpotato weevil (*Cylas formicarius) (Fab.*) *Tropical Pest Management*. 32(4): 304-315.

Sutherland, J. A. 1986b. Damage by *Cylas formicarius* Fab. to sweetpotato vines and tubers and their effect on infestation on total yield in Papua New Guinea. *Tropical Pest Management*. 32 (4): 316-323.

Sutherland, J. A. 1986c. Evaluation of foliar sprays, soil treatment and vine dip for the control of sweetpotato weevil, Cylas formicarius (Fab.) *Journal of Plant Protection in the Tropics*. 3(2) :95-103.

Talekar, N. S. 1987. Influence of cultural pest management techniques on the infestation of sweetpotato weevil. *Insect Science Applications*. 8 :809-814.

Talekar, N. S. 1988. How to control sweetpotato weevil: a practical approach. *International Co-operators Guide*. AVDRC. 88-292. 6 pages.

Thomas M. and J. Waage.1996. *Integration of biological control and host resistance breeding*. CTA. 15-34.

Ngunjiri M., A. Abubakar, A. O. Oketch and P. T. Ewell. 1993. *Sweetpotato in the food systems of four regions of Kenya.* A collaborative survey by the Kenya Agricultural Research Institute, the International Potato Centre and the collaborative study of cassava in Africa (COSCA/ IITA) . 14 pages.

Odindo, M. O. 1992. Future prospects for application of insect pathogens on a compact of integrated pest management in tropical root crops. In: *Biocontrol science and technology*. 2(3): 179-191.

Odongo B. and N. E. J M. Smit. 1997. The influence of planting time on infestation of sweetpotato by *Cylas spp.* (Coleoptera: Apionidae) in Uganda. In : *Proceedings of the fourth Triennial Congress of the African Potato* Association; Pretoria South Africa, 23-27 Feb. 1997: 135- 140.

Onueme, I. C. and W. B. Charles. 1994. *Tropical root and tuber crops. Production, perspectives and future prospects*. FAO 126: 127-130.

Oyunga , M. A, J. Low, V. Hagenemana, R. K. Kinyae, J. N. Kabene and S. M. Njoroge. 1997. A strategy for combating vitamin A defiency through the use of beta- carotene Rich sweetpotato Kenya: a woman centred approach. *Proceedings of the fourth Triennial Congress of the African Potato Association*; Pretoria South Africa, 23-27 Feb. 1997: 234-251.

Pillai K. S. , P. Rajamma and M. S. Palarniswami. 1993. New techniques in the control of sweetpotato weevil using synthetic sex pheromones in India. *International Journal of Pest Management*. 39: 84-89.

Pury, J. M. S. 1968. *Crop Pests of East Africa*. Oxford University Pres. 150-163.

Sherman M. and W. C., Mitchell. 1953. Control of sweetpotato insects in Hawaii. *Journal of Economic Entomology* 44(5): 652-656.

Smit, N. E. J. M., O. Magenya and G. Maisiba. 1992. Integrated Pest Management in Western Kenya. In Kabira J. and P. Ewell. *Current Research for the improvement of potato and sweetpotato in Kenya*. KARI/ CIP. 86-87.

Smit, N. E. J. M., O. Magenya and B. L. Parker. 1994. Biology and pheromone studies with sweetpotato weevils, *Cylas puncticollis* and *C. brunneus*. in

Talekar, N. S; R. M. Lai and K. W. Chang. 1989. Integrated control of sweetpotato weevil at Penghu Island. *Plant Protection Bulletin*. 31: 185-191.

Woolfe, G. W. 1991. The origin and dispersal of pest species of *Cylas* with a key to the pest species of the world. In: R. K. Janson and K. V. Raman (eds.) *Sweetpotato pest management a global perspective*. Westminster press. 13-14.

World Bank, 1989. *World Development Indicators*. Washington, D. C. USA.

Zera, D. L., S. E. Gueras and J. T. Carlos. 1982. Performance of sweetpotato varieties grown under coconut. In: Villareal R. L. and Griggs **J.** D. (eds.). 1982. Sweetpotato. Proceedings of the first International Symposium**.** 1983. AVDRC Publication No. 82-172. 233-242.

APPENDICES

- **Appendix 1. Rainfall for the period January to November, 1998 at Malava Divisional Agricultural Office, in Kabras division, Kakamega distict.**

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	35.9	42.8	328.9	195.5	131.8	281.6	121.5	275.5	221.1	254.7	13.3	64.5

- **Appendix 2. Record of planting and harvesting period of the exploratory Integrated Pest Management trial at Kakamega and Busia .**

Season	Time of planting	Date planted	Date harvested	Days in field
Short rains season, 1998				
Kakamega	Early	11/9/98	18/2/99	159
Kakamega	Late	12/10/98	12/3/99	150
Busia	Early	12/10/98	16/3/99	154
Busia	Late	9/11/98	14/4/99	155
Long rains season, 1999				
Kakamega	Early	30/3/99	3/9/99	156
Kakamega	Late	11/5/99	14/10/99	156
Busia	Early	11/5/99	18/10/99	159
Busia	Late	24/6/99	9/12/99	167

- **Appendix 3. Rainfall and Temperarature data for the period 1998 at Kakamega Research Station , data based on Kakamega Agromet Station Reg. No 8934096**

Month	Temperature (°C)			Rainfall (mm)
	Maximum	Minimum	Average	
January	26.9	15.0	20.8	204.2
February	28.6	14.7	21.7	81.8
March	29.8	15.0	22.4	130.2
April	28.4	15.3	21.9	268.8
May	27.8	15.1	21.5	291.7
June	26.2	13.6	19.9	158.1
July	25.6	13.8	19.7	139.3
August	26.5	13.8	20.1	82.6
September	27.2	13.2	20.2	215.3
October	26.7	14.2	20.5	220.1
November	27.2	14.0	20.6	108.7
December	-	-	-	15.1

- **Appendix 4 Rainfall and Temperarature data for the period Jan to Dec., 1999 at Kakamega Research Station, data based on Kakamega Agromet Reg. No 8934096**

Month	Temperature °C			Rainfall (mm)
	Maximum	Minimum	Average	
January	-	-	-	110.2
February	-	-	-	9.3
March	27.3	14.5	20.9	264.5
April	27.3	14.5	20.9	233.2
May	26.4	13.7	20.1	170.6
June	26.3	13.4	19.8	137.4
July	25.5	13.1	19.3	93.1
August	25.9	13.4	19.7	242.3
September	26.3	13.2	19.8	174.4
October	26.0	14.7	20.4	178.2
November	-	-	-	75.9
December	27.6	13.9	20.8	68.1

Appendix 5 Mean Rainfall and Temperarature data for the period Jan to Dec at data based on taken over 10 years at Busia cotton research centre, Alupe*.

