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黃肉甘藷與洋蔥間作效應對象鼻蟲的危害程度

Effects of Intercropping 'Orange-Fleshed' Sweetpotato with Onion on the Level of Weevil Damage

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ABSTRACT

The problem of household food and economic insecurity i.e. inability of families to produce and purchase enough food to meet basic needs is considered to be a major determinate of Malawi's nutrition problems. The major nutritional disorder in Malawi is Vitamin A deficiency. Orange-fleshed sweetpotato (*Ipomea batatas*) was introduced through the program "Rooting out hunger in Malawi with nutritious orange-flesh sweetpotato" to combat Vitamin A deficiency in addition to providing the daily calorie requirement. Production of sweetpotato is however challenged by the sweetpotato weevil damages and rotting problems. Unavailability of acceptable improved varieties, high incidence of pests and diseases, and poor cultural practices are also the main causes of low yields. A field experiment was carried out in Dedza (Malawi) from April to November 2013 to assess the "effects of intercropping orange-fleshed sweetpotato with onion on the level of weevil damage" with the objectives of developing a biological efficient onion intercropping for orange-fleshed sweetpotato (OFSP) production and determining the agronomic productivity of the intercrop systems. The experiment was conducted in a Randomized Complete Block Design (RCBD) with four treatments; sole cropped OFSP and Onion, and OFSP+Onion intercropped at ratios 2:1 and 4:1 respectively. Data were collected on the yield of OFSP roots and vines and onion bulbs, virus symptoms incidence and the level of weevil damages to the OFSP. Data were subjected to the general Analysis of Variance (ANOVA) using SAS statistical software version 9.1. and means were separated using Dunnett at alpha ≤ 0.05. Land use efficiency (Land Equivalent Ratio (LER)) was calculated to assess the relative advantage of intercrops compared to the sole culture. Gross margin analysis (GMA) was calculated to determine the economic benefits of the crops grown. Intercropped onion did not affect the growth and reproduction parameters of the orange-fleshed sweetpotato. Intercropping reduced the susceptibility of the weevils on sweetpotato and decreased the susceptibility of weevils on sweetpotato crops. Sole cropped OFSP were highly affected by the weevils. Intercropping practice at the OFSP-Onion ratio of 4:1 had the lowest weevil damage percentage followed by the Intercropping at 2:1 ratio. There was no significant difference in virus symptoms incidence at 6-8 weeks after planting from all treatments, whilst at one month before harvest; intercropping practice at the ratio of 4:1 indicated the lowest percentage of virus symptoms. In terms of yield, the results indicated that intercropping practices produced higher sweetpotato roots than the sole cropped OFSP. There was no significant difference between treatments in terms of vines yield. The land efficiency was increased with the intercropping practices. The LER shows that intercrops at ratios 4:1 and 2:1 had ratios above 1 meaning that there was intercropping advantage over the sole crops. The economic analysis proved that intercropping would fetch better profits than the sole cropping. Intercropping at ratio 4:1 generated higher profits, followed by intercropping at 2:1. The profits attained from the intercropping were strongly generated from the sweetpotato productions. Sole cropped onion did was not able to generate profits.

Keywords: Orange-fleshed sweetpotato, Onion, Intercropping, Sweetpotato weevil, Land equivalent ratio, Gross margin analysis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1. Introduction

Maize, mostly rain fed, is considered as the most important staple food in Malawi but it is threatened by drought and late rains associated with climate change. Since 1990, regularly occurring droughts have significantly compromised maize production throughout the country, resulting in food shortages that now take place every two to three years (cf. Moyo *et al*., 2004). Following these drought years, Cassava (*Manihot esculenta Crantiz*) and Sweetpotato (*Ipomea batatas*) have gained the importance as food crops in Sub-Saharan Africa (SSA) and therefore, considered to be fundamental complements for this setback.

One of the most important things that could be of help to the poor farmers is that, sweetpotato (*Ipomoea batatas* L.) Lam) is grown over a broad range of environments and cultural practices and is commonly grown in low-input agriculture systems (Prabawardani S, M. Johnston, R. Coventry and J. Holtum 2004). This is believed to be helpful to the poor/smallholder farmers in Malawi. "Zondeni", a newly introduced orange-fleshed sweetpotato variety was used for this study. Orange-Fleshed Sweetpotatoes (OFSPs) are rich in beta-carotene, a substance that can combat vitamin A deficiency (Low *et al*., 2007). This study was conducted as part of the project activities of the International Potato Centre (CIP) led-project "Rooting out Hunger in Malawi with Nutritious Orange-Fleshed Sweetppotato. In Malawi, the 4.5 year "Rooting out Hunger Project", supported by Irish Aid, is part of the Sweetpotato for Profit and Health Initiative (Abidin 2010), a 10-year, multi-donor, multi-project initiative that seeks to reduce child malnutrition and improve smallholder incomes in Sub-Saharan Africa through the effective production and expanded use of sweetpotato (Low 2009). The project is important to the Malawians as the prevalence of chronic malnutrition or stunting in Malawi is among the highest in the world with about 60% of children under five, 57% of non-pregnant women, and 38% of men and school aged children have vitamin A deficiency (Sindi *et al*., 2013).

In an effort to address malnutrition, the government of Malawi created an "Essential Nutrition Action Program" that introduced the fortification of sugar with vitamin A. Unfortunately, in a country where over 50% of the population live below the poverty line, vitamin A-enriched sugar is an unaffordable luxury to those who need it most (Carlton and Lewin 2013). Pro-vitamin A rich orange-fleshed sweetpotato (OFSP), which is one of the bio-fortified crops, is high in beta-carotene and it is believed to be a possible solution to vitamin A deficiency and under-nutrition. Orange-fleshed sweetpotato has the potential to combat vitamin A, protein deficiency and it is well accepted by young children, the group which is at high risk of Vitamin A Deficiency (VAD). More significantly, the development, promotion, and dissemination of pro-vitamin A rich orange-fleshed sweetpotato varieties align perfectly with the food security and nutrition objectives of Malawi (Abidin 2011). The long-term goal of this policy is to significantly improve the food and nutrition security of the population. The goal implies a rapid and substantial reduction in the degree and severity of malnutrition, in all its forms, i.e., chronic and acute malnutrition and micronutrient deficiencies among the men, and women, boys and girls, especially under-fives, expectant and lactating mothers of the population (WHO 2005). Sweetpotato is one of the important food crops in Malawi. It contributes appreciably to the food availability to the people in the country. However, recurrent weather conditions have contributed to the increasing negative trend that this crop is going through. This study's practice (intercropping) will help to contribute to improve food productivity and nutrition by using possible, locally available resources that might be easily accessible and affordable to most smallholder farmers in Malawi. Most losses in tubers (storage roots) are caused by the sweetpotato pests especially the sweetpotato weevils. *Cylas* spp. Weevils are the most damaging insect pests of sweetpotato worldwide. Three species, namely; *C. puncticollis*, *C. brunneus* and *C. formicarius* are found in East Africa and *C. puncticollis* is the most destructive sweetpotato pest in Malawi (Sathula *et al*., 1997).

The development of appropriate Integrated Pest Management (IPM) systems for sweetpotato pests within smallholder cropping systems presents a particular challenge in Malawi (Sathula *et al*., 1997); this study was designed to assess the effects of intercropping sweetpotato with onion on controlling these pests (Nampeera, *et al*., 2011). The purpose was to develop a possibly cheap, safe and socially acceptable solutions to manage these "most important" sweetpotato pest (*Cylas spp.*) in the country.

1.2. Problem Statement

Malawi's dependence on a grain (maize) with high energy content, but low protein, fat and micronutrient quantity has led to sustained issues of malnutrition which is the public concern in the country. Orange-fleshed sweetpotato variety which is rich in beta-carotene content has been introduced in Malawi to help in alleviating the vitamin A deficiency (Sindi *et al*., 2013). Growing this variety of sweetpotato is considered to be more economic as compared to the commonly grown staple maize. However, some of the challenges that face the production of this crop include the land scarcity and sweetpotato pests that reduce its potential for valuable productions. Intercropping sweetpotato and onion, using onion as a non-host plant intercrop may help in reducing the damages of sweetpotato roots caused by the sweetpotato weevils in the field which will help increasing the production. Onion produce a pungent alliaceous compound, allyl-epropyl-disulphide, which is responsible for its pest repellent attribute (Baidoo *et al*. 2012, Banful and Mochiah 2012). Vegetables such as onion (Allium cepa) and garlic (Allium sativum) have been used in the intercropping systems because of their ability to repel insects, therefore, crops grown next to garlic and onion are less prone to insect pest attacks. Onion and garlic plants produce excretions from their roots as well as aromas from their leaves that have a strong taste and smell (Katsaruware and Dubiwa 2014). These excretions and aromas have beneficial effects on surrounding plants because they discourage insects, and are therefore regarded as insect repellent plants.

One of the main reasons for the use of intercropping around the world is to produce more when crops are intercropped as compared to the pure cropping of the same amount of land (Mousavi and Eskandari, 2011). The average total land per farmer in Malawi is 0.97ha (Munthali and Murayama 2013) and this small holding land size is the key constraint to smallholder productivity in Malawi and therefore, intercropping system will help in improving the yields. Experiments have shown that intercropping has a higher total productivity per unit land area and greater stability of yields and revenues than its mono-cropping counterparts (Anand Reddy *et al.* 1980, Yildirimi and Guvenc 2005, Rusinamhodzi *et al*. 2012). Intercropping could therefore be seen as a system which could be used to fill the gap created by the problem of land scarcity, and also to improve household food insecurity (Spio 1996). Improving food security by using orange-fleshed sweetpotato variety will therefore, contribute to solving malnutrition problems in Sub Saharan Africa of which Malawi is also included. The orange-fleshed varieties provide vitamins A, B, K and C and in addition, the green leaves of the plant can be consumed by both humans and animals providing additional protein, vitamins and minerals (Yanggen and Nagujja 2006).

Intercropping OFSP and onion would help in improving yields, enhance food security and, level of malnutrition would be reduced by the increase in OFSP consumption. The land scarcity and sweetpotato weevil problems would also be improved. No information is, however available about the effect of intercropping OFSP with onion, hence, this study was undertaken to evaluate suitability of OFSP-Onion intercropping systems to help in combating food insecurity, malnutrition and land scarcity problems.

1.3. Objectives

1.3.1 Research Objectives

This study was aimed at evaluating the performance of sweetpotato and onion intercrop, and to calculate the land use of such an intercrop under different cropping patterns. The following specific objectives were considered for this study:

1. Determining the effect of intercropping onion and orange-fleshed sweetpotato (OFSP) on growth and yield of OFSP.
2. To determine the effect of intercropping these two crops on the yield of onion.
3. To find out the most favourable plant population ratios of inter-cropping onion and orange fleshed sweetpotato.
4. To discover the economic benefits of this intercrop practice.

1.4. Importance's of the Study

The findings for this study will also be used for scaling up investigation on using onion as a non-host plant for reducing the sweetpotato weevil (*cylas* spp) population and its damage on sweetpotato planting materials. In addition, this can be ideal for generating income for farmers at the household level, therefore, contributing to poverty alleviation in the country. Largely, the significance of this research is that, results from this study will be helpful and useful not just for the farmers in Malawi but also in other countries that have a similar problem of land scarcity.

1.5. Definition of Terms

Furrow Irrigation: The irrigation practice whereby the furrows (small, parallel channels) are made to carry water in order to irrigate the crop. The crop is usually grown on the ridges between the furrows (FAO.2014).

Gap Filling: The agricultural practice in which planting materials are filled in the spaces (gaps) of the planting stations that failed to emerge after the first planting.

Gross Margin Analysis: The financial output minus the variable costs i.e. Outputs minus Inputs.

Integrated Pest Management: A process used to solve pest problems while minimizing risks to people and environment (UC. 2013).

Intercropping: Growing two or more crops at the same time on a single field (Machado S. 2009).

Land Equivalent Ratio: A method for assessing intercrop performance as compared to pure stand yields (Sullivan P. 2003).

On-Farm Adaptive Trial: Part of the research continuum of the development of appropriate agricultural technologies to alleviate identified farming constraints (Murithi F.M. 2000).

Orange-Fleshed Sweetpotato: The varieties of sweetpotato whose internal root colour are Orange.

Pure Stand: The agricultural practice of producing or growing one single crop in a given area.

Randomized Complete Block Design: An experimental design in which the treatments in each block are assigned to the experimental units in random order. Blocks are all of the same size and each treatment appears in the same number of times within each block i.e., usually once (Science Dictionary, 2014).

Residual Moisture Land: The land that have an adequate amount of water content in the soil for the crops to be grown without depending much on other water sources for irrigating the crops.

Sweetpotato Weevil: The most serious pest of sweetpotato around the world. This weevil also feeds on plants within the plant family Convolvulaceae.

