EFFECT OF SEQUENTIAL PLANTING ON OCCURRENCE AND POPULATION DYNAMICS OF SWEET POTATO WEEVILS ON SELECTED VARIETIES IN CENTRAL TANZANIA

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EXTENDED ABSTRACT

The sweetpotato (*Ipomoea batatas* L.) is one of the most important food crops in Africa and the world that is in Tanzania produced in largest quantities in the central Regions where, however, yields are very low due to abiotic and biotic constraints. One of the most serious biotic constraints is the sweet potato weevil, an insect whose cryptic feeding nature of the very destructive larval stages makes chemical control often not effective. A survey was conducted in two Districts of central Tanzania (Ikungi – Singida and Gairo - Morogoro) to map the sweet potato weevil distribution and damage incidences. Ten villages in each District were randomly selected whereby three farmers in each village were interviewed and their fields intensively assessed for weevil infestation. Results showed varying distribution of weevils with locations (villages) surveyed. Gairo District was having more weevil infestation and damage incidences than Ikungi District. Due to the nature of damage in both vines and roots it was concluded that the species available in the area is *Cylas spp.* Further study was conducted to establish variety response to the weevil infestation at different times of planting. Four sweetpotato varieties were tested for weevil infestation in three timings of planting (December, January and March). Again, adult weevils were captured in traps throughout the growing season. Significant differences in percentage weevil infestation and yield amongst various planting periods was observed ($P \leq 0.05$) with the least infestation registered in December while the highest infestation was realized in March planting. Simama variety was most susceptible to weevil infestation followed by Polista and Mataya while Gudugudu was least susceptible. Despite its susceptibility, however, Simama yielded the highest. The weevil capture experiment suggested existence of only one species in central Tanzania, whose distribution was uneven among the two Districts. This species was *Cylas puncticollis*. Trends of population build up in the study locations indicated that adult weevils increased progressively along the growing season. The study concluded that *Cylas puncticollis* will remain a problem in sweetpotatoes in central Tanzania. Concerted efforts in form of IPM and education to farmers are required to minimize the pest’s damaging effects.

DECLATION

I, Lucas Peter Mkuki do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor concurrently being submitted for degree award in any other Institution.

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The above declaration is confirmed by;

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Prof. Dunstan G. Msuya	Date
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DEDICATION

This work is dedicated to my beloved mother the late Rosemary Kihendo, whose unfailing love and care she gave me has created the foundation for my education, May her soul rest in peace. Also it is dedicated to my dear wife Beatrice John Epiphan, as well as my children Joyce, Jackline, James, Rosemary, Gregory, Francis and Joshua who were hand in hand with me all the time encouraging and supporting me in every aspect until the completion of my work. May our almighty God each one of bless each one of them abundantly.

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LIST OF ABBREVIATIONS

°C	Degree centigrade
ANOVA	Analysis Of Variance
CARDI	Agricultural Research and Development Institute
CIP	International Potato Center
CV	Coefficient of Variation
DAP	Days After Planting
Df	Degree of freedom
DNMRT	Duncan’s New Multiple Range Test
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
GIS	Geographical information system
HSD	Honest Significant Difference
IMF	International Monetary Fund
masl	Meter above sea level
mm	Millimetre
ns	no significant
P	Probability
RAC	Reaching Agency for Change
RCBD	Randomized Complete Block Design
SE	Standard error of mean
Spp	species
SPSS	Statistical Package for the Social Science
SPW	Sweet Potato Weevil
SSA	Sub-Saharan Africa

SUA	Sokoine University of Agriculture
TACTRI	Taiwan Agricultural Chemicals and Toxic Substances Research Institute council of agriculture
tha^{-1}	Tonnes per hectare
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 Background Information

Sweetpotato (*Ipomoea batatas* (L.) Lam. (family: Convolvulaceae) is herbaceous perennial plant grown as an annual crop. It is widely cultivated in many parts of the world and ranks seventh among most important food crops after wheat, rice, maize, Irish potato, barley, and cassava (Kyamanywa *et al.,* 2011). Some orange fleshed varieties have high content of β-carotene that can be converted by the human body to vitamin A. It is an important crop in Africa as a staple (Mbua *et al.,* 2014). In 2014 the top five producers of sweetpotato Worldwide were China, Nigeria, Uganda, Indonesia, and the United Republic of Tanzania (FAOSTAT, 2015).

The crop is grown in almost all agro-ecological zones of Tanzania (Kapinga *et al*., 1997) and, being a staple, it is for household food requirements. It ranks third most important root crop in Africa after cassava and round potato (Sierra Leon IMF report, 2011) and is a staple food for a large proportion of the population in many parts of sub-Saharan Africa (Munyinza *et al.,* 2012; Rukarwa *et al.*, 2013). Collectively, the crop ranks fourth after maize, cassava and beans among food crops in Tanzania (Kapinga *et al.,* 1997). Of the East African countries, Tanzania is the second largest producer of sweetpotato after Uganda (URT, 2012). Since 1961, sweetpotato production has increased by 20% in developing countries (Gregory *et al.,* 1990). Sweetpotato is an important staple in areas of subsistence farming and is a drought tolerant crop (Mbua *et al.,* 2014). Its production adapts well to both low and high technology input agricultural systems.

The sweetpotato cultivation is believed to have occurred as early as about 3000 BC (FAO, 1994). During the time the ancient Peruvian and Mayan civilizations of tropical America, as well as the tropical Pacific Islands grew sweetpotato extensively. It is also believed that Columbus introduced the sweetpotato into Europe after voyages of discovery, while Spanish and Portuguese explorers and traders subsequently introduced it into Africa and Asia (Oke and Workneh, 2013). It is now grown circumglobally in tropical and subtropical latitudes and constitutes one of the seven most important crops worldwide (Kyamanywa *et al.,* 2011).

Sweetpotatoes are grown for food and feed in many developing countries (Low *et al.*, 2009). It is an important crop for food security, often crucial during famine periods because of its excellent drought tolerance and rapid production of storage roots (Mukhopadhyay *et al*., 2011). In Tanzania it is mostly grown by subsistence farmers (Kulembeka and Masumba, 2005) and contributes significantly to livelihoods of many households. The ability to grow potatoes in a wide range of climates and the crop adoption by a broad range of cultures has increased potato consumption worldwide (King and Slavin, 2013). As a result, it is becoming an increasingly important source of rural employment, income, and food for growing populations (Ephrem, 2015). Its plasticity to environmental conditions and its yielding capacity also make it the best crop for food and nutrition security (Kyamanywa *et al.*, 2011).

Sweetpotato roots are directly consumed as food and sometimes processed for a variety of confectionaries. The leaves are used as vegetable in either fresh or dried form. Some farmers use parts of the sweetpotato plant as livestock feed (Claessens *et al*., 2008). In some developed countries, light industries use sweetpotato roots as raw material for production of starch, natural colorants and fermented products such as wine, ethanol, lactic acid, acetone, and butanol (Duvernaya *et al*., 2013). In central Tanzania, sweet potato is an important food crop that is either boiled or fried. Although, the use of sweet potato for human consumption in the area seems to fluctuate probably due limited knowledge of its nutritional value (Rwegasira, G. M. Personal communication, 2016) the demand for potatoes continues to increase in conjunction with expanding diet diversity and a need for inexpensive foods. The ability to grow potatoes in a wide range of climates and their adoption by a broad range of cultures has increased potato consumption worldwide (King and Slavin, 2013). Sweetpotato production in many countries around the world gained significance due to its adaptability to marginal conditions such as drought, wet conditions and low soil fertility (Kapinga *et al.*, 1997). Thus, the crop is ranked high among food security crops as it often yields appreciably well even when local staple crops like maize and rice fail to adapt to the adverse weather (Low *et al.,* 2009). Another emerging potential for sweetpotato is that, it is one of the eight crops chosen by the United States National aeronautic and space administration as a possible food source for long term manned space mission (King and Slavin, 2013). This was chosen mainly because of its palatability, versatility and nutritional contents of the roots and shoots. According to the FAO (1994) the sweetpotato possesses several characteristics that make it the ideal crop for plugging gaps in household and national food security. Some of characteristics for its favorite include drought tolerance, ability to grow in low soil fertility, low labour requirement and early maturation tendency.

Planting time of sweetpotato is mainly determined by the climate of a location (Woolfe, 1992). In central Tanzania mid-November to mid-December is the best time to plant, and usually the crops get ready for harvest from April to May. The crop is commonly mono cropped in small patches scattered around the farm or the farm hut (Woolfe, 1992). It is also sometimes inter -or relay cropped with other crops such as maize, cassava, sorghum and plantain where it acts as live mulch and suppresses weeds. Yields of plants grown in mixed cropping systems are usually below those of plants grown in monoculture (Singh *et al.,* 1984). In the tropics, sweetpotato is normally propagated from vine tip cuttings harvested from fields, which are ready for harvest. Kay*'s*. (1985) suggested that, this practice enhances the severity of weevil infestation. The vines are planted on ridges, mounds, or even on flat land. The tillage method is often traditional and is influenced by such factors as soil type, fertility and drainage conditions.

In spite of the importance of sweetpotato in alleviating rural poverty, health and food security in Africa and Tanzania in particular, its increased and sustainable production is seriously hampered by the sweet potato weevils (Andrade *et al*., 2009; Kapinga *et al*., 1995). Some studies conducted in Ethiopia and Tanzania, indicated that pests, diseases, drought, and rain shortage were among the main factors affecting the sweetpotato yields (Gurmu *et al*., 2015; Kapinga *et al.,* 1995). The problems of insect pests both in the field and during storage are the most important causes of yield losses. Sweet potato weevils, of the genus Cylas (Chalfant *et al.*, 1990) are the most destructive insect pests of the crop at field level. Even at low populations, the weevils reduce yield and quality of root tubers (Kasina *et al.*, 2009). According to Akazawa and Uritani, (I960), attack by the weevils elicit the production of bitter tasting and toxic tarpenoids which render infested roots unfit for human consumption.

Lack of capital and credit facilities have caused farmers in sweetpotato production areas to remain underdeveloped for decades. Despite some farmers being trained on post-harvest processing technologies, lack of capital to purchase processing equipment has made the knowledge gained redundant (Ngailo *et al.*, 2015). Like other field crops, sweetpotato production also faces many production challenges. The aforementioned ecological, economic, and social factors make the crops of poor small-scale farmers vulnerable to failure (Gurmu *et al*., 2015). Planting of infested vines was noted to be one of the ways of weevils' dispersion (Hue and Low, 2015).

The importance of sweetpotato in central Tanzania and significance of the crop to the livelihoods of several communities as well as production constraints particularly the sweet potato weevils are scantly reported. Specific studies on the biology and ecological aspects of weevils in the area are also lacking. Due to little information on the trend of weevil occurrence in the study area, it is found important to identify major parameters that foster weevil occurrence in order to aid tackling of the pest problems in future.

1.2 Sweetpotato Production

Sweetpotato is grown throughout the world by small scale farmers, usually on marginal land. Productivity is below the agronomic potential of the crop and there is limited export and crop diversification in most African countries (Sefasi *et al.,* 2012). The plant is an indeterminate plant but is usually grown as an annual crop. In tropical regions, it can be grown all year long and is typically propagated from vine cuttings taken from other production fields (Benjamin *et al.,* 2014; Kapinga *et al.,* 1997). In temperate and subtropical regions, where winters are too harsh for year-long production roots are stored over the winter and used to produce slips to transplant during the following season (Benjamin *et al.,* 2014). Sweetpotato has wide ecological adaptabilities which enable the crop to perform well under poor soil conditions. Therefore, small-scale farmers can grow sweetpotato in poor soil with little or no fertilizers (Karyeija *et al*., 1998). Production is highly seasonal in most countries, leading to marked variation in the quantity and quality of roots in market and associated price swings (Oke and Workneh, 2013). Poor market intelligence and the limited knowledge of market opportunities and the potential uses of the crop are also contributory factors. Newly emerging root crops, like sweetpotato, require few inputs have high dual nutrition and energy values for both human and livestock (Claessens *et al*., 2008). The ability to perform well under different climatic conditions in different agro-ecological zones will enhance production and productivity of the crop.

The national fresh root yield at farm level in Tanzania is only 9.5 tha^{-1} (FAOSTAT, 2015; RAC Tanzania report, 2012) compared to potential yields of 20-50 tha^{-1} (Benjamin *et al.*, 2014). According to Titus *et al.* (2010), sweetpotato production is favoured by well-drained sandy or sandy loam soils with pH between 5.8 and 6.4, alkaline soil and annual rainfall of 500 - 1250 mm. It grows best at mean temperatures of 24 °C (Gajanayake *et al.*, 2015) or above (Rees *et al.*, 2001).

1.3 Factors Affecting Sweetpotato Production

Local crop production system influences exposure of sweet potatoes to disease and insect pests. Sweet potato weevils, elegant grasshoppers, white grubs, stem borer and sweet potato leaf beetle have been found to cause damage to sweetpotato storage roots and leaves (Gajanayake, *et al.,* 2015; Stathers *et al*., 2005). Several other constraints such as traditional potato production system, shortage of clean planting materials of improved varieties, limited knowledge on postharvest handling of the produce, and poor technology transfer systems also hinder its productivity worldwide (Gebru *et al.,* 2017). Unreliable markets with low prices were also regarded as major constraints of sweetpotato production limiting farmers to pull out of poverty. Farmers sell the produce in the fields, local markets and along roads. The price is usually very low and unprofitable to farmers (Ngailo *et al.*, 2015). Postharvest problem has remained a serious constraint for agricultural commodities in general and horticultural industry in particular almost in all sweetpotato growing areas.

1.4 Sweet Potato Weevils

Sweet potato weevils can attack sweet potatoes in the field and in storage. Larval tunneling causes trepan production in the storage roots, which imparts a bitter taste and left the sweetpotatoes unsuitable for human consumption (Kibrom *et al*., 2015). Among the sweet potato weevils, *Cylas spp* is one of the most destructive species of sweetpotato worldwide (Sefasi *et al.*, 2012). Its presence even in small number is viewed as economically important and warrant intensive management (Rees *et al.*, 2001). Yield losses attributed to weevil infestation ranges from 8 to 18 tha^{-1} in Africa and Asian countries (Munyiza *et al*., 2007; Shonga *et al*., 2013). Mmasa *et al.* (2012) reported shortage of planting materials, lack of capital, drought and insect pests as critical sweetpotato production constraints in Tanzania. Diseases and insects of paramount importance are sweet potato viruses and sweet potato weevils. Kapinga *et al.* (1997) reported that the intensity of sweet potato weevil infestation varies between wet and dry seasons. The weevil caused economic damage in areas with a marked dry season. The weevil is a problem wherever the crop is grown and often worse during dry times. It is reported to be most serious in areas with a marked dry season (Bourke, 1985). Wijmeersch (2000) reported that in parts of Papua New Guinea with well spread high rainfall, weevil damage is usually not a problem. Okonya and Kroschel (2013) reported that the mean root yield loss by *Cylas spp*. was significantly higher at low altitude (28.5%) than at mid (6.5%) and high (3.9%) altitudes indicating that altitude has influence on the incidence and abundance of sweet potato weevils.

