IDENTIFICATION OF INSECT PESTS IN SWEET POTATO AND THEIR MANAGEMENT

MD. ANWAR-UL-HAQUE LIMON

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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IDENTIFICATION OF INSECT PESTS IN SWEET POTATO AND THEIR MANAGEMENT

BY

MD. ANWAR-UL-HAQUE LIMON

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Approved by:

Professor Dr. Mohammed Ali
Department of Entomology
Sher-e-Bangla Agricultural University
Supervisor

Professor Dr. Abdul Latif
Department of Entomology
Sher-e-Bangla Agricultural University
Co-supervisor

Dr. Mst. Nur Mohal Akhter Banu
Associate Professor
Chairman
Department of Entomology and
Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/ENTOM/………… **Date: ………………...**

CERTIFICATE

This is to certify that the thesis entitled '**Identification of Insect Pests in Sweet Potato and their Management**' submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in ENTOMOLOGY**, embodies the results of a piece of bonafide research work carried out by **Md. Anwar-Ul-Haque Limon**, Registration No. **10-03802** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: June, 2017
Dhaka, Bangladesh

Professor Dr. Mohammed Ali
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

DEDICATED

TO

MY BELOVED PARENTS and GRANDPARENTS

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ABSTRACT

The present study regarding identification of insect pests in sweet potato and their management has been conducted during rabi season (November 2016 to March 2017) in the experimental field of Sher-e-Bangla Agricultural University, Dhaka. The variety of BARI Sweet Potato 8 was used as test crop. Six insecticidal treatments with one untreated control were tested in this study. They were T_1: Emamectin benzoate @ 2 ml/L of water; T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing; T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application); T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application); T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application); T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application) and T_7: Untreated control. The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. Under the present study 9 different species of insect pests were recorded and they were belonged to 9 family under 3 orders. Among the insect pests it was observed that sweet potato weevil was more destructive for storage roots of sweet potato. Data revealed that for sweet potato weevil, the lowest number of sweet potato weevil was T_2 (1.67), while the highest number from T_7 (6.73) treatment. At 15 days early harvest, in consideration of infestation level of storage roots in number and weight basis, the lowest infestation was recorded from T_2 (3.69% and 5.68%), whereas the highest infestation (12.25% and 12.98%) was observed from T_7 treatment. At optimum days harvest, for infestation level of storage roots in number and weight basis, the lowest infestation was recorded from T_2 (4.49% and 6.49%), whereas the highest infestation (13.56% and 14.16%) was observed from T_7 treatment. After 15 days from optimum harvest, in case of infestation level of storage roots in number and weight basis, the lowest infestation was recorded from T_2 (5.31% and 6.93%), whereas the highest infestation (16.37% and 17.05%) was observed from T_7 treatment. The highest yield was recorded from T_2 (41.86 t/ha), whereas the lowest from T_7 (30.27 t/ha) treatment. It was revealed that Carbofuran 5G @ 15 kg/ha at 60 days after sowing was the best for the controlling insect pests of sweet potato among different control measures under the study and also attaining highest yield of storage roots.

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SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Co-efficient of variation	cv
Days After Sowing	DAS
and others	*et al.*
Etcetera	etc
Food and Agriculture Organization	FAO
Journal	J.
Least Significance Difference	LSD
Muriate of Potash	MoP
Sher-e-Bangla Agricultural University	SAU
Soil Resources Development Institute	SRDI
Triple Superphosphate	TSP

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Sweet potato [***Ipomea batatas*. (L.) Lam**.] is very important crop in tropical and sub-tropical countries of the world including Africa, India, Bangladesh, China, Japan, the Pacific Island, Tropical America and the Southern part of the United States of America. Approximately 92% of the worlds sweet potato produced in Asia and the Pacific Island and 89% of this grown in China (Horton 1988b). Sweet potato is an introduced crop in Bangladesh during the second half of the 19th century (Rashid *et al.*, 1982). The crop belonging to the family Convolvulaceae in an important root crop in Bangladesh and commonly known as "Misti Alu" (Rabbi, 1995). Sweet potato is a major root crop which is grown for both export and local consumption. It is also the third most important root crop grown in eastern Africa after cassava and potato (FAO 2011).

Sweet potato is both a staple and a food security crop in eastern and southern Africa, and is mainly grown by smallholder women farmers (Mutuura *et al*., 1992; Bashaasha *et al*., 1995; Andrade *et al*., 2009). Sweet potato is also grown for its vines as planting material; leaves are often eaten as a vegetable while shoots and roots are used as animal feed in many countries. In Uganda and western Kenya, the sale of fresh sweet potato roots, vines and processed foods in both local and urban markets is becoming increasingly popular regarding cont- ributing to household cash income (Abidin 2004; Kaguongo *et al*., 2012). Orange- fleshed sweet potato is also a rich source of beta-carotene, a precursor of bio-available vitamin A, and has potential of combating Vitamin A deficiency among rural resource constrained farmers in many developing countries (Jalal *et al*., 1998; Jaarsveld *et al*., 2005; Low *et al*., 2007; Mwanga *et al*., 2003a; Burri, 2011).

The sweet potato is a multipurpose crop. In developed countries of the world, the sweet potato is primarily used for food, prepared mostly from its flesh but large quantities are canned and some are dehydrated. In Bangladesh, it is consumed in boiled condition. Sweet potato flour is good alternative to wheat flour. Cakes, biscuits, breads and many kinds of foods can be prepared with flour of sweet potato. In industries, it is used in manufacturing alcohol, syrup and starch. Sweet potato is a high calorie producing crop. Yield of sweet potato per hectare is higher than any other cereals. Storage roots of sweet potato are rich in starch. Leaves and stem tips of its vein are frequently used as green vegetables, salad and cattle feed (AVRDC, 1976).

Sweet potato is one of the important root crops in Bangladesh as well as in the world. Sweet potato ranks as the world's seventh most important food crop after wheat, rice, maize, potato, barley, and cassava. According to the Food and Agriculture Organization (FAO, 2012), sweet potato was under cultivation in 82,40,969 hectares of land in the world. Considering top 20 sweet potato producing countries in 2012, world's total production was 101,839,463 tons and a majority of which came from China, with a production of 77,375,000 tons (FAO, 2012). Bangladesh produces different varieties of sweet potato but some of the varieties are produced in more quantity based on consumer demand and easy cultivation technique as well as vine (planting materials) availability. It is cultivated more or less in all the districts of the country. However, the suitable areas of sweet potato cultivation are "char land" located on the both sides of rivers.

In Bangladesh sweet potato is the 4th most important source of carbohydrate after rice, wheat and potato. Sweet potato plays a significant role in increasing food security and income for the poor farmers of Bangladesh (Ahmed *et al.* 2015). The area and production under sweet potato was 24,567 hectare and 297,539 tons, respectively in Bangladesh during the year 2011 (FAOSTAT, 2011). The average per hectare production of sweet potato in Bangladesh is 9.8 tons (FAOSTAT, 2011). Most of the sweet potato producers in Bangladesh are smallholder. Smallholder farmers struggle because of their limited access to inputs (e.g. credit, technology, information) while working on low-productivity land located far distances from output markets via an inadequate, high-cost road system (Lunna and Wilson, 2015). The production of sweet potato has decreased from 435,000 MT in 1995-96 to 253,000 MT in 2011-12 (BBS, 2012).

Sweet potato is grown over a wide range of environmental and edaphic conditions. It requires low inputs and less management practices (AVRDC, 1977). A raw sweet potato contains water (77%), carbohydrate (20.1%), protein (1.6%), fiber (3%), and almost no fat. Many studies have suggested that increasing consumption of sweet potatoes decreases the risk of obesity, heart disease, diabetes and overall mortality while promoting a healthy complextion, increased energy and overall lower weight. Yield of local sweet potato in Bangladesh is 10 t/ha. But high yielding variety may produce 35-45 t/ha. At least 18 species of insect feed on sweet potato roots. Among those causing the greatest damage are the sweet potato weevil (*Cylas formicarius* Fab.), white fringed beetle, wireworm larvae and flea beetles. Sweet potato weevil is the most serious pest of sweet potato in Bangladesh. It's infestation may be found in the field, in storage sheds and in propagation beds. Losses due to insect feeding, especially sweet potato weevils may often reach 60-100% because most sweet potatoes are produced in low input agricultural system (Chalfant *et al.*, 1990). So effective management practices should be done to minimize the production loss by the insect pests and to minimize the pesticide hazards by using bio-rational insecticides.

Objectives:

1. To identify insect pests attacking in sweet potato.
2. To assess the damage severity of major insect pest.
3. To develop a suitable management packages for controlling the insect pest.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Infestation of the sweet potato crop by different insect species started immediately after the crop establishment and continued for five months in each year. More than 50 insects belonging to several orders and at different stages of development infested the crop. About eight insect species caused major damage on the crop leaves, vines and tubers. The most destructive and important economic pest species were sweet potato weevil (*Cylas puncticollis* Boh.) and the clearwing moth (*Synanthedon dascyeles*). Some 21 insect species were of minor importance, as their damaging effects were not noticeable on the plant and they had low effects on the yield. Other than pests, seven insect species were found to be beneficial as predators or parasitoids of the insect pests, implying that any management practice employed for control of the major pests should consider conservation of the natural enemies.

Most of the major and minor insect pests reported by this study have also been noted by earlier studies such as Kibata (1973) with the exception of *Systates* spp.

In Zimbabwe, thirteen pests are reported to infest sweet potato tubers, stems, crowns and leaves. However, among these, only *Cylas formicarius* elegantulus and termites were not observed in this present study. Most of the insect pests identified on sweet potato in this study have been reported by Ames *et al.*, (1996).

In his book, Hill (1975), indicates that *Bermisia tabaci*, *Synathedon dasysceles*, *Agrius convolvuli*, *Acraea acerata*, *Cylas puncticollis*, *Alcidodes dentipes* and *Aspidormorpha* spp. are the major pest of sweet potato in Africa.

Bohlen, (1973), reported that although many insect species were recorded, only a few were important pests of sweet potato. The key coleopteran pests included *Cylas puncticollis*, *Blosyrus obliqutus*, *Systates polinosus*, and Cassid beetles.

Coleopterans have also been recorded as major pests of sweet potatoes in Tanzania.

According to Panizzi and Slansky, (1985), *Prezotrachelus gestackerii* (Coleoptera: Curculionidae) was the only observed pest that had not been recorded in many places. It was the sixth most important pest observed during the second season. It's however a very minor pest and its effects do not cause any economical loss to the sweet potato. However, it has been recorded as a major pest in legumes.

Most of the minor pests observed are cosmopolitan, polyphagous and are pests of other crops. These include *Nezara viridula*, *Myzus persicae*, and *Acanthomia tomentosicollis* (Hill, 1975) and they infest many crops grown in the study site. Some insects present at the time of sampling were transients (tourists), which had no direct effect on the crop. These included banana weevil (Cosmopolites sordidus (Germ.), Mango weevil (Sternochetus mangiferae (F)) and *Dysdercus nigrofasciatus*, which is a major pest of okra and cotton. The study revealed that *Synathedon dascyceles* was a serious pest of sweet potato in the region, and there is need to study the biology and management of this moth. Though the study did not assess yield loss, continued infestation of the crop by these insects evidently showed that there were losses which could be incurred overtime.

2.1 Description, Diversity, Biology and Distribution of *Cylas formicarius*

2.1.1 Description of *cylas* spp.

Sweet potato weevils is in the genus *Cylas* (Coleoptera: Apionidae) (Chalfant *et al.,* 1990; Smit, 1997a). Contains three species namely *Cylas brunneus* (Olivier), *Cylas puncticollis* (Boheman) and *Cylas formicarius* (Fabricius) (Wolfe, 1991). Adult weevils are elongeted smooth and shine with ant like snouted beak but species can be differentieted by size and colour (Smit, 1997a). *C. formicarius* are small with a bluish black abdomen and a red thorax, *C. puncticollis* are black and large *C. brunneus* are small either black or brown (Wolfe, 1991).

2.1.2 Diversity of sweet potato weevils

Parker *et al.* (1990), stated that both *C. puncticollis* and *C. brunneus* are the most common species in East Africa. On the other hand, *Cylas formicarius* is the main pest species in Asia, the United States and Oceania, but in Africa it has been found in Natal, South Africa and on the coast in Kenya.

2.1.3 Biology of sweet potato weevils

Ames *et al.* (1996), found that all three species have a similar life history. The adult female lays eggs singly in cavities excavated in vine or in roots, preferring the latter. The egg cavity is sealed with a protective, gray fecal plug. The developing larvae tunnel in the vine or root. Pupation takes place within the larvae tunnels. A few days after eclosion, the adult emerge from the vine or roots because the female weevil cannot dig, she finds soil cracks. Alternate host of sweet potato weevils are *Ipomoea* spp. weeds.