Month	**Temperature (10 yrs) °C**			**Rainfall (mm)**		
	Max^{m}	**Min^{m}**	**Mean**	**over 10 yrs**	**short rains........ 1998**	**long rains 1999**
January	29.7	15.5	22.6	70	-	61.7
February	29.3	15.9	22.6	80	-	-
March	29.0	16.4	22.7	156	-	165.8
April	27.7	16.7	22.2	278	-	300.5
May	27.3	16.4	21.9	245	-	137
June	27.0	15.6	21.3	102	-	148.1
July	26.7	15.6	21.2	84	-	31.5
August	26.7	15.4	21.0	141	-	-
September	27.3	15.5	21.4	151	143.3	-
October	27.8	16.4	22.1	182	107	-
November	27.4	16.1	21.8	172	160.9	-
December	27.9	15.7	21.8	100	0	-

- *Mean rainfall over 10 years. source .Farm management Handbook for West Kenya. Vol (11A) by Jaetzold and Schmidt (1982).

- **Appendix 6. Analysis of variance table for the effect of Sweetpotato weevil (Cylas spp) on yield of sweetpotato roots harvested during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	2.307	1.154	32.6443	0.0297
Planting time (T)	1	2.118	2.118	59.9151	0.0163
Error	2	0.071	0.035		
Variety (V)	1	33.960	33.960	45.1140	0.0000
T x V	1	0.153	0.153	0.2035	NS
Insecticide (1)	1	0.859	0.859	1.1405	NS
T x I	1	0.857	0.857	1.1386	NS
V x I	1	0.024	0.024	0.0323	NS
T x V x I	1	0.039	0.039	0.0519	NS
Planting method (M)	1	3.348	3.348	4.4476	0.0440
T x M	1	2.355	2.355	3.1286	NS
V x M	1	0.009	0.009	0.0120	NS
T x V x M	1	0.250	0.250	0.3319	NS
I x M	1	0.003	0.003	0.0042	NS
T x I x M	1	0.529	0.529	0.7022	NS
V x I x M	1	2.298	2.298	3.0531	NS
T x V x I x M	1	0.054	0.054	0.0714	NS
Error	28	21.078	0.753		
Total	47	70.312			

Coefficient of Variation:	14.00%	
Planting Time	0.0384	Number of Observations: 24
Variety S.E:	0.1771	Number of Observations: 24
Planting Method	0.1771	Number of Observations: 24
Interaction S.E*.	0.2505	Number of Observations: 12

*All interaction S.E hereafter mentioned are for two factors only: T x V, V x I, V x M, T x M, I x M, T x I respectively.

- **Appendix 7. Analysis of variance table on treatment effects on number of sweetpotato roots infested by *Cylas* weevil during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	3.003	1.501	1.4650	NS
Planting time (T)	1	0.883	0.883	0.8621	NS
Error	2	2.050	1.025		
Variety (V)	1	69.121	69.121	93.7906	0.0000
T x V	1	0.088	0.088	0.1190	NS
Insecticide (1)	1	0.001	0.001	0.0007	NS
T x I	1	0.481	0.481	0.6521	NS
V x I	1	0.012	0.012	0.0163	NS
T x V x I	1	0.608	0.608	0.8254	NS
Planting method (M)	1	2.316	2.316	3.1420	
T x M	1	2.971	2.971	4.0317	NS
V x M	1	2.732	2.732	3.7068	NS
T x V x M	1	1.006	1.006	1.3649	NS
I x M	1	0.033	0.033	0.0445	NS
T x I x M	1	0.219	0.219	0.2974	NS
V x I x M	1	0.368	0.368	0.5000	NS
T x V x I x M	1	0.799	0.799	1.0848	NS
Error	28	20.635	0.737		
Total	47	107.326			

Coefficient of Variation:	36.10%%	
Planting Time	0.2066	Number of Observations: 24
Variety S.E:	0.1752	Number of Observations: 24
Planting Method	0.1752	Number of Observations: 24
Interaction S.E.	0.2478	Number of Observations: 12

■ **Appendix 8. Analysis of variance table of treatment effects on yield of sweetpotato roots harvested during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.734	0.367	3.0903	NS
Planting time (T)	1	0.681	0.681	5.7397	NS
Error	2	0.237	0.119		
Variety (V)	1	17.137	17.137	117.5620	0.0000
T x V	1	0.083	0.083	0.5697	NS
Insecticide (1)	1	0.171	0.171	1.1749	NS
T x I	1	0.144	0.144	0.9856	NS
V x I	1	0.012	0.012	0.0821	NS
T x V x I	1	0.008	0.008	0.0524	NS
Planting method (M)	1	0.801	0.801	5.4942	0.0264
T x M	1	0.580	0.580	3.9770	NS
V x M	1	0.035	0.035	0.2400	NS
T x V x M	1	0.091	0.091	0.6225	NS
I x M	1	0.070	0.070	0.4789	NS
T x I x M	1	0.006	0.006	0.0402	NS
V x I x M	1	0.441	0.441	3.0273	NS
T x V x I x M	1	0.027	0.027	0.1862	NS
Error	28	4.082	0.146		
Total	47	25.339			

Coefficient of Variation:	13.88%	
Planting Time	0.0703	Number of Observations: 24
Variety S.E:	0.0779	Number of Observations: 24
Planting Method	0.0779	Number of Observations: 24
Interaction S.E.	0.0779	Number of Observations: 12