1.5 Biology and Life Stages of Sweet Potato Weevils

Many literatures about pest biology concentrated on one specie *Cylas formicarius*. The adult sweet potato weevil is a snout beetle that resembles an ant. The weevil has a narrow head and thorax (Sorensen, 2009). The weevil eggs are white or pale yellow and broadly oval (Figure 1.1). Weevils lay eggs below the surface of the roots or vines and cover with dark coloured excrement from the female adults (Kasina *et al*., 2009). The egg cavity is sealed with a protective, gray fecal plug. The developing larvae tunnel in the vine or storage root. A few days after eclosion, the adult emerges from the vine or root. Because the female weevils cannot dig, they find storage roots in which to lay her eggs by entering through soil cracks. The larvae are dirty white with a C-shaped body and a pale brown head (Figure 1.1). The weevil spends its entire life cycle on the host plant, and both larval and adult stages damage the roots and vines (Sorensen, 2009). The weevils are generally nocturnal, but may also fly in response to the pheromone source (Reddy *et al.*, 2012) and be found on ipomoea plants during daytime. Adult weevils fly freely during the warm part of the year and are capable of ranging at least 1.6 kilometer per season (Gajanayake *et al.*, 2015). Flight takes place primarily at night and during the day if the insects are disturbed. Flight activity tends to be more general on dark nights than on bright moon lit nights (Amin, 2005). The pest species may produce several generations per year in the tropical climates, and does not undergo winter diapauses but moves to alternative hosts of *Ipomoea species* (Sherman and Tamashiro, 1954). The weevil requires 30 days to complete its life cycle and can make five to seven generations per season (Emana, 1990). In 90 days of her life time an adult female lays between 100 and 250 eggs. All sweet potato weevil species have a similar life history where by optimal temperatures of 27–30°C, is favorable for weevil regeneration (Kibrom *et al*., 2015). Alternate hosts of sweet potato weevils are *Ipomoea spp* weeds (Ames *et al*., 1997). Four main weevil's species known worldwide to cause the most harm to sweetpotato plantation are *Euscepes postfasciatus* (Fairmaire), *Cylas formicarius* (Fabricius), *Cylas puncticollis* (Boheman), and *Cylas brunneus* (Fabricius) (Chalfant *et al.*, 1990). *Euscepes postfasciatus* is a South American species that is more prevalent in Central and South America. *Cylas formicarius* is an Asian species found throughout the tropical regions worldwide. *Cylas brunneus* and *Cylas puncticollis* are African species and are restricted to Africa. There are other species of sweet potato weevils in the tropical regions in Africa such as *Blosyrus spp* and striped sweet potato weevil *Alcidodes dentipes* and *Alcidodes erroneous*) which are assumed to cause minor damage to sweetpotato compared to the *Cylas spp* (Nguya, 2015). Another species of weevil causing significant crop damage is the West Indian sweet potato weevil (*Euscepes batatae*) (Hughes, 2013).

Figure 1.1: The developmental stages of the sweet potato weevil, *Cylas puncticollis*; (A) egg, (B) larva, (C) pupae, and (D) adult

1.6 Damage caused by Sweet Potato Weevils

Adults feed on the epidermis of vines, scraping oval patches off the young vines and petioles, adults also feed on external surfaces of storage roots resulting in round feeding punctures. The developing larvae tunnel the vines and roots resulting in significant damage (Ray and Ravi, 2005). Frass is deposited in tunnels. Damaged roots produce terpene-like chemicals which render the roots inedible, even at low concentration and low levels of insect damage (Munyiza *et al*., 2007). Feeding inside the vines causes malformation, thickening and cracking of the vine (Reddy *et al.*, 2012). Leaves may become pale green and overall vigour of the plant may be adversely affected. In addition, the damage caused by weevil facilitates entry of soil-borne pathogens (Jansson *et al*., 1987) and render the product unsuitable for human consumption. Losses can be severe both in storage and in the field. Yield losses due to sweet potato weevil may range from 60 to 97% (Jansson *et al*., 1987; Ray and Ravi, 2005; Reddy *et al*., 2012).

1.7 Soil Characteristics for Sweetpotatoes Production

Sweetpotato requires well-drained soil with a pH of 5.5 to 6.5 (Woolfe, 1992). A well-drained sandy loam is preferred and heavy clay soils should be avoided as they can retard root development, resulting in growth cracks and poor root shape. The crop requires deep ripped and disk cultivated soil to provide enough loose soil for hilling of beds. The crop is extensively grown under rainfed conditions and is relatively drought tolerant (Sefasi *et al.*, 2012). Excess rainfall at early stage of establishment may aggravate weed problem resulting in low yield (Harrison and Jackson, 2011). However, prolonged and frequent dry spells or drought and erratic rainfall cause substantial yield reduction (Low *et al*., 2009).

1.8 Losses Associated with Weevil Damage

Weevil can cause losses of 10 – 100 % (Kapinga *et al*., 1997; Kasina *et al*., 2009; Shonga *et al.*, 2013; Smit, 1997; TACTRI, 2014). The bitterness resulting from sweet potato weevil damage makes even the partially damaged roots unsuitable for human consumption (Munyiza *et al*., 2007). According to Emana (1990) the infestation may increase from 29 to 68 % when harvesting is delayed from five to six months. Moreover, growing sweetpotato on the same plot of land for four consecutive years can result in over 70% infestation and where rotation of crops is practiced less than 20% infestation can occur (Emana, 1990). Yield loss is high towards the dry season due to low soil moisture, low biomass yield and high soil cracks (Shonga *et al.*, 2013). Losses inflicted by this pest can be severe both in storage facilities (Ray and Ravi, 2005) and in the field, where yield losses can be as high as 60 - 97% (Jansson *et al*., 1987; Sutherland, 1986). Sweet potato weevils cause damage by feeding on storage roots or in the crown of the plant (Sutherland, 1986). Jansson *et al*. (1990) reported that approximately 80-90% of the weevil population is below the soil surface. Thus, it is difficult to determine infestation levels or root damage. The severity of infestations can only be accurately determined by digging up and dissecting the storage roots (Munyiza *et al*., 2007). This is not only a difficult process, but it also destroys a portion of the crop.

1.9 Sweetpotato Varieties Response to Weevil Infestation

Variability in sweetpotato genotypes for resistance to sweet potato weevil has been reported by Emana (1990). It has been reported that, varieties with deeper roots suffer less from the attack of weevils compared to shallow rooted one (Tesfaye, 2002). Conversely, Shonga *et al.* (2013) reported that there are no resistant varieties to the sweet potato weevil although varieties differ in the degree of damage and infestation by the pest.

1.10 Management of Sweet Potato Weevil

Several control strategies and techniques have been used in different locations. However, control of sweet potato weevil in the field has met critical limitations. Limited successes are usually imminent because the larva, which is the most destructive stage of the insect, feeds on the inside of storage root which protect them from contact pesticides and most arthropod natural enemies (Harrison and Jackson, 2011). Successful management can include cultural practices such as using clean planting materials, and removal of alternate hosts (such as morning glory, “wild slip”, *Ipomoea spp*.) (Kibrom *et al.*, 2015). The use of chemical and natural enemies, have been tested for the control of adult *Cylas spp* (Tesfaye, 2002). Movement of adult weevils may facilitate the contact between the toxicant and the insect, thereby resulting in insect mortality (Adhanom and Tesfaye, 1994). Earthing up of the soil around the plant three times at monthly intervals starting from the second month after planting has been found to significantly reduce infestation of roots and this practice enables delayed harvesting (Smit, 1997). Hue and Low (2015) reported that hilling (ridging) a small area around the sweetpotato plant can prevent entry of weevils into roots. Farmers reduce sweet potato weevils in their field by crop rotation and hilling up (Stathers *et al*., 2005). Another strategy involves conducting field sanitation (destroying old sweetpotato fields, removing crop residues), ensuring adequate soil moisture, molding/hilling plants to reduce cracks in the soil area, harvesting promptly, rotating the crop, and using tolerant varieties (Shonga *et al.*, 2013). Sex pheromone traps can reduce number of sweet potato weevils. In developed countries biological control and chemical applications during the early stages of the crop, have become control measure (Jansson *et al*., 1987), where commercialization of sweet potato was given priority. Previous studies have shown that insect-pathogenic agents have the potential to control sweet potato weevil populations (Dotaona, 2015). As infested vines spread weevil infestation, treatment of infested vines with insecticides is currently being recommended to reduce weevil infestation (Hue and Low, 2015).

1.11 Sequential Planting against Weevil Occurrence

Sequential planting is referred as planting the crop in succession. It is usually applied in vegetable production for ensuring constant supply of produce in the market. In most case interval depend on the demand and objective of the succession. As per sweetpotato production sequential planting is practiced in Tanzania as a mean of multiplication of planting material. Surveys conducted in Lake Zone, Tanzania found that shortage of planting material was ranked third in sweetpotato production constraints (after weevil and drought), with 66% of farmers reportedly affected (Kapinga *et al*., 1995). Shortages of planting material are more common in areas with unmodal rainfall systems and a long dry season where there is higher risk of loss of planting material. In bimodal areas where there is a longer rainy season, there is always a crop in the ground to provide planting material, but there may be higher build-up of pests and diseases thus contributing to suboptimal root production. In other had it was observed to have notable pest problems in crops which are later planted. Emana (1990) reported more weevil damage and occurrence, as succession effect. In that case sequential planting in one way ensure constant supply of produce although in other hand create conducer environment for pest and alternative host to exist in the field.

1.12 Justification

Despite remarkable role of the sweetpotato, its productivity in Tanzania is very low, estimated at 9.5tha^{-1} (FAOSTAT, 2015) compared to the international usual range of 20–50 tha^{-1} (Benjamin *et al.*, 2014). Productivity data in the central zone of Tanzania are scarce, although it is assumed they are less or equal to the national average of 9.5tha^{-1}. Low productivity arises from several abiotic (drought, poor soil fertility and sometimes excessive rains) and biotic (poorly yielding varieties, diseases and insect pests) stresses (Ngailo *et al.*, 2013) as well as socio-economic constraints. The sweet potato weevils (*Cylas spp* and *Blocyrus spp*) have been implicated to largely cause poor quality of roots (Kapinga *et al*., 1995; RAC Tanzania Report, 2012) particularly in central Tanzania where intermittent drought during crop growth has been a common scenario. Sweet potato weevil damage on roots is usually high even at low levels of weevil infestation and can significantly reduce root quality rendering them non-marketable. The damaged roots produce unpalatable terpenoids in response to weevil feeding (Munyiza *et al*., 2007). Yield losses caused by weevils had been estimated to range from 15% to 73% in Tanzania and Uganda (Kapinga *et al*., 1997; Smit, 1997). In Taiwan the loss ranged from 1 to 18%, (TACTRI, 2014) while up to 100% losses have been reported in some areas in Eastern Kenya (Kasina *et al*., 2009). High infestation levels have been reported under dry conditions due to many cracks associated with drying of soils (Munyiza *et al*., 2007).

Prolonged dry spells and cracking of soils are key common features of central Tanzania particularly in Singida region and Gairo (Morogoro). In these areas sweetpotatoes are planted continuously from November to March depending on the occurrence of the rainy season and distribution of work load among farmers. Varied timing in crop establishment has potential influence on the occurrence and damage by sweet potato weevils but information to validate this is inexistent. The timing of occurrence, distribution, species dynamics and losses associated with the weevil infestation are still unknown. Given that most sweetpotato producers in central Tanzania are small scale resource-poor farmers, and that sweetpotato is not considered a high value crop currently, very few producers pay attention to weevils particularly on pest management because the management techniques often considered (insecticides) are costly. This underscores the importance of establishing time of occurrence, distribution, and population dynamics and loses associated with the pest as a way of seeking effective, low-cost and eco-friendly sweet potato weevil management strategy.

Rapid increase in weevil damage in the central Tanzania obviated the need for assessment and characterization of the pest (Rwegasira, G M. Personal communication, 2016). First efforts must be concentrated on evaluation of different planting for different varieties and location and filling some knowledge gaps in the nature of damage and seasonal occurrence of the weevil. The aim of the present research project was to gain insight into the population dynamics and occurrence trend of sweet potato weevil and based on these the pest sound management programme would be developed.

1.13 Objectives

1.13.1 Overall objective

The overall objective was to improve sweetpotato yield through understanding of the effect of sequential planting on management of sweet potato weevils in central Tanzania.

1.13.2 Specific objectives

Specifically the study intended;

i. To establish the spatial distribution of sweet potato weevils in the study area.
ii. To determine temporal abundance and spread of sweet potato weevils during the growing season.
iii. To quantify yield loss associated with sweet potato weevils.

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CHAPTER TWO

2.0 INCIDENCE, SPATIAL DISTRIBUTION AND DAMAGE SEVERITY BY THE SWEET POTATO WEEVIL IN SWEET POTATO PRODUCING AREAS IN CENTRAL TANZANIA

2.1 Abstract

Sweetpotato (*Ipomoea batatas* (L.) Lam) is an important staple food especially in central Tanzania. However, the marketable proportion of the crop yields usually harvested is low because of damages caused by the sweet potato weevils in the field. A study was conducted to generate information on the pest status and its distribution in Gairo and Ikungi Districts of central Tanzania. The study involve a diagnostic survey whereby a total of 60 farmers' randomly selected in 20 villages were interviewed and assessment of their fields performed. About 600m^2 sweetpotato fields in each of the selected farmers were earmarked and three quadrants placed diagonally to obtain three replications per field; one placed at the bottom, the second at the middle and the third at the top of a diagonal. Plants falling on the quadrants were dug for assessment of weevil infestation. Results revealed presence of weevils in all villages surveyed although incidence varied, in both vines and roots. The level of infestation was generally higher (80%) in vines. The pest incidence was higher in Gairo (35%) than in Ikungi (5%). It was concluded that Gairo District has much more weevil attack than Ikungi District. Despite of remarkable presence of pest and loss it cause in the area, knowledge about pests is generally limited and poorly understood among the farmers.

Key Words: Sweetpotato, Weevil incidence, Yield, Economic loss, central Tanzania.

2.2 Introduction

Sweetpotatoes are grown for food and feed in many developing countries (Low *et al*., 2009). It is an important food security crop, often crucial during famine periods because of its excellent drought tolerance and rapid production of storage roots (Mukhopadhyay *et al*., 2011). In East Africa, sweetpotato plays an important role in the diet and food security of the population as indicated by high per capita consumption (Mwanga, 2001). The crop production and utilization is often considered as means for generating income among the poorer segments of the rural population (Low *et al*., 2009). The national fresh root yield at farm level in Tanzania, for example, is only 9.5 tha^{-1} (FAOSTAT, 2015; RAC Tanzania report, 2012). This yield is very low compared to the yield potential of 20–50 tha^{-1} (Benjamin *et al.*, 2014). Low productivity arises from several biotic, abiotic and socio-economic constraints. The constraints attributed to low root yields in sub-Saharan Africa include diseases, insects and vertebrate pests, weed infestation, soil nutrient deficiencies, poor crop husbandry practices and socio-economic factors (Smit, 1997). Among the insects, sweet potato weevil (*Cylas puncticollis* and *Cylas brunneus*) is a priority problem. Disease includes viruses' mainly sweet potato virus and altenaria stem blight. Poor yielding varieties of low nutritive value (low or no ß-carotene), shortage of high quality planting materials, marketing problems (Mwanga, 2001)**,** as well as limited range of processing and utilization options leading to high postharvest losses estimated between 30-35% (Woolfe, 1992) are also important constraints to the crop.