2.1.3.1 Eggs

From Otto *et al.* (2006), Eggs are deposited in small cavities created by the female with her mouthparts in the sweet potato root or stem. The female deposits a single egg at a time, and seals the egg within the oviposition cavity with a plug of fecal material, making it difficult to observe the egg. Eggs will hatch after three to seven days depending on the environmental conditions.

According to Schimutterer (1969), the egg is oval, and yellowish-white.

2.1.3.2 Larvae

According to Allard (1990), The larvae have head, thorax and abdomen. The head is pale brown with darker brown mandibles, one pair of ocelli (stemmata), each containing two contiguous pigment spots.

From Otto *et al.* (2006), The thorax is divided into prothorax and mesothorax whereby mesothoracic spiracle located on a lobe very close to the prothorax. The abdomen is whitish, legless, slightly curved, approximately 10 millimetres length maximum width two millimetres cuticle speculate. Larvae have three instars, first larval instar, second larval instar, and third larval instar. Total larvae period varies from 10 – 25 days.

2.1.3.3 Pupae

Otto *et al*. (2006), found that the pupa of sweet potato weevil is white and approximately six millimetres in length; pronotal width one metre, cuticle glabrous. The head and rostrum are provided with setiferous tubercles, one pair between the eyes at base and two pairs on the rostrum. The posterior pair being close to the eyes and the anterior behind the middle. Pupation occurs inside the vine or root and takes eight days for adults to emerge.

2.1.3.4 Adults

The pest is black, with a faint, metallic blue luster, and not with a distinctly shiny, copper-like sheen, body length is eight millimetres. The length of male antennal club is equal to or greater than combined length of all preceding segments. Eyes close together in dorsal view; distance between eyes is about one sixth of minimum width of rostrum.

According to Ames *et al.* (1996), At an optimal temperature of 27-30^{0} C, *C. formicarius* completes development (from egg to adult) in about 33 days. Adult longevity is two to three months and females lay between 100 and 250 eggs in this period.

According to Okonyo (2013), The male and female adult sweet potato weevils can be told apart by the shape of their antennae. The antennae of the males are straight while those of the female are round or club-shaped. Under favourable conditions, sweet potato weevils can produce 13 generations a year and can live for three to four months.

2.1.4 Distribution

Parker *et al.* (1990), found that the sweet potato weevil is one of the major pests of sweet potato worldwide. Three species have been identified in Africa. Their distribution in Africa is being surveyed and it appears that all the three species have a similar life history, making all of them difficult targets for conventional pest control measures.

According to Nderitu *et al.* (2009), among the three, *C. formicarius* is an important pest in India, South East Asia, Oceania, the United States and the Carribean.

2.2 Economic Importance of Sweet Potato Weevils

Sweet potato weevil is one of the most important biotic factors limiting sweet potato production in Africa (Chalfant *et al.*, 1990; Pfeiffer, 1982; Smit and Matengo, 1995). Sweet potato is the sixth most important food crop in the world (Vietmeyer, 1986) and both adults and larvae cause serious damage to leaves and stems. Adults attack the leaves of sweet potatoes, but the larvae are more injurious boring into the stems and causing serious mortality to seedlings (Daiber, 1994).

Wolfe (1990), described that adults of all three Cylas species feed on the epidermis of vines and leaves, scraping oval patches off petioles, young vines and leaves. Yield loss is seldom serious. Adults also feed on the external surfaces of roots causing round feeding punctures which can be distinguished from oviposition sites by their greater depth and the absence of a faecal plug. The developing larvae tunnel in the vines and roots causing significant damage. Frass is deposited in the tunnels. In response to the damage, the root produces terpenes which render the infested root part inedible (Sato *et al.*, 1981).

Allard *et al.* (1991), reported on serious larval infestations disrupting sweet potato nurseries in Ethiopia, on established plants, the larvae feed in the tubers and stems producing larvae tunnels and later, pupal chambers stem damage is believed to be the main reason for yield loss, although damage to the vascular system caused by feeding, larvae tunnel secondary rots reduce the size and number of roots. In Eastern Africa both *C. puncticollis* and *C. brunneus* can be found infesting the same root. When a root is exclusively infested by C. puncticollis, the core of the root might still be untouched; *C. brunneus* larvae seem to tunnel further inside the root. First severe infestations render the crop unpalatable and therefore inedible to humans. Pest damage usually continues during storage, therefore infested tubers cannot be stored for a long time. In conjunction with other coleoptera pests, sweet potato weevil can completely destroy sweet potato plantations (Geisthardt and van Harten, 1992). Weevil feeding on storage roots induces terpenoid production that makes even slightly damaged root unpalatable (Uritani *et al.*, 1975; Sato *et al.*, 1981). Thus low weevil densities may cause devastating crop losses of up to 60 -100% (Chalfant *et al.*, 1990).

2.3 Management of Sweet Potato Weevils

2.3.1 Cultural control

Stathers *et al*. (2005), reported different successful cultural practices used in experiments conducted in East Africa, Taiwan, Philippines, Vietnam, America, India, Cuba and Indonesia. Cultural practices aimed at preventing infestation proved to be effective way of reducing weevil damage.

a) Field sanitation

Smit and Matengo (1995), studied on the farmer’s cultural practices in Kenya and suggested that crop protection workers should concentrate their research and extension efforts on crop sanitation and the avoidance of adjacent planting of successive crops.

According to Stathers *et al.* (2005) removal and destruction (through burning or feeding to livestock) of infested vine and root remains. If vines are left in the field to maintain soil fertility, care should be taken to ensure they are dead or dry and not able to sprout and then provide food for weevils. If peace meal harvesting of the crop is practiced, care should be taken to remove and destroy any infested roots that are found.

Komi (2000), repoted that removal of alternate host plants like *Calystegia soldanella*, *C. hederacea* and *Ipomoea indica* reduced the sweet potato weevil infestation in Japan. Removal of volunteer sweet potato plant and wild morning glories as these may be alternative hosts (Sato *et al*., 1981).

Geisthardt and van Harten (1992), stated that crop rotation with other crops for two to three seasons appears to be the most effective method of preventing infestations of weevils.

In a large ecosystem area or community burying can help to reduce sweet potato weevil infestation. Infested storage roots must be buried >15 cm underground (Stathers *et al*., 2005).

b) Hilling up

Allard *et al*. (1991), reported that collection of soil around the base of plants to prevent or fill soil cracks. This practice not only protects the plants from weevil attack but can also result in increased crop yield.

According to Palaniswami and Mohandas (1994), Re-ridging the crop at tuber formation stage prevents the weevil from laying the eggs and the entry of the grubs into the tuber. The efficacy of re-ridging in sweet potato crop, as a cultural practice for reducing weevil incidence was investigated over two seasons at Vellayani, Kerala, India. Five re-ridgings between 50 and 90 days after planting, at 10 days interval, significantly reduce the weevil damage to the tubers.

Deep planting into the hill, and planting into the furrow and earthing after six weeks offers protection against weevils (Macfarlane, 1987).

c) Mulching

Geisthardt and van Harten (1992), described that application of dry leaves on the soil to keep it moist, prevent cracks and provide a more favourable place for natural enemies. Care should be taken to make sure the weevils cannot feeds or develop on the mulching material.

According to AVRDC (1987), mulching with rice straw or black plastic reduced the infestation by SPW in the root zone. The availability of mulch is a problem especially in dry-lands coupled with higher temperatures. Termites are a problem during summer as they completely devour the dried grasses and other shrubs in dry lands.

d) Early harvesting

Ebregt *et al.* (2005), stated that harvesting two weeks earlier reduce the loss due to weevil from greater than 30 percent to less than five percent.

From Powell *et al.* (2001), early harvesting of the crop is practiced to ensure that infested roots are removed and destroyed. Vines left in the field should not be allowed to sprout and then provide food for weevils.

According to Stathers *et al*. (2005), timely harvesting to remove the largest storage root most at risk from weevil attack and subsequent hilling up of the soil around the remaining root to prevent weevils from accessing the root through cracks in the soil.

e) Flooding

Otto *et al.* (2006), found that flooding of the field for more than 48 hours kill the weevil larvae present in roots that have been left in the field. Flooding of fields between two consecutive sweet potato crops may reduce the immediate source of weevil from the field. Sweet potato weevils can be controlled by flooding of fields before planting (Stathers *et al.*, 2003)

Talekar (1987), reported that, flooding of infested field for at least 48 hours after completing harvest drown weevils and induces rotting of the left over plant materials and thereby reduces weevils' densities from one planting to the next. This is an option in areas where rotation is not possible

f) Intercropping

According to Stathers *et al.* (2005), In Taiwan, 103 different crops were tested as intercrops for sweet potato weevil control, the best result were obtained with coriander (*Coriandrum sativum* L.).

According to Rajasekhara Rao (2005) and Rajasekhara Rao *et al*. (2006), Mixed cropping systems with sweet potato and other crops (ginger, okra, maize, colocasia and yam) are practiced by farmers in North Eastern Region of India. Low incidence of *C. formicarius* was noticed in these systems and the interaction of intercrops and several insect pests of tuber crops, including sweet potato weevil, in these multiple cropping systems.

g) Use of clean planting material

Allard *et al.* (1991), described the following techniques that have been used in the management of sweet potato weevils. Planting only in fields that have had no weevil infestations within the last 12 months and preferably more than 1 km away from any infested land; planting resistant or tolerant cultivars; selecting deep-rooting cultivars, with long necks between the roots and the stems (which are less susceptible because the adult weevil cannot burrow downwards more than one centimeter); planting early-maturing cultivars which can escape serious damage; earthing up of plants (hilling), particularly those cultivars with the tendency to push out of the ground; removal of all plant debris and volunteer plants after harvest; re-ridging approximately 30 days after planting as this places the roots deeper and out of reach of the weevils; planting non-infested material; and use of intercropping.

Weevils tend to lay eggs in the older woodier parts of the sweet potato vine, so if the tender tips are used for planting they are less likely to be infested by weevils (Nair, 2006).

2.3.2 Biological control

2.3.2.1 Parasitoids

Maeto and Uesato (2007), reported a new species of braconid, *Bracon yasudai* from the south-west islands of Japan. It is a solitary idiobiont ectoparasitoid of the larvae of the West Indian sweet potato weevil, *Euscepes postfasciatus*, and the sweet potato weevil, *C. formicarius*, both feeding on *Ipomoea batatas* (L.).

Palaniswami and Rajamma (1986), reported the braconids *Rhaconotus* spp. and Bracon spp. and an unidentified hymenopterous parasitoid on the larvae of sweet potato weevil.

Jansson and Lecrone (1991), reported Euderus purpureas, an eulophid parasitizing on *C. formicarius* in Southern Florida. Nevertheless, the success of all these parasitoids at field conditions is doubtful since they are recorded in a very few numbers.

2.3.2.2 Predators

Lagnaoui *et al.* (2000), stated that the use of ants against weevils is another component of the control strategy adopted for the sweet potato weevil in Cuba. Two species of predatory ants, *Pheidole megacephala* and *Tetramorium guineense* (*Pheidole guineensis*), are common inhabitants of banana plantations. Rolled banana leaves were used as "temporary nests" to transport the ants from their natural reservoir to sweet potato fields, where they prey upon weevils and other insects. Setting up ant colonies in the field 30 days after planting with 60-110 nests has reduced weevil infestation from three to five percent.

Allard *et al.* (1991), described that the subterranean habitat of *C. puncticollis,* whilst making it less accessible to predators and parasitoids may enhance the impact of fungal pathogens which require a protected cool, humid environment for survival and reproduction; conditions generally found under dense foliage of sweet potato. The eggs are also well protected as they are laid within vines, or in tubers and egg cavity are sealed with a feacal plug that preserves moisture, disguises location and protects the eggs from predatory mites. Potential candidates for use as biological insecticides include *B. bassiana* and *M. anisopliae*. Isolates of the former have been collected from laboratory-reared adults originally collected in Kenya.

2.3.2.3 Entomopathogenic nematodes

Entomopathogenic nematodes (EPN) have beneficial interaction with sweetpotato within the roots and are promising for the control of sweet potato weevils (Jansson and Lecrone, 1997).

Among different species, Heterorhabditis was found to be most effective, infective and pathogenic than Steinernematids (Mannion and Jansson, 1992).

According to Jansson *et al*. (1991), Heterorhabditid nematodes were more pathogenic to pupae, than were Steinernematid nematodes. Weevil adults were the least susceptible to nematode infection. The number of applications of bacteriophora did not significantly reduce numbers of *C. formicarius* but consistently reduced damage to sweet potato tubers. Also bacteriophora, is more infective than Steinernematids carpocapsae ('All' strain). Subsequent field tests showed that one application of bacteriophora has found effective at protecting sweet potato tubers from weevil damage. This nematode persisted for over 130 and 250 days after application in two separate experiments, respectively. Nematode application rate had no effect on densities of *C. formicarius* or damage caused suggesting that a single application early in the growing season is adequate.