CHAPTER II

LITERATURE REVIEW

2.1. Sweetpotato Crop Production

Sweetpotato (*Ipomoea batatas Lam*) is among the world's most important, versatile, and under exploited food crops with more than 133 million tons in annual production (Kapinga *et al*. 2007). Sweetpotato (*Ipomea batatas L*) from the family convolvulanceae is a dicotyledonous plant with an annual world production of 122 million metric tons. It ranks fourth in importance in developing world after rice, wheat, and corn (Karyeija, Gibson, Valkonen 1998). In the book, "The sweetpotato, untapped food resource" written by Jennifer A, Woofle, the significance of sweetpotato as a crop was explained (Woolfe J.A. 1995). Woolfe mentioned that sweetpotato is one of the important food crops around the world, grown in more than 100 independent countries at present. The exact center of origin and domestication of the sweetpotato has not been well defined, neither has the wild ancestor of this species been found but the crop was originally domesticated in Tropical America (Rossel, Kriegner, Zhang 2000). Sweetpotato crop is mostly produced in the developing tropical world where a high proportion of the poorest people live. Growing this crop is vital as it has the potential for combating food shortages and malnutrition. These positive impacts in increasing human livelihood have resulted in intensified research efforts to enhance production and consumption. This crop is one of the important crops because it is grown for both food security and nutrition purposes. Sweetpotato is one of the widely grown root crops in sub-Saharan Africa (SSA), it generates large amounts of food per unit area per unit time, superior to other major crops. Therefore, this crop is expanding faster than any other major food crop in Sub Saharan Africa, covering around 2.9 million hectares with an estimated production of 12.6 million tons of roots in 2007 (Woolfe 1992, FAOSTAT 2008, Low *et al*. 2009).

2.2. Importance of Sweetpotato Production in Africa

2.2.1 Sweetpotato as a Staple Crop

Sweetpotato (*Ipomoea batatas* (L) Lam) is one of the most important staple carbohydrate foods in Sub-Saharan Africa (Mbanaso *et al.* 2012). It is a co-staple in East Africa's densely populated, intensively cultivated mid-elevation farming areas. In many other countries, it is an important secondary crop grown for an expanding fresh market. Africa's top producers are Uganda (1.7 million tons), Rwanda (980,000 t), Malawi (960,000 t) and Kenya (725,000 t). The largest producers on a per capita basis are Rwanda, Burundi and Uganda (90–100+ kg per capita per year) (Ewell 2002). This crop is particularly important in countries surrounding the great lakes in eastern and Central Africa namely Malawi, Angola, Mozambique, and Madagascar in southern Africa and Nigeria in West Africa with China being the largest producer worldwide (Low et al. 2009 and Shonga *et al*. 2013). Most significantly, sweetpotato is also considered as an important crop because it has a long history as a 'lifesaver'. The Japanese used it when typhoons demolished their rice fields (Loebenstein and Thottappilly 2009). It kept millions from starvation in famine-plagued China in the early 1960's and came to the rescue in Uganda in the 1990's, when a virus ravaged cassava crops (CIP 2010).

2.2.2. Sweetpotato as a Possible Solution to Climate Change

Sweetpotato requires fewer inputs and less labour than other crops such as maize. It is possible to grow sweetpotato crop without adding agro-chemicals as it was done in this research. No fertilizer was added to the production of OFSP and onion in this study, however, the yield of sweetpotato was good enough that it economic benefits were attained. Sweetpotato also tolerates marginal growing conditions such as dry spells (drought), and poor soil (Low *et al*. 2009). It is highly adaptable to relatively marginal soils and erratic rainfall. It has high productivity per unit land and labour, and guarantees some yield even under the most adverse conditions (Mbanaso, Agwu, Anyanwu and Asumugha 2012). Sweetpotato is also important and widely grown because it yields even on less fertile in contrast to other crops such as maize which are not drought resistant. Maize is the main food crop in Malawi and occupied 70% of the cultivated land.

2.2.3. Orange Fleshed Sweetpotato for Nutritional Importance

Deficiency in vitamin A is one of the most prevalent problems in developing countries and the most common cause of childhood blindness in the world. Orange-fleshed sweetpotato is a sweetpotato variety whose internal root colour is orange (Assimwe 2013). They have high level of beta-carotene, a precursor to vitamin A, unlike the white fleshed varieties that have little or no beta-carotene contents (Kulembeka *et al*. 2004). Growing orange fleshed sweetpotato in Malawi is very important and more practical to overcome the problems of food insecurities and malnutrition which are the two crucial situations in the country. Malawi, besides the problem of protein-energy malnutrition, it is also affected with vitamin A deficiency as well as micronutrients deficiencies of iodine and iron. Comparing all these mentioned nutrient deficiencies; vitamin A is a common and widespread nutritional disorder. Malawi is characterized by high level of child malnutrition with the estimated figures of 39.1%, 7%, and 48% of children under five years of age are under weight, wasted and stunted (Suresh 2000). Malnutrition occurs when one or more essential nutrients are lacking, even though caloric content is sufficient (Sheaffer and Moncada 2012). Even though malnutrition is commonly referred to under-nutrition, over consumption of any essential nutrients leads to over-malnutrition, therefore, leading into two extreme malnutrition situations namely hunger and obesity. Measures in alleviating vitamin A deficiency is a very important task in Malawi and other developing countries as it can limit growth, weaken the immunity and eyesight and lead to increasing mortality. In consideration of these problems, the Vitamin A for Africa (VITAA) partnership is promoting the increased production and use of Orange-fleshed sweetpotato (OFSP) to combat vitamin A deficiency in sub-Saharan Africa (SSA) with the target to young children and their mothers, who are the most vulnerable to vitamin A deficiency. Rooting out Hunger in Malawi with Nutritious Orange-Fleshed Sweetpotato project was launched in October 2009 for the benefit of women and children in the country as an initiative to alleviate vitamin A deficiency. This project is 4.5 year effort targets 70,000 households to improve vitamin A in-take using improved sweetpotato varieties (Abidin *et al*. 2012). In SSA, more than three million African children under age of five suffer from vitamin A-related blindness known as exophthalmia, or dry eye (Kapinga *et al*. 2005).

World Health Organization (WHO) (2013) also mentioned the effect of vitamin A deficiency (VAD) in pregnant women. They explained that in pregnant women VAD causes night blindness and may increase the risk of maternal mortality. The WHO database indicated that up to 2013, an estimated 250 000 to 500 000 VAD children become blind every year, half of them dying within 12 months of losing their sight. Thus, vitamin A malnutrition is a major public health concern of the developing countries and is responsible for millions of deaths annually among the young children (Surajit 2012). Increasing the consumption of foods rich in vitamin A is considered one of the food-based strategies in addressing VAD in the communities and for this reason, the use of foods rich in vitamin A to combat vitamin A deficiencies is gaining importance in most parts of Africa including Malawi. It is believed that one of the cheap sources of vitamin A is Orange-fleshed sweetpotato varieties because they are rich in pro-vitamin A. Increasing consumption of orange-fleshed sweetpotato at household level will increase supplementation of the diet with Vitamin A, where vitamin A rich food items are not readily available (Kulembeka *et al*. 2004).

Research papers have shown that 64,000 children die each year is sub-Saharan Africa from causes associated with VAD and it is believed that the Millennium Development Goal (MDG) of reducing the mortality rate of children less than five years of age by 20% can be achieved with the improvement in vitamin A intake (Anderson *et al*. 2007). Economists from International Potato Centre and Michigan University also conducted their study and they strongly suggested that 50 million Africa children under the age of six could benefit from the new orange-fleshed sweetpotato varieties (Kapinga *et al*. 2005). Orange-Fleshed Sweetpotato is a particularly promising food, because levels of β-carotene are extremely high in many varieties [100–1600 mg retinol activity equivalent (RAE)/100 g for varieties in Africa] and it is generally well accepted by young children (Low *et al*. 2007). Orange-fleshed sweetpotato varieties are a viable and sustainable strategy to VAD which is an option for Malawi (Obed and Chipungu 2010).

2.3. Issues of Sweetpotato Production

2.3.1. Sweetpotato Weevil Damage

Sweetpotato weevils of the genus *Cylas* are considered to be the most destructive pests of sweetpotato in the world (Smit and Huis 2009). They are the cosmopolitan insect and most serious insect pests of sweetpotato in Central America, Africa and Asia, even small weevil populations can reduce sweetpotato root quality. In response to weevil feeding, sweetpotato storage roots produce bitter tasting and toxic sesqui-terpenes that render them unfit for human consumption (Shonga *et al*. 2013).

For long, sweetpotatoes have been attacked by two types of weevils; *Cylas puncticollis* and *Cylas brunneus* the most common and deadly pests in East Africa (Kasozi 2012). The weevils cause damages in the field, in storage, and are of quarantine significance (Capinera 2009), and the yield losses of up to 80% can occur (Nottingham and Kays 2013). Sweetpotato weevils constitute a major constraint to sweetpotato production and utilization world-wide. The female sweetpotato weevil lays eggs singly in cavities excavated in their vines or the accessible roots of sweetpotatoes. The developing larvae tunnel while feeding within the vine or root and are the most destructive stage. 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. While external damage to roots can affect their quality and value, internal damage can lead to complete loss of marketable yield as high as 60-97% (Stathers et al. 2003). Published work in Cuba indicated, however, that about 10-20% increase in yield could be expected through a better control of sweetpotato weevil. Improved control could contribute to avoiding losses of yields already formed and increase the value of the roots for potential markets (CIP 2009).

2.4. Intercropping

Intercropping can be defined as a multiple cropping system that two or more crops are planted in a field during a growing season. Intercropping is a way to increase diversity in an agricultural ecosystem (Mousavi and Eskandari 2011). It is one of the options available to maintain soil fertility and crop yields. Other benefits of intercropping are risk spreading, weed control and the decrease of pest and disease incidence (Wolfswinkel 2013). Intercropping is divided into the following four groups: row intercropping, mixed intercropping, strip intercropping and relay intercropping (Ofori and Stern 1987, Vandermeer 1992). The practice is defined to as Row intercropping when two or more crops are grown simultaneously, where one or more crops are planted in regular rows, and crop or other crops may be grown simultaneously in row or randomly with the first crop. Different from row intercropping, growing two or more crops simultaneously with no distinct row arrangement is referred to as mixed intercropping. Strip intercropping is growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically. In relay intercropping, two or more crops are grown simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage, however, before it is ready to harvest.

2.4.1 Intercrop with Onion for Pest Control

Onions are one of the oldest vegetables in continuous cultivation dating back to at least 4,000 BC (Boyhan and Kelley 2007). Most researchers agree that the onion has been cultivated for 5000 years or more. Since onions grew wild in various regions, they were probably consumed for thousands of years and domesticated simultaneously all over the world (NOA 2013). The use of chemical insecticides in the control of insect pests has left in its wake resistance of some pests to some of the conventional insecticides; it is therefore important that alternative methods of managing pests such as cultural control have to be employed to reduce pest infestation of crops. Different studies indicated that onion was used in an intercrop as a non host for pest control. A research was conducted in Ghana to assess the effects of intercropping onion with organic cabbage for pest control. In this research, onion was used as a non host plant to control the pests in organic cabbage (*Brassica oleracea*) production system. The intercrop system of organic cabbage with onion helped in reducing a number of insect pests which were identified attacking the cabbage at different growth stages. The diamondback moth, *Plutella xylostella* (L), the cabbage aphid, *Brevicoryne brassicae* (L.), the cabbage webworm, *Hellula undalis* (F.), the whitefly, *Bemisia tabaci* (Genn.) and the cabbage looper, *Trichoplusia ni* (Hübner) were among the pests that were controlled and minimized in the field (Baidoo *et al*. 2012).

Intercropping reduces pest population because of the diversity of crops grown. When other crops are present in the field, pests movements are hindered. Baidoo (2012), Sullivan (2003) wrote that if susceptible plants are separated by non- host plants that can act as a physical barrier to the pest, the susceptible plant will suffer less damage and this correlates with the hypothesis of this study of which onion is planted on border ridges to reduce the level of sweetpotato weevil damages in the field. In other studies, mixed cropping of carrots and onion reduced attacks by carrot fly, *Psila rosae* Fab., on carrots(Uvah and Coaker 2011). A study was also conducted on effects of intercropping cucumber with onion on soil enzyme activities, microbial communities and cucumber yield by Zhou and his colleagues, and the results in their study indicated that intercropping cucumber with onion increased cucumber productivity and improved soil environment at different levels (Zhou *et al*., 2011). The effect of onion as a pest control was also shown on the study of "Efficacy of intercropping as a management tool for the control on insect pests of cabbage in Ghana" conducted by Tilimba and Nyako in 2001. Their results indicated that *Plutella xylostella* was effectively controlled when cabbage was intercropped with onion. Aswathanarayanareddy *et al*., 2006 also published their study about the "effect of intercropping on population dynamics of major pests of chilli (*Capsicum annuum* L.) under irrigated system" the results illustrated that chilli consistently recorded lower pest infestation levels with higher green chilli yield when it was intercropped with onion. All these studies proved that instead of applying chemical pesticides in the field, onion can be a major substitute for pesticides, and a sustainable way of producing different crops that requires intensive pesticides application for their pest control.