The sweet potato weevils have been implicated to largely cause poor quality of roots (Kapinga *et al*., 1995; RAC Tanzania Report, 2012), particularly in central Tanzania where intermittent drought during crop growth is a common scenario. Weevil damage to roots is reported to be usually high even at low levels of infestation, and can significantly reduce root quality rendering them non-marketable. Weevil damage results mainly from their larvae (Mansaray *et al.*, 2013) which feed within tuberous roots. Furthermore, in response to the weevil feeding, plants produce unpalatable terpenoids that render tubers unfit for consumption (Sefasi *et al*., 2012; Munyiza *et al*., 2007). Damage caused by sweet potato weevils on the vines occur due to the behaviour of the adult female weevils to lay eggs on the crown after which the hatched larva feed on the vine and cause tunnels or holes. Yield losses caused by weevils have been estimated to range from 15% to 73% in Tanzania and Uganda (Kapinga *et al.*, 1997; Smit, 1997). According to Mansaray *et al.*, (2013), plants may wilt or even die because of extensive stem damage, and damage to the vascular system can reduce the size and number of storage roots. Social factors, such as increased population growth which put pressure on the farming land often leaves the soil with no time to recover contributing to reduced sweet potato root yield (Kivuva *et al*., 2014). Literature reports that distribution and incidences of weevils varies between regions worldwide (Wolfe, 1991).

Research reports on sweet potato weevils in central Tanzania are scarce and inconsistent. There exists no reliable information on the distribution and incidences of sweet potato weevils in fields. This study was designed to address such knowledge gap. The study findings will create basis for management of sweet potato weevils to improve production and quality of produced sweetpotato in central Tanzania.

2.3 Materials and Methods

2.3.1 Pre testing the interview questions

The interview questions were pre-tested before conducting the actual survey. Three randomly selected farmers in each District were interviewed for the questions pre-testing exercise as well as discussions with extension officers, researchers, input suppliers and key village informants (retired officers and religion leaders). Also, observation visits to the research areas, including transect walks in each agro-ecological zone, took place during the first fieldwork trip to ensure that all the information is relevant to the sweet potato production in central Tanzania. During pre-testing it was observed that common local variety planted in Ikungi across the District was Gudugudu, which helped to compromise that the study should consider one variety instead of two as it was earlier proposed. In case of Gairo, Simama variety was considered for study for the same reason.

2.3.2 Diagnostic survey

Survey was conducted in twenty villages in Gairo and Ikungi Districts, in Morogoro and Singida Regions of Tanzania, respectively, between May to June, 2016. Gairo District lies on the geographical co-ordinates of 06° 08′ S, 36° 52′ E and Ikungi District on 05° 08′ S, 34° 46′ E. These Districts were selected because they are of high production of sweet potato in central Tanzania. The areas are characterized by predominantly unmodal rain (average annual range of 400 to 800 mm) followed by prolonged dry spell of five to six months. Gairo District is a hill (class T-Hypsographic) located at an elevation ranging between 1230 and 1370 meters above sea level (masl), with minimum temperature of about 22^{0}C (Rees *et al.,* 2001) and the soil is predominantly highly weathered red clay soil that tend to crack when dry. Ikungi is almost flat with slightly slopping elevation of 1540 masl (District economic profile, 2016).

2.3.3 Sampling procedures

Purposive sampling was employed to identify regions, districts, villages and farmers for the interview and field assessment. The Singida and Morogoro regions were selected because of their engagement in sweetpotato production (Kisetu and Honde, 2014). Gairo and Ikungi districts were chosen based on prior information on the importance of sweetpotato in these areas. Ten villages per district were selected based on their accessibility and production records. Three farmers among sweetpotato producers were randomly selected in each village with the help of agricultural extension officers. In each village, the selected farmers were interviewed and their fields intensively assessed for weevil infestation.

2.3.4 Field assessment for weevil infestation

A field area of 30 by 20 meters in size was earmarked using a measuring tape at random in each farmer's field and used for assessment and data collection. In each of the earmarked "$600m^{2}$" area three quadrants were placed diagonally to obtain three replications per field; one placed at the bottom, the second at the middle and the third at the top of a diagonal to avoid biasness. A quadrant of "$3m^{2}$" in size was used.

The farmers' fields were visited and assessed for weevil incidences and severity. During the visits discussions and detailed explanations of the weevil problem were made. Closed and open ended questions were used to collect general information on history of the crop in the area and perception of pests during the past two seasons.

2.3.5 Data collection and analysis

Infestation data were collected based on plants which fell in the quadrant. 10 centimetre long vines immediate from soil surface were considered for infestation assessment. Incidence and severity of sweetpotato damage on vines were recorded. Then, data were recorded on the roots after digging the plants. Marketable and non-marketable roots were separated according to Titus *et al.,* (2010). Marketable roots were those with bigger size and less infested ones while non marketable roots were smaller in size, infested and severely infested. Sweetpotato weevil incidence on both above ground and below ground were collected by counting the total number of harvested vines and number of vines which showed signs of infestation.

Severity of the weevil on both above and below ground were recorded by using a scale of 1 = 0%; 2 = 1 – 15%; 3 = 16 – 50%; 4 = 51 – 65%; 5 = 66 – 100%. Consequently, “category 1” was assigned to vines and roots that were not damaged, “category 2: slightly damaged;” Category 3: moderately damaged”, “category 4: high damage” and “category 5: very high damage”. The scale used was according to the Rees *et al.,* (2001) with slight modifications on categories 2 and 5 to have more un-biased rating on small roots, to accommodate all roots colours and to have wide range of severe damage.

Data were analyzed using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel (Windows Office, 2007). Important descriptive statistical measures such as percentage, frequency, and means were used to summarize and categorize the research data for each district. Cross tabulations were used in the analysis and data on number or percentages of farmers interviewed. Map for weevil distribution in the study area were developed using ARC GIS (Geographical information system) software.

2.4 Results

2.4.1 Incidence of the weevils in the study area

Sweetpotato weevils were observed in all the villages surveyed and among all farmers contacted and varied between and within villages. Mean percentage incidences of damage are presented in Figures 2.1 and 2.2. Overall, highest damage incidences were encountered in villages of Gairo District.

Percent incidences of weevils on sweetpotato in Gairo Distict are presented in Table 2.1. The highest mean incidence of weevil was 68.27% in Ibuti village; although generally incidences were high in Ibuti, Madege, Malimbika, Nguyami, Chakwale and Ngolongoni villages and low in Ihenje, Tabuhoteli, Ukwamani and Mahemu villages.Those that were low were significantly (P≤0.05) lower than incidences in Ibuti and Malimbika villages. The rest of the “high” incidences can therefore also be considered to be “intermediate”

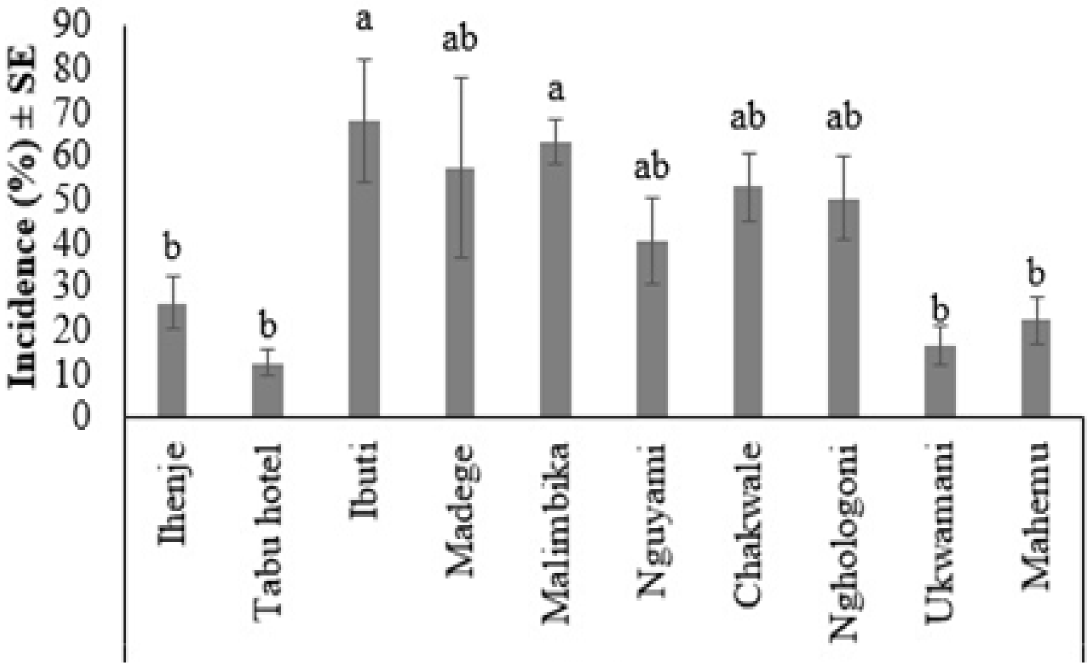

Figure 2.1: Mean incidence of weevils in sweet potato fields across villages of Gairo District. Bars with different letters as data labels represent means that are significantly different as per Turkey’s HSD

In Ikungi district, the difference in incidences could significantly be attributed to the varieties grown. The predominantly grown varieties were Gudugudu for Ikungi and Simama for Gairo which were all acknowledged by farmers to be susceptible to weevils. Highest incidence in weevils was observed in the village of Siuyu (53%) followed by Kimbwi (38.118%) and the lowest was in Wibia (2.01%) (Figure 2.2). Majority of the villages in Ikungi Distict were having incidences lower than 15%.

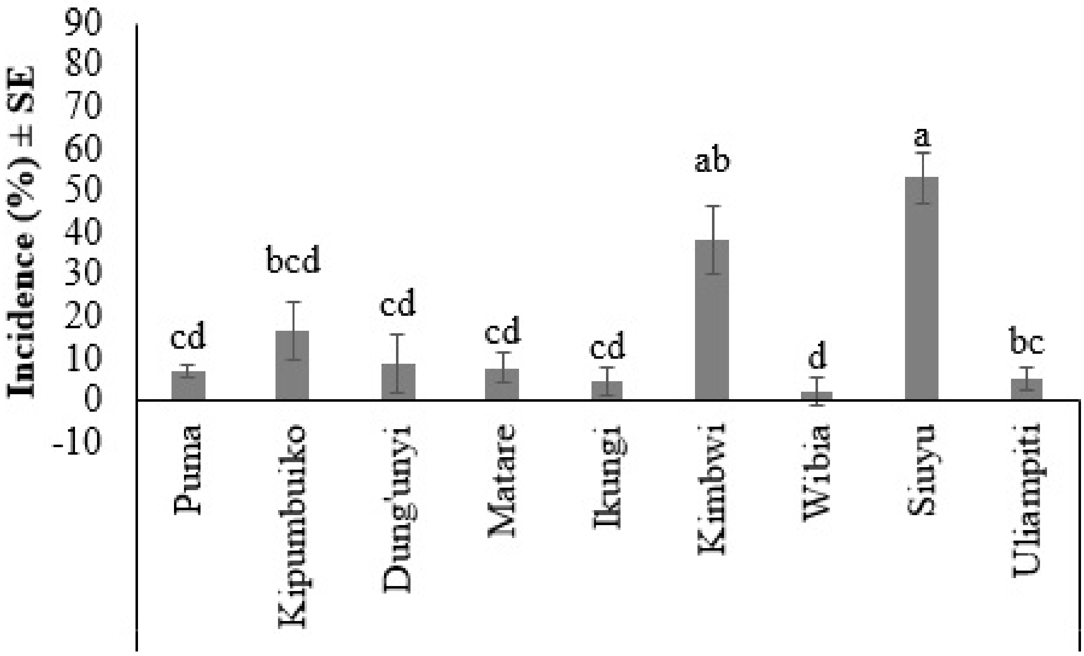

Figure 2.2: Mean incidence of weevils in sweet potato fields across villages in Ikungi district. Bars with different letters as data labels represent means that are significantly different as per Tukeys' HSD

2.4.2 Spatial distribution of the sweetpotato weevil in the study area

The study showed that no village was having zero infestation, although magnitudes among villages differed. Generally results revealed that pests are extensively distributed all over the study area, as evidenced from the damage incidence data. Damage incidences were observed to be higher in villages of Gairo District than those in Ikungi District. Only Ukwamani, Tabuhoteli and Mtumbatu in Gairo District were observed to have damage incidence of less than 50% although for Ikungi District all villages except Siuyu revealed that range of damage (Figure 2.3 and 2.4). More damage must have resulted from population density of weevil in the field. The higher the population the higher the damage. The developed map using coordinates of all fields surveyed explains the distribution detail of the pest and incidences across the villages in Gairo and Ikungi Districts (Figure 2.3 and 2.4). Therefore it is argued from the maps high population distribution in Gairo District based on the large area of the District been dominated by incidence categories “High” and “Very high”, against distribution dominated by low population density (damage incidence very low) in Ikungi District.