Weevil damage to plants treated with insecticides is intermediate to that on nematode-treated and untreated plants weevils (Jansson and Lecrone, 1997).

2.3.2.4 Entomopathogenic fungi

According to Su (1991a), most effective entomopathogenic fungi infecting sweet potato weevil has been identified as *Beauveria bassiana* (Bals.) Vuill, which can be applied as a foliar spray or in combination with pheromone trap, for its successful infection and dispersal. Spraying of *B. bassiana* solution (isolated from *C. formicarius*) at a concentration of $1.6x10^4$ conidia ml-1 at planting and rootstock formation, and broadcasting soybeans containing *B. bassiana* into the rows at planting controlled *C. formicarius* effectively.

Su (1991b), indicated that application of *B. bassiana* isolated from honey bees at a concentration of $1x10^6$ conidia ml^{-1} at planting and rootstock formation also gave the best results. The success of infection of *B. bassiana* on sweet potato weevil is dependent on the type of soil.

Yasuda *et al*. (1992), experimented on thirteen different soils were pernicious to sweet potato weevil out of eighty soils collected from central and southern

Taiwan because when they were added to the row at planting, mortality caused to the sweet potato weevil by *B. bassiana* was >80%. Environmental factors also govern the successful infection of sweet potato weevil by entomopathogenic fungi. Low relative humidity (<43%) and low temperatures below (<15^{o}C) were not conducive for *B. bassiana* infection of adults of sweet potato weevil.

Yasuda (1995), developed an auto-infection system consisting of a modified sex pheromone trap and a bottle with exit holes containing conidia of B. bassiana (9.3x10^{10} g^{-1} medium) successfully tested to control *C. formicarius* in Japan. Male weevils were attracted to the system by the action of pheromone and exited the bottle were found infected with *B. bassiana.*

From Yasuda *et al.* (2004), Formulations of *B. bassiana* conidia in a 10% corn oil mixture showed more superior infectivity in both sexes of *C. formicarius* than the formulation of conidia.

Low cost and effective technology of production of *B. bassiana* at a cottage industry level to control sweet potato weevil was successfully established and adopted by many farmers in Cuba (Lagnaoui *et al.,* 2000).

Use of the fungus is particularly attractive because it relieves farmers from the high cost of chemical pesticides. Incubation of entomopathogenic fungi in different growth media results in production of several metabolites with insecticidal activity. Squamulosone (aromadendr-1(10)-en-9-one) was isolated in large quantity from the plant *Hyptis verticillata* and incubated with the fungus *Curvularia lunata* in two different growth media (potato dextrose broth and beef extract medium) (Collins *et al.,* 2001).

C. lunata is well known for its efficient 11a-hydroxylation of steroids (Holland and Reimland, 1985; Chen and Wey, 1990) and also has been used to transform a number of terpenes (Azerad, 2000). *B. bassiana*, the fungus which is responsible for the muscardine disease in insects, was also known to affect the bioconversion of many substrates including alkaloids, steroids and terpenes. This strain, formerly known as *B. sulfurescens* or *Sporotrichum sulfurescens* has been used to effect the reduction of various carbonyl compounds (Davies *et al*., 1989). *B. bassiana* is also known to selectively hydroxylate non-activated carbon atoms (Lamare *et al.*, 1991; Holland, 1992). Incubation of cadina-4, 10 (15)-dien-3-one with *B. bassiana* results in the production of nine novel sesquiterpenes which are effective against *C. formicarius* elegantulus (Buchanan *et al.*, 2000). Labo-Lima (1990) conducted bioassays to evaluate the pathogenicity of the fungal pathogens *M. anisopliae* and *Beauveria bassiana* against *C. puncticollis*. Mortality rates obtained were encouraging for further research on the control of *C. puncticollis* with these fungi.

2.3.3 Chemical Control

Allard *et al.* (1991), stated that sweet potato weevil is a difficult target for conventional pest control measures as the larvae feed in the storage roots in the found, or inside the woody base of the stems. This means that with the possible exception of systemic insecticides, which are costly and pose the risk of residual contamination of the tubers, there is no effective chemical control of the larvae, nor of the other stages found within the plant tissue.

In Ethiopia, insecticidal screening trials tested the use of foliar sprays applied three months after planting, followed by four applications at fortnightly intervals, and also root dipping prior to planting. Deltamethrin and pirimiphos methyl gave good control of sweet potato pests (Allard, 1990).

Recommendations for the use of 19 insecticides for the control of sweet potato weevils are provided by Kasasian (1978).

Rajamma and Pillai (1991) studied on several insecticides were tested for the management of sweet potato weevil by using them after planting, either by foliar spray or basal granular applications and found showed that 0.05% fenthion or endosulfan spray at monthly intervals with or without running or soil application of carbofuran or phorate granules each 1 kg a.i. ha^{-1} 45 days after planting days after planting are all effective in reducing infestation by *C. formicarius* resulting in greater marketable tuber yields.

Some of the insecticides are also used for vine dipping for successful control of sweet potato weevil. Fenvalerate, permethrin and deltamethrin each 0.003% are the most effective insecticides to *C. formicarius* (Rajamma, 1990).

Teli and Salunkhe (1994), tried dipping cuttings in insecticide solution before planting and spraying the crop one month after planting, and further three times, at three week intervals, subsequently with cypermethrin or fenvalerate each 375 g a.i. ha^{-1}, was most effective in reducing damage caused by the insect. Similar works on the use of several other insecticides to achieve better control of sweet potato weevil are available (Mason *et al.*, 1991; Sinha, 1994).

Misra *et al*. (2001), reported that combination of vine dipping of 0.05% monocrotophos and three foliar sprays with 0.05% endosulfan proved very effective than that of basal application of phorate granules followed by vine dipping of 0.05% monocrotophos. Soil drenching at 50 and 80; 60 and 90; and 50, 65 and 80 days after planting were equally effective in suppressing the incidence and intensity of weevil damage (Palaniswami and Mohandas, 1996). Among the single soil drenching, application on the 65th day was assessed to be the most effective against the weevil.

Palaniswami *et al*. (2002), reported that endosulfan, fenthion and fenitrothion each at 0.05% applied as soil drench at 50 and 80 days after planting were effective against. formicarius and their residues in tubers at harvest were lower than the detectable levels. Chlorpyrifos and fensulfothion granules are more toxic to sweet potato weevil adults than the other insecticides, while their persistence was about 10 months (Hwang and Hung, 1991).

2.3.4 Host Plant resistance

Rajasekhara Rao (2002, 2005), stated that plant resistance provides a pivotal role in the management of insect pests. The physical attributes of the tuber namely, the shape, length, neck length, colour of the skin, flesh colour and thickness plays in important role in preference by *C. formicarius* apart from the inherent nutritional quality of the sweet potato plant and tuber. Round tubers are preferred by more than elongate and spindle-shaped ones.

Teli and Salunkhe (1996), reported that round and oval tubers of sweet potato were more infested in the field by *C. formicarius* than long stalked, spindle and elongate ones. Pink and red coloured tubers are considered less susceptible than white and brown coloured ones. Cultivars with thin foliage and lobed leaves with purple coloration at emergence were found less susceptible.

Stathers *et al.* (2003), reported that plant resistance in sweet potato to environmental stress is underway in many parts of the world to fulfil the requirements of farmers situated in arid and semi-arid tropics. Only a limited success has been achieved, because of the inconsistent expression of the resistance (Rajasekhara Rao, 2002). Drought stress may increase the activity of oviposition stimulant present in the genotypes because weevils deposited more eggs on drought-stressed plants (Mao *et al.,* 2004).

Harrison *et al.* (2003), described that some of the plant metabolites are produced and influenced by environment, which would have a bearing on resistance or tolerance. The analyses showed that the levels of resin glycosides and caffeic acid vary between sweet potato genotypes and within genotypes among years or areas of production and have shown insecticidal activities (Jackson and Peterson, 2000). This may indicate a relationship between the quantity of these two compounds and the antibiosis of sweet potato.

According to Singh *et al.* (1993), host plant nutritional parameters are also believed to affect incidence of sweet potato weevil. The relationship between potash and silica in sweet potato stems is negatively correlated with *C. formicarius* infestation. Nitrogen and potassium influence the storage root-surface chemistry of sweet potato genotypes which have a bearing on resistance to sweet potato weevil (Marti *et al*., 1993).

Rajasekhara Rao (2002), reported that selection of sweet potato genotypes with decreased volatile attractants (kairomones) and/or increased deterrents may significantly facilitate developing resistance to sweet potato weevil. Plant resistance can also be induced through alterations in nutritional regimes of the crop. A triterpenol acetate was identified in the root surface on a sweet potato weevil susceptible genotype ‘Centennial’, but not in more resistant genotype (Nottingham *et al*., 1989).

Wilson *et al.* (1988), demonstrated that a methylene chloride surface extract of the periderm of tubers of the susceptible ‘Centennial’ stimulated oviposition of *C. formicarius elegantulus*. Nottingham *et al.,* (1987) also showed that ovipositional stimulant resided in the tuber periderm, not in the core of the tuber.

Allard *et al.* (1991), researched on breeding and evaluating sweet potato germplams for resistance. The development of insect- resistance is seen as a viable component of integrated pest management programes. Mechanisms of resistance to sweet potato weevil in sweet potato include antibiosis, antixenosis (non – preference) and escape (for example, long and thin storage roots set deep in the soil and scattered within growing hills). Resistance characters identified as under polygenic inheritance include fleshy root density, dry matter and starch content, root depth, vine thickness and tuber chemistry.

Anota and Odebiyi (1984), found no evidence that nitrogen, starch, dry matter, or moisture content played a role in tuber resistance of five resistant sweet potato cultivars tested in Nigeria, but carotene content was identified as a major factor. No oviposition preference for tubers or vines was apparent. There was a lower survival rate in all life stages, smaller body weights and a longer developmental period of *C. puncticollis* raised on resistant cultivars. Two orange fleshed and 18 white fleshed cultivars evaluated in the field for resistance to C. puncticollis. Cultivars (TIS 3053 and TIS 3030) exhibited the least root damage, whereas Cultivars (TIS 2532, TIS 3017 and TIS 3030) showed the least shoot damage (all white – fleshed) (Hahn and Leuschner, 1981). Cheng (1981) identified 14 sweet potato lines resistance to C. puncticollis, but their yields were lower than those of the majority of susceptible lines (Cheng, 1981). Screening of 700 cultivars of sweet potato in Nigeria revealed low resistance levels to *C. puncticollis* (Hahn and Leuschner, 1981).

Shakoor *et al.* (1984), identified seven resistant sweet potato lines, including KSP 20, KSP1K, SP 19 and KSP 20 following screening of 93 accessions of diverse origin. In trials conducted in the Philippines by Petro et al. (1986), local cultivars Karingkit and Kadulaw gave the highest yields, whereas the improved cultivars tested exhibited undesirable agronomic characteristic and susceptibility to *C. puncticollis.*

2.3.5 Pheromonal control

According to Downham *et al*. (2001), the behaviour in both the laboratory and the field indicate that there is probably a sex pheromone for *C. puncticollis*, as is the case for *C. formicarius*. In rearing rooms, gregarious clumping behaviour has been noted, as well as the obvious attraction of males towards the females. In the field, males are predominantly found under the foliage, presumably seeking females. Simple laboratory tests have shown that males are attracted to females. The feasibility of using virgin, unmated females as baits for males in simple traps was investigated in Kenya (Allard, 1990).

Heath *et al*. (1986), stated that precise decision tool to assess the time of sweet potato weevil incidence on sweet potato, suggest the use of sex pheromones (boehmeryl acetate). Soon after the identification of female sex pheromone of *C. formicarius*, the course of weevil management in different parts of sweet potato growing countries around the world changed dramatically. The success of sweet potato weevil control in these countries is unequivocally assigned to the sex pheromone. The sex pheromone, alone contributed to significant reductions in weevil populations and tuber damage, which resulted in greater marketable storage root yield.

According to Yasuda *et al.* (1992), the sex pheromone (Z)-3-dodecen-1-ol (E)-2-

butenoate, proved to be a successful mating disruptant for the control of *C. formicarius* (Mason and Jansson, 1991; Yasuda, 1995; Yasuda *et al*., 1992). It is also used to trap both sexes of sweet potato weevil. With 100 mg of sex pheromone, the attraction was 60.88%. Entrapment of weevils differs significantly during different parts of the day.

Yasuda *et al*. (1992), reported that pheromone traps installed close to the ground trapped more males than those set above the ground. Most of the males approached the traps by walking. Different types of traps used for monitoring and mass trapping. When the sex pheromone discovered and synthesized, various designs and types of traps used for the weevil management viz. Light, sticky, water, plastic funnel live trap etc. Talekar and Lee (1989) reported that female sex pheromone identified in *C. formicarius elegantulus* was also active in *C. formicarius*.