- **Appendix 9. Analysis of variance table of treatment effects on on yield of weevil infested sweetpotato roots during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.960	0.480	1.7079	NS
Planting time (T)	1	0.176	0.176	0.6244	NS
Error	2	0.562	0.281		
Variety (V)	1	13.335	13.335	106.7850	0.0000
T x V	1	0.178	0.178	1.4274	NS
Insecticide (1)	1	0.007	0.007	0.0551	NS
T x I	1	0.088	0.088	0.7060	NS
V x I	1	0.006	0.006	0.0510	NS
T x V x I	1	0.090	0.090	0.7214	NS
Planting method (M)	1	0.737	0.737	5.9025	0.0218
T x M	1	1.090	1.090	8.7325	0.0063
V x M	1	0.682	0.682	5.4616	0.0268
T x V x M	1	0.566	0.566	4.5339	0.0422
I x M	1	0.006	0.006	0.0513	NS
T x I x M	1	0.016	0.016	0.1302	NS
V x I x M	1	0.013	0.013	0.1018	NS
T x V x I x M	1	0.026	0.026	0.2055	NS
Error	28	3.497	0.125		
Total	47	22.036			

Coefficient of Variation:	22.45%	
Planting Time	0.1082	Number of Observations: 24
Variety S.E:	0.0721	Number of Observations: 24
Planting Method	0.0721	Number of Observations: 24
Interaction S.E.	0.1020	Number of Observations: 12

- **Appendix 10. Analysis of variance table for treatment effects on yield of inedible sweetpotato roots infested by *Cylas spp*. during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.306	0.153	3.2945	NS
Planting time (T)	1	0.018	0.018	0.3801	NS
Error	2	0.093	0.046		
Variety (V)	1	4.754	4.754	95.7650	0.0000
T x V	1	0.006	0.006	0.1153	NS
Insecticide (1)	1	0.005	0.005	0.1080	NS
T x I	1	0.082	0.082	1.6482	NS
V x I	1	0.002	0.002	0.0435	NS
T x V x I	1	0.087	0.087	1.7555	NS
Planting method (M)	1	0.189	0.189	3.8016	NS
T x M	1	0.112	0.112	2.2582	NS
V x M	1	0.208	0.208	4.1831	NS
T x V x M	1	0.064	0.064	1.2831	NS
I x M	1	0.008	0.008	0.1524	NS
T x I x M	1	0.013	0.013	0.2589	NS
V x I x M	1	0.004	0.004	0.0731	NS
T x V x I x M	1	0.015	0.015	0.3024	NS
Error	28	1.390	0.050		
Total	47	7.353			

Coefficient of Variation:	16.73%	
Planting Time	0.0440	Number of Observations: 24
Variety S.E:	0.0455	Number of Observations: 24
Planting Method	0.0455	Number of Observations: 24
Interaction S.E.	0.0643	Number of Observations: 12

- **Appendix 11. Analysis of variance table for of treatment effects on number of sweetpotato roots. during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.277	0.139	1.3453	NS
Planting time (T)	1	3.938	3.938	38.2411	0.0252
Error	2	0.206	0.103		
Variety (V)	1	21.961	21.961	19.5695	0.0001
T x V	1	0.321	0.321	0.2861	NS
Insecticide (1)	1	0.074	0.074	0.0657	NS
T x I	1	0.550	0.550	0.4905	NS
V x I	1	0.014	0.014	0.0129	NS
T x V x I	1	1.889	1.889	1.6835	NS
Planting method (M)	1	20.362	20.362	18.1448	0.0002
T x M	1	0.766	0.766	0.6825	NS
V x M	1	2.806	2.806	2.5007	NS
T x V x M	1	0.000	0.000	0.0002	NS
I x M	1	0.002	0.002	0.0018	NS
T x I x M	1	0.643	0.643	0.5733	NS
V x I x M	1	0.002	0.002	0.0019	NS
T x V x I M	1	0.789	0.789	0.7027	NS
Error	28	31.422--	1.122		
Total	47	86.023			

Coefficient of Variation:	17.36%	
Planting Time	0.0655	Number of Observations: 24
Variety S.E:	0.2162	Number of Observations: 24
Planting Method	0.2162	Number of Observations: 24
Interaction S.E.	0.3058	Number of Observations: 12

■ **Appendix 12. Analysis of variance table for treatment effects on yield of sweetpotato roots during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.396	0.198	0.6004	NS
Planting time (T)	1	2.447	2.447	7.4100	NS
Error	2	0.660	0.330		
Variety (V)	1	1.263	1.263	5.2411	0.0298
T x V	1	0.547	0.547	2.2709	NS
Insecticide (1)	1	0.049	0.049	0.2030	NS
T x I	1	0.005	0.005	0.0194	NS
V x I	1	0.001	0.001	0.0021	NS
T x V x I	1	0.399	0.399	1.6556	NS
Planting method (M)	1	1.346	1.346	5.5838	0.0253
T x M	1	0.007	0.007	0.0282	NS
V x M	1	0.216	0.216	0.8968	NS
T x V x M	1	0.211	0.211		NS
I x M	1	0.119	0.119	0.4923	NS
T x I x M	1	0.079	0.079	0.3269	NS
V x I x M	1	0.045	0.045	0.1861	NS
T x V x I x M	1	0.056	0.056	0.2317	NS
Error	28	6.748	0.241		
Total	47	14.593			

Coefficient of Variation:	20.90%	
Planting Time	0.1173	Number of Observations: 24
Variety S.E:	0.1002	Number of Observations: 24
Planting Method	0.1002	Number of Observations: 24
Interaction S.E.	0.1417	Number of Observations: 12 wt/ha

■ **Appendix 13. Analysis of variance table for treatment effects on number of sweetpotato roots infested by *Cylas weevil* during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.609	0.305	0.4243	NS
Planting time (T)	1	61.532	61.532	85.7325	0.0115
Error	2	1.435	0.718		
Variety (V)	1	53.050	53.050	46.5906	0.0000
T x V	1	4.856	4.856	4.2645	0.0483
Insecticide (1)	1	0.189	0.189	0.1657	NS
T x I	1	0.029	0.029	0.0257	NS
V x I	1	0.050	0.050	0.0436	NS
T x V x I	1	0.017	0.017	0.0148	NS
Planting method (M)	1	2.489	2.489	2.1856	NS
T x M	1	0.828	0.828	0.7269	NS
V x M	1	2.250	2.250	1.9758	NS
T x V x M	1	0.303	0.303	0.2661	NS
I x M	1	0.050	0.050	0.0436	NS
T x I x M	1	0.509	0.509	0.4473	NS
V x I x M	1	0.714	0.714	0.6274	NS
ABCD	1	0.178	0.178	0.1560	NS
Error	28	31.882	1.139		
Total	47	160.969			