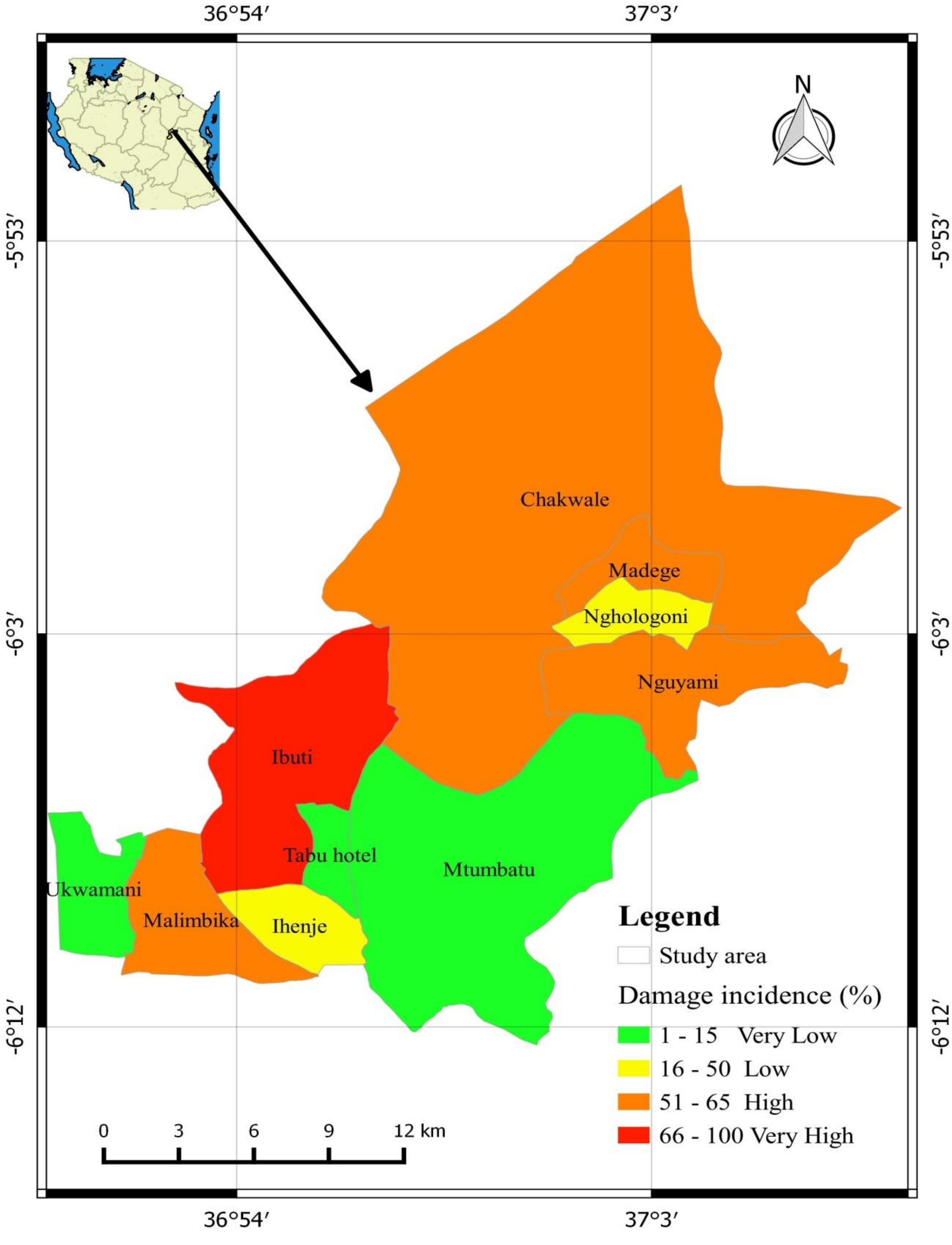

Figure 2.3: Sweet potato weevil root incidence in Gairo District

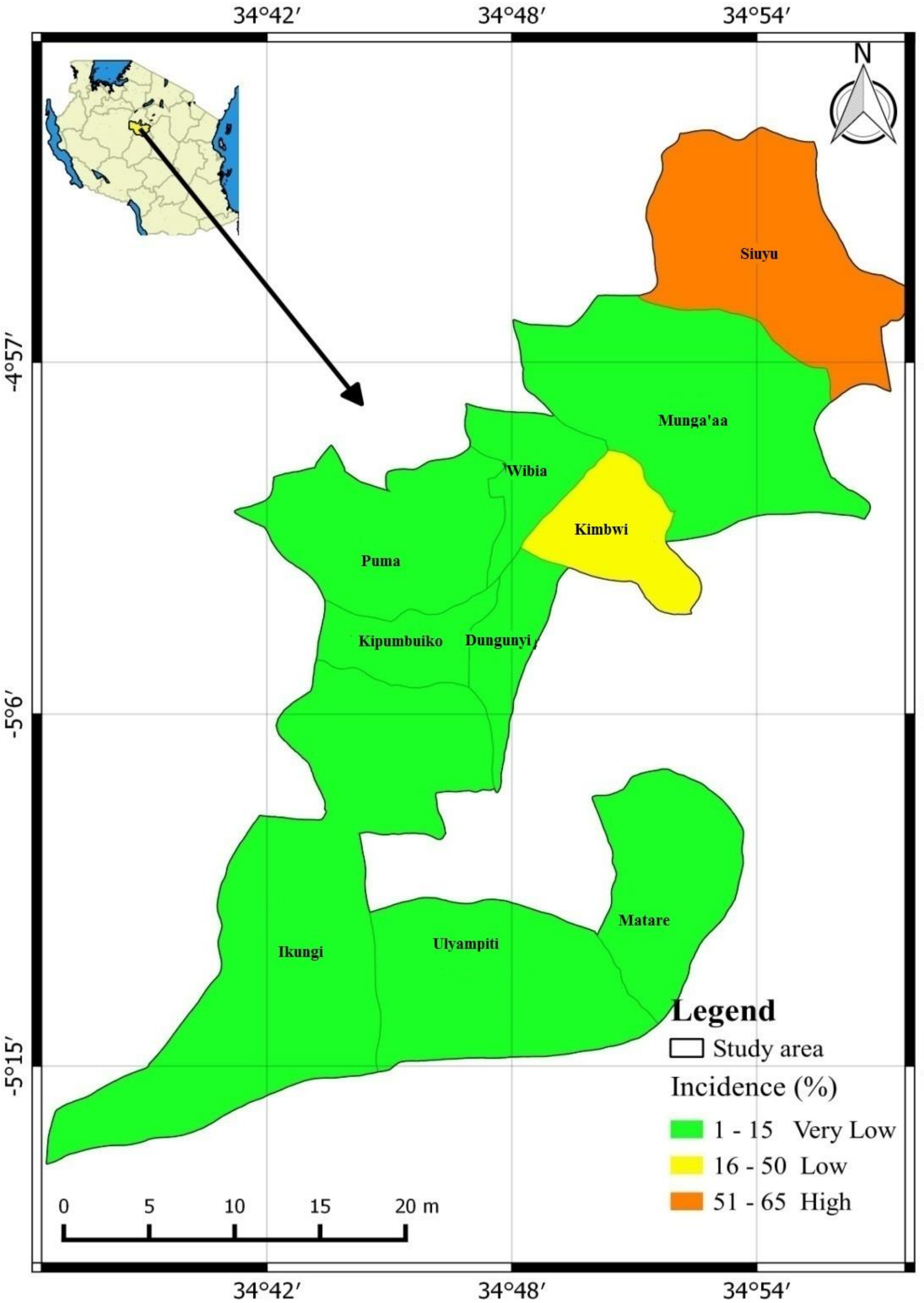

Figure 2.4: Sweet potato weevil root incidence in Ikungi District

2.4.3 Root damage severity

Severity across villages in Gairo and Ikungi are summarized in Table 2.1. Results of the mean of severity between the villages are statistically the same. However, the category of severity did vary significantly whereby most roots were not damaged in category one (Figure 2.5 and 2.6).

In Gairo higher severity was observed in Madege and Nguyami and lowest in Tabuhotel (Table 2.1). In Ikungi District notable severity was observed in Kimbwi and Siuyu villages, (Figure 2.6). These results have shown that higher potato weevil severity was found in Gairo District. The magnitude of weevil damage differed among villages surveyed.

Table 2.1: Severity of weevil damage in surveyed sweet potato fields in Ikungi and Gairo District

Village in Ikungi District	**Mean score of severity (%)**	**Village in Gairo District**	**Mean score of severity (%)**
Dung'unyi	5	Chakwale	11
Ikungu	3	Ibuti	11
Kimbwi	10	Ihenje	9
Kipumbuiko	5	Madege	18
Matare	4	Mahemu	12
Mungaa	8	Malimbika	12
Puma	4	Ngolongoni	12
Siuyu	12	Nguyami	20
Uliampiti	2	Tabu hotel	4
Wibia	0	Ukwamani	11
Chi-Square	4.9649	Chi-Square	3.818
Df	9	Df	9
P-value	0.8374	P-value	0.923

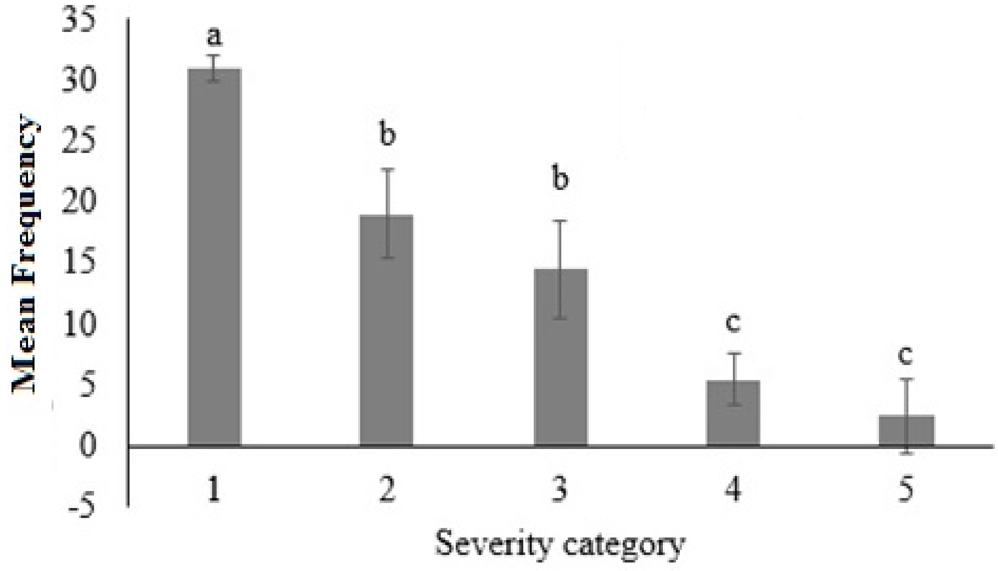

Figure 2.5: Number of roots per severity level of weevil damage in surveyed sweetpotato fields in Gairo District as per the Dunn-Bonferoni procedure

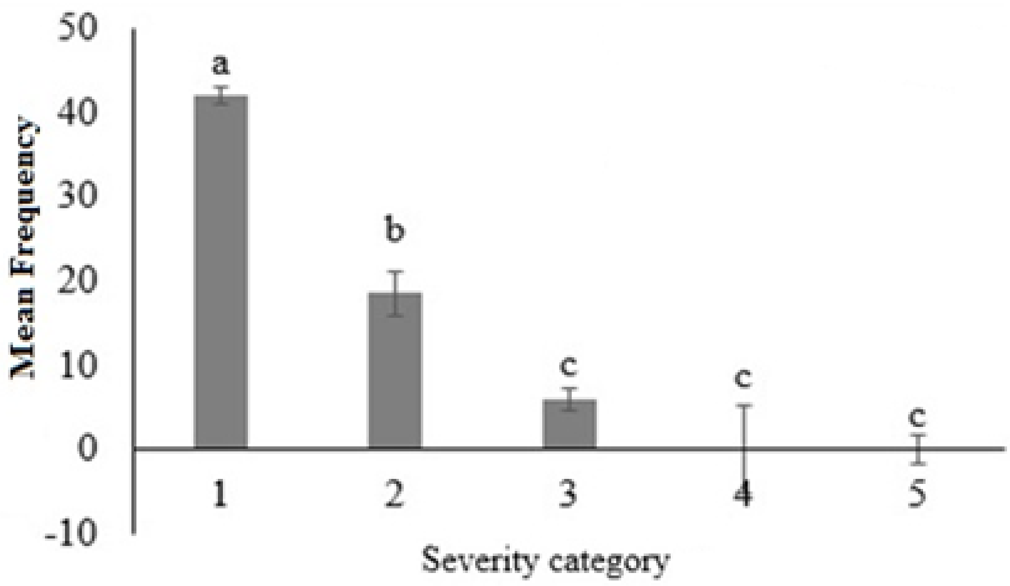

Figure 2.6: Number of root per severity level of weevil damage in surveyed sweetpotato fields in Ikungi District as per the Dunn-Bonferoni procedure

2.5 Discussions

Highest damage incidences were encountered in villages in Gairo District and lowest in villages in Ikungi District. The higher infestation and damage incidence may have resulted from the large number of the weevils in the area. One of the reasons for higher infestation may be the use of unclean or infested planting materials. Gairo district is dominated by prolonged dry spell of up to five months which causes shortages of planting materials forcing farmers to use whatever is available however unclean it might be. Scarcity of planting materials triggers the use of the lowest basal portion of sweetpotato stem which are inevitably infested with weevils eggs and some adults. This ensures perpetuation of the pest into a newly planted crop with subsequent presence of the pest foci in almost every field. A study by Hue and Low (2015) indicated that planting of infested vines is one of the ways for sweet potato weevils' distribution in a given area. Scarcity of planting materials in Gairo has led to commercialization of sweetpotato vines. Vines are usually conserved in river valleys at high concentration such that even the clean harvested vines would end up infested in concentration areas. At the beginning of planting season the vines demand is usually high and almost everybody enters the rush of money making business caring the less about qualities of vines. Planting materials introduced from other places might have been infested. I third reason was repeated planting of sweetpotato on the same piece of land has been reported to contribute highly to the continued presence of the pest making it endemic in many locations. Report by Emana, (1990) indicated that growing sweetpotato on the same plot of land for four consecutive years can result in over 70 % infestation and where rotation of crops is practiced less than 20 % infestation can occur. The use of sprouted planting materials from previous infested fields without any treatment measures was also established among the causes for higher incidences recorded in Gairo. Successful sweet potato weevil management can include cultural practices such as using clean planting materials, and removal of alternate hosts (Kibrom *et al.,* 2015). On the other hand, the differences in damage incidences may have resulted from climate and temperature variation. Altitude and temperature variation may constitute unfavorable ecological niches for some insect species (Badii *et al*., 2015). Musana *et al*. (2013) reported that *Cylas brunneus* is highly sensitive to extreme temperatures and cannot develop, survive or reproduce at temperature conditions less than 15 °C and above 35 °C. The optimal temperature conditions for development and fecundity occur between 25 °C and 30 °C. Temperatures in Ikungi are relatively lower during the year compared to the Gairo temperatures.

The physical characteristic of the soil has been reported to detor or promote the infestation with sweet potato weevils (Munyiza *et al*., 2007). Gairo District is dominated by clay soils characteristized by extensive cracking during the dry season or in period of intermittent drought during the growing season which enables weevil entrance down the soil. This phenomenon was not observed in Ikungi District which is dominated by sandy soils. Munyiza *et al*. (2007) reported high infestation levels recorded under dry conditions due to many cracks associated with drying of soils. Ashebir (2006) reported that the extent of yield loss was high towards the dry season due to low soil moisture, low biomass yield and high soil cracks. The pest is particularly serious under dry conditions (in clay loam soil) because the insect can reach the roots more easily through the cracks that appear as the soil dries out.

Results on root damage severity revealed that villages in Gairo District had higher damage severity than that of Ikungi District. The high damage was attributed to high population of weevils or have weevil species which were highly destructive. Some weevil species have been reported highly destructive than others in the same area. *Cylas forimicarius* is one of the most destructive pests of sweet potato worldwide (Sefasi *et al.*, 2012). Its presence even in small number is viewed as economically important and warrant intensive management (Rees *et al.*, 2001). The lowest infestation of villages of Ikungi District as up to zero incidence may be attributed to local variety namely Gudugudu which is highly planted. The variety does not expose roots above the soil surface. Tesfaye, (2002) reported that, varieties with deeper roots suffer less from the attack of weevils compared to shallow rooted ones.

2.6 Conclusion

Sweet potato weevil infestation and damage to both roots and vines were observed to be a key problem in sweetpotato production in the study areas. Nature of damage to both root and vines and observed insect specimen suggest that the species available in the area is *Cylas spp*. Infestation and damage magnitude were noted to differ in the two Districts. The study concluded that Gairo District has high weevil (*Cylas spp*) infestation than Ikungi Distict irrespective of local varieties considered during survey. The higher infestation and damage incidence may have resulted from the large number of the weevils in the area. The evidence of level of infestation and damage incidences concluded high population distribution of pest in Gairo District than in Ikungi District.

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CHAPTER THREE

3.0 EFFECT OF PLANTING TIME ON SEASONAL ABUNDANCE OF THE SWEET POTATO WEEVIL IN CENTRAL TANZANIA

3.1 Abstract

The sweet potato weevil (*Cylas spp*) is among constraints that cause low productivity of sweetpotatoes. An experiment was conducted in Gairo and Ikungi Districts of Morogoro and Singida Regions of Tanzania, respectively, to determine effects of planting time on weevil's seasonal spread and abundance. Vines obtained from a planting materials nursery were planted in the field on month of December, January and March on prepared beds at an equidistance of 30 cm with the 2/3 of the lower portion of the vine burred in the soil about 10cm deep. To determine temporal abundance and spread of sweetpotato weevils during the growing season five litre-gallon bait traps were placed in each of the experimental plots hanging with a stick for adult weevil capture. The traps were empted in two weeks interval for the captured insects count. Field management and data collection were done throughout the growing season. Based on physical characteristics one weevil species, *Cylas puncticollis*, was identified, that occurred in almost all areas where the experiments were established. The pest occurrence was observed to be affected by alternation of planting dates. Vines damage were observed to increase toward harvest.

Keywords: Planting date, abundance, *Cylas puncticollis*, Seasonality, Weevil trapping.

3.2 Introduction

Sweetpotato is considered as one of the most important primary crops in Africa and plays a significant role in the global food system (FAOSTAT, 2015). Its production and utilization is often considered as a means to ensure food security and generate some income among the poorer segment of the rural population (Low *et al*., 2009). In Tanzania, sweetpotato is the second-most important root crop after cassava (Kulembeka and Masumba, 2005). It contributes significantly to livelihoods of many households. Production and productivity of the crop is however, affected by a number of constraints including diseases, insects and vertebrate pests, weed infestation, soil nutrient deficiencies, poor crop husbandry practices and socio-economic factors (Smit and Matengo**,** 1995). Of these, insect pests are considered the most limiting, with the *Cylas spp*. complex being the most widely distributed and destructive group (Chalfant *et al*., 1990). *Cylas puncticollis* is especially one of the most important biotic factors limiting sweet potato production in Africa, notably in East Africa (Fite *et al.*, 2014; Kapinga *et al.*, 1997).