2.5. Land Equivalent Ratio (LER)

The land area required by sole crops to produce the same volume of yield produced by intercrops is defined as Land Equivalent Ratio (Mead and Willey 1980). The LER value greater than one indicates a yield advantage of intercropping over sole cropping while the LER value less than one indicates the yield advantage of sole cropping over the intercrop (Mu *et al.*, 2013). Studies have been conducted on intercropping and the productivity of the intercropping has been evaluated by the LER. Some of the studies also evaluated the land efficiency by using LER method (Asiimwe 2013, Yildirim and Guvec 2005, Rusinamhodzi *et al*. 2012, Verma *et al*. 2013, and Mu *et al*. 2013). The studies mentioned includes "Effect of Intercropping Orange-Fleshed Sweetpotato (*Ipomea batatas* L.) and Maize (*Zea mays* L.) at varied populations on yield and B-carotene content", "Intercropping based on Cauliflower: more productive, profitable and highly sustainable", "Performance of wheat/maize intercropping is a function of belowground interspecies interactions", "Improving production potential and resources use of peppermint (*Mentha piperita* L.) Intercropped with geranium (*Pelargonium graveolens* L.Herit ex Ait) under different plant density", and "Maize-grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in Central Mozambique." Results from these studies indicated that the resource use efficiency of intercropping was higher, and was over that of monocrops.

Other studies also showed the advantage of intercropping over sole crops practices. Examples include the research which was conducted on forage yield, quality and economic benefit of intercropped barley and annual medic in semi-arid conditions in Iran (Sadenghpour *et al.* 2013). Intercropping advantage and competition between barley and annual medic in intercrops were calculated to quantify the efficiency of the intercropping treatments and according to their results, the total LER unity in the addictive intercrops indicated that there was a yield advantage of mixed cropping system over monocultures in terms of more efficient use of resources for plant growth. In another study, Barley crop was intercropped with Faba bean. The highest LER of 1.23 was obtained from the binary combination of 100:37.5 Barley: Faba bean. Total LER from this study showed a positive relationship with the total grain yield of the two components crops (Agegnehu, Ghizaw, Sinebo 2006).

2.6. Hypothesis (Ho)

Damage caused by sweetpotato weevil (*Cylas spp*.) feeding on sweetpotato constitutes a major constraint to sweetpotato production and utilization in Africa. The following hypotheses have been drawn to be tested in the experiment: (1) intercropping sweetpotato with onion will reduce damages by weevils if onion becomes a boarder. (2) The population plant ratios in the sweetpotato and onion intercrops are not significantly: population plant ratios in the sweetpotato and onion intercrops are 2:1 orange-fleshed to onion ratio and 4:1 orange fleshed to Onion ratio. (3) Intercropping orange-fleshed sweetpotato and onion will increase land efficiency and economic benefits.

CHAPTER III

MATERIALS AND METHODS

3.1. Research Background

On-farm experiment was conducted in Malawi to assess the effects of intercropping orange fleshed sweetpotato and onion on level of weevil damages. Malawi is a landlocked country located in southeast Africa. It is surrounded by Mozambique, Zambia, and Tanzania (Fig. 1).

Malawi is separated from Mozambique and Tanzania to a large extent by Lake Malawi, which lies on the country's eastern edge (Banister, K. E., and M. A. Clarke 1980)

The circle on the map represents the specific location (district) at which the studies were conducted.

Figure 1. Map of Malawi

3.2. Description of the study area

Two sites with different conditions i.e., irrigated and residual moisture lands were set up for farm trials at Bembeke, Dedza Extension Planning Area (EPA) in the central region of Malawi. The two experiments were conducted at the same period of time (April – November, 2013) under the geographical coordinates of 14^{o} 21’ 41.57” S and 14^{o} 21’ 41.52” S longitudes, 34^{o} 20’ 24.08’’ E and 34^{o} 20’ 21.11” E latitudes for the first and second sites. Three months (April, June and August) average temperature range in these sites location was 17.2, 18.8, 19.6^{o}C at site one and 16.7, 17, 18.1^{o}C at site 2 respectively. Different soil characteristics were observed between these two experimental areas. Site one which was under irrigation system had loamy sand soil with pH of 6.2 and the soil at site two (under residual moisture) was silty clay loam with pH of 7.2.

3.3. Land preparation

The land was manually prepared by the local people using hoes. The purpose of land preparation was to provide required soil condition to enhance the successful establishment of young shoots. After the ridges were constructed by the local farmers, the demarcations were made according to the measurements required as per experimental design.

3.4. Planting materials

Orange-fleshed sweetpotato variety, “Zondeni” was used for the study. During the study, Zondeni variety was recommended to the local Malawians for improving their nutritional status. This variety is also preferred by the local farmers due to its early maturity, high yields and its ability to resist from sweetpotato virus diseases. Unlike Sweetpotato planting materials, onion variety was not considered important. Both

Sweetpotato and Onion planting materials were bought from the local farmers within the district. The onion seedlings were transplanted from the nursery bed into the ridges at site one and the matured onion bulbs were used as planting materials at site two. The buying price of onion seedlings did not differ from that of the onion bulbs.

3.5. Experimental design

The field layout for this research was completed following the patterns that have been used by International Potato Centre (CIP) in its intercropping farm practices. Orange-fleshed sweetpotato has been intercropped with maize and soybean crops as some of the CIP projects conducted in various African countries including Malawi. Matured sweetpotato vines of 30cm long were used at 30cm spacing between plants and 75cm between ridges. The spacing of onion plants was 10cm between plants and 75cm between ridges. Intercropping of these two crop types was done on the same day/same time. The experiment was laid out using a Randomized Complete Block Design (RCBD) with a total of 12 plots of 6m × 9m size, comprising 12 ridges of 6m long per plot with three replicates of each treatment.

3.6. Plant population

The sole crops and intercrops made four treatments for the study i.e., two pure stands of orange-fleshed sweetpotato (OFSP) and onion, and intercrops of OFSP and onion at different ratios. Treatment 1: Pure stand Sweetpotato (PSSP), Treatment 2: Pure stand Onion (PSON), Treatment 3: Sweetpotato and Onion intercrop at 2:1 ratio (OFSP/ON 2:1), Treatment 4: Sweetpotato and Onion intercrop at 4:1 ratio (ON/SP 1:4). The arrangements for intercrop ratios were 2 ridges of OFSP then one ridge of onion for the 2:1 ratio, and 4 ridges of OFSP then one ridge of onion for the 4:1 ratio. This sequence was repeated until all the plots under the intercrops practice were filled with the planting materials.

(i) Treatment 1: 12 ridges/rows of orange-fleshed sweetpotato (OFSP) spaced at 30cm on the top of the ridge. The length of the ridge was 600cm with 75cm space between the ridges. The general observable plot size for OFSP was 102.6m^2 comprising 540 plants.

(ii) Treatment 2: 12 ridges of onion spaced at 10cm on top of the ridge. The length of the ridge was 600cm with 75cm space between the ridges. The general observable plot size was 285.94m^2, comprised of 1740 plants.

(iii) Treatment 3: 8 ridges of orange-fleshed sweetpotato spaced at 30cm, and 4 ridges of onion spaced at 10cm on top of the ridge. 600cm length of the ridges the general observable plot size of 45.36m^2 and 19.72m^2 for OFSP and onion. The plant population for the two crops at treatment 3 was 432 plants and 696 plants for OFSP and onion respectively.

(iv) Treatment 4: 9 ridges of orange-fleshed sweetpotato spaced at 30cm, and 3 ridges of onion spaced at 10cm on top of the ridge. 600cm length of the ridges the general observable plot size of 51.03m^2 and 14.79m^2 for OFSP and onion. The plant population for the two crops at treatment 4 was 486 plants and 522 plants for OFSP and onion.

The general observable size was reduced in terms of ridge size and the plot size after removing the boarder ridges and the boarder plants. The general observable ridge length for orange-fleshed sweetpotato was 5.4m^2, while for the onion crop was 5.8m^2. The general observable plot sizes depended on the plant population per treatment as shown above.

3.7. Data collection and analysis

Plating of sweetpotato vines and onion was done on the same day. Three to four weeks after planting, data on verification of establishment were collected, and where gap filling was necessary, the gap was filled up with a new plant. Evaluation of virus symptoms was recorded two times; at six to eight weeks after planting (WAP), and one month before harvest (MBH). To collect virus symptoms data, plants with symptoms and signs of sweetpotato weevil damage were identified and number of affected plants per block was recorded and subjected to analysis. The disease incidence was examined using the 1-9 virus coding scheme provided by the International Potato Centre. Data collected on harvest included the weight of sweetpotato roots, sweetpotato vines and onion bulbs. The yield data were recorded in kilograms per square metre (kg/m^2) and later converted to metric ton per hectare (t/ha). Other related data collected on harvest were the; number of storage roots, number of bulbs onion, size of the roots, and weevil damages. To calculate the yield and test the significance for the treatments, the data were subjected to the One-Way Analysis of Variance (ANOVA) using SAS version 9.1. All percentages data were transformed using arc-sine transformations in excel 2007 to stabilize variances before subjected to the statistical analysis.

3.8. Land Use Efficiency

Land Equivalent Ratio (LER) was used to assess the land use efficiency using the mean yields of Intercrop and sole crops of orange-fleshed sweetpotato and onion. The intercrop yields were divided by the sole crop yields for each component crop in the intercrop, and then the figures were added together i.e., the partial LER's of OFSP and onion as shown in Table 6. The efficiency of land use in regards to sweetpotato and onion combinations was measured using the following equation;

LER=L-OFSP+L-Onion, where **L-OFSP** is the yield of orange fleshed sweetpotato under intercropping/yield of sole cropped orange-fleshed sweetpotato and **L-Onion** is the yield of onion under intercropping/yield of sole cropped onion.

3.9. Gross Margin Analysis (GMA)

Gross Margin Analysis for sweetpotato and onion crops was calculated based on the costs of inputs and actual yields for each of the treatments used for this study. The sweetpotato roots harvested were categorised into two groups i.e., marketable (>100gms, undamaged) and non-marketable (<100gms or damaged). Only marketable products were considered for the GMA calculations. All calculations were made in local currency (Malawi Kwacha (MK)) and then converted to US Dollar (USD) using the rate of MK398/USD i.e., the average rate for November 2013 (the month that the crops were harvested). Income calculations were based on existing prices of MK100/kg for sweetpotato and MK395/kg for onion which were the actual market prices by the time of harvest. The gross margin analysis was calculated by subtracting total revenue minus variable cost (Total Revenue-Variable cost), where total revenue (TR) is equal to $P_1Q_1 + P_nQ_n$.

P1 = Price of orange-fleshed sweetpotato (MK)

Q1 = Output of orange-fleshed sweetpotato (kg)

Pn = Price of Onion

Qn = Output of onion (kg)

Total variable costs include cost of labour (land preparation, planting, weeding, watering and harvesting), planting materials (Sweetpotato vines and onion bulbs/seedlings, and other variable inputs.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Yield of Sweetpotato and Onion

4.1.1 Weight of orange-fleshed sweetpotato storage roots (t/ha)

Collecting yield data for crops at harvest time is an important step when it comes to agricultural food production. The weight of the sweetpotato roots harvested is correlated with the income referred to us as how much the grower is going to earn from the produce. The yield allows the estimation of the profits from the crops harvested and is considered as a good indicator for food security.

In Table 1, the yield data for orange-fleshed sweetpotato showed a significant difference between the sole cropping of orange-fleshed sweetpotato and the intercropping practice (4:1 OFSP to Onion ratio) for site 1 but no significant difference was indicated when sole cropping and intercropping practice at OFSP to Onion ratio 2:1 were compared ($P \leq 0.05$). The mean values for orange-fleshed sweetpotato yield at site 1 were 507.33, 382.67 and 365.33 respectively for sole cropped, intercropping at 2:1 ratio, and intercropping at 4:1 ratio. Intercropping practices yielded higher results with 4:1 OFSP to Onion ratio intercropping results showed the higher number. However, the results from site 2 did not differ significantly for all treatments where the mean values for orange-fleshed sweetpotato yield were 456.0, 366.0 and 453.67 for sole cropped, Intercrop (OFSP to Onion ratio 4:1) and intercrop (OFSP to Onion ratio 2:1) respectively. The results differed between site 1 and site two because the field conditions that the experiments were conducted were different.

Table 1. Yield of Orange-Fleshed Sweetpotato Potato Storage Roots (t/ha)

Treatments	SITE 1	SITE 2
Pure Stand of OFSP	507.33 ± 41.36[a]	456.00 ± 62.39[a]
OFSP + Onion at 2:1 Ratio	382. 67 ± 57.01[a]	356.00 ± 1.00[a]
OFSP + Onion at 4:1 Ratio	365.33 ± 90.53[b]	453.67 ± 70.87[a]

NOTE: Mean ± SD

a, b indicate significant difference ($P \leq 0.05$).