Coefficient of Variation:	34.56%	
Planting Time	0.1729	Number of Observations: 24
Variety S.E:	0.2178	Number of Observations: 24
Planting Method	0.2178	Number of Observations: 24
Interaction S.E.	0.3080	Number of Observations: 12

■ **Appendix 14. Analysis of variance table for treatment effects on weight of sweetpotato roots infested by *Cylas weevil* during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.120	0.060	0.8319	NS
Planting time (T)	1	7.626	7.626	105.6538	0.0093
Error	2	0.144	0.072		
Variety (V)	1	3.307	3.307	31.5629	0.0000
T x V	1	1.043	1.043	9.9588	0.0038
Insecticide (1)	1	0.000	0.000	0.0000	NS
T x I	1	0.015	0.015	0.1399	NS
V x I	1	0.006	0.006	0.0549	NS
T x V x I	1	0.004	0.004	0.0374	NS
Planting method (M)	1	0.133	0.133	1.2688	NS
T x M	1	0.000	0.000	0.0047	NS
V x M	1	0.124	0.124	1.1839	NS
T x V x M	1	0.046	0.046	0.4387	NS
I x M	1	0.075	0.075	0.7159	NS
T x I x M	1	0.157	0.157	1.4938	NS
V x I x M	1	0.005	0.005	0.0470	NS
T x V x I x M	1	0.007	0.007	0.0629	NS
Error	28				
Total	47	7.353			

Coefficient of Variation:	20.98%	
Planting Time	0.0548	Number of Observations: 24
Variety S.E:	0.0661	Number of Observations: 24
Planting Method	0.0661	Number of Observations: 24
Interaction S.E.	0.0934	Number of Observations: 12

■ **Appendix 15. Analysis of variance table for treatment effects on the weight inedible roots damaged by *Cylas* weevil the during the short rains season at Busia, 1998.**

Source of variation	DF	S. S.	M.S.S	F value.	Probability
Replicates	2	0.029	0.015	2.9610	NS
Planting time (T)	1	2.309	2.309	468.1375	0.0021
Error	2	0.010	0.005		
Variety (V)	1	1.372	1.372	20.5602	0.0001
T x V	1	0.568	0.568	8.5097	0.0069
Insecticide (1)	1	0.000	0.000	0.0006	NS
T x I	1	0.009	0.009	0.1302	NS
V x I	1	0.002	0.002	0.0298	NS
T x V x I	1	0.003	0.003	0.0410	NS
Planting method (M)	1	0.003	0.003	0.0453	NS
T x M	1	0.064	0.064	0.9632	NS
V x M	1	0.006	0.006	0.0907	NS
T x V x M	1	0.000	0.000	0.0031	NS
I x M	1	0.068	0.068	1.0160	NS
T x I x M	1	0.102	0.102	1.5250	NS
V x I M	1	0.000	0.000	0.0036	NS
T x V x I x M	1	0.000	0.000	0.0047	NS
Error	28	1.868	0.067		
Total	47	6.413			

Coefficient of Variation: 19.95%%

Planting Time 0.0143 Number of Observations: 24

Variety S.E: 0.0527 Number of Observations: 24

Planting Method 0.0527 Number of Observations: 24

Interaction S. E. 0.0746 Number of Observations: 12

■ **Appendix 16. Analysis of variance table for on the total number of sweetpotato roots harvested during the long rains season, 1999 at Kakamega.**

Source of variation	D>F	S. S.	M.S.S	F value.	Probability
Replicates	2	2.198	1.099	10.3442	NS
Planting time (T)	1	0.023	0.023	0.2163	NS
Error	2	0.212	0.106		
Variety (V)	1	32.178	32.178	9.9517	0.0038
T x V	1	36.047	36.047	11.1485	0.0024
Insecticide (1)	1	0.048	0.048	0.0150	NS
T x I	1	0.965	0.965	0.2985	NS
V x I	1	2.308	2.308	0.7137	NS
T x V x I	1	3.189	3.189	0.9863	NS
Planting method (M)	1	0.912	0.912	0.2821	NS
T x M	1	19.361	19.361	5.9877	0.0209
V x M	1	0.114	0.114	0.0353	NS
T x V x M	1	0.256	0.256	0.0793	NS
I x M	1	0.150	0.150	0.0465	NS
T x I x M	1	0.280	0.280	0.0866	NS
V x I M	1	1.577	1.577	0.4878	NS
T x V x I x M	1	1.096	1.096	0.3390	NS
Error	28	90.535	3.233		
Total	47	191.450			

Coefficient of Variation:	35.1%	
Planting Time	0.0665	Number of Observations: 24
Variety S.E:	0.3670	Number of Observations: 24
Planting Method	0.3670	Number of Observations: 24
Interaction S.E.	0.5191	Number of Observations: 12

Appendix 17. Analysis of variance table for treatment effects on number of sweetpotato roots infested by *Cylas spp.* during the long rains season at Kakamega, 1999.

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.348	0.174	0.7651	NS
Planting time (T)	1	1.172	1.172	5.1583	NS
Error	2	0.454	0.227		
Variety (V)	1	2.366	2.366	15.0391	0.0006
T x V	1	1.473	1.473	9.3617	0.0048
Insecticide (1)	1	0.096	0.096	0.6097	NS
T x I	1	0.041	0.041	0.2617	NS
V x I	1	0.194	0.194	1.2352	NS
T x V x I	1	0.050	0.050	0.3162	NS
Planting method (M)	1	0.096	0.096	0.6097	NS
T x M	1	0.000	0.000	0.0014	NS
V x M	1	0.194	0.194	1.2352	NS
T x V x M	1	0.194	0.194	1.2352	NS
I x M	1	0.009	0.009	0.0562	NS
T x I x M	1	0.574	0.574	3.6510	NS
V x I x M	1	0.270	0.270	1.7185	NS
T x V x I x M	1	0.001	0.001	0.0088	NS
Error	28	4.405	0.157		
Total	47	11.938			

Coefficient of Variation:	28.98%	
Planting Time	0.0973	Number of Observations: 24
Variety S.E:	0.0810	Number of Observations: 24
Planting Method	0.0810	Number of Observations: 24
Interaction S.E.	0.1145	Number of Observations: 12

Appendix 18. Analysis of variance table for treatment effects on yields of sweetpotato roots during the long rains season at Kakamega, 1999.