According to Li (1998), sweet potato weevil sex pheromone traps each 30 hectares with a distance of 15 m between traps reduced the tuber damage by 10.1% and controlled the sweet potato weevil up to 53.1-58.2% in China.

Pillai *et al.* (1996), reported that trap containing synthetic sex pheromone (100 traps per hectare) is highly effective for mass trapping the male sweet potato weevil which significantly reduced population build-up, consequently resulted in greater marketable tuber yield. Pheromone traps each 40 per hectare reduced sweet potato tuber damage by 65% by sweet potato weevil and use of chlorpyrifos each two kilogrammes active ingredient per hectare in addition to the pheromone reduced the damage by an extra 10% over the pheromone treatment (Hwang and Hung, 1991).

Yasuda *et al.* (2004), described that integration of sex pheromone traps with insecticides or entomopathogenic fungi are practiced successfully. Development of a new pheromone formulation to increase exposure time to insecticide for control of the sweet potato weevil. The attracted males located and tried to mate with the ball. They were thereby efficiently exposed to the insecticide for a longer time. The concentration of the new formulation was extremely low compared to the conventional formulations, and therefore, lowers the cost of application. The formulation was a combination of sex pheromone, butenoate, and an insecticide impregnated into blue ball made of the diatomaceous soil. The male weevils were attracted to the visual stimulation in addition to the sex pheromone (Smit *et al.,* 2001).

2.4 Constraints to Sweet Potato Weevil Management

Stathers *et al.* (2005), indicated that pesticides kill natural enemies that under natural circumstances quite effectively control weevil populations, and can also present health, risks for human and animals. In some countries planting materials are dipped into on synthetic pesticide before planting, which can delay pest infestation for several months, however, most pesticides are expensive and highly toxic therefore dipping is only likely to be economical for large scale commercial root production or vine multiplication nurseries. Other varieties escape weevil damage because their storage roots mature quickly and can be harvested early. Breeders have spent many years trying to develop varieties that are resistant to the weevil. So far they have not been successful (Stevenson *et al*., 2009). However, varieties that form root relatively deep in the soil are less attacked because the weevils cannot easily reach the roots to lay eggs (Kays *et al*., 1993). Chemical control is not effective because the weevils are protected for, at least part of their life cycle by their development within roots or stems, where they are not easily reached by pesticides (Mason *et al*., 1991)

Kabi *et al*. (2001), recorded that the larvae feed on storage root in the ground or inside the woody base of the stems. This means with the possible exception of systemic insecticides, which are costly and pose risk of residual contamination of the roots there is no effective chemical control of all stages of the pest found within the plant tissues. This subterranean habitat also makes the insect less accessible to predator and parasitoids but increases the impact of pathogens and nematodes, natural enemies which requires a protected, cool and humid environment for survival and reproduction (Stathers *et al.,* 2005).

CHAPTER III
MATERIALS AND METHODS

The present study regarding documentation of insect pests in sweet potato and their management has been conducted during rabi season (November 2016 to March 2017) in the experimental field of Sher-e-Bangla Agricultural University, Dhaka. Required materials and methodology are described below under the following sub-headings.

3.1. Location

The experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The location of the experimental site was $23^0 74^/$ N latitude and $90^0 35^/$ E longitude and an elevation of 8.2 m from sea level (Anon., 1989).

3.2. Climate

The climate of the study site was under the subtropical climate, characterized by three distinct seasons, the Rabi from November to February and the Kharif- I, pre-monsoon period or hot season from March to April and the Kharif- II monsoon period from May to October (Edris *et al.*, 1979). The monthly average temperature, relative humidity and rainfall during the crop growing period were collected from weather yard, Bangladesh Meteorological Department and presented in Appendix I. During the experimental period the maximum temperature (27.1^0C) and highest rainfall (30 mm) was recorded in the month of February 2017, whereas the minimum temperature (12.4^0C) and no rainfall was recorded in the month of January 2017.

3.3. Soil

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al.*, 1991). The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988).

3.4. Land Preparation

The land is ploughed or dug to a depth of about 20 cm and harrowed to pulverize the soil. Mound method, ridge and furrow method, bed method and flat method are practiced in sweet potato cultivation in different localities. It is preferable to plant sweet potato on mounds in areas experiencing problems of drainage. In sloppy lands, ridge and furrow system is recommended for the control of soil erosion. The higher yield recorded when planted on mounds is probably be due to better soil aeration permitted by mounds and less tendency for soil compaction. In Bangladesh, higher yields were reported with trench planting followed by ridge and flat method of planting in alluvial soils under irrigated conditions (Bhuiyan *et al*., 2006). The experimental plot was opened in the first week of November 2016 with a power tiller, and was exposed to the sun for a week, after which the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and later clods were broken into smaller pieces. After ploughing and laddering, all the stabbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiments were followed immediately after land preparation.

3.5. Manure and Fertilizer

The fertilizers N, P, K in the form of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP) respectively and as an organic manure, Cowdung were applied. The entire amount of organic manure, TSP, MP and half amount of Urea were applied as basal during the final land preparation. Rest amount of Urea was applied 60 days after planting of vine in the side of row. The dose and method of application of fertilizers are shown in Table (BARI).

Fertilizer name	Amount/ha
Cowdung (ton)	8-10
Urea(kg)	160-250
TSP(kg)	150-170
MP(kg)	150-250

3.6. Vine Collection

Vines of sweet potato that were used in this experiment were collect from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. The variety name was BARI Sweet Potato -8.

3.7. Design of Experiment

The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. The experimental field was divided into three blocks maintaining 1m block to block distance and each block was subdivided into 7 plots for 7 treatments each maintaining 3 m x 2 m plot size. Thus the total number of plots was 21. The plot to plot distance was 0.5 m was kept to facilitate different intercultural operations.

3.8. Planting

Time of planting has been identified as one of the most important factors affecting growth, yield and quality of roots (Nedunchezhiyan and Byju, 2005). In Malaysia, higher root yield was noticed during drier growing season (January to July) compared to wet season (August to December) (Zaharah and Tan, 2006). In India, sweet potato is grown throughout the country, utilizing monsoon rain during *kharif*, (June-August), and with supplemental irrigation during *rabi* (October-December). The major area under sweet potato is planted during *kharif* season, though *rabi* planted sweet potato enjoys warm sunny days and cool nights with moderate rainfall conductive for higher root yield. Investigations carried out at different regions of India on the optimum time of planting revealed that rainfed crops should be planted immediately after onset of monsoon (Nedunchezhiyan and Reddy 2006) whereas dry season crops should be planted in October-November (Nath *et al*., 2006) for higher storage root yield. In India, it is observed that the tuber yield of sweet potato is comparatively more during *rabi* than *kharif* season (Nawale and Salvi 1983; Nedunchezhiyan and Byju, 2005). In Taiwan, high yields of sweet potato were obtained when the mean daily temperature was maintained around 22ºC for the 1st 60 DAP (Sajjapongse, 1989). In Korea, as per the demand of sweet potatoes, transplanting time is advanced from May-June to March-April and the harvesting time is advanced from September-October to June-August with the modification of cultural requirements (Jeong, 2000). In the experiment field sweet potato vines were planted in the 21st November, 2016.

3.9. Treatments of the Experiment

Seven treatment combinations were tested under the present ssudy. These are as follows

T_1: Emamectin benzoate @ 2 ml/L before tuber formation

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval before tuber form ation (3times application)

T_5: Volian flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

Earthing-up was commonly done for each treatment

3.10. Intercultural Operations

Various intercultural operations such as gap filling, weeding, earthing up, irrigation etc. were accomplished for better growth and development of the sweet potato.

3.10.1. Irrigation

Sweet potato vines are succulent and fragile and if sufficient moisture is not available in the soil immediately after planting it dries up. Hence, sufficient soil moisture at the time of planting is to be ensured for proper sprouting and establishment of vines. Sweet potato is mostly grown under rain fed conditions. Hence, planting is carried out on rainy day or immediately after rain. It is also grown in dry season under protective irrigation. Under such conditions, if sufficient moisture is not available after planting, irrigation need to be provided on alternate days initially for the first fortnight and thereafter once in 7-10 days. Trials conducted in the sweet potato growing areas have conclusively proved the beneficial effect of irrigation. Sweet potato required on an average of 2 mm of water per day in the early parts of the growing season and gradually increased to 5-6 mm of water/day prior to harvest (Gomes and Carr 2003). Biswal (2008), found that when soil moisture was high or the soil was compacted sweet potato had luxuriant vegetative growth with little or no tuberization of root. Excessive irrigation should be avoided as poor aeration may cause poor storage root induction or development (Chua and Kays 1981).

Indira and Kabeerathumma (1988), imposed water stress for 20 days to sweet potato grown in lysimeter during early growth phase (10-30 days), root development phase (30-50 DAP) and root maturity phase (75-90 DAP) and observed significant reduction in root yield for the stress induced during early growth phase. Stress induced during root development phase however slightly improved the yield while stress during root maturity phase resulted in a slight reduction in yield. Martin (1988), stated that sweet potato could not tolerate dry conditions at planting. According to Yassen and Thompson (1988) irrigation increased the number of root and total marketable yield.

According to Goswami *et al*. (1995), three irrigations at root initiation, early bulking and late bulking stages were most favourable for higher number of roots/plant, root bulking rate and dry matter content resulting in higher root yield (27.8 t ha^{-1}).

In this experiment field light watering in every alternative day after planting to 20 days were done. After that when the root is developed then watering in the sweet potato field after 30 days, 60 days and 90 days.

3.10.2. Gap filling

The planted vines in the experimental plot were kept under careful observation. Very few seedlings were damaged after planting and that vines were replaced by new vines from the stock.

3.10.3. Weeding and Earthing Up

To protect the crop from weeds, at least two weedings followed by earthing up have to be given between 15 and 30 and 35 and 60 days after planting (Nedunchezhiyan and Ray, 2010).

3.11. Harvesting

Harvesting of sweet potato has been done in three steps from 5 selected vines in the plot. 1st harvest was done at 15 days early harvest, 2nd harvest was done at optimum time of 130 days and 3rd harvest was done after 15 days from optimum harvest for assess sweet potato weevil. Finally per hectare yield was calculated by converting the yield of optimum days harvest.

3.12. Data Collection

The data on the following parameters were recorded at different time intervals as given below:

- Identify different insect pests in sweet potato field
- Number of insect pests on leaves and branches
- Total number of sweet potato storage roots/plant
- Total number of infested sweet potato storage roots/plant
- Vine length (cm)
- Number of storage roots/vine
- Weight of individual storage root (g)
- Yield of storage roots (t/ha)

3.13. Calculation:

3.13.1 Determination of storage roots infestation in number

All the storage roots were counted from 5 randomly selected plants from middle rows of each plot and examined. The collected data were divided into early, mid and late harvesting stage. The healthy and damaged storage roots were counted and the percent storage root infestation was calculated using the following formula:

$$\%\ \text{infestation} = \frac{\text{Number of infested storage roots}}{\text{Total number of storage roots}} \times 100$$

3.13.2 Determination of storage roots infestation in weight

All the storage roots were counted from 5 randomly selected plants from middle rows of each plot and examined. The collected data were divided into early, mid and late harvesting stage. The healthy and damaged storage roots were weighted and the percent storage root infestation was calculated using the following formula:

$$\% \text{ infestation } = \frac{\text{Weight of infested storage roots}}{\text{Total weight of storage roots}} \times 100$$

3.14. Insect Pests of Sweet Potato

3.14.1. Sweetpotato Bug

Physomerus grossipes

Description and biology: The sweet potato bug lays groups of eggs on the undersides of leaves or on the stem. The mother bug guards her eggs and the young gregarious nymphs.

Damage: The nymphs and adults pierce the stems and petioles of the sweet potato and suck the plant sap, thus causing wilting and stunting.

Plate 1. Photograph showing Sweet potato bug

3.14.2. Mealybug

Phenacoccus solenopsis

Description and biology: Females are white, waxy and 3-4 mm long. Bare areas on the abdomen appear as dark bands. Adult males are grey and 1 mm long.

Damage: Adult females and nymphs suck sap. Leaves become yellow, vigour is reduced and young plants may die.

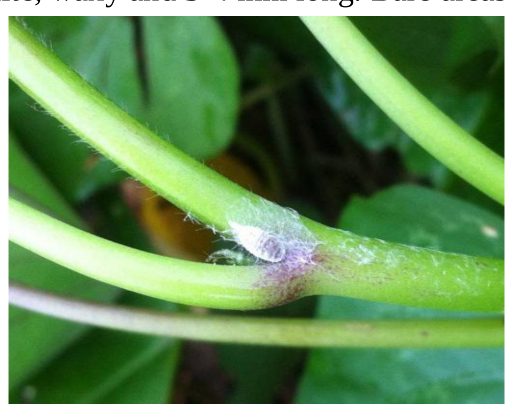

Plate 2. Photograph showing Mealybug

3.14.3. Green vegetable bug
Nezara viridula

Description and biology: Green, shield-shaped bug around 15 mm long. Initially dark red and orange, then green with distinctive black, white and red patterning.