4.1.2. Weight of orange-fleshed sweetpotato Vines (t/ha)

Sweetpotato vines are the main planting materials for sweetpotato production. It is very important for clean (free from diseases) vines to be produced during sweetpotato cultivation to increase the production of sweetpotato for the next season. Multiplication and distribution of clean planting materials or vines are considered important at all levels; individual farmers, farmer groups that manage secondary multiplication sites and national agricultural research institutes and supply-side partners such as extension and non-governmental organization staff that do the backstopping and monitoring (Sindi *et al*., 2013). Results for the sweetpotato vines yield as shown in Table 2 indicate no significant differences from all treatments at site 1. The total means recorded for the OFSP vines at site 1 were 139.6, 81.67, and 97.67 for sole cropped, intercrop (4:1 OFSP to Onion ratio) and intercrop (2:1 OFSP to Onion ratio). Results for the vines yield were different at site 2. There was a significant difference for all intercropping systems in comparison to the sole cropped practice with mean values of 113.0 for sole cropped, 77.33 for intercrop at 4:1 OFSP to Onion ratio and 48.67 for intercrop at 2:1 OFSP to Onion ratio. Sweetpotato is normally propagated vegetatively by vine cuttings but various propagation materials can be used to establish the crop. In areas where production cannot be carried on continuously and vines are unavailable for planting, roots sprouts and storage root pieces are used for propagation (Belehu 2003). There have been attempts to increase the yield of sweetpotato vines through modifications in cutting technique.

Table 2. Yield of Orange-Fleshed Sweetpotato Vines (t/ha)

Treatments	SITE 1	SITE 2
Pure Stand of OFSP	139.6 ± 10.69[a]	113.00 ± 16.09[a]
OFSP + Onion at 2:1 Ratio	81.67 ± 20.03[a]	77.33 ± 6.51[b]
OFSP + Onion at 4:1 Ratio	97.67 ± 24.01[a]	48.67 ± 7.51[c]

NOTE: Mean ± SD

a, b, c indicate significant difference ($P \leq 0.05$).

4.1.3 Number of orange-fleshed sweetpotato storage roots harvested

Storage roots (tubers) yield was based on the actual area of the whole plot and appeared to provide a good estimate of the true yield of the sweetpotato. The total number of storage roots harvested was categorized into “marketable and non-marketable” roots according to the specified size. Orange-fleshed sweetpotato roots that weighed more than 100grams (gms) and were not damaged (>100gms, undamaged) were considered marketable, while all the tubers weighed less or equal to 100 grams, and damaged were considered as non-marketable (<=100gms) products. This criterion was important for the market value as the marketable products were used as the basis for calculating the gross margin analysis for this production. Most of the products (storage roots) yielded were non-marketable as compared to the marketable roots (Table 3 and Table 4). The total number of roots harvested at Site 1 for the respective treatments was 332.0/plot, 263.67/plot and 261.67/plot for sole cropped OFSP, intercropping at 2:1 ratio and intercropping at 4:1 ratio. The separation of marketable and non-marketable roots yielded 31.32%, 31.10% and 35.33% of marketable roots, and 68.88%, 68.90 and 64.67% of non-marketable products as it was shown in Table 3. Site 2 produced 120.67, 80.0 and 115.33 number of marketable roots/plot for sole cropped OFSP, intercropping at 2:1 ratio and intercropping at 4:1 ratio, and 152.0 125.0, 153.33 number of non-marketable roots for sole cropped OFSP, intercropping at 2:1 ratio and intercropping at 4:1 ratio respectively representing 44.25%, 39.02% and 42.93% of marketable roots, and 55.75%, 60.98% and 57.07% of non-marketable roots (Table 4).

Results in table 3 shows a significant different for total number of storage roots harvested and total number of non-marketable products. Regarding the total number of roots harvested, there was a significant difference between sole cropped orange-fleshed sweetpotato and intercrop practice (4:1 OFSP to Onion). There was no significant difference for all treatments in terms of the total number of marketable roots. In non-marketable roots, there was a significant difference for sole cropped OFSP and intercrop (4:1 OFSP to Onion). However, number of roots harvested and total number of roots were significantly different between sole cropped OFSP and intercropped practice (2:1) as shown in table 4. There was no significant difference for sole cropped and intercrops for non-marketable roots (Table 4).

Table 3. Number of Orange-Fleshed Sweetpotato Storage Roots Harvested

Treatments	**Total No. of Roots Harvested**	**Total No. of Marketable Roots**	**Total No.of Non-Markertable Roots**
Pure Stand of OFSP	332.00 ± 22.65^{a}	103.33 ± 7.77^{a}	228.67 ± 15.70^{a}
OFSP + Onion at 2:1 Ratio	263.67 ± 24.01^{a}	82.00 ± 14.00^{a}	181.67 ± 29.19^{a}
OFSP + Onion at 4:1 Ratio	261.33 ± 49.97^{b}	92.33 ± 17.93^{a}	169.00 ± 34.00^{b}

***Marketable: >100gms, undamaged; Non-Marketable: <=100gms, damaged.

NOTE: Mean ± SD

a, b indicate significant difference ($P \leq 0.05$).

Table 4. Number of Orange-Fleshed Sweetpotato Roots Harvested

Treatments	**No. of Roots Harvested**	**Total No. of Marketable Roots**	**Total No.of Non-Markertable Roots**
Pure Stand of OFSP	272.67 ± 30.89[a]	120. 67 ± 5.51[a]	152.00 ± 26.06[a]
OFSP + Onion at 2:1 Ratio	205.00 ± 7.00[b]	80.00 ± 12.29[b]	125.00 ± 5.29[a]
OFSP + Onion at 4:1 Ratio	268.67 ± 41.97[a]	115.33 ± 17.90[a]	153.33 ± 24.21[a]

***Marketable: >100gms, undamaged; Non-Marketable: <=100gms, damaged.

NOTE: Mean ± SD

a, b indicate significant difference (P ≤ 0.05).

4.1.4 Weight and number of onion bulbs harvested (t/ha)

Both purple and white onions are grown nationwide in Malawi. They are popular food and are common ingredient in the local 'relish'. The weight of onion bulbs determines the price at the market. Harvested onion bulbs are also a good source of onion planting materials. The use of onion bulbs as planting material is preferred by most onion growers as compared to onion seeds during planting because bulbs are easier to use as compared to seeds. Planted bulbs also sprout and mature earlier than seeds. In addition, bulbs produce true-to-type plants which signify that the plant would reproduce itself to exactly the plant it reproduced from (Addai 2014). Data for the number of onion bulbs and weight data was recorded at harvest. Weight information showed the mean values of 156.67 from sole cropped practice, 43.33 from the 2:1 OFSP to Onion intercropped and 44.67 for OFSP and onion intercropped at ratio 4: 1 respectively (Table 5). There was significant different from the sole cropped yield to intercrops of weight of onion bulbs for site 1, whereas all treatments from site 2 did not differ significantly. In terms of number of bulbs, the number of bulbs harvested did not differ significantly for all the respective treatments from both sites 1 and 2 (Table 6). The mean values for the total number of onion bulbs harvested were 320.0, 94.33 and 87.33 for sole cropped onion, intercrop at 2:1 OFSP to Onion, and intercrop at 4:1 OFSP to onion practices for site 1 and 378.67, 160.0 and 129.0 the same order for the respective treatments from site 2.

Table 5. Weight of Onion Bulbs Harvested (t/ha)

Treatments	SITE 1	SITE 2
Pure Stand of Onion	156.67 ± 14.98^{a}	166.00 ± 84.12^{a}
OFSP + Onion at 2:1 Ratio	43.33 ± 21.94^{b}	71.33 ± 10.26^{a}
OFSP + Onion at 4:1 Ratio	44.67 ± 2.89^{b}	52.67 ± 17.01^{a}

NOTE: Mean ± SD

a, b indicate significant difference ($P \leq 0.05$).

Table 6. Total Number of Onion Bulbs Harvested

Treatments	SITE 1	SITE 2
Pure Stand of Onion	320.00 ± 79.00^{a}	378.67 ± 192.86^{a}
OFSP + Onion at 2:1 Ratio	94. 33 ± 33.08^{a}	160.00 ± 21.38^{a}
OFSP + Onion at 4:1 Ratio	87. 33 ± 13.65^{a}	129.00 ± 42.57^{a}

NOTE: Mean ± SD

a, b indicate significant difference ($P \leq 0.05$).

4.2. Size of Orange-Fleshed Sweetpotato Storage Roots Site 1 and Site 2

The roots/tuber size for tuber crops is one of the important agronomic characters in estimating production. The size of the root/tuber relates the cost at the market because the bigger the size of the roots the higher the selling price, bigger size of the roots increases the income for the growers. The size of tubers measured by using a 1-5 scale: unacceptable, poor, average, good and excellent yielded different results from all treatments at different sites (Site 1 and Site 2). Results from site 1 (Fig.2) indicated that 33.33% of the roots harvested from the sole cropped practice were poor, and the size of 66.67% roots harvested was average. The tuber/roots harvested from the orange-fleshed sweetpotato to onion intercrops at site 1 yielded similar results. 33.33% of the roots at site 1 for intercrops treatments were considered as average size while 66.67% of the roots size was good. Results for the roots size differed slightly at site 2 (Fig.3). There were no tubers that were not acceptable and poor sized. Sole cropped orange-fleshed sweetpotato produced 66.67% of the average size, and 33.33% of the roots were of good size. Intercropping OFSP with Onion at 2:1 ratio yielded similar results with the sole cropped practice while intercropping at 4:1 ratio of OFSP and onion produced better quality roots. 66.67% of the roots from this treatment were categorized as good size and 33.33% of the roots were considered as excellent root size.

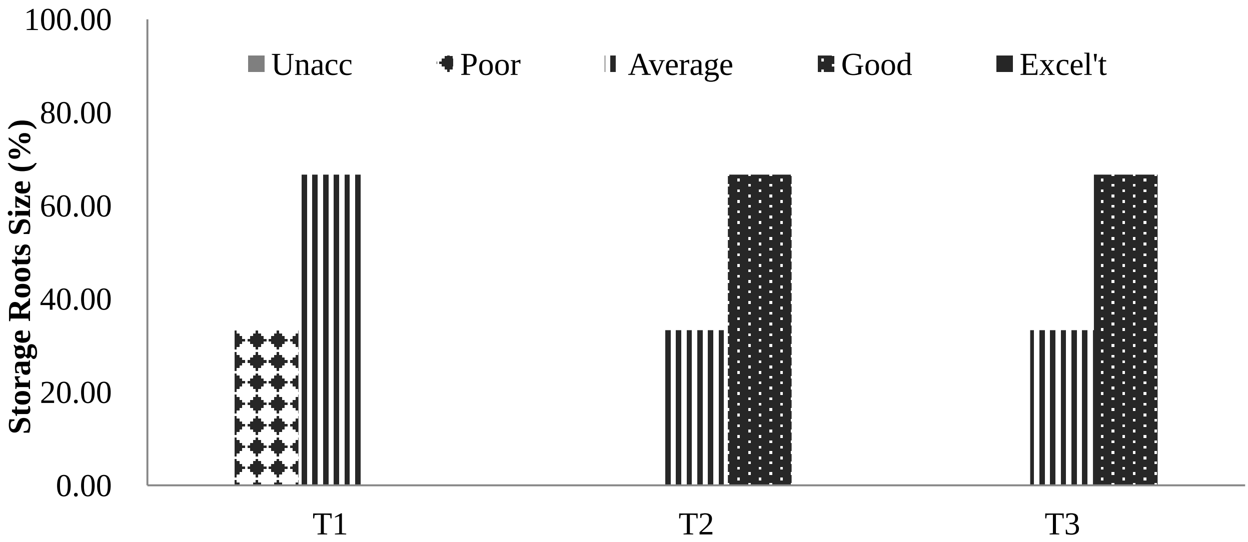


Figure 2. Average Size of Orange-Fleshed Sweetpotato Storage Roots (Site 1)

NOTE: T1, T2, T3 = Sole Cropped OFSP, OFSP + Onion (2:1), OFSP + Onion (4:1)