The insect damages vines, roots and occasionally the foliage, reducing both yield and quality of the crop. Some control practices like chemical and biological controls are ineffective due to the cryptic feeding nature of the pest (Dotaona *et al*., 2015). The sweet potato weevil infestations can lead to losses in crop yield of up to 50% (Andrade *et al*., 2009). Losses can be severe both in storage facilities and in the field, where yield losses due to the weevil may be as high as 60 to 97% (Reddy *et al.*, 2012; Shonga *et al.*, 2013). Crop loss due to sweet potato weevils may however, vary from place to place, time to time, variety to variety and even at different stages of the crop phenology. Yield loss is high towards the dry season due to low soil moisture, low biomass yield and high soil cracks (Shonga *et al.*, 2013). The weevils are widely dispersed in tropical regions of the world. Their management is a key issue faced by farmers in major sweetpotato producing countries. The weevils are generally nocturnal, although may also fly in response to a pheromone source (Reddy *et al.,* 2012) and be found on *Ipomoea* plants during daytime. Adult weevils fly freely during the warm part of the year and are capable of ranging at least 1.6 kilometer per season (Hue and Low, 2015).

It is not well established of cropping system may in some extent favor or deter weevil dispersal from one field to another. The essence of using different system in this study was to trace and document the weevil dispersal within and across field such that understanding of the promising system of the weevil dispersal would help to counteract their infestation rate.

The simplest method for management of SPW in farmer field in developing countries is earthing-up. The method prevents exposure of tubers to weevil infestation by thickening the soils around the roots and filling up the soil cracks, so that the adult weevil cannot reach tubers to cause damage (Emana, 1990; Fite *et al.*, 2014). This method has been found difficult to apply in normal management for local varieties which trail long distance and cover three to four beds. There is a need to establish altenative management methods for the SPW. The unavailability of comprehensive report on the sweetpotato weevil species and its seasonal occurrence in central Tanzania largely affects decisions and strategies on SPW management. Thus, this study was conducted in order to establish the effect of planting time on seasonal abundance of SPW in central Tanzania upon which management strategies would be based.

3.3 Materials and Methods

3.3.1 Location of study area

The study was conducted in Gairo and Ikungi districts, Morogoro and Singida regions respectively. Gairo District lies on the geographical co-ordinates of 06° 08′S, 36° 52′ E and Ikungi District on 05° 08′S, 34° 46′ E. These Districts were selected because they are of high production of sweetpotato in central Tanzania. The areas are characterized by predominantly unimodal rain (average annual range of 400 to 800 mm) followed by prolonged dry spell of five to six months. Gairo district is a hill (class T-Hypsographic) located at an elevation ranging between 1230 and 1370 meter above sea level (masl), with maximum temperature of about 22^0C (Rees *et al.,* 2001) and the soil is predominantly highly weathered red clay soil that tend to crack when dry. Ikungi is almost flat with slightly slopping elevation of 1540 masl (District economic profile, 2016).

3.3.2 Establishment of Experiment

The experiment was set in a spilt plot laid out in RCBD. Treatments were varieties (Main plot) and time of planting (Sub plot) with three replication. Variety treatments were Simama, Gudugudu, Mataya and Polista. Time of planting treatments were early (December), mid (January) and late (March). Experimental layout and size of entire experimental plot attached in Appendix 2. Planting materials were obtained from SUA crop museum. Tip cuttings of about 30 to 40 cm long with approximately eight nodes were collected from the nursery beds. Tip cuttings were taken from crops that are old enough 2.5 months. Cuttings were kept under a moist cloth in the shade for five days to promote nodal rooting before planting in the field. Vines were planted on bed at an equidistance of 30 cm with the 2/3 of the lower portion burred in the soil at about 10cm deep. Each bed was 40 cm high, 1 m wide by 3 m long and 50cm from one bed to another. Bed preparation was done one week before planting. Recommended field management practices inclusive of weeding and earthing up were adhered to. Planting was done sequentially starting from December, January and March (early, mid and late rainy planting seasons). Harvesting was done after four months from planting date (CIP recommendation, 2013).

3.3.3 Weevil trapping

Trapping of weevils throughout the growing season was done adhering to the CIP trap design (CIP, 2013). Immediately after planting, five litre-gallon bait traps were placed in each of the experimental block (one trap per plot) (Figure 3.1). This is modification of CIP trap of three litre gallon which sometimes were filled with water when it rained for long time consequently flashed out the trapped weevils (Figure 3.1).

Figure 3.1: Sweetpotato weevil three litre gallon (A) and modified traps (B)

The traps were randomly placed in experimental plot, hanging in a stick and the sticks forced down the soil for ease of holding. To avoid escape, the traps were half filled with water and 100g of 7 days fermented sweetpotato was used as a lure material. Trapped adult weevils were collected once every two weeks. Captures of sweetpotato weevils in traps was done throughout the growing season. One trap per plot was set and considered to be optimum for effective weevil capture.

3.3.4 Data collection and analysis

Data collected were number of adult weevils caught in traps per planting date and number of vines damage throughout the growing season. Data on weevil counts was transformed using square root transformation for normality. Data were subjected to the analysis of variance (ANOVA) basing on statistical model of split plot design ($Yijk = \mu + \beta i + Aj + \delta ij + Bk + ABik + \varepsilon ijk$ = Output; where μ=General mean, βi=Block effect, A and B= Factor A and B respectively, δij= Error A main plot error and εijk = Error B (sub- plot) random error effect) and means comparison were done using Least Significant Different test at $P \leq 0.05$ significance using Gen-Stat statistical package.

3.4 Results

3.4.1 Effect of planting time on weevil occurrence

Results revealed that planting time has influence on occurrence and dispersal of the sweet potato weevil in the field. Average trappings of weevils were found to vary significantly between the months of assessment (Figure 3.2). Results showed the average number of trapped weevils to be significantly highest in March planted than December planted crop. The average number of weevils trapped in the month of January was intermediate and did not significantly differ from average number of weevils trapped for December and March.

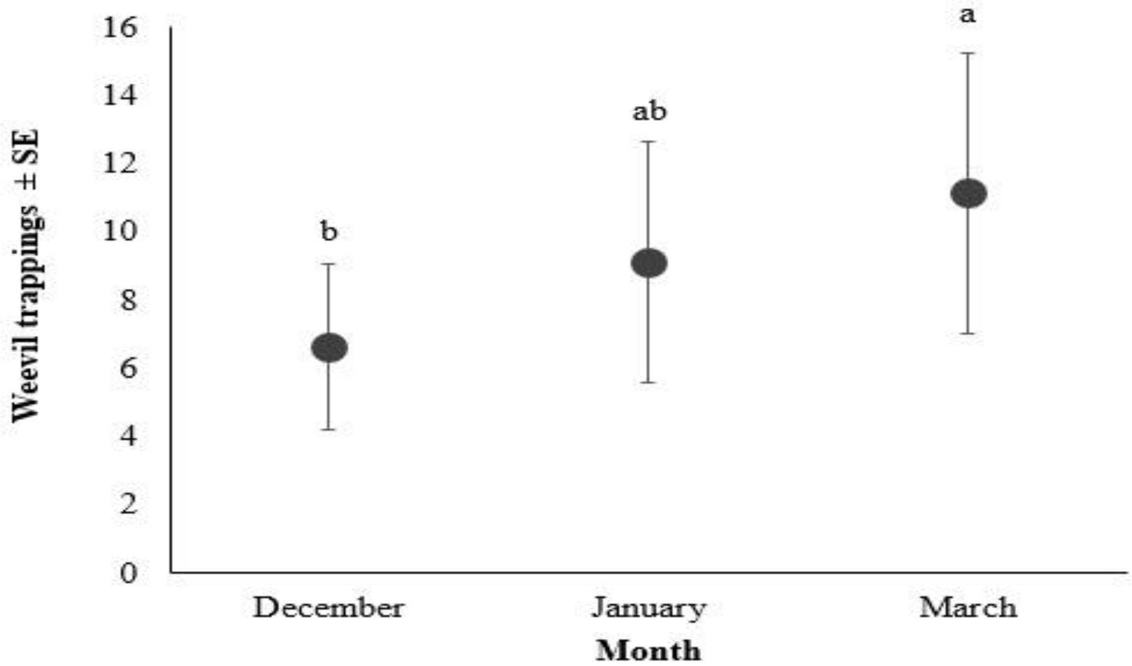

Figure 3.2: Number of weevils trapped at different times of planting. Mean points with different letters as data labels are significantly different by Tukeys' HSD test.

3.4.2 Sweetpotato weevil populations in relation to the time of planting

The population of adult weevils increased along the growing season in both Gairo and Ikungi District for combined and separate analysis (Figure 3.3 and Table 3.1). Some decrease was observed at the end of February and early March in separate analysis for both Gairo and Ikungi Disticts. It however increased again from March to July. The highest density was captured in May in Gairo District while in Ikungi the pick capture was in July. Planting date was recorded to have influence on weevil occurrence (Figure 3.3). *S*weetpotato weevil was at greater abundance in Gairo District than in Ikungi District (Figure 3.4).

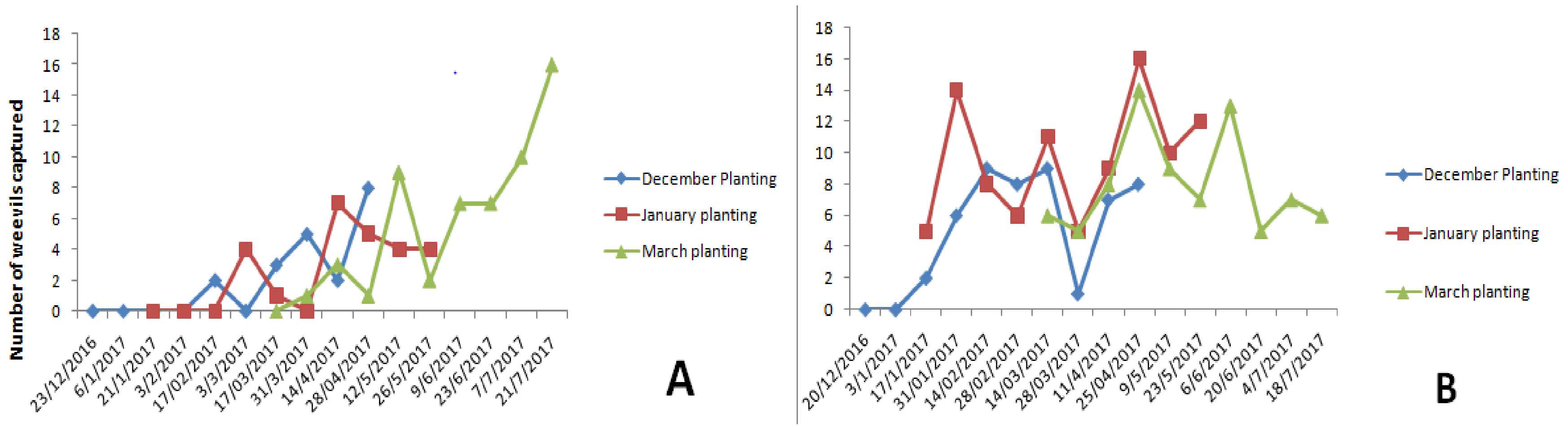

Figure 3.3: Adult weevils captured over the growing season in Ikungi (A) and Gairo (B) Districts

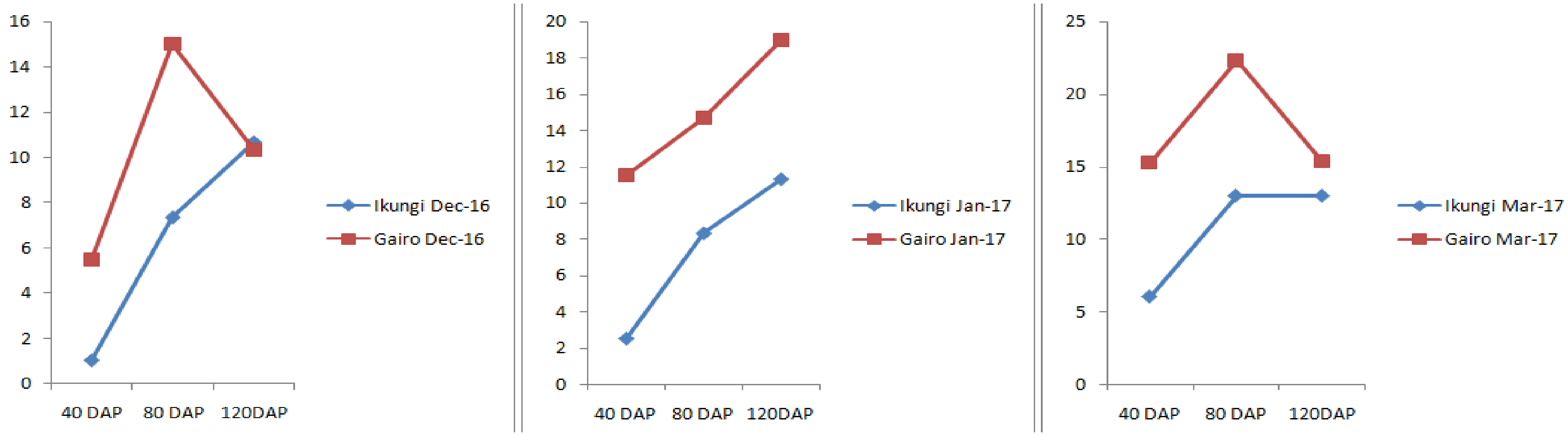

Figure 3.4: Weevil abudance in different times of planting

3.3.3 Species composition in the study area

The results showed that one specie, *Cylas puncticollis* was the only one occuring in central Tanzania (Table 3.1). The highest number of weevils were collected from Madege village of Gairo District. Only a few weevils were collected from Kimbwi village of Ikungi District. Table 3.1 shows the comparative number of *Cylas* species found in the various locations. Distinctive contrasting characteristics of the *spp* were black in colour, slender and their antennae are straight.

Table 3.1: Composition of weevil species in the study area

District	**Village**	***Cylas* species present**		
		puncticollis	*brunneus*	*formicarius*
Gairo	Madege	69	Nil	Nil
	Malimbika	60	Nil	Nil
Ikungi	Siuyu	21	Nil	Nil
	Kimbwi	15	Nil	Nil
	Total	**165**	**Nil**	**Nil**

3.4.4 Sweetpotato vines damage over the growing season

Table 3.2 shows the results on vines damage throughout the growing season. Simama and Polista were observed to have more vines damage in all interval observation. Gudugudu seems to be tolerant variety to weevil damage. Again, vines damage signs were observed to increase as the crop stayed in the field. March planted crop were having more vines damage signs than the rest of planted crop. Combination of variety and planting time were noted to have influence on vines damage. December planting and Gudugudu variety seems to have less damage while March planting and Simama variety mark the highest damage.