Damage: Young shoots are damaged by sap sucking.

Plate 3. Photograph showing green vegetable bug

3.14.4. Leaf hopper

Amrasca sp.

Description and biology: Look like tiny cicadas; torpedo-shaped and ranging in colour from yellowish to green and mottled brown.

Damage: Feeding leaves speckled yellow tracks on the leaves.

Plate 4. Photograph showing leaf hopper

3.14.5. Minor Leaf Feeders

Zonocerous variegatus

Description and biology: An Asian species, the polyphagous slant-faced grasshopper is bright green and characterized by a pointed conical head and short antennae. It measures 30-40 mm in length.

Damage: It bores through the petiole of the host plant to lay its eggs. These are covered with a reddish brown gummy substance.

Plate 5. Photograph showing minor leaf feeders

3.14.6. Sweet potato beetle

Colasposoma sellatum

Description and biology: Glossy black beetle, 6-9 mm long with thickened wing covers and thorax. White grub up to 12 mm long, rather hairy, with six small legs.

Damage: Larvae feed on storage roots, creating tracks on the surface of the root. Damage is similar to that caused by flea beetle larvae, but deeper. Adults chew on leaves.

Plate 6. Photograph showing sweet potato beetle

3.14.7. Tortoiseshell Beetle

Aspidomorpha spp**.**

Description and biology: Eggs are laid on the underside of the sweetpotato leaves or other Convolvulaceae in batches cemented to the leaves. The eggs of some species are concealed in a papery oothecum. Larvae are characteristically flattened and spiny. In some species, the tail is held up over the back and the larva may carry excreta and previous cast skins. The pupa is less spiny than the larva, and is fixed inert to the leaf The adults are broadly oval and may be bright and patterned. Larvae, pupae and adult are found on both sides of the foliage. Development from egg to adult takes 3-6 weeks depending on the species.

Plate 7. Photograph showing Tortoiseshell Beetle

Damage: Both adults and larvae eat large round holes in the leaves. Attacks are sometimes sufficiently severe to completely skeletonize the leaves and peel the stems.

3.14.8. Whitefly

Bemisia tabaci

Description and biology: Snow white, around 1 mm long with wings held in a peak along the body. First instar nymphs are flat, greenish, mobile and around 0.3 mm long. Later instar nymphs are also flat but opaque white and stationary, appearing similar to soft scale insects but with pointed tails. Mature nymphs turn golden, their bodies thicken and eyes turn red.

Plate 8. Photograph showing whitefly

Damage: Nymphs and adults suck sap from plants, causing yellow or purplish stippling between the veins on leaves. Growth may be stunted. Whitefly can also transmit some viruses.

3.14.9. Sweet potato weevil

Cylas spp**.**

Description and biology: Three species of the genus *Cylas* are pests of sweet potato; they are commonly called sweet potato weevils. All three species-*Cylas formicarius, C. puncticollis*, and *C. brunneus*-are found in Africa. *C. formicarius* is present in Asia and in parts of the Caribbean. The elongated ant-like adults of the three species can be distinguished from each other. *Cylas puncticollis* is the easiest to distinguish because the adult is all black and larger than the other two. *C. formicarius* has a bluish black abdomen and a reddish brown thorax. *C. brunneus* adults are small and not uniform in coloring. The most common type can easily be confused with *C. formicarius*. In

Plate 9. Photograph showing sweet potato weevil larva

all species, the eggs are shiny and round. The legless larvae are white and curved, and the pupae are white.

Damage: Damage symptoms are similar for all three species. Adult sweetpotato weevils feed on the epidermis of vines and leaves. Adults also feed on the external surfaces of storage roots, causing round feeding punctures, which can be distinguished from oviposition sites by their greater depth. The developing larvae of the weevil tunnel in the vines and storage roots, causing significant damage. Frass is deposited in the tunnels. In response to damage, storage roots produce toxic terpenes, which render storage roots inedible even at low concentrations and low levels of physical damage. Feeding inside the vines causes malformation, thickening, and cracking of the affected vine.

3.15. Beneficial insect in the field

3.15.1. Ladybird beetle

Coccinella transversa

Description and biology: Most are brightly coloured, dome-shaped beetles 3-5 mm long with distinctive spots and stripes on their outer wing covers. Black with coloured markings a 'crocodile like' appearance.

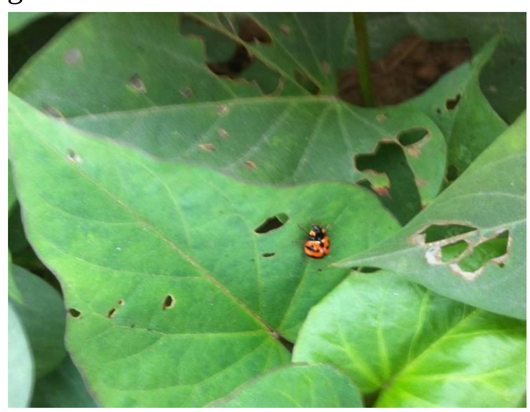

Plate 10. Photograph showing Ladybird beetle

3.15.2. Spider

The importance of spiders as predators has been clearly demonstrated for rice, but their role has not been studied adequately in many other crops and little is known about their contribution to biological control of sweet potato pests.The lynx spider Oxyopes sp. and the wolf spider Lycosa sp. are abundant insweet potato fields. These do not spin webs but rather hunt prey directly. Web-spinning spiders are also common

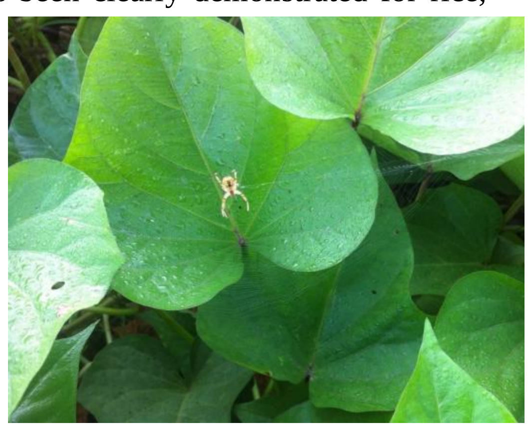

Plate 11. Photograph showing spider

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted for the identification of insect pests in sweet potato and their management. Data was recorded on insect pest incidence, number of healthy, infested leaves and branches for different insect pests and their infestation

level, healthy and infested storage roots of sweet potato and their infestation level and also yield contributing characters and yield of sweet potato. The analysis of

variance (ANOVA) of the data on different parameters has been presented in Appendix II-IX. The results have been discussed and presented under the following headings and sub-headings:

4.1 Incidence of different insect pest in sweet potato

4.1.1 Species of insect pests

During the entire growing period sweet potato competes with numerous insect pests under favorable condition which is the common phenomenon for the cultivation of this crop. Under the present study 9 different species of insect pests were found and they were belongs to 9 family under 3 orders. The common name, scientific name, order, family and nature of damage of these insect pests are presented in Table 1. Among the recorded insect pests 5 species belong to the order Hemiptera, 3 species belong to Coleoptera and only 1 species under Othoptera order and different family.

Among the insect pests it was observed that sweet potato weevil was more destructive for storage roots of sweet potato. The natures of the damage of these insects are presented in Table 1.

4.1.2 Insect population

Number of insect population of 5 selected vine/plot was observed in the experimental plot for the entire growing period. The number of observed insect pests was presented in Table 2.

Table 1. List of the insect pests found in the experimental sweet potato field during study period

Sl. No.	Common name	Scientific name	Order	Family	Nature of damage
1.	Sweet potato Bug	*Physomerus grossipes*	Hemiptera	Coreidae	The nymphs and adults pierce the stems and petioles of sweet potato and suck the plant sap
2.	Mealybug	*Phenacoccus solenopsis*	Hemiptera	Pseudococcidae	Adult females and nymphs suck sap. Leaves become yellow, vigour is reduced and young plants may die
3.	Green vegetable bug	*Nezara viridula*	Hemiptera	Pentatomidae	Young shoots are damaged by sap sucking
4.	Leaf hopper	*Amrasca* spp.	Homoptera	Cicadellidae	Feeding leaves speckled yellow tracks on the leaves
5.	Minor leaf feeders	*Zonocerous variegatus*	Orthoptera	Pyrgomoriphidae	It bores through the petiole of the host plant to lay its eggs.
6.	Sweet potato beetle	*Colasposoma sellatum*	Coleoptera	Chrysomelidae	Larvae feed and creating tracks on the surface on storage roots and adults chew on leaves
7.	Whitefly	*Bemisia tabaci*	Homoptera	Aleyrodidae	Nymphs and adults suck sap, causing yellow or purplish stippling between the leaf veins
8.	Tortoiseshell Beetles	*Aspidomorpha* spp.	Coleoptera	Chrysomelidae	Both adults and larvae eat large round holes in the leaves. Attacks are sometimes sufficiently severe to completely skeletonize the leaves and peel the stems
9.	Sweet potato weevil	*Cylas formicarius*	Coleoptera	Curculionidae	Adult sweet potato weevils feed on the epidermis of vines and leaves and also the external surfaces of storage roots, causing round feeding punctures. The developing larvae of the weevil tunnel in the vines and storage roots, causing significant damage.

4.1.2.1 Sweet potato bug

Data revealed that for the consideration of sweet potato bug, the lowest number (1.27) of sweet potato bug was observed from T_2 (Carbofuran 5G @ 15 kg/ha at 60 days after sowing) treatment which was closely followed (1.86, 1.93 and 2.07) by T_4 (Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval: 3 times application), T_3 (Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval: 3 times application) and T_5 (Voliam flexi 300SC @ 1 ml/L at 15 days interval: 3 times application), respectively and they were statistically similar, whereas the highest number of sweet potato bug (5.13) was recorded from T_7 (Untreated control) treatment (Table 2). Allard (1990) reported that deltamethrin and pirimiphos methyl gave good control of sweet potato pests.

4.1.2.2 Mealybug

In case of mealybug, the lowest number of mealybug was observed from T_2 (1.67) treatment which was closely followed by T_4 (2.27) treatment and then T_3 (2.87), whereas the highest number of mealybug was found from T_7 (6.93) treatment (Table 2).

4.1.2.3 Green vegetable bug

In consideration of green vegetable bug, the lowest number of green vegetable bug was recorded from T_2 (1.07) treatment which was statistically similar to T_4 (1.27) and closely followed by T_3 (1.87) treatment and T_5 (2.07) and they were statistically similar, while the highest number of green vegetable bug was observed from T_7 (4.20) treatment (Table 2). Misra *et al*. (2001) reported from earlier experiment that combination of vine dipping of 0.05% monocrotophos and three foliar sprays with 0.05% endosulfan proved very effective in controlling green vegetable bug.

Table 2. Number of identified insect pests in sweet potato during the growing period for different management practices

Treatments	Number of different insect pests								
	Sweet potato bug	Mealybug	Green vegetable bug	Leaf hopper	Minor leaf feeders	Sweet potato beetle	Whitefly	Tortoiseshell beetle	Sweet potato weevil
T_1	2.93 b	3.94 b	2.93 b	4.80 b	2.33 b	3.87 b	3.93 b	2.53 b	4.20 b
T_2	1.27 d	1.67 f	1.07 d	2.07 e	1.13 e	1.47 f	1.67 e	1.13 e	1.67 e
T_3	1.93 c	2.87 d	1.87 c	3.47 d	1.87 d	2.33 e	2.53 d	1.80 cd	2.67 d
T_4	1.86 c	2.27 e	1.27 d	2.53 e	1.33 e	2.13 e	2.27 d	1.47 de	2.33 d
T_5	2.07 c	3.27 c	2.07 c	4.27 c	1.93 cd	2.87 d	3.27 c	1.87 c	3.13 c
T_6	2.73 b	3.87 b	2.67 b	4.33 bc	2.20 bc	3.33 c	3.33 c	2.07 c	4.07 b
T_7	5.13 a	6.93 a	4.20 a	6.40 a	4.73 a	6.33 a	6.73 a	4.33 a	6.73 a
$LSD_{(0.05)}$	0.323	0.356	0.347	0.471	0.276	0.347	0.347	0.342	0.369
CV(%)	6.95	5.66	8.47	6.64	7.05	6.12	5.76	8.88	5.84

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

4.1.2.4 Leaf hopper

In case of leaf hopper, the lowest number of leaf hopper was recorded from T_2 (2.07) treatment which was statistically similar to T_4 (2.53) and closely followed by T_3 (3.47) treatment, whereas the highest number of leaf hopper was found from T_7 (6.40) which was followed by T_1 (4.80) and T_6 (4.33) treatment and they were statistically similar (Table 2).