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.002	0.001	0.0246	NS
Planting time (T)	1	0.002	0.002	0.0577	NS
Error	2	0.074	0.037		
Variety (V)	1	4.685	4.685	5.2827	0.0292
T x V	1	9.105	9.105	10.2653	0.0034
Insecticide (1)	1	0.036	0.036	0.0408	NS
T x I	1	0.232	0.232	0.2614	NS
V x I	1	0.263	0.263	0.2969	NS
T x V x I	1	1.076	1.076	1.2129	NS
Planting method (M)	1	0.135	0.135	0.1522	NS
T x M	1	6.149	6.149	6.9325	0.0136
V x M	1	0.317	0.317	0.3569	NS
T x V x M	1	0.212	0.212	0.2386	NS
I x M	1	0.051	0.051	0.0577	NS
T x I x M	1	0.100	0.100	0.1125	NS
V x I x M	1	0.563	0.563	0.6350	NS
T x V x I x M	1	0.479	0.479	0.5401	NS
Error	28	24.834	0.887		
Total	47	48.315			

Coefficient of Variation:	38.62%	
Planting Time	0.0393	Number of Observations: 24
Variety S.E:	0.1922	Number of Observations: 24
Planting Method	0.1922	Number of Observations: 24
Interaction S.E.	0.2719	Number of Observations: 12

Appendix 19 Analysis of variance table for treatment effects on yield of sweetpotato roots infested by *Cylas spp.* during the long rains season at Kakamega, 1999.

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.147	0.073	8.0546	NS
Planting time (T)	1	0.198	0.198	21.7087	0.0431
Error	2	0.018	0.009		
Variety (V)	1	0.581	0.581	10.6777	0.0029
T x V	1	0.227	0.227	4.1681	NS
Insecticide (1)	1	0.000	0.000	0.0002	NS
T x I	1	0.001	0.001	0.0152	NS
V x I	1	0.001	0.001	0.0147	NS
T x V x I	1	0.078	0.078	1.4365	NS
Planting method (M)	1	0.013	0.013	0.2314	NS
T x M	1	0.020	0.020	0.3683	NS
V x M	1	0.031	0.031	0.5701	NS
T x V x M	1	0.174	0.174	3.2057	NS
I x M	1	0.013	0.013	0.2475	NS
T x I x M	1	0.025	0.025	0.4683	NS
V x I x M	1	0.026	0.026	0.4707	NS
T x V x I x M	1	0.002	0.002	0.0354	NS
Error	28	1.523	0.054		
Total	47	3.077			

Coefficient of Variation:	19.86%	
Planting Time	0.0195	Number of Observations: 24
Variety S.E:	0.0476	Number of Observations: 24
Planting Method	0.0476	Number of Observations: 24
Interaction S.E.	0.0673	Number of Observations: 12

- **Appendix 20. .Analysis of variance table for treatment effects on the yield of inedible roots grown in the long rains season at Kakamega.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.009	0.004	0.3081	NS
Planting time (T)	1	0.068	0.068	4.7984	NS
Error	2	0.028	0.014		
Variety (V)	1	0.025	0.025	1.6646	**
T x V	1	0.007	0.007	0.4903	NS
Insecticide (1)	1	0.010	0.010	0.6381	NS
T x I	1	0.001	0.001	0.0436	NS
V x I	1	0.032	0.032	2.1055	NS
T x V x I	1	0.011	0.011	0.7415	NS
Planting method (M)	1	0.033	0.033	2.2133	NS
T x M	1	0.012	0.012	0.8060	NS
V x M	1	0.069	0.069	4.5793	0.041
T x V x M	1	0.036	0.036	2.4025	NS
I x M	1	0.041	0.041	2.7177	NS
T x I x M	1	0.017	0.017	1.1207	NS
V x I M	1	0.001	0.001	0.0502	NS
T x V x I x M	1	0.002	0.002	0.1338	NS
Error	28	0.421	0.015		
Total	47	0.823			

Coefficient of Variation:	11.70%	
Planting Time S.E.	0.0243	Number of Observations: 24
Variety S.E:	0.0250	Number of Observations: 24
Planting Method	0.0250	Number of Observations: 24
Interaction S. E.	0.0354	Number of Observations: 12

- **Appendix 21. Analysis of variance table for treatment effects on total number of sweetpotato roots harvested during the long rains season at Busia, 1999.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	17.581	8.790	1.4729	NS
Planting time (T)	1	2.513	2.513	0.4211	NS
Error	2	11.936	5.968		
Variety (V)	1	0.162	0.162	0.1077	NS
T x V	1	0.621	0.621	0.4134	NS
Insecticide (1)	1	0.056	0.056	0.0375	NS
T x I	1	1.269	1.269	0.8442	NS
V x I	1	0.714	0.714	0.4753	NS
T x V x I	1	0.028	0.028	0.0185	NS
Planting method (M)	1	1.358	1.358	0.9035	NS
T x M	1	0.000	0.000	0.0000	NS
V x M	1	0.158	0.158	0.1049	NS
T x V x M	1	1.628	1.628	1.0834	NS
I x M	1	1.798	1.798	1.1963	NS
T x I x M	1	0.575	0.575	0.3826	NS
V x I x M	1	0.445	0.445	0.2960	NS
T x V x I x M	1	1.399	1.399	0.9306	NS
Error	28	42.080	1.503		
Total	47	84.321			

Coefficient of Variation:	20.14%	
Planting Time	0.4987	Number of Observations: 24
Variety S.E:	0.2502	Number of Observations: 24
Planting Method	0.2502	Number of Observations: 24
Interaction S.E.	0.3539	Number of Observations: 12

- **Appendix 22. Analysis of variance table for treatment effects on number of sweetpotato roots infested during the long rains season at Busia, 1999.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.479	0.239	0.7357	NS
Planting time (T)	1	0.467	0.467	1.4361	NS
Error	2	0.650	0.325		
Variety (V)	1	0.587	0.587	2.1704	NS
T x V	1	0.396	0.396	1.4653	NS
Insecticide (1)	1	0.420	0.420	1.5550	NS
T x I	1	0.262	0.262	0.9687	NS
V x I	1	0.791	0.791	2.9246	NS
T x V x I	1	0.875	0.875	3.2354	NS
Planting method (M)	1	0.932	0.932	3.4474	NS
T x M	1	0.687	0.687	2.5407	NS
V x M	1	2.955	2.955	10.9277	0.0026
T x V x M	1	0.011	0.011	0.0413	NS
I x M	1	1.914	1.914	7.0788	0.0128
T x I x M	1	0.195	0.195	0.7195	NS
V x I x M	1	0.024	0.024	0.0879	NS
T x V x I x M	1	0.000	0.000	0.0011	NS
Error	28	7.571	0.270		
Total	47	19.215			