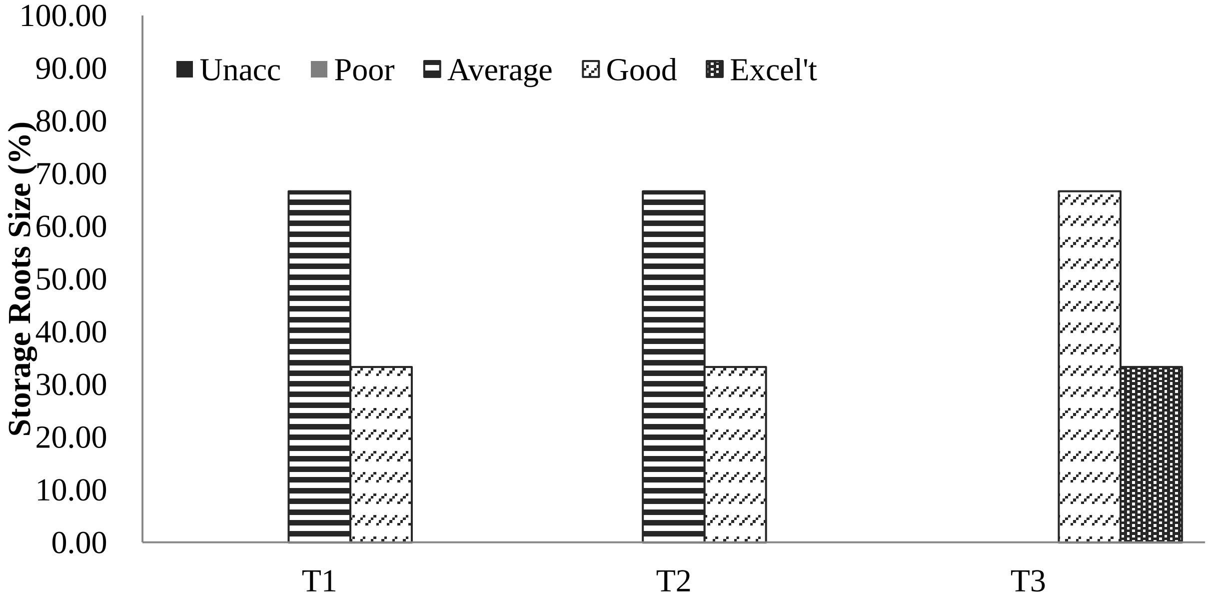


Figure 3. Average Size of Orange-Fleshed Sweetpotato Storage Roots (Site 2)

4.3. Virus Symptoms Site 1and Site 2

Sweet potato virus disease (SPVD) causes severe disease symptoms of various combinations of leaf strapping, vein-clearing, puckering and stunting (Hahn 1979). The disease is widespread, especially in Africa, and yield is adversely affected, though there are no figures to quantify this effect nor is it known how yield is affected. Loss of tuberous root yield due to SPVD can be as high as 98% (Gibson *et al. 1997*). The incidence of virus symptoms was observed as one of the qualitative measures of orange-fleshed sweetpotato productions. Data were collected at 6-8 weeks after planting and one month before harvest using a 1-9 virus coding scheme: No Virus Symptoms (NVS), Unclear Virus Symptoms (UVS), Clear Virus Symptom (CVS), CVS at one Plant per Plot (P/P), CVS at 2-3 P/P, CVS at 5-10% of P/P, CVS at 10-25% of P/P, CVS at 25-50% of P/P, CVS at nearly all plants per plot, CVS and clearly reduced growth in all plants. The incidence of virus symptoms was low from all treatments for both site 1 and site 2. OFSP at site 1 showed the virus symptoms at a range of 0-4 of the 1-9 virus symptoms coding scheme (Figs. 4 &5). At 6-8 weeks after planting sole cropped orange-fleshed sweetpotato showed no virus symptoms for 33% of the plants, 33% of the plants had unclear virus symptoms and 33% of the remaining plants showed clear virus symptoms at 2-3 plants /plot, at 1 month before harvest the incidence of the virus symptoms recorded was 33% of plants with unclear virus symptoms, 33% with clear virus symptoms at 1 plant/plot and 33% of plants with clear virus symptoms at 2-3 plants per plot representing 1-4 of the virus symptoms incidence coding scheme. The virus symptoms incidence from the Intercropping practice at OFSP to Onion ratio of 2:1 presented 33% of plants with no clear virus symptoms, 33% of plants with clear virus symptoms at 1 plant per plot and 33% of plants showed clear virus symptoms at 2-3 plants per plot at 6-8 weeks after planting and 67% of plants with clear virus symptoms at 2-3 plants per plot and 33% of plants with clear virus symptoms at 5-10% plants/plot falling in the range of 0-5 of the 1-9 coding scheme. Intercropping practice at the ratio of 4:1 showed similar results to with those intercropped at the ratio of 2:1 for the results recorded at 6-8 weeks after planting while at one month before harvest 67% of the plants showed clear virus symptoms at 1 plant/plot and 33% of plants showed clear virus symptoms at 2-3 plants/plot ranging between 0-4 from the virus symptoms incidence coding scheme (Figs. 4 & 5). On the other hand, results from Site 2 indicated the following; there were 33% of plants with no virus symptoms and 67% of plants with clear virus symptoms at 2-3 plants/plot at 6-8 weeks after planting, and 67% of the plants with clear virus symptoms at 5-10% of plants per plot and 33% of plants with clear virus symptoms at 25-50% of plants per plot at one month before harvest. Results at 6-8 weeks after planting were similar for the intercrop at 2:1 and 4:1 OFSP to Onion ratio, while at 1 month before harvest 33% of the plants showed clear virus symptom at one plant per plot, and 67% of the plants showed clear virus symptom at 2-3 plants per plot representing the virus coding incidence scheme range of 1-4 respectively (Figs. 6 & 7).

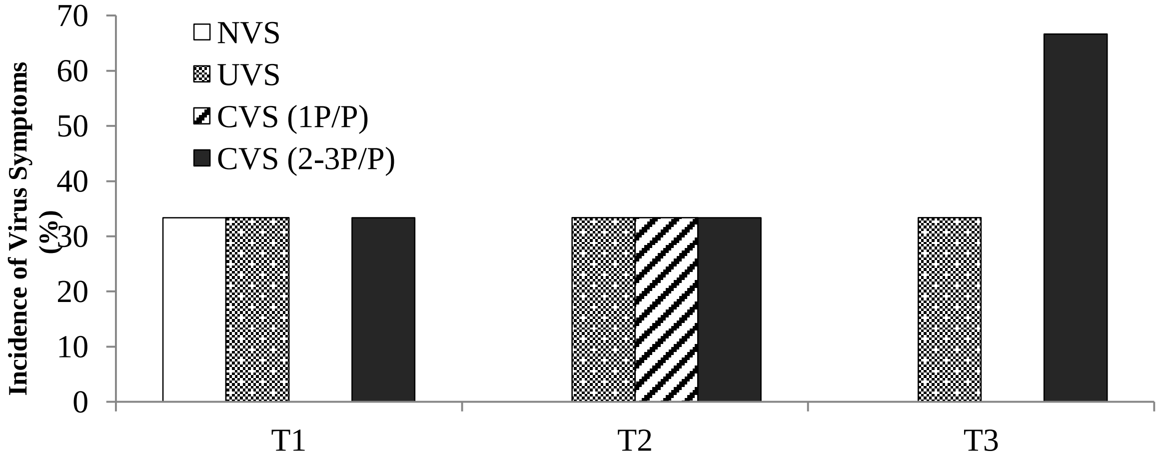


Figure 4. Virus Symptoms Incidence on OFSP Crop at 6-8 Weeks after Planting (Site 1)

***NVS = No Virus Symptoms, UVS = Unclear Virus Symptoms, CVS = Clear Virus Symptoms, P/P = Plants per Plot.**

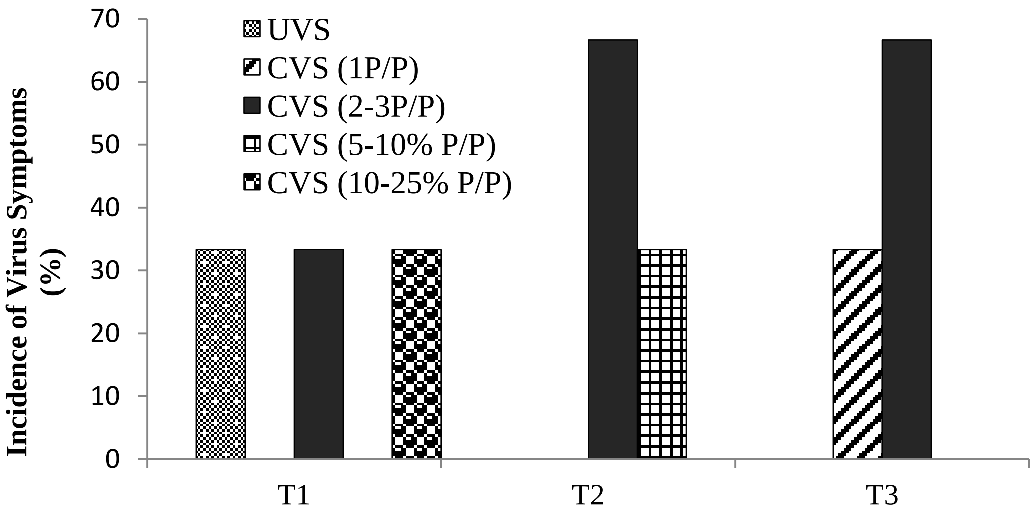


Figure 5. Virus Symptoms Incidence on OFSP Crop at One Month before Harvest (Site 1).

***NVS = No Virus Symptoms, UVS = Unclear Virus Symptoms, CVS = Clear Virus Symptoms, P/P = Plants per Plot.**

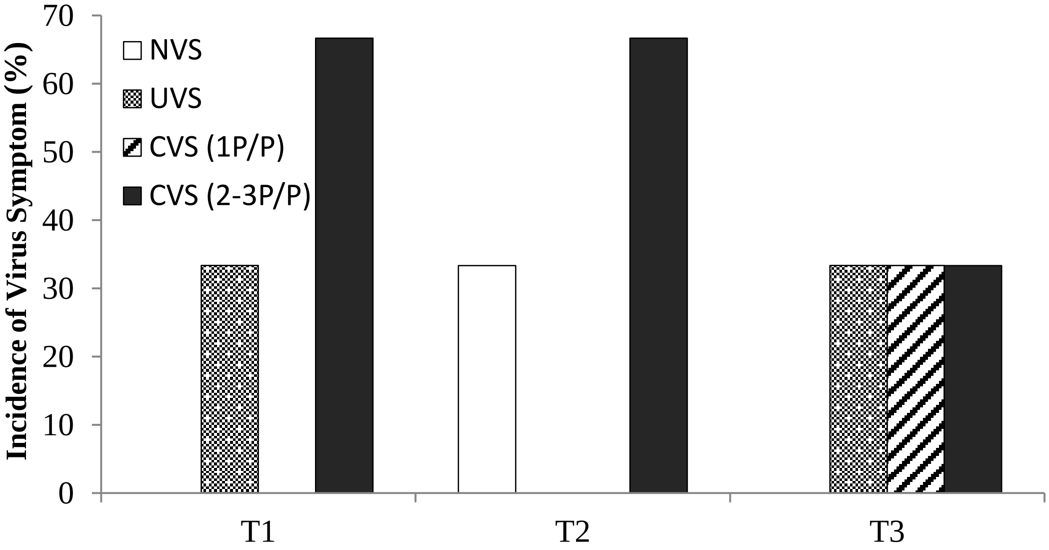


Figure 6. Virus Symptoms Incidence on OFSP Crops at 6-8 Weeks after Planting (Site 2).

***NVS = No Virus Symptoms, UVS = Unclear Virus Symptoms, CVS = Clear Virus Symptoms, P/P = Plants per Plot.**

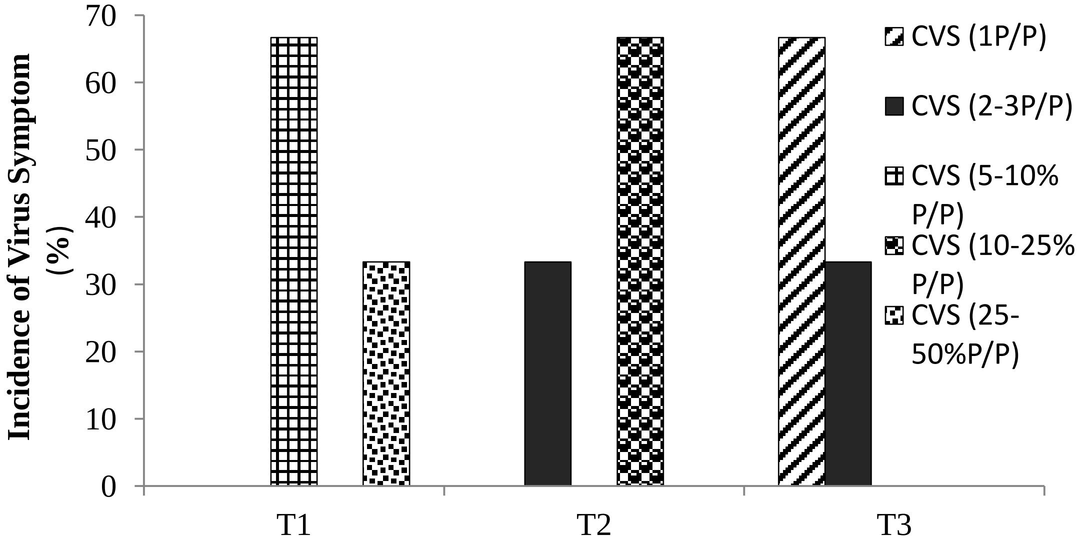


Figure 7. Virus Symptoms Incidence on OFSP Crop at One Month before Harvest (Site 2).