4.1.2.5 Minor leaf feeders

Data revealed that for minor leaf feeders, the lowest number of minor leaf feeders was recorded from T_2 (1.13) treatment which was statistically similar to T_4 (1.33) and closely followed by T_3 (1.87) and T_5 (1.93) treatment and they were statistically similar, whereas the highest number of minor leaf feeders was found from T_7 (4.73) which was followed by T_1 (2.33) and T_6 (2.20) treatment and they were statistically similar (Table 2).

4.1.2.6 Sweet potato beetle

In consideration of sweet potato beetle, the lowest number of sweet potato beetle was recorded from T_2 (1.47) treatment which closely followed by T_4 (2.13) and T_3 (2.33) and they were statistically similar, whereas the highest number of was found from T_7 (6.33) which was followed by T_1 (3.87) treatment (Table 2).

4.1.2.7 Whitefly

In case of whitefly, the lowest number of whitefly was recorded from T_2 (1.67) treatment which closely followed by T_4 (2.27) and T_3 (2.53) and they were statistically similar, whereas the highest number of whitefly was found from T_7 (6.73) which was followed by T_1 (3.93) treatment (Table 2).

4.1.2.8 Tortoiseshell beetle

From the recorded data in case of tortoiseshell beetle, the lowest number of tortoiseshell beetle was found from T_2 (1.13) which was statistically similar to T_4 (1.47) and closely followed by T_3 (1.80) treatment, whereas the highest number from T_7 (4.33) which was followed by T_1 (2.53) treatment (Table 2).

4.1.2.9 Sweet potato weevil

Data revealed that for sweet potato weevil, the lowest number of sweet potato weevil was observed from T_2 (1.67) treatment which was closely followed by T_4 (2.33) and T_3 (2.67) treatment and they were statistically similar, while the highest number of sweet potato weevil was recorded from T_7 (6.73) which was followed by T_1 (4.20) and T_6 (4.07) treatment and they were statistically similar (Table 2). Parker *et al* (1990) found that the sweet potato weevil is one of the major pests of sweet potato worldwide.

4.2 Leaf and branches infestation by different insect pests in different stages

4.2.1 At early growth stages (1-45 days)

Statistically significant variation was recorded due to different treatments in terms of healthy, infested leaves and branches and also % of infestation caused by different insect pests at early growth stages of sweet potato (Table 3).

4.2.1.1 Leaves of sweet potato

In case of leaves of sweet potato at early growth stage, it was observed that the highest number of healthy leaves/vine was recorded from T_2 (46.20) treatment which was statistically similar with other treatment except T_7, while the lowest number of healthy leaves (36.73) was observed from T_7 treatment (Table 3). In case of infested leaves, the lowest number (1.87) was observed from T_2 treatment which was statistically similar to T_4 (2.00) and T_3 (2.33) treatment and closely followed by T_5 (2.73) treatment, while the highest number of infested leaves was found from T_7 (5.13) treatment which was followed by T_1 (3.87) treatment. In consideration of infestation level of leaves, the lowest infestation was recorded from T_2 (3.90%) treatment which was statistically similar to T_4 (4.38%) and T_3 (5.11%) treatment and closely followed by T_5 (5.93%) treatment, whereas the highest infestation (12.30%) was observed from T_7 treatment which was closely followed by T_1 (8.39%) and T_6 (6.83%) treatment and they were statistically similar. In case of leaf infestation reduction over control the highest value was recorded from T_2 (68.29) and the lowest value was found from T_1 (31.79) treatment.

Table 3. Incidence of insect pests on leaf and branches of sweet potato at early growth stage for different management practices

Treatments	Leaf of sweet potato				Branches of sweet potato			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control
T_1	42.33 a	3.87 b	8.39 b	31.79	4.53 cd	0.40 b	8.11 b	36.94
T_2	46.20 a	1.87 e	3.90 e	68.29	5.27 a	0.13 d	2.39 e	81.42
T_3	43.53 a	2.33 de	5.11 cde	58.46	5.00 abc	0.27 bcd	5.14 cde	60.03
T_4	44.20 a	2.00 e	4.38 de	64.39	5.13 ab	0.20 cd	3.75 de	70.84
T_5	43.40 a	2.73 cd	5.93 cd	51.79	4.87 abc	0.33 bc	6.37 bcd	50.47
T_6	42.67 a	3.13 c	6.83 bc	44.47	4.67 bc	0.40 b	7.90 bc	38.57
T_7	36.73 b	5.13 a	12.30 a	--	4.07 d	0.60 a	12.86 a	--
$LSD_{(0.05)}$	4.683	0.577	1.677	--	0.481	0.138	2.720	--
CV(%)	6.16	10.79	14.09	--	5.64	13.90	12.00	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

4.2.1.2 Branches of sweet potato

For branches/vine of sweet potato at early growth stage, data revealed that the highest number of healthy branches was recorded from T_2 (5.27) treatment which was statistically similar to T_4 (5.13), T_3 (5.00) and T_5 (4.87) treatment and closely followed by T_6 (4.67) treatment, while the lowest number of healthy branches (4.07) was observed from T_7 treatment which was statistically similar to T_1 (4.53) treatment (Table 3). In case of infested branches, the lowest number (0.13) was observed from T_2 treatment which was statistically similar to T_4 (0.20) and T_3 (0.27) treatment, while the highest number of infested branches was found from T_7 (0.60) treatment which was followed by T_1 (0.40) and T_6 (0.40) treatment. In consideration of infestation level of branches, the lowest infestation was recorded from T_2 (2.39%) treatment which was statistically similar to T_4 (3.75%) and T_3 (5.14%) treatment and closely followed by T_5 (6.37%) treatment, whereas the highest infestation (12.86%) was observed from T_7 treatment which was closely followed by T_1 (8.11%) and T_6 (7.90%) treatment and they were statistically similar. In case of infestation reduction over control, the highest value was recorded from T_2 (81.42) and the lowest value was found from T_1 (36.94) treatment.

4.2.2 At mid growth stages (46-85 days)

Statistically significant variation was recorded for healthy, infested leaves and branches and also % of infestation caused by different insect pests at mid growth stages of sweet potato due to different treatments (Table 4).

4.2.2.1 Leaves of sweet potato

In case of leaves/vine of sweet potato at mid growth stage, it was observed that the highest number of healthy leaves was recorded from T_2 (88.67) treatment which was statistically similar with other treatment except T_7, while the lowest number of healthy leaves (74.47) was observed from T_7 treatment (Table 4). In case of infested leaves, the lowest number (2.47) was observed from T_2 treatment which was closely followed by T_4 (2.87) treatment, whereas the highest number of infested leaves was found from T_7 (8.33) treatment which was

Table 4. Incidence of insect pests on leaf and branches of sweet potato at mid growth stage for different management practices

Treatments	Leaf of sweet potato				Branches of sweet potato			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control
T_1	83.07 a	4.93 b	5.61 b	44.29	11.20 bc	0.93 b	7.68 b	34.58
T_2	88.67 a	2.47 g	2.71 e	73.09	13.33 a	0.33 e	2.45 e	79.13
T_3	85.73 a	3.27 e	3.68 d	63.46	12.27 ab	0.67 cd	5.14 d	56.22
T_4	87.53 a	2.87 f	3.18 de	68.42	13.13 a	0.47 de	3.40 e	71.04
T_5	85.73 a	3.80 d	4.26 c	57.70	12.27 ab	0.80 bc	6.10 cd	48.04
T_6	84.80 a	4.13 c	4.66 c	53.72	11.73 abc	0.93 b	7.39 bc	37.05
T_7	74.47 b	8.33 a	10.07 a	--	10.53 c	1.40 a	11.74 a	--
$LSD_{(0.05)}$	8.024	0.323	0.522	--	1.514	0.225	1.457	--
CV(%)	5.35	4.29	6.01	--	7.05	15.78	13.06	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

followed by T_1 (4.93) treatment. In consideration of infestation level of leaves, the lowest infestation was recorded from T_2 (2.71%) treatment which was statistically similar to T_4 (3.18%) and closely followed by T_3 (3.68%) treatment, whereas the highest infestation (10.07%) was observed from T_7 treatment which was followed by T_1 (5.61%). In case of infestation reduction over control the highest value was recorded from T_2 (73.09) and the lowest value was found from T_1 (44.29) treatment.

4.2.2.2 Branches of sweet potato

For branches of sweet potato at mid growth stage, data revealed that the highest number of healthy branches/vine was recorded from T_2 (13.33) treatment which was statistically similar with other treatment except T_7 and T_1 treatment, while the lowest number of healthy branches (10.53) was observed from T_7 treatment which was statistically similar to T_1 (11.20) treatment (Table 4). In case of infested branches, the lowest number (0.33) was observed from T_2 treatment which was statistically similar to T_4 (0.47) and closely followed by T_3 (0.67) treatment, while the highest number of infested branches was found from T_7 (1.40) treatment which was followed by T_1 (0.93), T_6 (0.93) and T_5 (0.80) treatment and they were statistically similar. In case of infestation level of branches, the lowest infestation was recorded from T_2 (2.45%) treatment which was statistically similar to T_4 (3.40%) and closely followed by T_3 (5.14%) and T_5 (6.10%) treatment and they were statistically similar, whereas the highest infestation (11.74%) was observed from T_7 treatment which was closely followed by T_1 (7.68%) and T_6 (7.39%) treatment and they were statistically similar. In case of reduction over control, the highest value was recorded from T_2 (79.13) and the lowest value was found from T_1 (34.58) treatment.

4.2.3 At late growth stages (86-130 days)

Different treatments showed statistically significant differences in terms of healthy, infested leaves and branches and also % of infestation caused by different insect pests at late growth stages of sweet potato (Table 5).

Table 5. Incidence of insect pests on leaf and branches of sweet potato at late growth stage for different management practices

Treatments	Leaf of sweet potato				Branches of sweet potato			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control
T_1	135.27 a	7.00 b	4.92 b	45.87	19.33 bc	1.67 b	7.93 b	28.49
T_2	143.33 a	3.80 e	2.58 e	71.62	22.53 a	0.60 d	2.61 d	76.47
T_3	139.80 a	5.13 d	3.55 d	60.95	21.67 ab	1.00 c	4.42 c	60.14
T_4	142.00 a	4.13 e	2.83 e	68.87	22.47 a	0.73 d	3.16 d	71.51
T_5	138.73 a	5.67 d	3.92 d	56.88	20.47 abc	1.20 c	5.55 c	49.95
T_6	136.87 a	6.40 c	4.47 c	50.83	19.67 bc	1.47 b	7.00 b	36.88
T_7	122.73 b	12.27 a	9.09 a	--	18.13 c	2.27 a	11.09 a	--
$LSD_{(0.05)}$	12.03	0.540	0.410	--	2.397	0.252	1.263	--
CV(%)	4.94	4.78	5.16	--	6.54	11.08	11.91	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

4.2.3.1 Leaves of sweet potato

In case of leaves/vine of sweet potato at late growth stage, it was observed that the highest number of healthy leaves/vine was recorded from T_2 (143.33) treatment which was statistically similar with other treatment except T_7, while the lowest number of healthy leaves (122.73) was observed from T_7 treatment (Table 5). In case of infested leaves, the lowest number (3.80) was observed from T_2 treatment which was statistically similar to T_4 (4.13) and closely followed by T_3 (5.13) and T_5 (5.67) treatment and they were statistically similar, while the highest number of infested leaves was found from T_7 (12.27) treatment which was followed by T_1 (7.00) treatment. In consideration of infestation level of leaves, the lowest infestation was recorded from T_2 (2.58%) treatment which was statistically similar to T_4 (2.83%) and closely followed by T_3 (3.55%) and T_5 (3.92%) treatment and they were statistically similar, whereas the highest infestation (9.09%) was observed from T_7 treatment which was closely followed by T_1 (4.92%) treatment and they were statistically similar. In case of reduction over control the highest value was recorded from T_2 (71.62) and the lowest value was found from T_1 (45.87) treatment.

4.2.3.2 Branches of sweet potato

For branches/vine of sweet potato at late growth stage, data revealed that the highest number of healthy branches/vine was recorded from T_2 (22.53) treatment which was statistically similar to T_4 (22.47), T_3 (21.67) and T_5 (20.47) treatment, while the lowest number of healthy branches (18.13) was observed from T_7 treatment which was statistically similar to T_6 (19.67) and T_1 (19.33) treatment (Table 5). In case of infested branches, the lowest number (0.60) was observed from T_2 treatment which was statistically similar to T_4 (0.73) and closely followed by T_3 (1.00) and T_5 (1.20) treatment and they were statistically similar, while the highest number of infested branches was found from T_7 (2.27) treatment which was followed by T_1 (1.67) and T_6 (1.47) treatment and they were statistically similar. In consideration of infestation level of branches, the lowest infestation was recorded from T_2 (2.61%) treatment which was statistically similar to T_4 (3.16%) and closely followed by T_5 (5.55%) and T_3 (4.42%) treatment and they were statistically similar, whereas the highest infestation (11.09%) was observed from T_7 treatment which was closely followed by T_1 (7.93%) and T_6 (7.00%) treatment and they were statistically similar. In case of reduction over control, the highest value was recorded from T_2 (76.47) and the lowest value was found from T_1 (28.49) treatment.