Coefficient of Variation:	38.18%	
Planting Time	0.1164	Number of Observations: 24
Variety S.E:	0.1061	Number of Observations: 24
Planting Method	0.1061	Number of Observations: 24
Interaction S.E.	0.1501	Number of Observations: 12

- **Appendix 23. Analysis of variance table for treatment effects on yield of sweetpotato roots harvested during the long rains season at Busia, 1999.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	1.953	0.976	0.5911	NS
Planting time (T)	1	14.382	14.382	8.7062	NS
Error	2	3.304	1.652		
Variety (V)	1	0.997	0.997	2.7263	NS
T x V	1	0.046	0.046	0.1270	NS
Insecticide (1)	1	0.159	0.159	0.4349	NS
T x I	1	0.057	0.057	0.1552	NS
V x I	1	0.573	0.573	1.5658	NS
T x V x I	1	0.131	0.131	0.3587	NS
Planting method (M)	1	0.135	0.135	0.3696	NS
T x M	1	0.004	0.004	0.0115	NS
V x M	1	0.463	0.463	1.2647	NS
T x V x M	1	0.258	0.258	0.7042	NS
I x M	1	0.000	0.000	0.0000	NS
T x I x M	1	0.023	0.023	0.0627	NS
V x I x M	1	0.000	0.000	0.0002	NS
TxVxIxM	1	0.005	0.005	0.0138	NS
Error	28	10.243	0.366		
Total	47	32.733			

Coefficient of Variation:	21.81%	
Planting Time	0.2624	Number of Observations: 24
Variety S.E:	0.1235	Number of Observations: 24
Planting Method	0.1235	Number of Observations: 24
Interaction S.E.	0.1746	Number of Observations: 12

- **Appendix 24. Analysis of variance table for treatment effects on yield of sweetpotato roots infested during the long rains season at Busia, 1999.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.137	0.068	1.0826	NS
Planting time (T)	1	0.000	0.000	0.0067	NS
Error	2	0.126	0.063		
Variety (V)	1	0.011	0.011	0.1704	NS
T x V	1	0.009	0.009	0.1362	NS
Insecticide (1)	1	0.072	0.072	1.1023	NS
T x I	1	0.066	0.066	1.0124	NS
V x I	1	0.142	0.142	2.1881	NS
T x V x I	1	0.204	0.204	3.1376	NS
Planting method (M)	1	0.022	0.022	0.3344	NS
T x M	1	0.019	0.019	0.2857	NS
V x M	1	0.278	0.278	4.2702	0.0481
T x V x M	1	0.091	0. 091	1.4021	NS
I x M	1	0.207	0.207	3.1878	NS
T x I x M	1	0.140	0.140	2.1465	NS
V x I x M	1	0.000	0.000	0.0055	NS
T x V x Ix M	1	0.001	0.001	0.0139	NS
Error	28	1.820	0.065		
Total	47	3.344			

Coefficient of Variation:	22.71%	
Planting Time	0.0513	Number of Observations: 24
Variety S.E:	0.0520	Number of Observations: 24
Planting Method	0.0520	Number of Observations: 24
Interaction S.E.	0.0736	Number of Observations: 12

- **Appendix 25. Analysis of variance table for treatment effects on yield of inedible sweetpotato roots infested during the long rains season at Busia, 1999.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.000	0.000	0.0471	NS
Planting time (T)	1	0.003	0.003	1.1737	NS
Error	2	0.005	0.002		
Variety (V)	1	0.000	0.000	0.0858	NS
T x V	1	0.000	0.000	0.1051	NS
Insecticide (1)	1	0.001	0.001	0.6053	NS
T x I	1	0.003	0.003	1.9462	NS
V x I	1	0.001	0.001	0.4847	NS
T x V x I	1	0.005	0.005	2.6455	NS
Planting method (M)	1	0.002	0.002	1.3557	NS
T x M	1	0.006	0.006	3.1733	NS
V x M	1	0.004	0.004	2.3055	NS
T x V x M	1	0.001	0.001	0.6470	NS
I x M	1	0.009	0.009	5.4261	0.0273
T x I x M	1	0.000	0.000	0.0000	NS
V x I x M	1	0.002	0.002	1.2434	NS
T x V x I x M	1	0.000	0.000	0.2480	NS
Error	28	0.049	0.002		
Total	47	0.092			

Coefficient of Variation:	4.09%	
Planting Time	0.0100	Number of Observations: 24
Variety S.E:	0.0085	Number of Observations: 24
Planting Method	0.0085	Number of Observations: 24
Interaction S.E.	0.0121	Number of Observations: 12

■ **Appendix 26. Analysis of variance table for treatment effects on external crown damage of sweetpotato roots infested during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	2.985	1.492	3.8025	NS
Planting time (T)	1	0.750	0.750	1.9108	NS
Error	2	0.785	0.392		
Variety (V)	1	0.653	0.653	1.8918	NS
T x V	1	0.480	0.480	1.3899	NS
Insecticide (1)	1	0.403	0.403	1.1679	NS
T x I	1	0.030	0.030	0.0869	NS
V x I	1	0.013	0.013	0.0386	NS
T x V x I	1	0.120	.120	00.3475	NS
Planting method (M)	1	0.083	0.083	0.2413	NS
T x M	1	0.403	0.403	1.1679	NS
V x M	1	0.653	0.653	1.8918	NS
T x V x M	1	0.120	0.120	0.3475	NS
I x M	1	1.203	1.203	3.4843	NS
T x I x M	1	0.403	0.403	1.1679	NS
V x I x M	1	0.120	0.120	0.3475	NS
T x V x I x M	1	0.213	0.213	0.6177	NS
Error	28				
Total	47	19.090			

Coefficient of Variation:	30.53%%	
Planting Time	0.1279	Number of Observations: 24
Variety S.E:	0.1200	Number of Observations: 24
Planting Method	0.1200	Number of Observations: 24
Interaction S.E.	0.1696	Number of Observations: 12