Table 3.2: Vines damaged throughout the growing season both in Gairo and Ikungi Districts

Treatments	Number of vines damaged		
	40 DAP	**80 DAP**	**120 DAP**
Gudugudu	0.0833	0.5	1.417
Mataya	0.4167	1.25	2.75
Polista	0.8333	2.167	3.25
Simama	0.9167	2.083	4.583
LSD $_{0.05}$	ns	0.974	1.632
CV%	82.4	33.6	49.7
SE±	0.363	0.478	0.802
P value	0.097	0.004	0.004
December	0.0625	0.438	1.438
January	0.4375	1.688	3.375
March	1.1875	2.375	4.188
LSD $_{0.05}$	0.639	0.843	1.413
CV%	157.9	78.1	65.5
SE±	0.314	0.414	0.694
P value	0.004	<.001	0.001
Gudugudu* December	0	0.5	1
Gudugudu* January	0	0.5	1.25
Gudugudu* March	0.25	0.5	2
Mataya *December	0.25	0.5	1.25
Mataya* January	0.25	1.25	3
Mataya* March	0.75	2	4
Simama *December	0	0.25	2.25
Simama* January	0.5	2	5
Simama* March	2.25	4	6.5
Polista *December	0	0.5	1.25
Polista *January	1	3	4.25
Polista *March	1.5	3	4.25
LSD $_{0.05}$	ns	ns	ns
SE±	0.628	0.829	1.389
P value	0.283	0.064	0.693

3.5 Discussion

Planting time noted to have influence on weevil occurrence and spread. Results revealed that more weevil occur during late planting. Possible reasons may be availability of alternative host as succession effect from previous planting. This concurs with the study by Emana (1990) who reported more weevil damage and occurrence on late planted fields. Lower weevil occurrence in December and January may be due to high moisture as result of more rain in that particular period which prevented soil from cracking. Soil cracks foster entrance of weevil down the soil. This concurs with the study by Kapinga *et al.* (1997) which reported that the intensity of sweetpotato weevil infestation varies between wet and dry seasons. The weevil caused economic damage in areas with a marked dry season.

From weevil capture results at different time of planting only one species, *Cylas puncticollis* was occuring in area. *Cylas puncticollis* was at greater abundance and caused severe damage in Gairo District than in Ikungi District. This species has been reported to be native to Africa in previous studies (Wolfe, 1991). *Cylas brunneus* is also known to be existent in East Africa (Okonya *et al*., 2016) but appears to be absent in central Tanzania. The absence of this species in the study area suggests that it prefer more stable conditions and may also have problems to colonize, disperse, or survive in areas with diverse temperature variation. Musana *et al*. (2013) reported that *Cylas brunneus* is highly sensitive to extreme temperatures and cannot develop, survive or reproduce at temperature conditions less than 15°C and above 35°C. The optimal temperature conditions for development and fecundity occur between 25°C and 30°C. Okonya and Kroschel (2013) reported presence of both *Cylas puncticollis* and *Cylas brunneus* at high altitude (2400 masl) in Kabale District in Uganda and concluded that a possible geographical shift by the weevil to higher altitudes could have occurred due to global warming. The occurrence of *Cylas puncticollis* in all fields where experiments were conducted in the current study suggests that the species is very versatile and highly adapted to all different types of environments in central Tanzania. Observation of decrease in trend of weevil captures may have resulted from mating activity and dormant stages exist as result of unfavorable condition. These findings are similar to the study by Smit and Van Huis (1999) who reported that *Cylas puncticollis* with longer oviposition rate can survive in extended periods when oviposition sites are not available and then resume egg laying when conditions improve. Again, considering weevil captures trends December was not a promising planting time for both locations. It has higher weevil capture even at harvest. To be in safe side as this planting your better harvest one month (three month after planting) before recommended one (four month). Late harvest may cause more weevil infestation. This is in agreement with the study by Emana (1990) which reported that level of infestation could increase from 29 to 68 % when harvesting was delayed from five to six months.

Vine damage was increasing with planting dates as the early planted crop sustained lower damages compared to the later planted crop. The reason may be high multiplication rate due to availability of alternative host from other plots. This is in agreement with the study by Shonga *et al.* (2013) who reported on the effect of field distance on weevil occurrence. Sweet potato plots belonging to the same farmers or neighbors' are located immediately next to the older plots, which create conducive conditions for continued infestation by the sweet potato weevil. Therefore neighboring infested sweetpotato fields and left over infested sweet potato tubers are the most important source of infestation for newly planted sweetpotato plots.

Considering varieties under study, magnitude of weevil vine damage was observed to differ among varieties planted. Simama variety was severely damaged followed by Polista, Mataya and Gudugudu. This may have resulted from gene variation. This concur with the study by Emana, (1990) which verified that level of resistance of Koka-26 and Cemsa varieties tested in Areka fields was a result of genotype variation. Shonga *et al.* (2013) reported that there are no resistant varieties to the sweet potato weevil although varieties differ in the degree of damage and infestation by the pest.

3.6 Conclusion

Planting dates were noted to have influence on seasonal abundance of SPW subsequently captured in the crop fields in central Tanzania. December (early) planting, the main rainy season was noted to encounter low weevil infestation. Again weevil population built up across the sites were increasing towards the end of season where the more the increase the more the vines damage. Among the study sites Gairo District had more SPW infestation than Ikungi District. Varieties under study also were found to vary in damage magnitude. Simama and Polista are more vulnerable to SPW attack than Mataya and Gudugudu.

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CHAPTER FOUR

4.0 SWEETPOTATO YIELD LOSSES ASSOCIATED WITH WEEVIL INFESTATION

4.1 Abstract

Sweet potato weevil, *Cylas puncticollis* is a major threat to sweetpotato in Sub-Saharan Africa. The pest can devastate sweetpotato fields, leading to total crop loss. Field experiments were conducted in two Districts: Gairo and Ikungi in Morogoro and Singida Regions of Tanzania, respectively, to determine yield losses associated with the weevil infestation. Planting was done sequentially (early, mid and late) in December, January and March respectively after land preparation. Field management practices including weeding and earthing up were performed accordingly. Harvesting was done after four months from planting date. Interaction of planting date and variety gave superior yield in December planting due to lowest weevil infestation. High weevil infestation and yield loss were recorded in late planting (March) almost in all the studied varieties. Simama variety was observed to be highly susceptible to weevil infestation followed by Polista, Mataya and lastly Gugugudu. Despite having the higher infestation, both January and March plantings gave the highest root weight for Simama variety. Due to significant $P \leq 0.05$ weevil infestation and damage noted during the study, integrated pest management programs are highly needed against the sweet potato weevil in central Tanzania for sustainable production of the crop.

Key words: Central Tanzania, *Cylas puncticollis,* planting date, sweet potato weevil, varieties.

4.2 Introduction

The sweetpotato (*Ipomoea batatas* L.) is an important food security crop in East Africa (Stathers *et al.*, 2013; FAO, 2011) in general and central Tanzania in particular (Kisetu and Honde, 2014). The crop is grown in almost all agro-ecological zones of Tanzania (Kapinga *et al*., 1997) especially for household food requirements and also for cash. The crop provides a healthy diet for millions of people in African countries (Gurmu *et al*., 2015). Currently the crop ranks the seventh most important crop in the world with a total production of 103 million tons in 2013 (FAOSTAT, 2015). The crop productivity in Tanzania is, however extremely low, estimated at 9.5tha^{-1} (FAOSTAT, 2015) compared to the International potential of 20–50 tha^{-1} (Benjamin *et al.,* 2014). Sweetpotato has high content of β-carotene, which can be converted by the body to vitamin A. Moreover, orange-fleshed sweetpotato is a good source of vitamin A (Low *et al*., 2009). It is a rich source of starch, contains proper amount of secondary metabolites and small molecules that play an important role in various processes (Low *et al.*, 2009). It is usually eaten cooked but can also be processed as a snack food and for animal feed. Sweetpotato is, rich in energy, dietary fibre, biologically active phytochemicals, vitamins and minerals which render it good functional food ingredient (Brinley *et al.,* 2006). The β-carotene fortified orange-fleshed varieties are used to combat vitamin A deficiency and hence blindness in children. These distinctive capabilities classify sweetpotato as a food and nutrition security crop (Kivuva *et al.*, 2014).

In spite of its importance, increase and sustainable production of sweetpotato is seriously hampered by the sweet potato weevil (Andrade *et al*., 2009), which is seemingly the most serious menace to the production of the crop. Most of other insect pests' damage to sweet potato is often cosmetic and not yield reducing (Temesgen *et al.,* 2000). Yield losses caused by weevils, on the other hand, have been estimated to range from 15% to 73% in Tanzania and Uganda (Kapinga *et al*., 1997; Smit, 1997). The sweet potato weevil larvae and adults feed on the roots, causing extensive damage, both in field and during storage and transit handling. Weevil damage produces quantitative losses and aesthetically unappealing roots which may be discolored with bitter taste. The weevil stimulates production of phenolic compounds which cause brown discoloration of the flesh (Wolfe, 1991).

Shonga *et al*. (2013) reported that different planting dates have effect on weevil infestation. Higher tuber infestation was obtained from the late plantings among series of planting dates (Tesfaye, 2002). Information on possibility of escape from weevil damage using different planting dates is still lacking in central Tanzania despite the pest being endemic. The zone is dominated by small scale resource-poor farmers and sweetpotato is currently considered a high value crop grown as staple and for income generation. This underscores the importance of seeking for effective, low-cost and eco-friendly sweet potato weevil management methods. This research was initiated with aim to control sweet potato weevils by using a combination of planting date as an escape mechanism and select varieties which are less susceptible to weevil infestation; as appropriate, resource poor farmer friendly strategies to combat the weevil.

4.3 Materials and Methods

4.3.1 Location

The study was conducted in Gairo and Ikungi Districts of Morogoro and Singida Regions respectively, between December 2016 and July, 2017. Gairo District lies on the geographical co-ordinates of 06° 08′ South and 36° 52′ East and Ikungi District on 05° 08′

South and 34° 46′ East. These Districts were selected because they are of high production of sweet potato in central Tanzania. The areas are characterized by predominantly unimodal rain (average annual range of 400 to 800 mm) followed by prolonged dry spell of five to six months Gairo District is a hill (class T-Hypsographic) located at an elevation ranging between 1230 and 1370 meter above sea level (masl), with maximum temperature of about 22^0C (Rees *et al.,* 2001) and the soil is predominantly highly weathered red clay soil that tend to crack when dry. Ikungi is almost flat with slightly slopping elevation of 1540 masl (District economic profile, 2016).

4.3.2 Experimental design

An experiment was set on with varieties as main plots and time of planting as subplots in a RCBD in spilt plot layout with four replications. Four sweetpotatoes varieties (Gudugudu (local var. Singida), Simama (local var. Morogoro), Mataya and Polista) were used in the study. As per this study local variety in the area was treated as control while the other three were treated as introduced ones. Planting date were December (early), January (mid) and March (late). The choice of these 4 varieties was based on origin, diversity and adaptabilities within the two sites (Gairo and Ikungi). A nursery was established at SUA crop museum to multiply the planting materials before the start of growing season.

Tip cuttings of about 30 to 40 cm long with approximately eight nodes were collected from the nursery bed. The cuttings were taken from crops that were old enough (2.5 months) to provide planting material without affecting the crop growth. The cuttings were kept under a moist cloth in the shade for five days to promote nodal rooting before planting in the field. Vines were planted on beds at an equidistance of 30 cm with the 2/3 of the lower portion buried in the soil at about 10cm deepth. Each bed was 40 cm high, 1 m wide by 3 m long and 50cm from one bed to another. Bed preparation was done one week before planting.

Planting was done sequentially in December, January and March (respectively early, mid and late rainy season planting). Recommended field management practices inclusive of weeding and earthing up were adhered to.

4.3.3 Data collection and analysis

Harvesting was done after four months from planting date (CIP recommendation). Observation on vines and roots damaged at harvest were recorded. Comparison on level of infestation per variety at different planting times was done by separating marketable and non marketable roots. Yield of each variety was assessed despite infestation, using a weighing balance.

Sweetpotato weevil severity on both above ground and below ground was recorded by using a scale of 1 = 0%; 2 = 1 – 15%; 3 = 16 – 50%; 4 = 51 – 65%; 5 = 66 – 100%. Consequently, “category 1” was assigned to vines and roots that were not damaged, “category 2: slightly damaged;” Category 3: moderately damaged”, “category 4: high damage” and “category 5: very high damage”. The scale used was according to the protocol of Rees *et al.* (2001) with slight modifications on categories 2 and 5 to have more un-biased rating on small roots, to accommodate variation in roots to tested varieties and to allow wide range of damage severity scores.

Data were collected on number of roots harvested, number of damaged roots (scoring according to Rees *et al*., 2001 with modification), number of marketable roots, number of vines with crown damaged, weight of damaged and non damaged roots. Data were subjected to the analysis of variance (ANOVA) basing on statistical model of split plot design ($Yijk = \mu + \beta i + Aj + \delta ij + Bk + ABik + \varepsilon ijk$ = Output; where μ=General mean, βi=Block effect, *A* and *B*= Factor *A* and *B* respectively, δij= Error A main plot error and εijk = Error B (sub- plot) random error effect). Means comparison was perfomed using Least Significant Different test at $P \leq 0.05$, $P \leq 0.01$, and $P \leq 0.001$ significance, using Gen-Stat statistical package.

4.4 Results

4.4.1 Sweetpotato yield and yield loss as a result of sweetpotato weevil infestation

Yield loss parameters considered during this study include percent root damage incidence, weight of roots (harvested, damaged and discarded) in tha^{-1} and yield loss in percentage. Responses of all parameters in both separated and combined analysis results are summarized in Table 4.1. At different statistical tests some varieties under the study and varying planting dates were observed to influence yield loss.

Table 4.1: Analysis of variance summary for yield loss parameters as a result of sweetpotato weevil infestation

Sources of variation	Df	Sum of squares					
		Vine damage incidence %	Root damage incidence %	Weight of roots harvested (tha^{-1})	Weight of roots damaged (tha^{-1})	Weight of roots discarded (tha^{-1})	Yield loss %
Ikungi District							
Replication	1	1446.1	536.86	45.53	6.292	0.15218	5.376
Variety	3	1414.7	2573.93*	62.13	27.632	0.69741*	39.204*
Error A	3	451.7	94.59	17.46	8.141	0.22062	3.555
Planting dates	2	1571.9*	3568.94***	33.22	50.658*	1.28096**	84.685**
Variety *Planting dates	6	834.4	405.96	54.26	3.225	0.20164	23.563
Error B	8	914.8	734.72	162.15	30.2	0.58547	24.709
Total	**23**	**6633.6**	**7915.01**	**374.74**	**126.148**	**3.13827**	**181.093**
Gairo District							
Replication	1	1039.7	38.4	17.99	10.593	0.16667	1.28
Variety	3	654.8	1644.7	131.06*	99.47*	5.04029*	200.298*
Error A	3	467.5	385.7	13.95	0.331	0.06251	7.356
Planting dates	2	708.1	1092.1*	48.97	45.346**	2.00507**	72.941***
Variety *Planting dates	6	654.8	213	39.5	15.436	0.60974	69.365
Error B	8	880	886.9	156.56	17.658	0.78848	12.489
Total	**23**	**4404.9**	**4260.8**	**408.02**	**188.833**	**8.67276**	**363.729**
Combined							
Replication	3	2984.7	1890.6	71.99	40.018	1.94852	85.445
Variety	3	1831.3*	3966.4*	169.64**	93.188**	3.90504*	155.122*
Error A	9	1157.4	732.6	54.95	42.385	2.11578	95.291
Planting dates	2	1853.8**	3775.4***	80.91	94.889***	3.22817***	148.086***
Variety *Planting dates	6	413.4	284.7	54.72	11.796	0.68206	75.546*
Error B	24	3296.8	2841.5	359.02	55.838	1.56113	64.121
Total	**47**	**11537.3**	**13491.2**	**791.24**	**338.114**	**13.4407**	**623.61**

*Significant at 0.05 ** Significant at 0.01 *** Significant at 0.001

4.4.2 Effect of varieties on yield loss due to weevil damage

Effect of varieties on yield loss due to weevil damage is summarized in Table 4.2. Influence of variety to weevil damage was significantly different in separate analysis for three parameters of yield loss in Ikungi and Gairo Districts (Table 4.2 and 4.3). Combined result on varieties response to weevil infestation indicated that damage magnitude was higher in Simama variety and low in Gudugudu variety (Table 4.4). Generally, results also showed that Simama variety was highly susceptible to weevil infestation followed by Polista and Mataya while Gudugudu was tolerant (less susceptible).