***NVS = No Virus Symptoms, UVS = Unclear Virus Symptoms, CVS = Clear Virus Symptoms, P/P = Plants per Plot.**

4.4. Weevil Damages

Sweetpotato weevil *Cylas Spp*. constitutes a major constraint to sweetpotato production and utilization in Africa. Weevil damage to sweetpotato was visually assessed and scored using a 1-5 scale; none, light, moderate, severe and very severe i.e., moderate = 30-60%, and severe = 30-60% and very severe = >60% weevil damage. A root was considered to be damaged if it had a bore characteristic, dark scarred spots on the surface of the root-a typical symptom of weevil penetration and feeding (Mansaray et al. 2013). Data for weevil damage on sweetpotato crop were recorded at 6-8 weeks after planting and one month before harvest. Results from site 1 showed that only sole cropped sweetpotato was affected with weevils with 33% of the plants recorded as slightly affected according to the scale. At one month before harvest, almost all plants on sole cropped orange-fleshed sweetpotato were affected by the weevils. 33% of the plants were moderately affected, 33% of the plants were recorded as severe damaged, and the remaining 33% were severely damaged (Fig.9). Site 2 presented different results from those of the site 1. There was no weevil damage problem observed for all treatments from site 2 at 6-8 weeks after planting. Damages on the plants at one month before harvest were recorded as 33% light damaged, 33% severe damaged and 33% very severe damaged by the sweetpotato weevils. The intercropping practices of OFSP to Onion ratios 4:1 and 2:1 yielded different results. On 2:1 ratio, 33% of the plants were not damaged, 33% were light damaged and 33% were moderately damaged, while on 4:1 ratio was produced a higher number of roots that were not damaged by the weevils as compared to other treatments. 66.7% of the plants were not affected while 33.33% were light damaged (Fig. 10) as categorized by the weevil damage scale of 1-5 used.

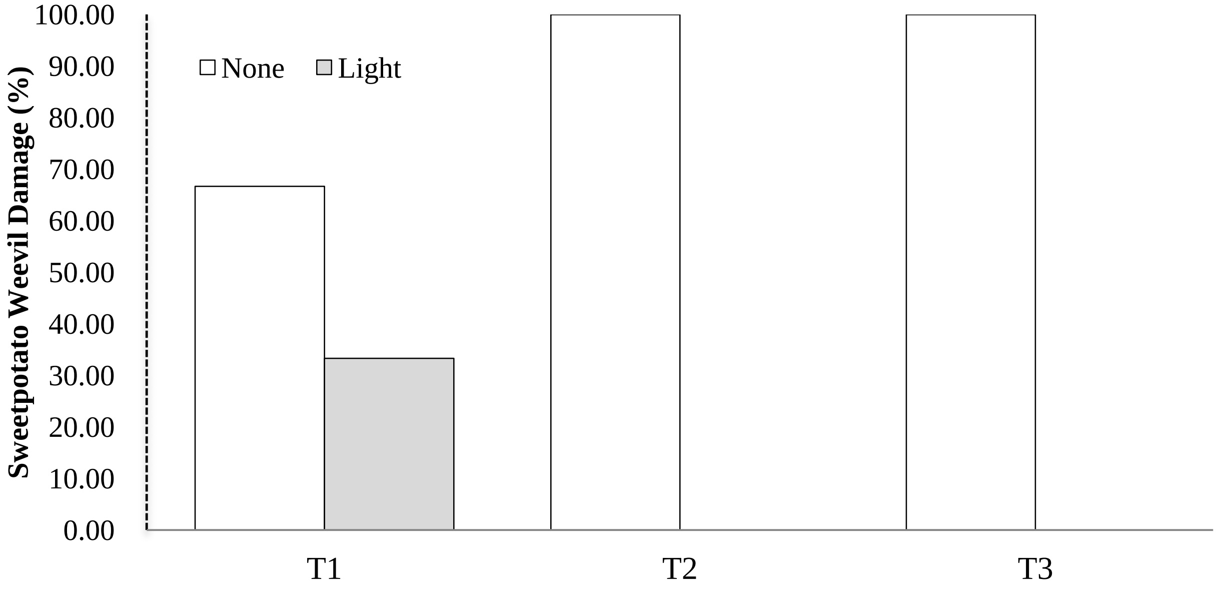
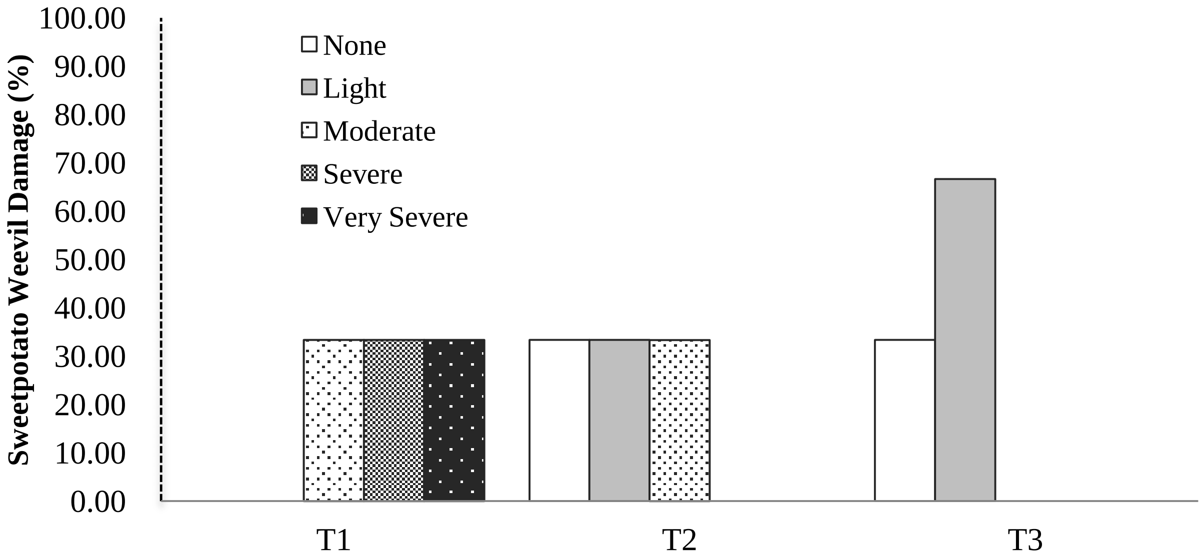


Figure 8. Percentage of Sweetpotato Weevil Damage at 6-8 Weeks after Planting (Site 1)



Moderate = 10-30%, Severe = 30-60%, V. Severe = >60%

Figure 9. Percentage of Sweetpotato Weevil Damage at one Month before Harvest (Site 1)

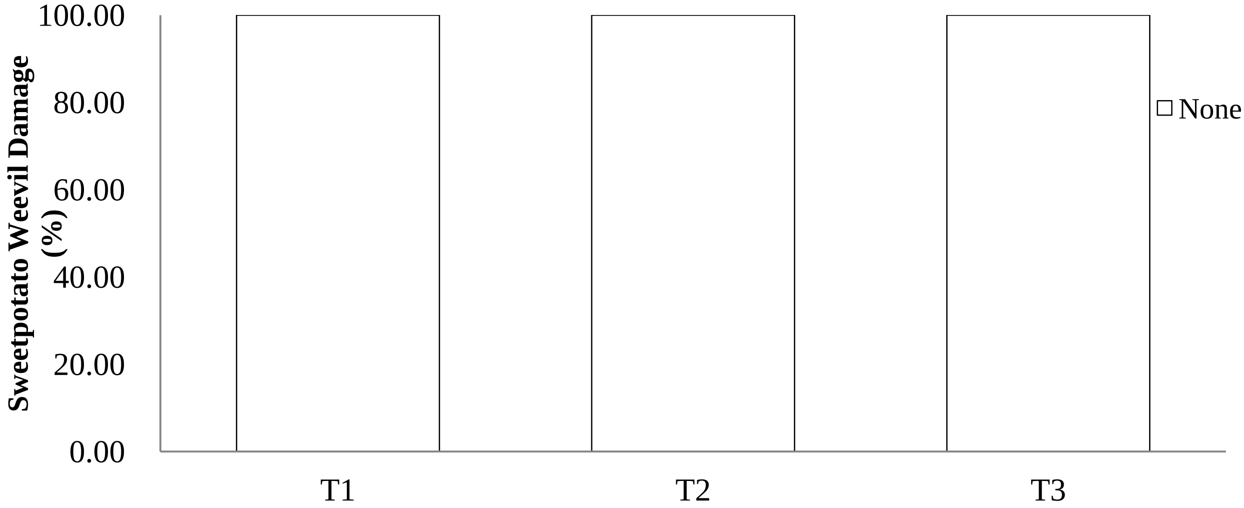


Figure 10. Percentage of Sweetpotato Weevil Damage at 6-8 Weeks after Planting

(Site 2)

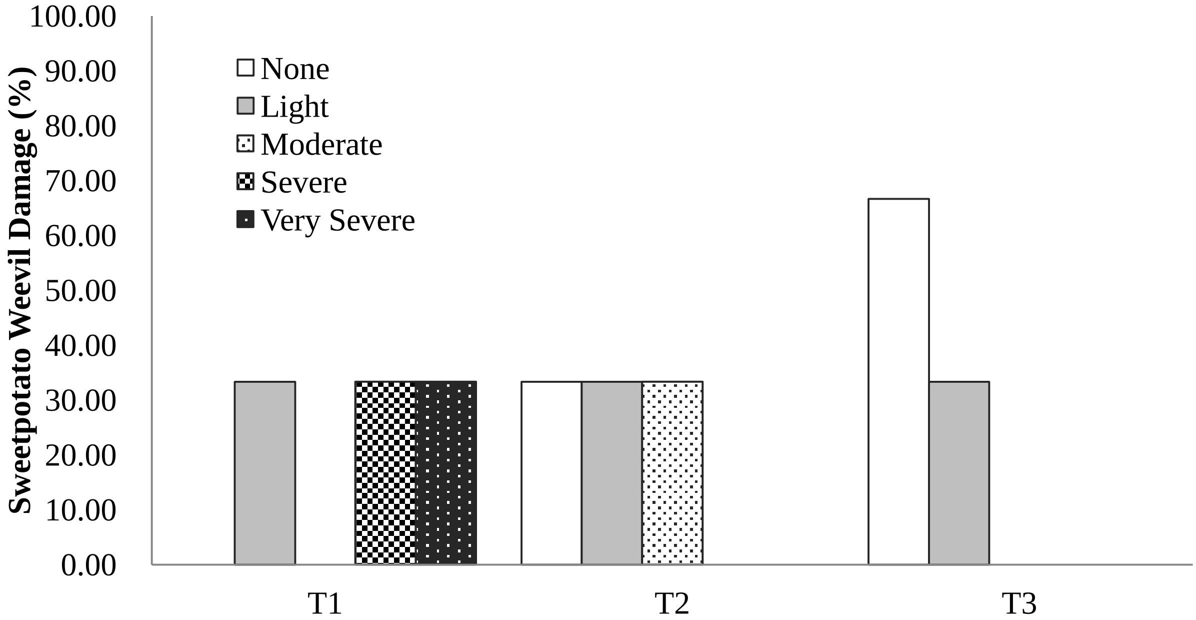


Figure 11. Percentage of Sweetpotato Weevil Damage at One Month before Harvest

(Site2)

4.5. Land Equivalent Ratio (LER)

Intercropping has been recognized that it can often produce high yields than sole crops (Mohammed 2012). However, assessing the degree of yield advantage can be challenging. A number of researchers realized that calculating the Land Equivalent Ratio (LER) is an important tool for evaluating the intercropping system (Dariush et al., 2006, Magino et al., 2004). The concept of LER is considered for situations where intercropping must be compared with each crop sole, originally proposed to help judge the relative performance of a component of a crop combination compared to sole stands of those species (Mead and Willey 1980).

Intercropping advantage and competition between orange-fleshed sweetpotato (OFSP) and Onion was calculated for this study. The LER was calculated to quantify the efficiency of the intercropping treatments. The yield data for both OFSP and onion crops were collected and their averages per treatment were recorded (Table 5). The table shows the average yields for each treatment for two sites (Site 1 and Site 2).