- **Appendix 27. Analysis of variance table for treatment effects on internal crown damage of sweetpotato roots infested during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	4.922	2.461	7.4383	NS
Planting time (T)	1	0.563	0.563	1.7028	NS
Error	2	0.662	0.331		
Variety (V)	1	0.053	0.053	0.1347	NS
T x V	1	0.030	0.030	0.0758	NS
Insecticide (1)	1	0.053	0.053	0.1347	NS
T x I	1	0.083	0.083	0.2105	NS
V x I	1	0.013	0.013	0.0337	NS
T x V x I	1	0.270	0.270	0.6821	NS
Planting method (M)	1	0.163	0.163	0.4126	NS
T x M	1	0.000	0.000	0.0000	NS
V x M	1	0.403	0.403	1.0189	NS
T x V x M	1	0.480	0.480	1.2126	NS
I x M	1	1.470	1.470	3.7137	NS
T x I x M	1	0.120	0.120	0.3032	NS
V x I x M	1	1.203	1.203	3.0400	NS
T x V x I x M	1	0.853	0.853	2.1558	NS
Error	28	11.083	0.396		
Total	47	22.427			

Coefficient of Variation:	30.94%	
Planting Time	0.1174	Number of Observations: 24
Variety S.E:	0.1284	Number of Observations: 24
Planting Method	0.1284	Number of Observations: 24
Interaction S.E.	0.1816	Number of Observations: 12

- **Appendix 28. Analysis of variance table for treatment effects on external root damage of sweetpotato roots infested during the short rains season at Kakmaega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.512	0.256	0.6055	NS
Planting time (T)	1	1.920	1.920	4.5444	NS
Error	2	0.845	0.422		
Variety (V)	1	11.603	11.603	38.9094	0.0000
T x V	1	0.163	0.163	0.5477	NS
Insecticide (1)	1	0.013	0.013	0.0447	NS
T x I	1	0.653	0.653	2.1908	NS
V x I	1	0.963	0.963	3.2303	NS
T x V x I	1	0.003	0.003	0.0112	NS
Planting method (M)	1	0.480	0.480	1.6096	NS
T x M	1	0.213	0.213	0.7154	NS
V x M	1	0.030	0.030	0.1006	NS
T x V x M	1	0.270	0.270	0.9054	NS
I x M	1	0.120	0.120	0.4024	NS
T x I x M	1	0.053	0.053	0.1788	NS
V x I x M	1	0.163	0.163	0.5477	NS
T x V x I x M	1	0.030	0.030	0.1006	NS
Error	28	8.350	0.298		
Total	47	26.387			

Coefficient of Variation:	30.06%	
Planting Time	0.1327	Number of Observations: 24
Variety S.E:	0.1115	Number of Observations: 24
Planting Method	0.1115	Number of Observations: 24
Interaction S.E.	0.1576	Number of Observations: 12

- **Appendix 29. Analysis of variance table for treatment effects on internal root damage of sweetpotato roots infested during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.412	0.206	1.4615	NS
Planting time (T)	1	1.141	1.141	8.1006	NS
Error	2	0.282	0.141		
Variety (V)	1	4.441	4.441	34.2858	0.0000
T x V	1	0.141	0.141	1.0873	NS
Insecticide (1)	1	0.021	0.021	0.1608	NS
T x I	1	0.188	0.188	1.4476	NS
V x I	1	0.241	0.241	1.8594	NS
T x V x I	1	0.041	0.041	0.3153	NS
Planting method (M)	1	0.521	0.521	4.0211	NS
T x M	1	0.068	0.068	0.5211	NS
V x M	1	0.041	0.041	0.3153	NS
T x V x M	1	0.101	0.101	0.7785	NS
I x M	1	0.141	0.141	1.0873	NS
T x I x M	1	0.067	0.067	0.5211	NS
V x I x M	1	0.301	0.301	2.3226	NS
T x V x I x M	1	0.008	0.008	0.0579	NS
Error	28	3.627	0.130		
Total	47	11.779			

Coefficient of Variation:	22.79%	
Planting Time	0.0766	Number of Observations: 24
Variety S.E:	0.0735	Number of Observations: 24
Planting Method	0.0735	Number of Observations: 24
Interaction S.E.	0.1039	Number of Observations: 12

■ **Appendix 30. Analysis of variance table for treatment effects on density of weevils in 5 crowns of sweetpotato during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.682	0.341	24.4095	0.0394
Planting time (T)	1	0.025	0.025	1.7711	NS
Error	2	0.028	0.014		
Variety (V)	1	0.000	0.000	0.0000	NS
T x V	1	0.133	0.133	0.9549	NS
Insecticide (1)	1	0.011	0.011	0.0771	NS
T x I	1	0.307	0.307	2.2072	NS
V x I	1	0.277	0.277	1.9911	NS
T x V x I	1	0.120	0.120	0.8654	NS
Planting method (M)	1	0.099	0.099	0.7130	NS
T x M	1	0.018	0.018	0.1322	NS
V x M	1	0.099	0.099	0.7130	NS
T x V x M	1	0.018	0.018	0.1322	NS
I x M	1	0.033	0.033	0.2353	NS
T x I x M	1	0.034	0.034	0.2464	NS
V x I x M	1	0.157	0.157	1.1302	NS
T x V x I x M	1	0.154	0.154	1.1063	NS
Error	28	3.894	0.139		
Total	47	6.089			

Coefficient of Variation:	29.08%	
Planting Time	0.0241	Number of Observations: 24
Variety S.E:	0.0761	Number of Observations: 24
Planting Method	0.0761	Number of Observations: 24
Interaction S.E.	0.1077	Number of Observations: 12

- **Appendix 31. Analysis of variance table for treatment effects on density of 5 sweetpotato roots infested during the short rains season at Kakamega, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	13.635	6.817	1.6225	NS
Planting time (T)	1	1.259	1.259	0.2997	NS
Error	2	8.404	4.202		
Variety (V)	1	53.403	53.403	10.9705	0.0026
T x V	1	7.189	7.189	1.4769	NS
Insecticide (1)	1	0.039	0.039	0.0081	NS
T x I	1	0.252	0.252	0.0518	NS
V x I	1	1.781	1.781	0.3659	NS
T x V x I	1	3.526	3.526	0.7243	NS
Planting method (M)	1	11.615	11.615	2.3859	NS
T x M	1	16.266	16.266	3.3415	NS
V x M	1	20.651	20.651	4.2423	NS
T x V x M	1	7.063	7.063	1.4509	NS
I x M	1	6.651	6.651	1.3664	NS
T x I x M	1	1.564	1.564	0.3213	NS
V x I x M	1	0.610	0.610	0.1253	NS
T x V x I x M	1	0.095	0.095	0.0195	NS
Error	28	136.302	4.868		
Total	47	290.307			