Table 4.2: Effect of varieties on yield loss due to weevil damage of sweet potatoes (*Ipomea batatas*) in Ikungi District

Varieties	Vine damage incidence (%)	Root damage incidence (%)	Weight of roots harvested (tha^{-1})	Weight of roots Damaged (tha^{-1})	Weight of roots discarded (tha^{-1})	Yield loss (%)
Gudugudu	3.57	7.63	9.48	1.178	0.0759	0.8
Mataya	15.46	9.37	10.33	1.857	0.237	2.29
Simama	25.46	18.35	13.78	3.235	0.4593	3.33
Polista	13.15	33.77	11.29	3.520	0.4944	4.38
Mean	14.14	17.3	11.22	2.72	0.317	2.7
P value	0.043	0.011	0.162	0.101	0.025	0.04
SE±	5.01	2.29	1.343	0.951	0.1566	0.44
CV%	49.4	18.8	91.8	35	49.4	24.8
$LSD_{0.05}$	14.16	10.38	ns	ns	0.2669	2.00

Table 4.3: Effect of varieties on yield loss due to weevil damage of sweet potatoes (*Ipomea batatas*) in Gairo District

Varieties	Vine damage incidence (%)	Root damage incidence (%)	Weight of roots harvested (tha^{-1})	Weight of roots damaged (tha^{-1})	Weight of roots discarded (tha^{-1})	Yield loss (%)
Gudugudu	14.11	15.99	8.26	2.08	0.25	3.03
Polista	24.40	28.32	12.35	3.16	0.43	3.48
Mataya	17.48	27.31	13.06	3.71	0.62	4.75
Simama	27.15	39.38	14.57	7.49	1.44	9.88
Mean	20.8	27.7	12.06	4.11	0.685	5.29
P value	0.394	0.023	0.049	<.001	0.002	0.011
SE±	7.21	6.55	1.25	0.14	0.06	0.9
CV%	34.7	23.6	10.3	22.9	17.2	17.7
$LSD_{0.05}$	ns	13.67	5.003	1.625	0.3534	1.707

Table 4.4: Combined effect of varieties on yield loss due to weevil damage of sweet potatoes (*Ipomea batatas*) in Gairo and Ikungi Districts

Varieties	Vine damage incidence (%)	Root damage incidence (%)	Weight of roots harvested (tha^{-1})	Weight of roots damaged (tha^{-1})	Weight of roots discarded (tha^{-1})	Yield loss (%)
Gudugudu	8.84	11.81	8.87	1.70	0.16	1.80
Mataya	16.47	18.34	11.69	2.89	0.43	3.68
Polista	18.78	23.34	11.82	3.53	0.46	3.89
Simama	26.16	36.58	14.18	5.54	0.95	6.70
Mean	17.6	22.5	11.64	3.41	0.51	4.02
P value	0.03	<.001	0.004	0.012	0.02	0.028
SE±	3.35	4.25	1.45	0.71	0.19	0.94
CV%	51.9	32.2	12.1	36.7	46.4	40.4
$LSD_{0.05}$	9.23	8.21	2.648	1.290	0.2495	1.826

4.4.3 Effect of planting date on yield loss due to weevil damage

Results show that yield loss for the various planting periods differed significantly ($P \leq 0.05$) both in combined and separate analyses results. Late planting was observed to have high weevil infestation than early and mid in both Gairo and Ikungi Districts (Table 4.5 – 4.7). Generally, level of weevil infestation was high on sweet potato roots during late planting. In terms of yield, late planting were observed to have more yields regardless of varieties under study.

Table 4.5: Effect of planting date on yield loss due to weevil damage in Ikungi District

Planting dates	Vine damage incidence (%)	Root damage incidence (%)	Weight of roots harvested (tha^{-1})	Weight of roots damaged (tha^{-1})	Weight of roots discarded (tha^{-1})	Yield loss (%)
December	5.38	5.5	10.04	1.447	0.1028	1.02
January	12.64	12.62	10.79	1.958	0.2097	1.95
March	24.99	24.88	12.83	4.753	0.6375	4.97
Mean	14.3	17.3	11.22	2.72	0.317	2.65
P value	0.018	<.001	0.475	0.019	0.01	0.003
SE±	3.78	3.39	2.251	0.971	0.1353	0.621
CV%	74.6	55.5	40.1	71.4	85.4	69.4
$LSD_{0.05}$	12.00	8.99	ns	1.485	0.2312	2.03

Table 4.6: Effect of planting date on yield loss due to weevil damage in Gairo District

Planting dates	Vine damage incidence (%)	Root damage incidence (%)	Weight of roots harvested (tha^{-1})	Weight of roots damaged (tha^{-1})	Weight of roots discarded (tha^{-1})	Yield loss (%)
December	13.19	18.21	10.88	2.614	0.38	3.49
January	25.61	32.68	11.24	3.778	0.61	5.43
March	23.55	32.36	14.07	5.932	1.07	7. 60
Mean	20.8	27.7	12.06	4.11	0.69	5.51
P value	0.094	0.04	0.337	0.006	0.006	<.001
SE±	5.24	5.26	2.21	0.53	0.11	0.63
CV%	50.5	37.9	36.7	4.7	12.2	24.5
$LSD_{0.05}$	ns	11.84	ns	1.407	0.3061	1.478

Table 4.7: Combined effect of planting date on yield loss due to weevil damage both in Gairo and Ikungi Districts

Planting dates	Vine damage incidence (%)	Root damage incidence (%)	Weight of roots harvested (tha^{-1})	Weight of roots damaged (tha^{-1})	Weight of roots discarded (tha^{-1})	Yield loss (%)
December	9.29	11.32	10.46	2.03	0.24	2.29
January	19.12	23.21	11.01	2.87	0.41	3.72
March	24.27	33.01	13.45	5.34	0.85	6.32
Mean	17.6	22.5	11.64	3.41	0.501	4.11
P value	0.005	<.001	0.087	<.001	<.001	<.001
SE±	2.9	3.68	1.25	0.61	0.09	0.41
CV%	37.3	23.1	30.4	50.5	55.9	49.3
$LSD_{0.05}$	7.99	7.11	ns	1.117	0.2161	1.581

4.4.4 Interaction effects of planting dates and Varieties on yield loss

There was no significant difference on storage root yield loss in combined analysis and Ikungi District in interaction of variety and planting date at $P \leq 0.05$. Some significant effects were observed in Gairo District (Table 4.8). Combination of Gudugudu and early planting was observed to have low yield loss due to weevil infestation whereas Simama variety and mid planting were noted to have higher yield loss. The planting done during the rainy season (December) were noted to have lower storage roots damage compared to the highest damage recorded during January to March for all varieties except Gudugudu variety in mid (January) planting. Generally results show that varieties Simama and Polista are susceptible while Mataya and Gudugudu are tolerant to weevil infestation irrespective of the planting dates (Table 4.8). December planting recorded low infestation for all varieties.

Table 4.8: Effects of different planting dates and Varieties of sweet potato on yield loss in Gairo District

Treatment combination	Vine damage incidence (%)	Roots damage incidence (%)	Weight of roots harvested (tha^{-1})	weight roots damaged (tha^{-1})	Weight of discarded roots (tha^{-1})	Yield loss %
December* Mataya	7.47	8.34	11.33	2.08	0.28	2.47
December *Polista	8.41	12.15	11.67	2.31	0.17	1.46
December* Simama	14.33	22.37	14.22	5.51	1.06	7.45
December *Gudugudu	6.94	2.44	6.28	0.56	0.01	0.16
January *Mataya	18.16	18.75	11.44	3.12	0.48	4.20
January *Polista	23.61	27.54	13.39	1.72	0.12	0.90
January *Simama	27.78	38.50	11.72	6.94	1.39	11.86
January *Gudugudu	6.94	8.04	8.39	3.33	0.44	5.24
March *Mataya	23.78	27.92	16.39	5.92	1.11	6.77
March *Polista	24.31	30.31	12.00	5.44	0.99	8.25
March *Simama	36.36	48.87	17.78	10.00	1.89	10.63
March *Gudugudu	12.63	24.95	10.11	2.36	0.29	2.87
Mean	17.6	22.5	12.06	4.11	0.685	5.19
P value	0.801	0.871	0.899	0.409	0.47	0.006
SE±	66.7	48.3	2.702	0.868	0.1906	1.363
CV%	5.81	7.36	36.7	36.2	45.8	24.5
$LSD_{0.05}$	ns	ns	ns	ns	ns	3.162

4.4.5 Correlation of yield and yield loss components associated with weevil's infestation

Table 4.9 presents correlation of mean yield and yield loss components with weevil infestation incidence and severity in the study area. Yield loss was observed to correlate positively or negatively with other yield loss parameters. Positive correlation indicate the loss is influenced by that parameter while negative correlation notifying that the parameter does not influence yield loss. Yield loss was strongly positively correlated with severity damage category five, (r = 0.617***), weight of root damaged (r = 0.880***), weight of root discarded (r = 0.923***) and was strongly negatively correlated with severity damaged category one (r = -0.233*).

Table 4.9: Pearson correlation matrix for yield and yield loss components with weevils

	IVD**%**	**IRD%**	**SCG 1**	**SCG 2**	**SCG 3**	**SCG 4**	**SCG 5**	**WTRH**	**WTRD**	**WTRL**	**YLOS**	**YLDL%**
IVD %	1.000											
IRD%	0.731**	1.000										
SCG 1	-0.571***	-0.669 ***	1.000									
SCG 2	-0.003	0.001	-0.414**	1.000								
SCG 3	0.443**	0.622***	-0.352*	0.040	1.000							
SCG 4	0.638***	0.752***	-0.418**	-0.014	0.327*	1.000						
SCG 5	0.495***	0.785***	-0.540***	0.074	0.313*	0.397**	1.000					
WTRH	0.038	0.394**	-0.142	0.091	0.264	0.282	0.376*	1.000				
WTRD	0.254	0.579 ***	-0.239	0.021	0.271	0.393**	0.644***	0.681***	1.000			
WTRL	0.289	0.575***	-0.244	-0.022	0.256	0.425**	0.658***	0.632***	0.961***	1.000		
YLOS	0.355*	0.563***	-0.233	-0.032	0.260	0.414**	0.617***	0.390**	0.880***	0.923***	1.000	
YLDL%	0.355*	0.563***	-0.233*	-0.032	0.260	0.414**	0.617***	0.390**	0.880***	0.923***	1.000	1.000

Number of observations: 48 * Significant at 0.05 ** Significant at 0.01 *** Significant at 0.001 level

Key; IVD % = Percentage incidence vines damage, IRD %= Percentage incidence roots damage, SCG 1 = Severity of number of root damage category one, SCG 2 = Severity of number of root damage category two, SCG 3 = Severity of number of root damage category three, SCG 4 = Severity of number of root damage category four, SCG 5 = Severity of number of root damage category five, WTRH = Weight (kg) of roots harvested ,WTRD = Weight (kg) of roots damaged, WTRL = Weight (kg) of roots discarded or rejected, YLOS = Yield loss (kg) and YLDL%=Yield loss in percentage.

4.5 Discussion

Effect of varieties on yield loss due to weevil damage results revealed that Simama variety was highly susceptible to weevil infestation followed by Polista and Mataya while Gudugudu was tolerant (less susceptible). The reason for this is to the limited exposure of roots above the ground. Some varieties tend to expose their roots above the ground hence suffer more infestation than those whose roots are retained below the ground. Among four varieties used during the study Gudugudu which does not expose roots to the soil surface. Available report has indicated that varieties with deeper roots suffer less from the attack of sweet potato weevils (Shonga *et al*., 2013). Again, variety susceptibility may also be due to genotype variability. Several researches have verified the presence of variability in sweetpotato genotypes for resistance to sweet potato weevils. Emana (1990) evaluated sweetpotato varieties for resistance to the weevil from 1987- 1989 and found that 38 % of the varieties were resistant and remaining were highly susceptible to weevil infestation. It was concluded that, varieties differed in the degree of damage and infestation levels they sustained.

Effect of planting date on yield loss due to weevil damage results indicated that, late planting have high weevil infestation than early and mid planting in both Gairo and Ikungi Districts though magnitude differ. This was possibly because weevils find difficult to penetrate wet soils compared to dry soils. During the wet period, the soil is sticky with no cracks thereby hindering access of the weevil to the roots. This is similar to the observations made by Bourke (1985) that the weevil caused economic damage in areas with a marked dry season. Weevils are generally more important under dry conditions and in traditional systems where roots are harvested sequentially (Amin, 2005).

Moreover, late planting was noted to have more yields regardless of varieties under study. The reason for this could be that during wet period plants tend to grow vegetatively since on first planting after four month (recommended time for harvesting) the roots of almost all varieties were small (not yet filled) while on dry period root harvested were big in size and heavy in weight indicating there is more root expansion than vegetative growth. This is consistent with a study conducted by Frederick *et al*. (1996) on the effect of water logging on growth and yield of sweetpotato where root and shoot growth declined tremendously during water-logging. Also this is similar to a study by Amin, (2005) who found that increasing the frequency of irrigation during the season not only tend to reduce weevil infestation but also reduces root yield. The study revealed that, with more rain fall or irrigation, growth of roots is less than vegetative growth.

Interaction between planting dates and varieties has influence on yield loss. Combination of Gudugudu and early planting was observed to have low yield loss due to weevil infestation whereas Simama variety and mid planting was noted to have higher yield loss. Sweetpotato roots harvested in late planting had higher infestation compared to the first two planting dates. This is probably due to significant soil cracking as a result of dry condition and root expansion. Cracking of soil is a common scenario of Gairo District. Some studies have reported that weevil populations increase when the conditions are dry (Smit, 1997; Okonya and Kroschel, 2013). High temperatures induce soil cracking which provides favorable conditions for the weevils to reach the roots, lay eggs and build up a vital population (Okonya and Kroschel, 2013). Hence, the weevil pest problem is particularly serious under dry conditions because the insect can reach the roots more easily through the cracks that appear as the soil dries out and their population has increased. As harvesting is delayed, there is greater likelihood that infestation would increase. Given this, it would be advisable to harvest as soon as the crop is mature and ready for consumption or other uses.

In Correlation test yield loss parameters seem to have relation with yield loss. The highest positive correlation with yield loss was recorded in weight of root damaged and weight of roots discarded which indicate that the more the root damage the more they are discarded and results to higher yield loss. Severity category one and two were negatively correlated with yield loss. These two categories are for marketable roots. Again, percentage incidence of root damage was observed to correlate positively with yield loss. This concur with the study by Fite *et al.* (2014) which reported that percentage damaged tubers was positively (r = 0.68) correlated with yield loss although negatively correlated with marketable healthy tubers (r = - 61). Other Parameters such as severity category three which is intermediate between marketable and non marketable roots and weight of roots harvested showed weak correlation with yield loss.

4.6 Conclusion

The infestation rate was noted to have effect on yield loss. The higher the infestation rates either in roots or vines the higher the yield loss. Again infestation levels were increasing as the growing season advanced with March planted crop sustaining highest infestation compared to January and December. Susceptibility of varieties under the study on weevil infestation differed with Simama been the leading followed by Polista, Mataya and Gudugudu in all location. In terms of location Gairo District suffered more yield loss than Ikungi irrespective of varieties under study and varying time of planting.