Table 5. Yields of OFSP and Onion (t/ha)

	SITE 1		**SITE 2**	
Treatments	**OFSP**	**Onion**	**OFSP**	**Onion**
Pure Stand of OFSP	313	470	365	498
OFSP + Onion at 2:1 Ratio	249	145	243	214
OFSP + Onion at 4:1 Ratio	280	135	349	158

NOTE: OFSP stands for Orange-Fleshed Sweetpotato

Results for the Land Equivalent Ratio are shown in the table 6:

Table 6. The LER's of Orange-Fleshed Sweetpotato and Onion Intercrop for the two Trial Sites (Site 1 and Site 2)

	SITE 1			SITE 2		
Treatment	**OFSP**	**Onion**	**LER**	**OFSP**	**Onion**	**LER**
OFSP + Onion at 2:1 Ratio	0.80	0.31	1.11	0.67	0.43	1.10
OFSP + Onion at 4:1 Ratio	0.90	0.29	1.19	0.96	0.32	1.28

Results for the LER illustrate the higher partial LER's in Orange-Fleshed sweetpotato than in onion for both site 1 and site 2. Although the crops yield of the components crops in mixtures were low as compared to their respective sole crop yields (Table 6), the total land productivity was improved in mixed cultures as reported by the higher total LERs. The LER results indicate that the plant population of treatments 3 and 4 (1:2 and 1:4 intercrop ratios) for sweetpotato and onion was a positive interaction. According to the results shown in the LER table, the higher yield advantages were recorded in intercropping than those of the sole crops. Interactions for both trials (Site 1 and Site 2) had LER of greater than 1 (LER > 1), indicating the advantage to intercropping i.e., Intercropping was more efficient than the pure stand. The yield advantage of the intercrops suggests the additional yield required in the sole crops to equal the amount of yield achieved in the Intercrop (Sullivan, 2003). Regarding the results from the LER (table 6), the LER for OFSP and Onion planted at ratio 4:1 was a bit higher than that planted at 2:1 ratios with values of 1.11 and 1.19 for the trial at site 1, and 1.10 and 1.28 at site 2 respectively. The average LER of the OFSP and onion intercrops were 1.2 for both site 1 and site 2 with L-OFSP and L-Onion of 0.80 and 0.31 at intercrop ratio of 2:1 and 0.90 and 0.29 at 4:1 intercrop ratio at site 1. In site 2's LER values for the L-OFSP and L-Onion were 0.67 and 0.43 at intercrop ratio of 2:1 and 0.96 and 0.32 at 1:4 planting ratio respectively. The overall production for both intercrop systems used showed intercrops yield advantage even though there was only a slight difference in comparison with the LER results for treatments 3 and 4 (2:1 and 4:1 ratios) as their LER results ranged between 1.1 to 1.3 for both two different trial sites. The highest LER was 1.28 for the 1:4 planting ratio from site 2 followed by 1.19 from site one at ratio 1:4. These results conclude that, in terms of the analysis by the LER, the intercropping combination of 4 ridges of orange-fleshed sweetpotato and one ridge of onion was more efficient. Results for the LER at OFSP and Onion intercrop practiced at ratio 2:1 were 1.11 for site 1 and 1.10 at site 2 respectively. Since none of the LER results for both combinations was less than 1 (LER <1), it means that there was no negative interaction occurrence for the plant populations.

The conclusion drawn regarding the LER results was that, the area planted to sole crops (pure stands) would be greater than the area under intercrops by 11% and 19% for site 1, and 10% and 28% for site 2 for the two crops to produce the same combined yields from the intercrops indicating that the land-use efficiency of intercrops is greater than the sole crops. Similar results were reported for the mixtures of barley and faba beans (Agegnehu et al., 2006), cauliflower and cos lettuce, leaf lettuce, onion, snap bean (Yildirim and Guvenc, 2005), barley and annual medic (Sadeghpour et al., 2013), maize and cow pea, a grain legume (Rusinamhodzi et. al., 2012). The measurement for interpreting the LER results convey that if the LER = 1.0, then the amount required for two different crops grown together is the same as that for each individual crop grown in pure. In other words, there’s no advantage to intercropping over pure stands. The LER > 1.0 expresses the advantage to intercropping and the LER < 1.0 indicates the disadvantage to intercropping.

The partial LER’s of orange-fleshed sweetpotato (Table 6) were higher than those of onion in both trial sites and in all intercrop combinations. This happened because the population of onion at harvest was very low than required due to mismanagement as those onion plants that did not establish were not replaced. Theft also occurred at the field which contributed to the low yield of onion crop.

4.6. Gross Margin Analysis (GMA)

Gross margin analysis (GMA) for sweetpotato and onion was based on the costs of inputs and actual yield for each treatment. Labour cost incurred for the cropping systems was due to the land preparation, planting, weeding, watering and harvesting (Table 7). The labour cost were MK995.72 for sole cropped orange-fleshed sweetpotato (OFSP), MK2789.69 for sole cropped onion, MK634.93 for OFSP and onion intercrop at ratio 2:1 and MK642.15 for OFSP and onion intercrop at ratio 4:1. 'Zondeni' OFSP variety was used for this study, the cost of its planting materials was MK342.00 for sole cropped OFSP, MK273.60 for Intercropping at ratio 2:1, and MK 307.15 for intercropping at ratio 4:1 respectively. The variety of onion was not considered in this study. The costs of onion materials used for the respective treatments were MK17400.00 for sole cropped onion, MK6960.00 for an intercrop of OFSP and onion at 2:1 ratio, and MK5220.00 for an intercrop at ration 4:1. Total variable cost for the respective treatments at site 1 and site two were the same since this research was done at the same period of time, and at the same district where costs of the inputs were the same (Table 7). Planting materials were the highest variable costs incurred mainly from the onion based cropping systems. Gross returns are shown in Tables 8 and 10 for sites 1 and 2. The gross returns were calculated by multiplying the total quantity of the outputs harvested by the average market price prevailing the period of harvest. The same method was used by Olorunsanya and Akinyemi (2004) in their study; "Gross Margin Analysis of Maize-based Cropping System in Oyo State, Nigeria". In their study, Maize-Yam cropping system had the highest gross return per hectare compared with the Maize-Cassava, and Maize-soybeans cropping systems. Table 10 shows that intercropping of orange-fleshed sweetpotato with onion at ratio 4:1 has the higher number in terms of the profits (gross margin) per metre squared compared with other cropping systems in the study area from both Site 1 and Site 2. All the calculations regarding the costs were made using the local currency (Malawi Kwacha (MK)) and then converted to U.S dollars (USD) using the rate of MK398/USD. The income prices were based on products' selling price at the local markets. The prices used for the income were MK100/kg for sweetpotato and MK395/kg for onion. The profits were strongly due to sweetpotato production as compared to the low production of onion. The following tables (Table 8 & 10) show the economic efficiency for sweetpotato and onion productions for sites 1 and 2.

Table7. Total Variable Cost and Relative Input Cost for Site 1 and Site 2 (MK/m^2)

Cropping System	Planting Materials		Labour Cost	Total Variable Cost
	OFSP	Onion		
Sole Cropped OFSP	342.00	0.00	995.72	1337.72
Sole Cropped Onion	0.00	17400.00	2789.69	20189.69
OFSP+Onion (2:1 Ratio)	273.60	6960.00	634.93	7868.53
OFSP+Onion (4:1 Ratio)	307.15	5220.00	642.15	6169.95

*Labour Cost: Land preparation, planting, weeding, watering, harvesting, MK = Malawi Kwacha

Table 8. Gross Returns Per Square Metre for Orange-Fleshed Sweetpotato and Onion Based Cropping Systems (Site 1)

Cropping System	Output (kg/m^2)		Average Marketing Price		Total Revenue
	OFSP	Onion	OFSP	Onion	
Sole Cropped OFSP	31.30	0.00	3130.00	0.00	3130.00
Sole Cropped Onion	0.00	47.00	0.00	18565.00	18565.00
OFSP+Onion (2:1 Ratio)	24.90	14.50	2490.00	5727.50	8217.50
OFSP+Onion (4:1 Ratio)	28.00	13.50	2800.00	5332.50	8132.50

Table 9. Cost and Returns Per Square Metre of Orange-Fleshed Sweetpotato and Onion Based Cropping Systems (Site 1)

Items	Sole Cropped OFSP	Sole Cropped Onion	OFSP+Onion (2:1 Ratio)	OFSP+Onion (4:1 Ratio)
Gross Returns	3130.00	18565.00	8217.50	8132.50
Total Variable Cost	1337.72	20189.69	7868.53	6169.95
Gross Margins	1792.28	-1624.69	348.97	1962.55

Table 10. Gross Returns Per Square Metre for Orange-Fleshed Sweetpotato and Onion Based Cropping Systems (Site 2)

Cropping System	Output (kg/m2)		Average Marketing Price		Total Revenue
	OFSP	Onion	OFSP (MK100/kg)	Onion (MK395/kg)	
Sole Cropped OFSP	36.50	0.00	3650.00	0.00	36.50
Sole Cropped Onion	0.00	49.80	0.00	19671.00	19671.00
OFSP+Onion (2:1 Ratio)	24.30	21.40	2430.00	8453.00	10883.00
OFSP+Onion (4:1 Ratio)	34.90	15.80	3490.00	6241.00	9731.00

Table 11. Cost and Returns Per Square Metre of Orange-Fleshed Sweetpotato and Onion Based Cropping Systems (Site 2)

Items	Sole Cropped OFSP	Sole Cropped Onion	OFSP+Onion (2:1 Ratio)	OFSP+Onion (4:1 Ratio)
Gross Returns	3650.00	1967.00	10883.00	9731.00
Total Variable Cost	1337.72	20189.69	7868.53	6169.95
Gross Margins	2314.28	-518.69	3014.47	3561.05

The information recorded in the tables above is also shown graphically in the figures 2 and 3 below. Figure 12 represents the gross margin calculated at site 1 and figure 13 illustrates the costs and returns for site 2 of the field trials.

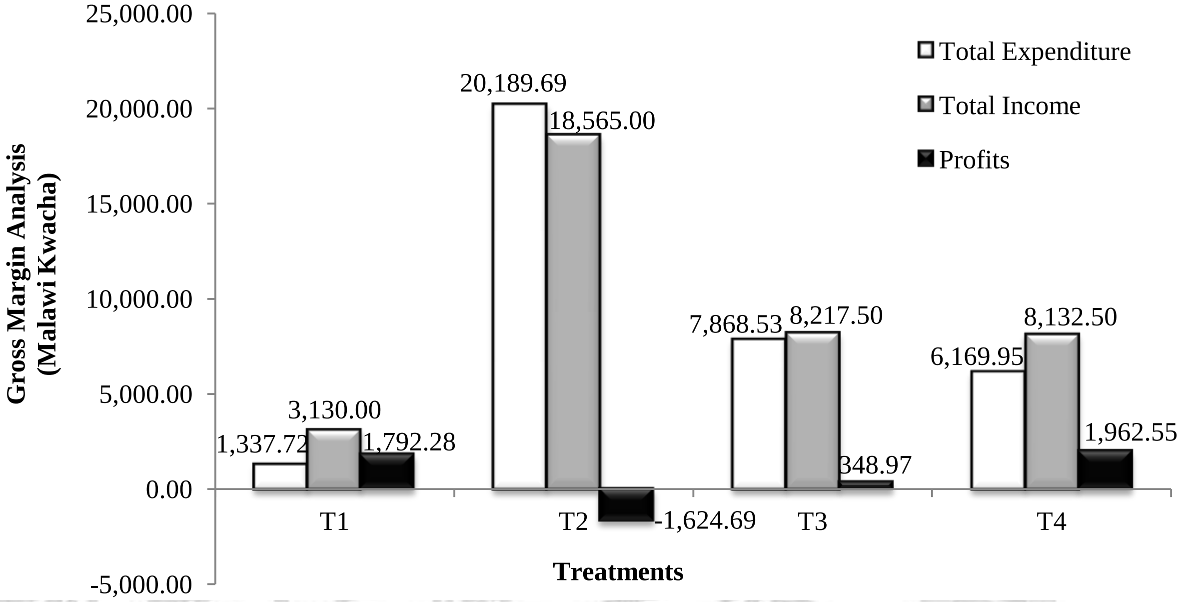


Figure 12. Gross Margins of Sweet Potato and Onion Crops (Site 1)

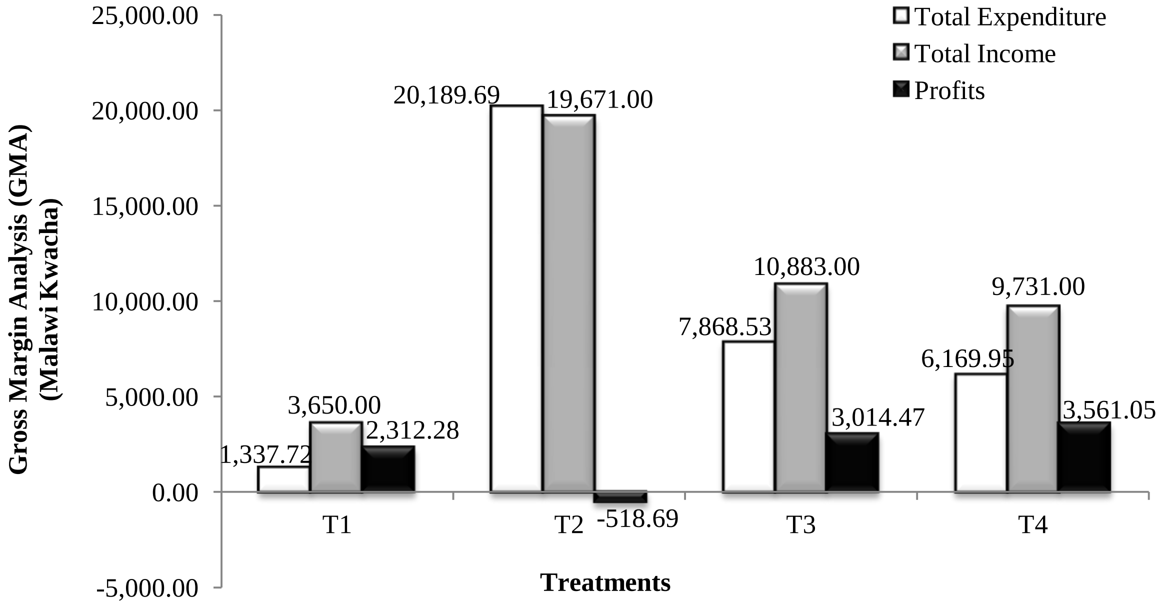


Figure 13. Gross Margins of Sweet Potato and Onion Crops (Site 2)

Results from the income and expenditure calculations indicated the profits gained in all treatments except the sole cropped onion. Results showed the loss of MK1624.69 in onion production for site 1 and MK518.69 for site 2, respectively. The profits gained from other treatments were MK1792.28, MK348.97 and MK1962.55 for sole cropped orange-fleshed sweetpotato, OFSP and onion intercrop (2:1), and OFSP and onion intercrops (4:1) representing a high returns for OFSP-Onion intercrops at ratio 4:1. The profits from the intercropping practices from site 2 did not differ much. The total returns for OFSP-onion 2:1 intercrop were MK3014.47, while those of OFSP-onion 4:1 was MK3516.05.