Coefficient of Variation:	95.33%	
Planting Time	0.4184	Number of Observations: 24
Variety S.E:	0.4504	Number of Observations: 24
Planting Method	0.4504	Number of Observations: 24
Interaction S.E.	0.6369	Number of Observations: 12

■ **Appendix 32. Analysis of variance table for treatment effects on external crown damage of sweetpotato infested during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.073	0.036	0.3684	NS
Planting time (T)	1	0.005	0.005	0.0526	NS
Error	2	0.198	0.099		
Variety (V)	1	2.755	2.755	13.4655	0.0010
T x V	1	0.005	0.005	0.0255	NS
Insecticide (1)	1	0.422	0.422	2.0618	NS
T x I	1	0.630	0.630	3.0800	NS
V x I	1	0.130	0.130	0.6364	NS
T x V x I	1	0.255	0.255	1.2473	NS
Planting method (M)	1	0.880	0.880	4.3018	0.0474
T x M	1	0.047	0.047	0.2291	NS
V x M	1	0.047	0.047	0.2291	NS
T x V x M	1	0.047	0.047	0.2291	NS
I x M	1	0.630	0.630	3.0800	NS
T x I x M	1	0.005	0.005	0.0255	NS
V x I x M	1	0.255	0.255	1.2473	NS
T x V x I x M	1	0.130	0.130	0.6364	NS
Error	28	5.729	0.205		
Total	47	12.245			

Coefficient of Variation:	15.13%	
Planting Time	0.0642	Number of Observations: 24
Variety S.E:	0.0923	Number of Observations: 24
Planting Method	0.0923	Number of Observations: 24
Interaction S.E.	0.1306	Number of Observations: 12

■ **Appendix 33. Analysis of variance table for treatment effects on internal crown damage of sweetpotato infested during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	0.167	0.083	4.0000	NS
Planting time (T)	1	1.880	1.880	90.2500	0.0109
Error	2	0.042	0.021		
Variety (V)	1	6.380	6.380	32.7290	0.0000
T x V	1	0.255	0.255	1.3092	NS
Insecticide (1)	1	0.630	0.630	3.2328	NS
T x I	1	0.255	0.255	1.3092	NS
V x I	1	0.047	0.047	0.2405	NS
T x V x I	1	0.255	0.255	1.3092	NS
Planting method (M)	1	0.422	0.422	2.1641	
T x M	1	0.255	0.255	1.3092	NS
V x M	1	0.005	0.005	0.0267	NS
T x V x M	1	0.005	0.005	0.0267	NS
I x M	1	0.130	0.130	0.6679	NS
T x I x M	1	0.130	0.130	0.6679	NS
V x I x M	1	0.005	0.005	0.0267	NS
T x V x I x M	1	0.422	0.422	2.1641	NS
Error	28	5.458	0.195		
Total	47	16.745			

Coefficient of Variation:	14.77%	
Planting Time	0.0295	Number of Observations: 24
Variety S.E:	0.0901	Number of Observations: 24
Planting Method	0.0901	Number of Observations: 24
Interaction S.E.	0.1275	Number of Observations: 12

- **Appendix 34. Analysis of variance table for treatment effects on weevil density in crowns of sweetpotato infested during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	2.394	1.197	0.7254	NS
Planting time (T)	1	17.052	17.052	10.3316	NS
Error	2	3.301	1.651		
Variety (V)	1	7.243	7.243	5.5159	0.0261
T x V	1	1.739	1.739	1.3246	NS
Insecticide (1)	1	0.534	0.534	0.4068	NS
T x I	1	0.977	0.977	0.7442	NS
V x I	1	0.154	0.154	0.1170	NS
T x V x I	1	0.566	0.566	0.4311	NS
Planting method (M)	1	0.403	0.403	0.3066	
T x M	1	0.571	0.571	0.4351	NS
V x M	1	2.356	2.356	1.7943	NS
T x V x M	1	4.576	4.576	3.4852	NS
I x M	1	0.194	0.194	0.1477	NS
T x I x M	1	0.641	0.641	0.4878	NS
V x I x M	1	0.160	0.160	0.1215	NS
T x V x I x M	1	2.013	2.013	1.5328	NS
Error	28	36.767	1.313		
Total	47	81.642			

Coefficient of Variation:	44.71%	
Planting Time	0.2622	Number of Observations: 24
Variety S.E:	0.2339	Number of Observations: 24
Planting Method	0.2339	Number of Observations: 24
Interaction S.E.	0.3308	Number of Observations: 12

■ **Appendix 35. Analysis of variance table for treatment effects on weevil density of roots of sweetpotato infested during the short rains season at Busia, 1998.**

Source of variation	D.F	S. S.	M.S.S	F value.	Probability
Replicates	2	5.949	2.975	0.7076	NS
Planting time (T)	1	296.374	296.374	70.4960	0.0139
Error	2	8.408	4.204		
Variety (V)	1	23.615	23.615	10.0533	0.0037
T x V	1	6.944	6.944	2.9561	NS
Insecticide (1)	1	3.206	3.206	1.3649	NS
T x I	1	0.267	0.267	0.1135	NS
V x I	1	0.191	0.191	0.0815	NS
T x V x I	1	1.662	1.662	0.7075	NS
Planting method (M)	1	5.159	5.159	2.1961	
T x M	1	0.141	0.141	0.0601	NS
V x M	1	3.180	3.180	1.3538	NS
T x V x M	1	0.195	0.195	0.0829	NS
I x M	1	13.227	13.227	5.6309	0.0247
T x I x M	1	5.582	5.582	2.3763	NS
V x I x M	1	0.104	0.104	0.0444	NS
T x V x I x M	1	0.280	0.280	0.1190	NS
Error	28	65.771	2.349		
Total	47	440.254			

Coefficient of Variation:	39.63%	
Planting Time	0.4185	Number of Observations: 24
Variety S.E:	0.3128	Number of Observations: 24
Planting Method	0.3128	Number of Observations: 24
Interaction S.E.	0.4424	Number of Observations: 12