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CHAPTER FIVE

5.0 GENERAL CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

This study has provided insight into sweetpotato production in the main production Districts of central Tanzania. Production of sweetpotato in the area is seriously hampered by sweet potato weevil. Only *Cylas puncticollis* was found to be present in central Tanzania. Based on the results, weevil damage and infestation was found to be higher in Gairo District than Ikungi District. One of the reason for higher infestation is the result of high population density. Gairo District is more prone to SPW infestation than Ikungi District, this is because of cracking nature of soil in Gairo District. Varieties under the study seemed to suffer unequal weevil damage and infestation regardless of same management practice. Gudugudu suffered less, followed by Mataya. The rooting pattern and genotype variability of different varieties might be the source of such variation. Planting time have influence on weevil occurrence and damage to both roots and vines. December (early) planting bears less weevil infestation and weevil occurrence in general.

5.2 Recommendations

Technologies for managing *Cylas puncticollis* sustainably would greatly boost sweet potato production and impact positively on the livelihoods of farmers in central Tanzania. The following recommendations are made base on results of this study;

1. Farmers lack knowledge on *Cylas* spp. biology, damage and control. Hence, training about the biology and ecology of this important pest is needed.

2. Management option to be developed in the area should focus *Cylas puncticollis* because it is dominant and causes serious damage in sweetpotatoes.

3. Promoting use of cultural methods such as clean planting vines, crop rotation, early planting and harvesting have potential to reduce damage by *Cylas* spp.

4. Farmers should be advised to plant tolerant varieties as rains start (early) for optimum yield and less weevil infestation. Mataya and Gudugudu varieties are best option for sweet potato for Gairo and Ikungi Districts respectively.

5. Planting of sweetpotato in December (early) rainy seasons is recommended as a sustainable way to crop loss due to weevil infestation.

6. Screening the farmer preferred and newly certified sweetpotato varieties against sweet potato weevils should be prioritized by researchers.

APPENDICES

Appendix 1: Field survey on sweetpotato production and weevil infestation

Check list questions for field survey

SECTION 1: IDENTIFICATION PARTICULARS

1. NAME OF INTERVIEWER:…………………………………………………………..
2. DATEOF INTERVIEW:……………………………………………………………

DISTRICT:	
DIVISION:	
WARD: GPS	
VILLAGE/STREET:	
SEX	1. Male…… 2. Female…….
NAME OF RESPONDENT	
RESPONDENT PHONE NUMBER	

SECTION 2: INFORMATION ON FARM

1. Position of the field
   a. Elevated or flat……………………………………………………………………
   b. Water lodging/dry land…………………………………………………………...
2. Field history
   a. Which crop(s) were planted last season?……………………………………..
   b. If sweet potato there were any weevil infestation?---------------------------
   c. If yes in (b) above what was the level of infestation?------------------------
3. Planting date
   a. What was the best timing of planting for weevil escape?---------------------
   b. What was the time of planting preferred most by farmers and why?..............
   c. What is the harvesting time practiced by farmers in the area and how it divert from recommended?..
   d. Is there any relation between harvest timing and weevil occurrence?
4. Variety planted
   a. Which variety is normally planted by most farmers in the area?……………..

b. Which variety planted in the area is more susceptible to weevil infestation?..

c. What was the reasons for susceptibility in “b” above?……………………….

d. Among planted variety which one is high yielding and why?.........................

e. What portion of vines is commonly planted by farmers and why?…………..

f. Does the farmers preserve planting materials?...

g. What is the common source of planting material (Farm saved or Improved?) ……………………………………………………………………………………

5. Nature/type of soil

a. What type of soil usually planted sweetpotato in the area?...

b. Is the planted soil cracking?--

c. Which type of soil favors weevil attack?...

6. Field history and management of weevils practices

i. Normal field preparation practices (Making ridge or plant on flat land?)--

ii. Are the farmers practicing Earthing up as a control measures?…………..

iii. What weed management practices is been employed regular?…………....

iv. What common control method used by farmers in the area?.....................

v. Does the farmers use traps to control weevil?...

vi. If yes in "vii" above what were the traps commonly used?.......................

7. Major pests problems Status/quality of harvested crops

a. Which pest apart from weevil that attack the crop in the field?...…………

b. Which species of weevil is common in the area?...

c. Among species available in the area which one cause severe yield loss to crop and why?

8. Distance of separation from other sweetpotato fields

a. What is normal distance of separation between field practicing by most farmers?…………………………………………………………………

b. What is the actual separation?...

c. Is there any relationship between distance of separation and weevil occurrence? ....

d. If yes in “c” above what is recommended separation?.............................

9. Rooting pattern of the crop
   a. What were the nature of root set?---
   b. Which rooting nature are more attacked by weevil and why?--------------
   c. What is the rooting set preferred by most farmers and why?...................
10. Other information on sweetpotato production with relation to weevil infestation were not included
11. Information from field diagnosed (Attached)

……………………………………………………………………………….............

....

....

12. Remarks……………………………………………………………………………..

……………………………………………………………………………………

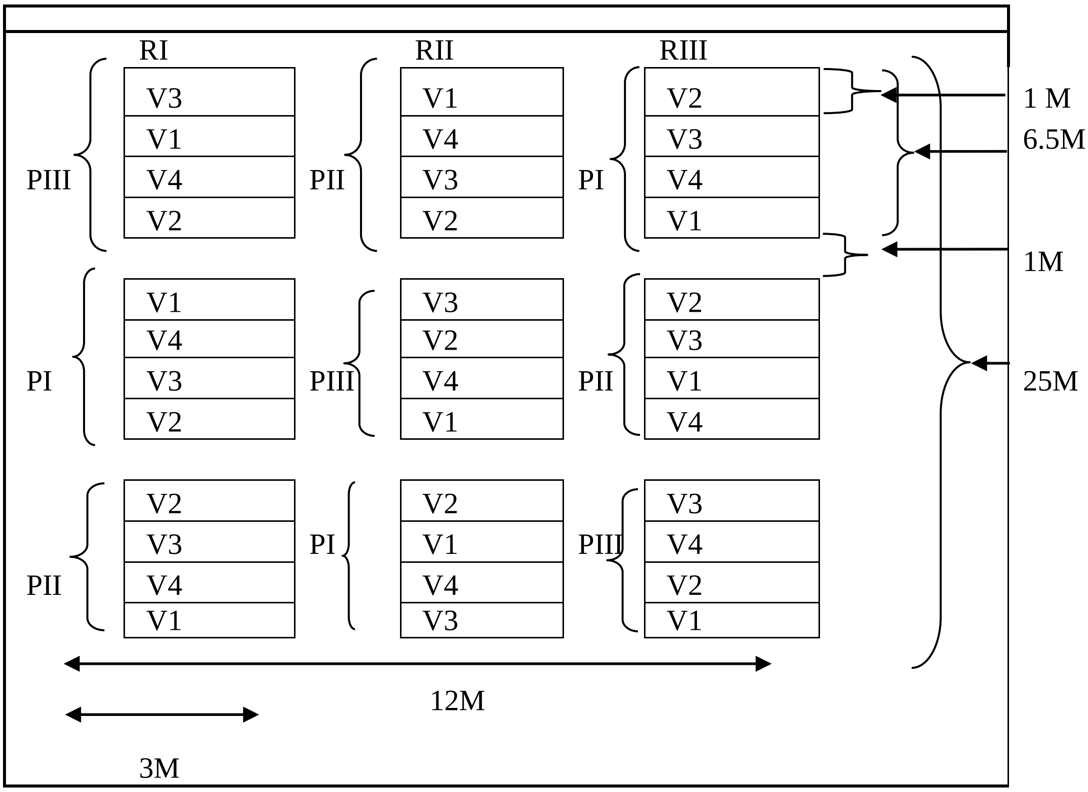
……………………………………………………………………………………

…………………………………………………………………

Information from the field surveyed

Name of the District	Name of the Village	Name of the Farmer	Coordinate	No. root harvested	No. of root damaged	Weight of root harvested	Weight of roots damaged	No.Vines observed	No.Vines damaged

Appendix 2: Field layout (split plot)



Key; R= Replication

P= Planting time (date)

Appendix 3: ANOVA Tables for yield and yield loss parameters

1. Combined analysis for both Gairo and Ikungi District

Vines damaged Incidence (%) both in Ikungi and Gairo Districts

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	3	2984.7	994.9	7.74	
Variety	3	1831.3	610.4	4.75	0.03
Residual	9	1157.4	128.6	0.94	
Planting date	2	1853.8	926.9	6.75	0.005
Variety*Planting date	6	413.4	68.9	0.5	0.801
Residual	24	3296.8	137.4		
Total	**47**	**11537.3**			

Root damaged Incidence (%) both in Ikungi and Gairo Districts

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	3	1890.6	630.2	7.74	
Variety	3	3966.4	1322.1	16.24	<.001
Residual	9	732.6	81.4	0.69	
Planting date	2	3775.4	1887.7	15.94	<.001
Variety*Planting date	6	284.7	47.4	0.4	0.871
Residual	24	2841.5	118.4		
Total	**47**	**13491.2**			

Weight roots harvested (tha^{-1})

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	3	71.99	24	3.93	
Variety	3	169.64	56.55	9.26	0.004
Residual	9	54.95	6.11	0.41	
Planting date	2	80.91	40.46	2.7	0.087
Variety*Planting date	6	54.72	9.12	0.61	0.72
Residual	24	359.02	14.96		
Total	**47**	**791.24**			

Yield loss %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	3	85.445	28.482	2.69	
Variety	3	155.122	51.707	4.88	0.028
Residual	9	95.291	10.588	3.96	
Planting_date	2	148.086	74.043	27.71	<.001
Variety*Planting_date	6	75.546	12.591	4.71	0.003
Residual	24	64.121	2.672		
Total	**47**	**623.61**			

2. Separate analysis

Weight roots harvested(tha^{-1}) in Ikungi District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Location stratum	1	45.53	45.53	7.82	
Variety	3	62.13	20.71	3.56	0.162
Residual	3	17.46	5.82	0.29	
Planting_date	2	33.22	16.61	0.82	0.475
Variety.Planting_date	6	54.26	9.04	0.45	0.829
Residual	8	162.15	20.27		
Total	**23**	**374.74**			
Weight roots Damaged (tha^{-1}) in Ikungi District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	6.292	6.292	2.32	
Variety	3	27.632	9.211	3.39	0.171
Residual	3	8.141	2.714	0.72	
Planting_date	2	50.658	25.329	6.71	0.019
Variety.Planting_date	6	3.225	0.538	0.14	0.986
Residual	8	30.2	3.775		
Total	**23**	**126.148**			
Weight of roots discarded (tha^{-1}) in Ikungi District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	0.15218	0.15218	2.07	
Variety	3	0.69741	0.23247	3.16	0.025
Residual	3	0.22062	0.07354	1	
Planting_date	2	1.28096	0.64048	8.75	0.01
Variety.Planting_date	6	0.20164	0.03361	0.46	0.821
Residual	8	0.58547	0.07318		
Total	**23**	**3.13827**			
Yield loss % in Ikungi District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Location stratum	1	5.376	5.376	4.54	
Variety	3	39.204	13.068	11.03	0.04
Residual	3	3.555	1.185	0.38	
Planting date	2	84.685	42.342	13.71	0.003
Variety*Planting date	6	23.563	3.927	1.27	0.366
Residual	8	24.709	3.089		
Total	**23**	**181.093**			
Weight roots harvested (tha^{-1}) in Gairo District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	17.99	17.99	3.87	
Variety	3	131.06	43.69	9.39	0.049
Residual	3	13.95	4.65	0.24	
Planting date	2	48.97	24.48	1.25	0.337
Variety*Planting date	6	39.5	6.58	0.34	0.899
Residual	8	156.56	19.57		
Total	**23**	**408.02**			

Weight of roots damaged (tha^{-1}) in Gairo District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Location stratum	1	10.593	10.593	96.05	
Variety	3	99.47	33.157	300.66	<.001
Residual	3	0.331	0.11	0.05	
Planting date	2	45.346	22.673	10.27	0.006
Variety*Planting date	6	15.436	2.573	1.17	0.409
Residual	8	17.658	2.207		
Total	**23**	**188.833**			
Weight of roots discarded (tha^{-1}) in Gairo District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	0.16667	0.16667	8	
Variety	3	5.04029	1.6801	80.63	0.002
Residual	3	0.06251	0.02084	0.21	
Planting date	2	2.00507	1.00254	10.17	0.006
Variety*Planting date	6	0.60974	0.10162	1.03	0.47
Residual	8	0.78848	0.09856		
Total	**23**	**8.67276**			
Yield loss % in Gairo District					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	1.28	1.28	0.52	
Variety	3	200.298	66.766	27.23	0.011
Residual	3	7.356	2.452	1.57	
Planting_date	2	72.941	36.471	23.36	<.001
Variety.Planting_date	6	69.365	11.561	7.41	0.006
Residual	8	12.489	1.561		
Total	**23**	**363.729**			

Appendix 4: ANOVA table for Vines damage by weevil throughout the growing season

1. Combined analysis.

Vines damaged 120 DAP both in Ikungi and Gairo Districts

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep.	3	9.7226	3.2409	8.48	
Variety	3	7.7318	2.5773	6.74	0.011
Residual	9	3.4407	0.3823	0.67	
Planting date	2	7.0270	3.5135	6.15	0.007
Variety*Planting date	6	1.3060	0.2177	0.38	0.884
Residual	24	13.7112	0.5713		
Total	**47**	**42.9394**			

Vines damaged 80 DAP both in Ikungi and Gairo Districts

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep.	3	2.0895	0.6965	4.54	
Variety	3	5.7978	1.9326	12.60	0.001
Residual	9	1.3808	0.1534	0.38	
Planting date	2	7.3828	3.6914	9.12	0.001
Variety*Planting date	6	3.3810	0.5635	1.39	0.258
Residual	24	9.7146	0.4048		
Total	**47**	**29.7463**			

Vines damaged 40 DAP both in Ikungi and Gairo Districts

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep.	3	2.8309	0.9436	5.45	
Variety	3	1.6880	0.5627	3.25	0.074
Residual	9	1.5574	0.1730	0.46	
Planting date	2	3.3786	1.6893	4.51	0.022
Variety * Planting date	6	2.1121	0.3520	0.94	0.485
Residual	24	8.9907	0.3746		
Total	**47**	**20.5576**			

2. Separate analysis

Vines damage at 80 DAP at Gairo District

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	0.667	0.667	0.46	
Variety	3	11.500	3.833	2.65	0.222
Residual	3	4.333	1.444	0.96	
Planting date	2	14.083	7.042	4.69	0.045
Variety*Planting date	6	17.250	2.875	1.92	0.194
Residual	8	12.000	1.500		
Total	**23**	**59.833**			

Vines damage at 80 DAP at Ikungi District

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	8.167	8.167	7.74	
Variety	3	13.833	4.611	4.37	0.129
Residual	3	3.167	1.056	0.79	
Planting date	2	20.583	10.292	7.72	0.014
Variety* Planting date	6	9.417	1.569	1.18	0.404
Residual	8	10.667	1.333		
Total	**23**	**65.833**			

Vines damage at 120 DAP at Ikungi District

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	40.042	40.042	7.94	
Variety	3	48.125	16.042	3.18	0.184
Residual	3	15.125	5.042	1.81	
Planting date	2	46.083	23.042	8.25	0.011
Variety* Planting date	6	26.250	4.375	1.57	0.272
Residual	8	22.333	2.792		
Total	**23**	**197.958**			