The overall GMA results showed a higher profit gain when the two crops were intercropped at ratio 4:1. Site 2 returned higher profits as compared to those of site 1 on similar treatments. Poor yield was recorded for site one as compared to site 2, hence the poor returns. To calculate the gross margin, only marketable products were considered. Following the criteria (>100gms: Markertable, <=100gms: Non-Marketable), the majority of the storage roots harvested were considered non-marketable as compared to the marketable products (Tables 3&4). The overall percentage of the non-marketable products were recorded to be higher (67.48% and 57.93%) as compared to 32.59% and 42.07% for the marketable products produced at Site 1 and Site 2, respectively.

CHAPTER V

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

This chapter will provide a brief summary of the study, relating the findings to prior research, and suggesting possible directions for the future studies.

5.1. Conclusion

Some differences were observed between the treatments which were under evaluation. There was a significant difference between the sole cropped orange-fleshed sweetpotato (OFSP) and the intercrop practice (4: 1 ratio) in terms of OFSP yield (t/ha), but no significant difference from sole cropped OFSP to intercrop (2:1 ratio). The yield of vines (t/ha) at site 1 showed no significant different from all the treatments under evaluation, while at site 2, there were significant differences from sole cropped OFSP to intercrops at all ratios. At both sites 1 and 2, the number of onion bulbs did not differ significantly from all the treatments, but in terms of the weight, sole cropped practice differed significantly with the intercrops.

The size of the orange-fleshed storage roots at site 1 ranged from poor to good size, while at site 2 the roots fell into the category of average to excellent size following the 1-5 scale: unacceptable, poor, average, good and excellent size of the roots. There was no difference for the root size from the intercrops at site 1 but observed at site 2. Intercropping OFSP-Onion at the ratio of 4:1 yielded a good percentage of the roots that was categorized as excellent size according to the scale. Sole cropped practice and intercrop practice at the ratio of 2:1 produced similar results in terms of the storage roots size.

Intercropping decreased the susceptibility of weevils on sweetpotatoes. Sole cropped orange-fleshed sweetpotatoes were highly affected by the weevils. Intercropping practice at the OFSP-Onion ratio of 4:1 had the lowest weevil damage percentage followed by the Intercropping at 2:1 ratio. The same trend was observed for the virus symptoms incidence. The virus symptoms results at 6-8weeks after planting were the same for all treatments at both site 1 and 2. Intercropping practice at the ratio of 4:1 indicated the lowest percentage of virus symptoms.

Intercropping increased the land use efficiency for growing orange-fleshed sweetpotato crop and onion together. Results from LER from site 1 and site 2 showed the higher partial LER in orange-fleshed sweetpotato than in onion (Table 6). Though the partial LER of onion was very low, the total land productivity was improved in mixed cultures. This indicated the positive interaction for intercropping practices. The values of LER from both site 1 and site 2 were greater than 1, representing that the intercropping advantage is over the sole cropped practice.

The economic efficiency was attained with profits strongly generated from the sweetpotato productions. Intercropping treatments produced higher profits than the sole crop with the intercropping of OFSP to Onion at ratio 4:1 generated the highest profits, followed by the intercropping at ratio 2:1.

Even though the yield was not very high in terms of number and weight of the harvested products (OFSP storage roots and onion bulbs), positive results were attained. Land efficiency and economic efficiency were achieved, and more importantly, weevil damages on sweetpotato crops were not severe. This draws a conclusion that onion can be used as a guard row/physical barrier for orange-fleshed sweet and onion intercrop; it has a significant efficiency of using the land, and highest GMA, and reduced the sweetpotato weevil damages effectively.

5.3. Recommendations

Based on the findings of the study, the following are recommendations for the future enhancement of this kind of research.

1. The timing of planting should be considered following the farming calendar at a specified location of which the trials are planned to be conducted.
2. The same experiment should be conducted with adequate water supply to the plants especially for the onion which is not a drought tolerant plant as the case of sweetpotato crop to increase the yield and income of onion crop.
3. The experiment should be conducted for more than one season to produce reliable results that will be based on seasonal comparisons and also to be conducted again in different agro-ecologies to determine the causes for the seasonal effect.
4. The experiment should be conducted with enough budgets to avoid the situation of shortage of resources required in the field. This will help in getting accurate results.
5. Further research should be carried out to establish the exact level of intercropping at which weevils will positively be controlled.
6. By introducing OFSP and onion intercropping practice, this significantly generates income for the rural poor who have limited land for agriculture.
7. By investing more on the resources during production, the income will be significantly increased.

5.2. Limitations

This study was positive in most aspect but there were a few problems that were as well transpired at field level. Due to poor timing, it was difficult to find the onion planting materials from the local farmers which could be more affordable compared to buy onion bulbs at the market. At the time this research conducted, there were not enough onion seedlings which were available on the nursery beds. The cost of onion bulbs at the market was too expensive; therefore, onion plants that failed to emerge/grow after the first planting were not replanted as per requirement (gap filling).

Another limitation for this study was water supply problem. Malawi’s agriculture is mostly rain-fed, but this experiment was conducted without rainfall. Though people were hired to water the crops, the water supplied was not very sufficient; therefore, the crops grew very slow and were not very healthy, even death of some plants occurred. This affected the yield because the number of plants harvested was less than the required number of crops to achieve the target.

Another limitation for my study was the distance. Travelling to the sites where the trials were conducted was not convenient since the location was very far from the main road. This reduces the chances for me to be able to observe the field problems such as watering, weeding at the right time, just to mention a few.

Another limitation encountered was the cost. Since this project was not fully funded, some practices were compromised. The labour cost for the people to help in carrying out the field activities from land preparation to harvesting was a bit higher.

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APPENDICES

Appendix 1. Anova Table for Weight of OFSP Storage Roots (Site 1)

Source	DF	SS	MS	F	Pr > F
Treatment	3	429971.67	143323.89	43.57	<.0001
Error	8	26314.00	328.25		

Appendix 2. Anova Table for Weight of OFSP Storage Roots (Site 2)

Source	DF	SS	MS	F	Pr > F
Treatment	3	420022.25	14000.42	62.82	<.0001
Error	8	17830.67	2228.83		

Appendix 3. Anova Table for Weight of OFSP Vines (Site 1)

Source	DF	SS	MS	F	Pr > F
Treatment	3	30824.75	10274.75	62.82	<.0001
Error	8	2184.00	273.00		

Appendix 4. Anova Table for Weight of OFSP Vines (Site 2)

Source	DF	SS	MS	F	Pr > F
Treatment	3	20512.92	6837.64	76.47	<.0001
Error	8	715.33	89.42		

Appendix 5. Anova Table for Number of Harvested OFSP Storage Roots (Site 1)

Source	DF	SS	MS	F	Pr > F
Treatment	3	193280.92	64426.97	71.85	<.0001
Error	8	7173.33	896.67		

Appendix 6. Anova Table for Number of Harvested OFSP Storage Roots (Site 2)

Source	DF	SS	MS	F	Pr > F
Treatment	3	147901.53	49300.53	71.33	<.0001
Error	8	5529.33	691.17		

Appendix 7. Anova Table for Number of Marketable OFSP Storage Roots (Site 1)

Source	DF	SS	MS	F	Pr > F
Treatment	3	19957.58	6652.53	46.06	<.0001
Error	8	1155.33	144.42		

Appendix 8. Anova Table for Number of Marketable OFSP Storage Roots (Site 2)

Source	DF	SS	MS	F	Pr > F
Treatment	3	27894.67	9298.22	74.14	<.0001
Error	8	1003.33	125.42		

Appendix 9. Anova Table for Number of Non-Marketable OFSP Storage Roots (Site 1)

Source	DF	SS	MS	F	Pr > F
Treatment	3	89836.33	29945.44	53.13	<.0001
Error	8	94345.67	563.67		

Appendix 10. Anova Table for Number of Non-Marketable OFSP Storage Roots (Site 2)

Source	DF	SS	MS	F	Pr > F
Treatment	3	47830.25	15943.42	49.81	<.0001
Error	8	2586.67	323.33		

Appendix 11. Anova Table for Weight of Harvested Onion Bulbs (Site 1)

Source	DF	SS	MS	F	Pr > F
Treatment	2	24293.56	12146.78	51.04	0.0002
Error	6	1428.00	238.00		

Appendix 12. Anova Table for Weight of Harvested Onion Bulbs (Site 2)

Source	DF	SS	MS	F	Pr > F
Treatment	2	22154.67	11077.33	4.45	0.0654
Error	6	14951.33	2491.89		

Appendix 13. Anova Table for Number of Harvested Onion Bulbs (Site 1)

Source	DF	SS	MS	F	Pr > F
Treatment	2	105108.22	52554.11	20.96	0.0020
Error	6	15043.33	2507.22		

Appendix 14. Anova Table for Number of Harvested Onion Bulbs (Site 2)

Source	DF	SS	MS	F	Pr > F
Treatment	2	111109.56	55554.78	4.22	0.0716
Error	6	78930.67	13155.11		

Appendix 15. Data Collection Form of On Farm Adaptive Trial of Intercropping Sweet Potato with Onion

1. **Country:** ______________
2. **Location of Trial:**
   a. District: ______________
   b. Site name: ______________
   c. Agro-ecology: ______________
3. **Latitude: Degree** ______________ Minutes: _________________
   Longtude: Degree ______________ Minutes: _________________
4. **Type of Trial:** ______________
   Season: ______________
5. **Table 1 Dates:**

	Day	Month	Year
Planting			
Verification of establishment (3-4wks after planting)			
Gap filling			
1st Virus Symptoms Evaluation (6-8wks after planting)			
2nd Virus Symptoms Evaluation (1 month before Harvest)			
Harvest			

6. **Crop Duration from Planting to Harvest:** ____________________________________

7. Plot Description:

a. Plot type: ____

b. # of rows/plot (includes the border rows): _________________________

c. # of boarder rows per plot: __________________________________

d. # of plants intended for final harvest (excludes border rows and end plants: _______

e. Cuttings/plot actually used to achieve target: _____________________

f. Target plant spacing within rows: ______________________________

g. Space between rows: _____________________________________

8. **Net Plot Size (m^2)**: ____

9. Crop Rotation:

a. Crop (s) from previous season: ________________________________

b. Crop (s) from 2^{nd} to last season: ______________________________

10. Soil Description:

a. Soil group: ____

b. Soil texture: _______________________________________

c. Soil pH: ____

11. **Meteorological Data during Trial:** Collected at: ____

Table 2 Meteorological Data

	First	**Second**	**Third**
Specify Month			
Code for month			
Rainfall (mm)			
Temperature (^{o}C)			
Mean			
Mean Minimum			
Mean maximum			

Appendix 16. Pre-Harvest Form of On Farm Adaptive Trial of Intercropping Sweet Potato with Onion

Rep. No.	Plot No.	Treatment	3-4 Weeks after Planting (AP)				Virus Symptoms		Weevil Damage	
			No. of vines planted	No. of onion seedlings planted	No. of Plants established		6-8 Weeks. After Planting	One Month before Harvest	6-8 Weeks. After Planting	One Month before Harvest
					Sweet Potato	Onion				

Appendix 17. Harvest Form of On Farm Adaptive Trial of Intercropping Sweet Potato with Onion

Rep .No.	Plot No.	Treatment	# plants Harvested (SP)	# plants with roots (SP)	# Roots (SP)		Weight of Roots (SP) (kgs)		Vine Weight At Harvest	Size	Weevil Damage & Any Damages	ONION	
					>100 gms undamaged	*<=100gms or damaged*			Kgs	1. Unacceptable 2. Poor 3. Average 4. Good 5. Excellent	1. None 2. Light 3. Moderate (10-30%) 4. Severe (30-60%) 5. Very severe (>60%)		
					Marketable	Non-Marketable	Marketable	Non-Marketable				Number of bulbs harvested	Wt of bulbs (kgs)