4.3 Storage root infestation by sweet potato weevil in different stages

4.3.1 At 15 days early harvest

Healthy, infested storage roots of sweet potato in number and weight basis per vine and also % of infestation caused by sweet potato weevil at 15 days early harvest varied significantly for different treatment (Table 6).

4.3.1.1 Storage roots of sweet potato in number basis

In case of storage roots of sweet potato/vine in number basis at 15 days early harvest, it was observed that the highest number of healthy storage roots/vine was recorded from T_2 (6.87) treatment which was statistically similar with other treatment except T_7, while the lowest number (5.73) was observed from T_7 treatment (Table 6). In case of infested storage roots, the lowest number (0.27) was observed from T_2 treatment which was statistically similar to T_4 (0.40) and T_5 (0.33) closely followed by T_3 (0.47) treatment, while the highest number was found from T_7 (0.80) treatment which was followed by T_1 (0.60) and T_6 (0.53) treatment and they were statistically similar. In consideration of infestation level of storage roots in number basis, the lowest infestation was recorded from T_2 (3.69%) treatment which was statistically similar to T_4 (4.74%) and T_5 (5.95) and closely followed by T_3 (6.63%) treatment, whereas the highest infestation (12.25%) was observed from T_7 treatment which was closely followed by T_1 (8.67%) and T_6 (7.82%) treatment and they were statistically similar. In case of reduction over control the highest value was recorded from T_2 (69.88) and the lowest value was found from T_1 (29.22) treatment. Ebregt *et al.,* (2005) stated that harvesting two weeks earlier reduce the loss due to weevil from greater than 30 percent to less than five percent.

Table 6. Incidence of sweet potato weevil on storage roots of sweet potato at 15 days early harvest in number and weight basis for different management practices

Treatments	Storage roots of sweet potato in number basis				Storage roots of sweet potato in weight basis			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control
T_1	6.33 ab	0.60 b	8.67 b	29.22	678.14 a	69.48 b	9.29 b	28.43
T_2	6.87 a	0.27 e	3.69 e	69.88	713.71 a	42.95 d	5.68 e	56.24
T_3	6.53 a	0.47 bcd	6.63 bcd	45.88	701.02 a	54.69 c	7.24 c	44.22
T_4	6.67 a	0.33 de	4.74 de	61.31	707.11 a	48.66 d	6.45 d	50.31
T_5	6.33 ab	0.40 cde	5.95 cde	51.43	696.48 a	56.34 c	7.48 c	42.37
T_6	6.33 ab	0.53 bc	7.82 bc	36.16	683.90 a	65.52 b	8.75 b	32.59
T_7	5.73 b	0.80 a	12.25 a	--	608.97 b	90.85 a	12.98 a	--
$LSD_{(0.05)}$	0.577	0.159	2.164	--	61.73	5.937	0.748	--
CV(%)	5.06	18.34	17.12	--	5.07	5.45	5.09	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

4.3.1.2 Storage roots of sweet potato in weight basis

In case of storage roots of sweet potato/vine in weight basis at 15 days early harvest, it was observed that the highest weight of healthy storage roots/vine was recorded from T_2 (713.71 g) treatment which was statistically similar with other treatment except T_7, while the lowest weight (608.97 g) was observed from T_7 treatment (Table 6). In case of infested storage roots, the lowest weight (42.95 g) was observed from T_2 treatment which was statistically similar to T_4 (48.66 g) and closely followed by T_3 (54.69 g) and T_5 (56.34 g) treatment and they were statistically similar, while the highest weight was found from T_7 (90.85 g) treatment which was followed by T_1 (69.48 g) and T_6 (65.52 g) treatment and they were statistically similar. In consideration of infestation level of storage roots in weight basis, the lowest infestation was recorded from T_2 (5.68%) treatment which was closely followed by T_4 (6.45%) treatment, whereas the highest infestation (12.98%) was observed from T_7 treatment which was closely followed by T_1 (9.29%) and T_6 (8.75%) treatment and they were statistically similar. In case of reduction over control the highest value was recorded from T_2 (56.24) and the lowest value was found from T_1 (28.43) treatment.

4.3.2 At optimum days harvest

Statistically significant variation was recorded due to different treatments for healthy, infested storage roots of sweet potato in number and weight basis per vine and also % of infestation caused by sweet potato weevil at optimum days harvest (Table 7).

4.3.2.1 Storage roots of sweet potato in number basis

In case of storage roots of sweet potato/vine in number basis at optimum days harvest, it was observed that the highest number of healthy storage roots/vine was recorded from T_2 (7.00) treatment which was statistically similar with other treatment except T_7, while the lowest number (5.93) was observed from T_7 treatment (Table 7). In case of infested storage roots, the lowest number (0.33) was observed from T_2 treatment which was statistically similar to T_4 (0.40), T_5 (0.53) and T_3 (0.53) treatment, while the highest number was found from

Table 7. Incidence of sweet potato weevil on storage roots of sweet potato at optimum days harvest in number and weight basis for different management practices

Treatments	Storage roots of sweet potato in number basis				Storage roots of sweet potato in weight basis			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control
T_1	6.60 a	0.73 b	9.97 b	26.47	692.78 a	76.26 b	9.91 b	30.01
T_2	7.00 a	0.33 c	4.49 e	66.89	734.06 a	50.91 d	6.49 e	54.17
T_3	6.67 a	0.53 bc	7.35 cd	45.80	723.43 a	62.09 c	7.92 cd	44.07
T_4	6.80 a	0.40 c	5.56 de	59.00	726.26 a	55.63 cd	7.10 de	49.86
T_5	6.60 a	0.53 bc	7.49 bcd	44.76	717.08 a	63.75 c	8.16 c	42.37
T_6	6.60 a	0.67 b	9.21 bc	32.08	702.30 a	72.91 b	9.41 b	33.55
T_7	5.93 b	0.93 a	13.56 a	--	627.41 b	103.46 a	14.16 a	--
$LSD_{(0.05)}$	0.557	0.195	2.411	--	61.69	7.931	0.928	--
CV(%)	4.74	18.60	16.46	--	4.93	6.43	5.78	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

T_7 (0.93) treatment which was followed by T_1 (0.73) and T_6 (0.67) treatment and they were statistically similar. In consideration of infestation level of storage roots in number basis, the lowest infestation was recorded from T_2 (4.49%) treatment which was statistically similar to T_4 (5.56%) and closely followed by T_3 (7.35%) treatment, whereas the highest infestation (13.56%) was observed from T_7 treatment which was closely followed by T_1 (9.97%) and T_6 (9.21%) treatment and they were statistically similar. In case of reduction over control the highest value was recorded from T_2 (66.89) and the lowest value was found from T_1 (26.47) treatment.

4.3.2.2 Storage roots of sweet potato in weight basis

In case of storage roots of sweet potato/vine in weight basis at optimum days harvest, it was observed that the highest weight of healthy storage roots/vine was recorded from T_2 (734.06 g) treatment which was statistically similar with other treatment except T_7, while the lowest weight (627.41 g) was observed from T_7 treatment (Table 7). In case of infested storage roots, the lowest weight (50.91 g) was observed from T_2 treatment which was statistically similar to T_4 (55.63 g) and closely followed by T_3 (62.09 g) and T_5 (63.75 g) treatment and they were statistically similar, while the highest weight was found from T_7 (103.46 g) treatment which was followed by T_1 (76.26 g) and T_6 (72.91 g) treatment and they were statistically similar. In consideration of infestation level of storage roots in weight basis, the lowest infestation was recorded from T_2 (6.49%) treatment which was statistically similar to T_4 (7.10%) treatment, whereas the highest infestation (14.16%) was observed from T_7 treatment which was closely followed by T_1 (9.91%) and T_6 (9.41%) treatment and they were statistically similar. In case of reduction over control the highest value was recorded from T_2 (54.17) and the lowest value was found from T_1 (30.01) treatment.

4.3.3 After 15 days from optimum harvests

Statistically significant variation was recorded due to different treatments for healthy, infested storage roots of sweet potato in number and weight basis per vine and also % of infestation caused by sweet potato weevil after 15 days from optimum harvests (Table 8).

4.3.3.1 Storage roots of sweet potato in number basis

In case of storage roots of sweet potato/vine in number basis after 15 days from optimum harvest, it was observed that the highest number of healthy storage roots/vine was recorded from T_2 (7.13) which was statistically similar with other treatment except T_7, while the lowest number (6.13) from T_7 treatment (Table 8). In case of infested storage roots, the lowest number (0.40) was observed from T_2 treatment which was statistically similar to T_4 (0.47) and followed by T_5 (0.67), T_6 (0.67) and T_3 (0.73) treatment, while the highest number was found from T_7 (1.20) treatment which was followed by T_1 (0.87) treatment. In consideration of infestation level of storage roots in number basis, the lowest infestation was recorded from T_2 (5.31%) which was statistically similar to T_4 (5.98%) and followed by T_5 (8.92%) and T_6 (8.98), whereas the highest infestation (16.37%) was observed from T_7 treatment which was closely followed by T_1 (11.38%) treatment. In case of reduction over control the highest value was recorded from T_2 (67.56) and the lowest value was found from T_1 (30.48) treatment.

4.3.3.2 Storage roots of sweet potato in weight basis

In case of storage roots of sweet potato/vine in weight basis after 15 days from optimum harvest, it was observed that the highest weight of healthy storage roots/vine was recorded from T_2 (743.79 g) treatment which was statistically similar with other treatment except T_7, while the lowest weight (638.30 g) was observed from T_7 treatment (Table 8). In case of infested storage roots, the lowest weight (55.30 g) was observed from T_2 treatment which was statistically similar to T_4 (61.23 g) and followed by T_3 (67.45 g) and T_5 (70.10 g) treatment and they were statistically similar, while the highest weight from T_7 (131.23 g) treatment which was followed by T_1 (91.74 g) treatment. In consideration of

Table 8. Incidence of sweet potato weevil on storage roots of sweet potato after 15 days from optimum harvest in number and weight basis for different management practices

Treatments	Storage roots of sweet potato in number basis				Storage roots of sweet potato in weight basis			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control
T_1	6.73 a	0.87 b	11.38 b	30.48	710.19 a	91.74 b	11.43 b	32.96
T_2	7.13 a	0.40 d	5.31 d	67.56	743.79 a	55.30 f	6.93 f	59.35
T_3	6.87 a	0.73 bc	9.62 bc	41.23	733.64 a	67.45 de	8.43 de	50.56
T_4	7.27 a	0.47 d	5.98 d	63.47	736.52 a	61.23 ef	7.69 ef	54.90
T_5	6.80 a	0.67 c	8.92 c	45.51	726.03 a	70.10 cd	8.80 d	48.39
T_6	6.73 a	0.67 c	8.98 c	45.14	713.52 a	76.96 c	9.74 c	42.87
T_7	6.13 b	1.20 a	16.37 a	--	638.30 b	131.23 a	17.05 a	--
$LSD_{(0.05)}$	0.537	0.187	1.892	--	61.86	8.423	0.924	--
CV(%)	4.43	14.76	11.18	--	4.87	5.98	5.19	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

infestation level of storage roots in weight basis, the lowest infestation was recorded from T_2 (6.93%) treatment which statistically similar to T_4 (7.69%) treatment, whereas the highest infestation (17.05%) was observed from T_7 which was closely followed by T_1 (11.43%) treatment. In case of reduction over control the highest value was recorded from T_2 (59.35) and the lowest value was found from T_1 (32.96) treatment. According to Stathers *et al*., (2005) reported that timely harvesting to remove the largest storage root most at risk from weevil attack and subsequent hilling up of the soil around the roots prevent weevils from accessing the root through cracks in the soil.

4.4 Yield contributing characters and yield

Yield contributing characters and yield of sweet potato showed statistically significant variation due to different treatment (Table 9).

4.4.1 Vine length at harvest

In consideration of vine length at harvest, the longest vine was recorded from T_2 (205.54 cm) treatment, which was statistically similar with other treatment except T_7, whereas the shortest vine from T_7 (169.56 cm) treatment (Table 9).

4.4.2 Number of storage roots/vine

For number of storage roots/vine, the highest number was recorded from T_2 (7.00) treatment, which was statistically similar with other treatment except T_7 and the minimum number was found from T_7 (5.93) treatment (Table 9).

4.4.3 Weight of individual storage root

In case of weight of individual storage root, the highest weight was recorded from T_2 (148.48 g), which was statistically similar with other treatment except T_7, while the lowest weight was found from T_7 (127.01 g) treatment (Table 9).

4.4.4 Yield of storage roots

In consideration of yield of storage roots, the highest yield was recorded from T_2 (41.86 t/ha), which was statistically similar with other treatment except T_7 and the lowest yield was found from T_7 (30.27 t/ha) treatment (Table 9).

Table 9. Yield and yield contributing characters of sweet potato for different management practices

Treatments	Vine length (cm) at harvest	Number of storage roots/vine	Weight of individual storage root (g)	Yield of storage roots (t/ha)
T_1	191.80 a	6.56 a	141.00 a	38.54 a
T_2	205.54 a	7.00 a	148.48 a	41.86 a
T_3	199.25 a	6.69 a	146.21 a	39.84 a
T_4	202.01 a	6.91 a	147.01 a	40.14 a
T_5	197.80 a	6.58 a	144.96 a	39.66 a
T_6	194.85 a	6.56 a	142.26 a	39.68 a
T_7	169.56 b	5.93 b	127.01 b	30.27 b
$LSD_{(0.05)}$	19.57	0.439	12.52	3.907
CV(%)	5.66	3.73	4.94	5.69

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 selected vine/plot of each treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1: Emamectin benzoate @ 2 ml/L of water

T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing

T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application)

T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application)

T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application)

T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application)

T_7: Untreated control

CHAPTER V

SUMMARY AND CONCLUSION

The present study regarding documentation of insect pests in sweet potato and their management has been conducted during rabi season (November 2016 to March 2017) in the experimental fields of Sher-e-Bangla Agricultural University, Dhaka. The variety of BARI Sweet Potato 8 were used as test crop. Seven treatments with one untreated control were tested in this experiment. They were T_1: Emamectin benzoate @ 2 ml/L of water; T_2: Carbofuran 5G @ 15 kg/ha at 60 days after sowing; T_3: Diazinon 10G @ 12 kg/ha at 60 days after sowing + Azadiractin @ 3 ml/L at 10 days interval (3 times application); T_4: Sevin 85WP @ 3 g/L + Admire @ 1 ml/l at 15 days interval (3 times application); T_5: Voliam flexi 300SC @ 1 ml/L at 15 days interval (3 times application); T_6: Lamda cyhalothin @ 1 ml/L at 10 days interval (3 times application) and T_7: Untreated control. The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. Data were recorded on insect pest incidence, vine and branch infestation, infestation of storage roots in number and weight basis and statistically significant variation was recorded for different treatment.

Under the present study 9 different species of insect pests were found and they were belongs to 9 family under 3 orders. Among the recorded insect pests 5 species belong to the order Hemiptera, 3 species belong to Coleoptera and only 1 species under Orthoptera order and there is different family for each of the insect pests species. Among the insect pests it was observed that sweet potato weevil was more destructive for storage roots of sweet potato. Data revealed that for the consideration of sweet potato bug, the lowest number of sweet potato bug was observed from T_2 (1.27), whereas the highest number from T_7 (5.13). In case of mealybug, the lowest number of mealybug was recorded from T_2 (1.67), whereas the highest from T_7 (6.93) treatment. In consideration of green vegetable bug, the lowest number of green vegetable bug was recorded from T_2 (1.07), while the highest number from T_7 (4.20) treatment. In case of leaf hopper, the lowest number of leaf hopper was recorded from T_2 (2.07) treatment, whereas the highest number from T_7 (6.40) treatment. Data revealed that for minor leaf feeders, the lowest number of minor leaf feeders was recorded from T_2 (1.13), whereas the highest number from T_7 (4.73) treatment. In consideration of sweet potato beetle, the lowest number of sweet potato beetle was recorded from T_2 (1.47), whereas the highest number from T_7 (6.33) treatment. In case of whitefly, the lowest number of whitefly was recorded from T_2 (1.67), whereas the highest number from T_7 (6.73) treatment. From the recorded data in case of tortoiseshell beetle, the lowest number of tortoiseshell beetle was found from T_2 (1.13), whereas the highest number from T_7 (4.33) treatment. Data revealed that for sweet potato weevil, the lowest number of sweet potato weevil was observed from T_2 (1.67), while the highest number from T_7 (6.73) treatment.

In case of leaves of sweet potato at early growth stage, it was observed that the lowest infestation was recorded from T_2 (3.90%), whereas the highest infestation (12.30%) was observed from T_7 treatment. In case of leaf infestation reduction over control the highest value was recorded from T_2 (68.29) and the lowest value from T_1 (31.79) treatment. At mid growth stage, the lowest infestation was recorded from T_2 (2.71%), whereas the highest infestation (10.07%) was observed from T_7 treatment. In case of infestation reduction over control the highest value was recorded from T_2 (73.09) and the lowest value was found from T_1 (44.29) treatment. At late growth stage, the lowest infestation was recorded from T_2 (2.58%), whereas the highest infestation (9.09%) was observed from T_7 treatment. In case of reduction over control the highest value was recorded from T_2 (71.62) and the lowest value was found from T_1 (45.87) treatment.

For branches/vine of sweet potato at early growth stage, the lowest infestation was recorded from T_2 (2.39%), whereas the highest infestation (12.86%) from T_7 treatment. In case of infestation reduction over control, the highest value was recorded from T_2 (81.42) and the lowest value was found from T_1 (36.94) treatment. At mid growth stage, the lowest infestation was recorded from T_2

(2.45%), whereas the highest infestation (11.74%) from T_7 treatment. In case of reduction over control, the highest value was recorded from T_2 (79.13) and the lowest value was found from T_1 (34.58) treatment. At late growth stage, the lowest infestation was recorded from T_2 (2.61%), whereas the highest infestation (11.09%) from T_7 treatment. In case of reduction over control, the highest value was recorded from T_2 (76.47) and the lowest value from T_1 (28.49) treatment.

In case of storage roots of sweet potato/vine in number basis at 15 days early harvest, the lowest infestation was recorded from T_2 (3.69%), whereas the highest infestation (12.25%) was observed from T_7 treatment. In case of reduction over control the highest value was recorded from T_2 (69.88) and the lowest value was found from T_1 (29.22) treatment. At optimum days harvest, it was observed that the lowest infestation was recorded from T_2 (4.49%), whereas the highest infestation (13.56%) from T_7 treatment. In case of reduction over control the highest value was recorded from T_2 (66.89) and the lowest value from T_1 (26.47) treatment. After 15 days from optimum harvest, the lowest infestation was recorded from T_2 (5.31%), whereas the highest infestation (16.37%) from T_7 treatment. In case of reduction over control the highest value was recorded from T_2 (67.56) and the lowest value from T_1 (30.48) treatment.

In case of storage roots of sweet potato/vine in weight basis at 15 days early harvest, it was observed that the lowest infestation was recorded from T_2 (5.68%), whereas the highest infestation (12.98%) was observed from T_7 treatment. In case of reduction over control the highest value was recorded from T_2 (56.24) and the lowest value was found from T_1 (28.43) treatment. At optimum days harvest, the lowest infestation was recorded from T_2 (6.49%), whereas the highest infestation (14.16%) from T_7 treatment. In case of reduction over control the highest value was recorded from T_2 (54.17) and the lowest value was found from T_1 (30.01) treatment. After 15 days from optimum harvest, the lowest infestation was from T_2 (6.93%), whereas the highest infestation (17.05%) from T_7 treatment. In case of reduction over control the highest value was recorded from T_2 (59.35) and the lowest from T_1 (32.96) treatment.

In consideration of vine length at harvest, the longest vine was recorded from T_2 (205.54 cm), whereas the shortest vine from T_7 (169.56 cm) treatment. For number of storage roots/vine, the highest number was recorded from T_2 (7.00), while the minimum number from T_7 (5.93) treatment. In case of weight of individual storage root, the highest weight was recorded from T_2 (148.48 g), whereas the lowest from T_7 (127.01 g) treatment. For yield of storage roots, the highest yield was recorded from T_2 (41.86 t/ha), whereas the lowest from T_7 (30.27 t/ha) treatment.

Conclusion:

From the above discussion it can be concluded that among the different control measures, Carbofuran 5G @ 15 kg/ha at 60 days after sowing was the best for the controlling insect pests of sweet potato and also attaining highest yield of sto-rage roots.

Recommendation:

Due to some limitations a few number of control measures were used for the controlling insect pests of sweet potato. So, more bio-pesticides and chemical pesticides can be included for the further studies to find out the more profitable yield of sweet potato storage roots. However, further study of this experiment is also needed in different agro-ecological zones of Bangladesh for accuracy of the results obtained from the present experiment.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November, 2016 to March 2017

Month	Air temperature (^0C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November, 2016	25.8	16.0	78	00
December, 2016	22.4	13.5	74	00
January, 2017	24.5	12.4	68	00
February, 2017	27.1	16.7	67	30
March, 2017	31.4	19.7	54	11

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1212

Appendix II. Analysis of variance of the data on number of identified insect pests in sweet potato during the growing period for different management practices

Source of variation	Degrees of freedom	Mean square								
		Number of different insect pests								
		Sweet potato bug	Mealybug	Green vegetable bug	Leaf hopper	Minor leaf feeders	Sweet potato beetle	Whitefly	Tortoisesh ell beetle	Sweet potato weevil
Replication	2	0.017	0.013	0.013	0.048	0.013	0.025	0.025	0.017	0.023
Treatment	6	4.769**	8.693**	3.488**	6.377**	4.252**	7.642**	8.229**	3.310**	8.402**
Error	12	0.033	0.040	0.038	0.070	0.024	0.038	0.038	0.037	0.043

**: Significant at 0.01 level of significance

Appendix III. Analysis of variance of the data on incidence of insect pests on leaf and branches of sweet potato at early growth stage for different management practices

Source of variation	Degrees of freedom	Mean square					
		Leaf of sweet potato			Branches of sweet potato		
		Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Replication	2	0.310	0.008	0.007	0.002	0.002	0.890
Treatment	6	25.709*	4.060**	25.286**	0.500**	0.071**	35.585**
Error	12	6.930	0.105	0.889	0.073	0.006	2.337

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on incidence of insect pests on leaf and branches of sweet potato at mid growth stage for different management practices

Source of variation	Degrees of freedom	Mean square					
		Leaf of sweet potato			Branches of sweet potato		
		Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Replication	2	2.749	0.0001	0.041	0.173	0.013	0.927
Treatment	6	66.048*	11.709**	18.487**	3.018**	0.371**	28.629**
Error	12	20.342	0.033	0.086	0.724	0.016	0.671

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on incidence of insect pests on leaf and branches of sweet potato at late growth stage for different management practices

Source of variation	Degrees of freedom	Mean square					
		Leaf of sweet potato			Branches of sweet potato		
		Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Replication	2	41.202	0.023	0.021	0.196	0.013	0.221
Treatment	6	141.253**	24.397**	14.464**	8.469**	1.002**	26.492**
Error	12	45.697	0.092	0.053	1.816	0.020	0.504

**: Significant at 0.01 level of significance

Appendix VI. Analysis of variance of the data on incidence of sweet potato weevil on storage roots of sweet potato at 15 days early harvest in number and weight basis for different management practices

Source of variation	Degrees of freedom	Mean square					
		Storage roots of sweet potato in number basis			Storage roots of sweet potato in weight basis		
		Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Replication	2	0.023	0.006	1.339	36.800	0.741	0.014
Treatment	6	0.382**	0.097**	24.138**	3763.029**	761.459**	17.596**
Error	12	0.105	0.008	1.480	1204.061	11.139	0.177

**: Significant at 0.01 level of significance

Appendix VII. Analysis of variance of the data on incidence of sweet potato weevil on storage roots of sweet potato at optimum days harvest in number and weight basis for different management practices

Source of variation	Degrees of freedom	Mean square					
		Storage roots of sweet potato in number basis			Storage roots of sweet potato in weight basis		
		Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Replication	2	0.040	0.008	0.916	22.698	9.829	0.112
Treatment	6	0.324*	0.126**	27.418**	3969.564*	918.037**	19.683**
Error	12	0.098	0.012	1.837	1202.432	19.877	0.272

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on incidence of sweet potato weevil on storage roots of sweet potato after 15 days from optimum harvest in number and weight basis for different management practices

Source of variation	Degrees of freedom	Mean square					
		Storage roots of sweet potato in number basis			Storage roots of sweet potato in weight basis		
		Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Replication	2	0.013	0.0001	0.009	64.860	1.613	0.012
Treatment	6	0.393*	0.212**	40.660**	3833.876*	1992.259**	35.242**
Error	12	0.091	0.011	1.131	1209.132	22.418	0.270

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on yield and yield contributing characters of sweet potato for different management practices

Source of variation	Degrees of freedom	Mean square			
		Storage roots of sweet potato in number basis			
		Vine length (cm) at Harvest	Number of storage roots/vine	Weight of individual storage roots (g)	Yield of storage roots (t/ha)
Replication	2	14.704	0.008	1.432	0.008
Treatment	6	420.515*	0.357**	159.059*	0.145**
Error	12	120.994	0.061	49.524	0.029

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance