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Original Research Article

Review the Mechanisms of action of Weevil on sweet potato and infestation of sweet potato feathery mottle virus and its management followed by cultural practice, biological control, chemical control and integrated pest management practice

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Abstract
Sweet potato (Ipomoea batatas (L.) is an important food crop affected by several pests throughout the world, especially in tropical, subtropical, and temperate regions. Sweet potato weevil is the most disastrous pest affecting sweet potato plantations, causing millions of dollars losses annually. Insect pests of sweet potato are best controlled by integrated pest management (IPM) approaches. The sweet potato weevil, Cylas formicarius, is the most important worldwide pest, however in some Caribbean nations, the West Indian sweet potato weevil, Euscepes post fasciatus, is the predominant species An effective integrated pest management (IPM) method will help to prevent economic losses, and it is crucial to understand the factors that contribute to weevil infestation, Sweet potato Feathery Mottle Virus (SPFMV) Aphid-transmitted posy virus, and strategies that are available to overcome them. This review summarizes the mechanisms of action of weevil on sweet potato and infestation of sweet potato Feathery Mottle Virus and its management followed by: (1) Cultural practice, (2) Biological control, (3) Chemical contoroll and discussion on current IPM practices used in the different, including intercropping, entomo pathogenic fungi and bacteria, sex pheromones, and pesticides. Weevils (Curculionidae) and Sweet potato Feathery Mottle Virus (SPFMV) were reportedly the most damaging pests and disease where present in crops. Symptoms of scab (caused by the fungus Elisnoe batatus) were the most common folia symptoms and this was the disease of most concern to farmers. Most producers reported root damage from the former and foliar damage from the latter but the general level of knowledge of pest and disease types was low. In this Term paper, we describe the current status and integrated pest management options for sweet potato pests and diseases.

Keywords: Disease, sweet potato, management.

1.INTRODUCTION

Sweet potato, (Ipomoea batatas L.) is currently ranked as the seventh most important crop in the world with a total production of 103 million tons in 2013 (FAOSTAT 2015). It is produced largely in Asia (accounting for up to 76.1% of world production in 2013), followed by the African continent (19.5%), (FAOSTAT 2015).

The top five sweet potato-producing nations in 2014 were China, Nigeria, Uganda, Indonesia, and the United Republic of Tanzania (FAOSTAT 2015). After the potato (Solanum tuberosum L.) and cassava (Mani hot esculenta Crantz), sweet potato is the third most important root crop in the world (FAO, 2008).

Sweet potato is an important crop in tropical, subtropical, and temperate areas, and it is an efficient producer of starch. The local crop production system influences exposure of sweet potatoes to disease and insect pests. Sweet potato is an indeterminate plant that is usually grown as an annual crop. Sweet potato widespread production in many tropical and sub-tropical, developing regions such as Africa, southern Asia and the Pacific where it is important for local consumption in subsistence communities (Wolfe 1992, Bourke 2009, Loebenstein and Thottapilly 2009, Zhang et al. 2009).

In these areas, sweet potato is critical for food security as it is often a major source of calories as well as vitamins such as carotenoids which are vital in preventing malnutrition in children (Lebot 2010, Woolfe 1992, Kismul, Van den Broeck, and Lunde, 2014).

The storage roots of sweet potato have high sugar and water content making them highly susceptible to biotic threats, especially during storage and if roots have been damaged by harvesting or pest attack (Woolfe 1992).

In developed country production systems, losses are prevented by the availability of infrastructure such as cool storage facilities and rapid transportation systems. In subsistence production systems, however, post-harvest losses are avoided only by progressive harvest on-demand for immediate use (Okonya et al., 2014); with the general lack of infrastructure otherwise leading to high levels of damage (Johnson and Gurr, 2016).

This slows the development of commercial production and the livelihood benefits that value chains and processing potentially offer to impoverished rural communities. Sweet potato is attacked by around 300 species of arthropods (Talekar 1991) that can cause severe to complete crop loss, as well as at least 30 diseases (Clark et al. 2013).

According to Johnson and Gurr (2016) provide a recent, comprehensive review of those most common in smallholder production. The fact that sweet potato is vegetative propagated, either by storage root fragments (slips) or by stem cuttings means that there is high scope for transfer of pest and pathogen inoculums from old to new crops. For example, eggs and larvae of the sweet potato weevil Cylas formicarius (Fabric us), an especially important pest, can be found in these props gules (Hartemink et al. 2000).

Still more difficult for subsistence farmers to manage is the fact that plant pathogen in oculm, especially o viruses, is readily multiplied and distributed in slips and cuttings (Clark et al. 2012). Pests and diseases of sweet potato are generally well controlled in developed countries by the use of pathogen-tested (clean) planting material, pheromone trapping and pesticides (Clark et al. 2013,).

Overall, sweet potato production in developing countries is critical for food security but threatened in a general sense - by pests and diseases; and effective management is difficult because well studied technologies that are used in developed counties are not appropriate. Further, traditional practices that have allowed production for many generations are becoming less viable because of land shortages whilst research on management approaches that can be implemented has lagged because these regions are often lack funding and capacity for agricultural research. Despite the crop's economic importance, widespread sweet potato weevil infestation results in losses of millions of dollars annually (Jackson et al., 2006).

1.1. Objective

To Review of major important insect pests, plant pathogen of sweet potato and it's managed mental practice

2. EFFECT OF MAJOR PEST ON SWEET POTATO PRODUCTION

2.1. Effect Weevils *Cylas* spp. (*Coleoptera: Curculionidae*) Sweet potato

2.1.1. Description of weevil's 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 elongated smooth and shine with ant like snouted beak but species can be differentiated 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. Biology of sweet potato weevils

The biology of sweet potato weevil was studied in Awassa and Nazareth Research Centers. The weevil required 30 and 31.5 days to complete its life cycle in Awassa and Nazareth, respectively. It was also reported that the weevil could complete nine generations at Awassa and eight at Nazareth (Emana and Amanuel, 1992).

The sweet potato weevil is the most destructive insect throughout tropical and subtropical sweet potato production areas. Sweet potato weevils can attack sweet potatoes in the field and in storage. All three species have a similar life history.

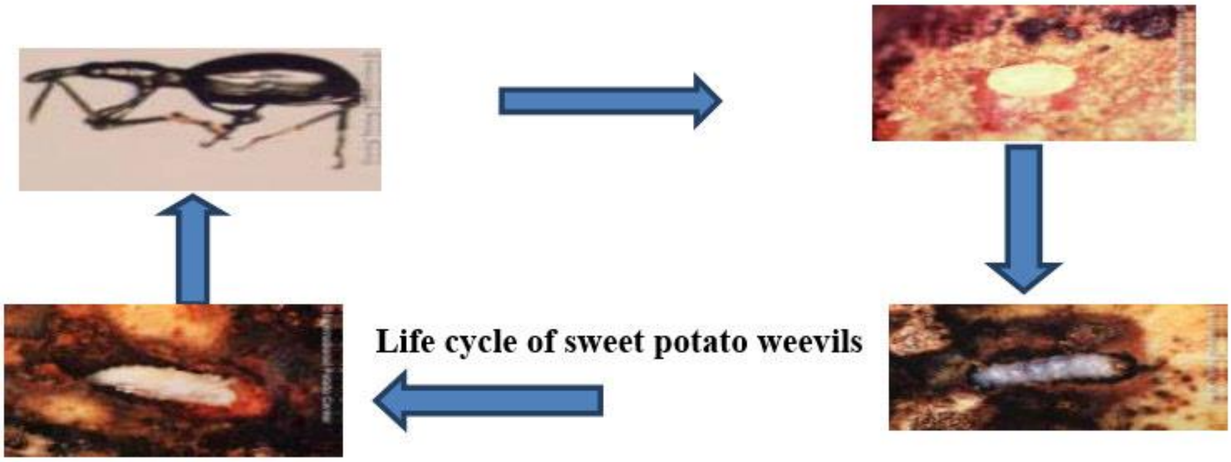

Fig_1: Life cycle of sweet potato weevils

Source: T. Ames, N.E.J.M. Smit, O'Sullivan, and L.G. Skoglund. 1996.

Eggs is the oval, and yellowish-white (Schimutterer, 1969). 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 (Otto *et al.*, 2006).

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 (Allard, 1990). The thorax is divided into prothorax and meso thorax whereby meso thoracic 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 has three instars, first larval in star, second larval in star, and third larval in star. Total larvae period varies from 10-25 days (Otto *et al.*, 2006).

Pupa of sweet potato weevil is white and approximately six millimeters 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 (Otto *et al.*, 2006).

Adult of sweet potato weevil is a snout beetle that resembles an ant the pest is black, with a faint, metallic blue luster, and not with a distinctly shiny, copper-like sheen, body length is eight millimeters. 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 favorable conditions, sweet potato weevils can produce 13 generations a year and can live for three to four months (Okonyo, 2013).

2.1.3. Distribution of sweet potato weevils

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 (Parker *et al.*, 1990).

Among the three, *C. formicarius* is an important pest in India, South East Asia, Oceania, the United States and the Caribbean. Several studies have shown that only *C. puncticollis* and *C. brunneus* have been confirmed to commonly occur in Kenya (Nderitu *et al.*, 2009).

2.1.4. Host plant resistance

Plant resistance provides a pivotal role in the management of insect pests (Painter, 1951; Rajasekhara Rao, 2002). 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 more than elongate and spindle-shaped ones.

According to 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.

2.1.5. Damage of sweet potato by weevils

Sweet potato weevil is by far the most destructive pest of the sweet potato plant. The degree of infestation varies from region to region but weevils nevertheless cause severe damage to plantations. A research conducted by the Taiwan Agricultural Chemical and Toxic Substances Research Institute Council of Agriculture revealed that the damage caused by sweet potato weevil reduced sweet potato production in Taiwan by 1–5%, while the damage in extensive commercial produced fields was up to 18% (Shanghai, 2014).

Damage symptoms are similar for all three species. Adult sweet potato 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 position sites by their greater depth and the absence of a fecal plug, (Bo *et al.* 2010).

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. In China's Guangdong Province, yield generally shrunk by 5–20% and, in some cases, by up to 80%, (Vietnam, 1995).

Farm level plantations losses were documented to suffer up to 40% of reduction in yield. Losses of 3–80% were recorded in Indonesia, throughout several locations and seasons and with higher damage observed during the dry season (A. R. Braun and E. van de Fliert, 1999).

Sweet potato weevils generally cause serious damage to all parts of sweet potato plant throughout their life cycle, from egg to adult. When laying eggs, female weevils excavate cavities and create egg-laying punctures in the roots. The eggs are laid below the surface of the roots and covered with dark colour excrement from the female adults (Smith *et al.* 2013).

As a result of the un slightly punctures, the appeal of the roots and market price of sweet potato become greatly reduced, resulting in major economic losses. Even if adults prefer a given cultivar for food and oviposition, the pest cannot increase rapidly unless the quality of the storage root also provides for larval development. Sweet potato resistance to weevils has been reported in the laboratory and field (Blank *et al.* 2001).

Fig_2: Major Sweet potato disease and pests.

2.2. Rough Sweet potato Weevil *Blosyrus* sp. (*Coleopteran: Curculionidae*)

2.2.1. Description and Biology of weevils *Blosyrus sp.*

Adult weevils are blackish or brownish and the surface of the elytra is ridged and this makes them look like a lump of soil. Larvae are whitish and C-shaped. Adult weevils lay eggs underneath fallen leaves. The larvae develop in the soil and pupate there. Adult weevils are found on the ground underneath foliage during the day.

2.2.2. Damage of sweet potato by weevils *Blosyrus sp*

Adult weevils feed on foliage, but the larvae cause greater damage. While feeding under the soil surface, they gouge shallow channels on the enlarging storage roots (Fig. 2). These "grooves" reduce marketability. When extensively damaged, the skin of the storage root has to be thickly peeled before eating, because the flesh discolors just under the grooves.

Fig_3: Major sweet potato and weevils Blosyrus sp

2.3. Peloropus Weevil Peloropus batatae (*Coleopteran: Curculionidae*)

This reddish brown, compact, 3-4 mm weevil has been found inside stems and storage roots at some locations in East and Central Africa. The last in star of the white larva is longer than one would expect considering the small size of the adult.

The larva makes long tunnels in the stem and can go down to the storage root via the storage root "neck." Pupae and adults are found at the end of the tunnels. The life cycle is long compared with that of other sweet potato weevils-2 months or more. Because the larva enters via the storage root neck, storage roots that seem undamaged on the outside could be inedible because of several tunnels on the inside.

2.4. Sweet potato Feathery Mottle Virus (SPFMV) Aphid-transmitted potyvirus

2.4.1. Description of Sweet potato Feathery Mottle Virus

Descriptions of sweet potato feathery mottle virus on the foliage of sweet potato are generally slight or absent. If present, they appear as faint, irregular chlorotic spots occasionally bordered by purplish pigment. Chlorosis (feathering) along midribs and faint-to-distinct chlorotic spots with or without purple margins occur in some cultivars. Symptom visibility on foliage is influenced by cultivar susceptibility, degree of stress, growth stage, and strain virulence.

Increased stress can lead to symptom expression, whereas rapid growth may result in symptom remission. Symptoms on storage roots depend on the strain of SPFMV and the sweet potato variety. The common strain causes no symptom on any variety, but the "russet crack" strain causes external necrotic lesions or internal corking on certain varieties. SPFMV can be latent in vines different types of viral, fungal and bacterial diseases have been recorded in Ethiopia. The first virus disease (SPFMV) has been reported in Ethiopia by Scientific Phyto pathological Laboratory in 1986 (SPL, 1986) Of all diseases, viral diseases are considered as major constraint for production and productivity of the crop in the country.

On the other hand, most of the fungal and bacterial diseases recorded in the country are considered as minor disease except sweet potato stem blight caused by Alternariaspp (Tesfaye, 2013).

2 .4.2. Host range sweet potato feathery mottle virus

Sweet potato feathery mottle virus (SPFMV) is found nearly everywhere sweet potatoes are grown. According to Karyeija, et al (1998) SPFMV is the most important poty viruses infecting sweet potatoes in Africa and elsewhere in the world. It was first isolated from sweet potato and purified by Moyer & Kennedy, (1978).

A complex of viruses; the internal cork virus, the leaf spot virus, and the white fly transmitted yellow dwarf virus apparently because the feathery mottle complex. The white flies concerned are Bemisia and Trialeurodes. These three viruses, when present together, causes severe symptoms which none-of them individually can cause.

Feathery mottle disease is characterized by dwarfing of the plants, yellowing of the veins in the younger leaves, and yellowish spotting in older leaves. Internodes are short and tubers are small. Strains of this virus have been shown to be the causal agents to several of the virus diseases of sweet potato (Campbell, et al., 1974; Cadena-Hinojosa & Campbell, 1981; Cali & Moyer, 1981).

2.4.3. Biology of Sweet potato feathery mottle virus caused by aphids

Sweet potato feathery mottle virus (SPFMV) is transmitted by a wide range of aphid species in the non-persistent manner through brief feeds of only 20–30 seconds. Both colonizing species of aphids and winged aphids of no colonizing species may transmit the disease. It is also perpetuated between cropping cycles in infected cuttings, but the lack of symptoms in the foliage makes it difficult for farmers to select SPFMV-free cuttings. In Uganda, symptom-free cuttings were mostly virus-free. SPFMV is found with SPSVV (see next section) in some countries; the combination results in a severe disease known as sweet potato virus disease (SPVD).

Other viruses of sweet potato include leaf spot, sweet potato vein mosaic virus, sweet potato mild mottle virus, sweet potato latent virus and sweet potato yellow dwarf virus. Three viruses namely SPFMV, SPCSV and SPVG were detected in sweet potato plants Collected from farmers' fields in the main growing areas of Ethiopia. SPFMV is the most widespread followed by SPCSV (Tewodros *et al.*, 2011).

These two viruses are the most common and damaging as reported in other East African countries like Uganda, Kenya and Tanzania (Mukasa *et al*., 2003; Ateka *et al.*, 2004).

2.4.4. Damage and losses of sweet potato by virus disease

Sweet potato virus disease (SPVD) is currently threatening sweet potato production in Ethiopia than ever, with more viruses unidentified earlier being detected in more recent years (Shiferaw M. *et al.*, 2016). The importance of diseases becomes paramount because the crop is highly sensitive to virus infection (Teddy *et al*., 2011).

Sweet potato virus disease is becoming the important and serious problem of sweet potato production causes considerable yield losses in Ethiopia. Previous studies have indicated that the yield loss due to virus infection vary from 50- 100% in different countries.

According to Tesfa from 24.58 to 63.60 and 9.76 to 59.62 percent per plant, respectively, Due ye *et al.* (2013) reported the average reduction in number of roots and weight (kg) of roots was ranged to the virus disease infection in major sweet potato growing areas, SNNPR, Ethiopia.

Three viruses namely SPFMV, SPCSV and SPVG were detected in sweet potato plants Collected from farmers' fields in the main growing areas of Ethiopia. SPFMV is the most widespread followed by SPCSV (Tewodros *et al.*, 2011).

Fig_4: The degree of vigor between SPVD, SPVG, SPCSV and SPFMV infected sweet potato plants as compared to the healthy plants, pictures taken in the screen house. Adapted From: (Tewodros et al., 2011)

2.5. Manage mental practice of infestation of Sweet Potato insect pest disease and pathogen

2.5.1. Cultural practice

When sweet potato weevil populations are high, no single control method provides adequate protection the integration of different techniques, with emphasis on the prevention of infestation, provides sustainable protection. Cultural practices aimed at preventing infestation proved to be effective way of reducing weevil damage. Stathers *et al.* (2005) reported different successful cultural practices used in experiments conducted in East Africa, Taiwan, Philippines, Vietnam, America, India, Cuba and Indonesia. The main controls are avoidance of use of diseased plants for cutting material, sanitation, and use of resistant varieties. Currently, several sweet potato viruses have been identified and confirmed to cause diseases either in single or dual infection. The diseases are causing severe sweet potato yield losses worldwide. Although control of viral diseases (Tesfaye *et al.*, 2013).

❖ Field sanitation

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 piece meal harvesting of the crop is practiced, care should be taken to remove and destroy any infested roots that are found (Stathers *et al.*, 2005). Removal of volunteer sweet potato plant and wild morning glories as these may be alternative hosts (Sato *et al.*, 1981).

Removal of alternate host plants like *Calystegia soldanella*, C. *hederacea* and *Ipomoea indica* reduced the sweet potato weevil infestation in Japan (Komi, 2000).

Crop rotation with other crops for two to three seasons appears to be the most effective method of preventing infestations of weevils (Geisthardt and van Harten, 1992). In a large ecosystem area or community burying can help to reduce weevil infestation. Infested roots must be buried >15 cm underground (Stathers *et al.*, 2005).

❖ Mulching

Application of dry leaves on the soil to keep it moist, prevent cracks and provide a more favorable place for natural enemies. Care should be taken to make sure the weevils cannot feeds or develop on the mulching material (Geisthardt and van Harten, 1992). Mulching with rice straw or black plastic reduced the infestation by SPW in the root zone (AVRDC, 1987). 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.

❖ Early harvesting

Harvesting two weeks earlier reduce the loss due to weevil from greater than 30 percent to less than five percent (Ebregt *et al.*, 2005). 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 (Powell *et al.*, 2001). 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 (Stathers *et al.*, 2005).

❖ Flooding

Sweet potato weevils can be controlled by flooding of fields before planting (Stathers *et al*., 2003). Flooding of the field for more than 48 hours kill the weevil larvae present in roots that have been left in the field (Otto *et al.,* 2006).

Also, 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. Flooding of fields between two consecutive sweet potato crops may reduce the immediate source of weevil from the field (Otto *et al.*, 2006).

❖ Intercropping

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

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 are described by Rajasekhara Rao (2005) and Rajasekhara Rao *et al.*, (2006).

2.5.2. Biological control

○ Parasitoids

According to 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 post fasciatus, 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 hymenop terous 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.

○ Predators

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 (Lagnaoui *et al.*, 2000).

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 (Allard *et al.*, 1991).

○ Entomo pathogenic nematodes

Entomopathogenic nematodes (EPN) have beneficial interaction with sweet potato 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).

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 (Jansson *et al.,* 1991).

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 (Jannson *et al.,* 1991).

Weevil damage to plants treated with insecticides is intermediate to that on nematode-treated and untreated plants weevils (Jansson and Lecrone, 1997). Jannson *et al.* (1991) indicated that bacteriophora, is more infective than *Steinernematids* c*arpocapsae* ('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.

- ### Entomo pathogenic fungi

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 1.6x104 conidia ml-1 at planting and rootstock formation, and broadcasting soybeans containing *B. bassian*a into the rows at planting controlled *C. formicarius* effectively (Su, 1991a).

Application of *B. bassiana* isolated from honey bees at a concentration of 1x106 conidia ml-1 at planting and rootstock formation also gave the best results. 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 (Yasuda *et al.,* 2004). 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 entomo pathogenic 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).

Incubation of cadina-4, 10 (15)-dien-3-ones with *B. bassiana* results in the production of nine -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 novel sesqui terpenes which are effective against *C. formicarius elegant tulus* (Buchanan *et al.,* 2000).

2.5.3 Chemical Control

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, or of the other stages found within the plant tissue (Allard *et al.,* 1991).

According to Misra *et al.* (2011) reported that combination of vine dipping of 0.05% monocrotophos 40EC and 3 foliar sprays with 0.05% endo sulfan 35EC proved very effective than that of basal application of phorate 10G followed by vine dipping of 0.05% monocrotophos. The maximum marketable tuber yield (195.33 q ha-1) was also obtained when vines were dipped in 0.05% monocrotophos along with 3 foliar sprays of 0.05% endo sulfan at three equal intervals. The spraying of endosulfan at 0.05% was found effective and gave the highest return (Rs 10.00 per rupee invested). The crop which received the foliar sprays of one month after planting had better protection and produced quality tubers, thereby resulting in the maximum profit over cost incurred compared to insecticidal treatments.

According to Palaniswami *et al*. (2012) reported that endosulfan, fenthion and fenitrothion each at 0.05% applied as soil drench at 50 and 80 DAP were effective against C. formicarius and their residues in tubers at harvest were lower than the detectable levels. Chlorpyrifos and fensul fothion granules are more toxic to SPW adults than the other insecticides, while their persistence was about 8-10 months (Hwang and Hung, 1991).

Aphid control is not economically feasible. According to Shiferaw M. *et al*. (2016), in research plots difference has been observed for virus disease severity and storage root yield among sweet potato genotypes indicating the possibility of selection for resistant /tolerant/ clones against sweet potato virus disease. Moreover, within virus susceptible genotypes, 47.8% –92.6% yield reduction was witnessed in the third year of the experimental period.

In Ethiopia different management practices including, the use of resistance/ tolerant varieties integrating with selection of healthy vines, timely removal of SPVD (Sweet potato virus disease) infected plants (to prevent further spread of virus by vectors) and establishment of isolated sites/nurseries (for virus free planting materials production) and control of vectors have been used in major growing areas of Ethiopia (Tesfaye *et al.*, 2013). Prevention sweet potato of the virus from getting established in the areas where currently not affected and/ or little affected is among the option of its management (Tesfaye *et al.*, 2013; Tewodros T. *et al.*, 2011).

In order to manage these threatening diseases, it is also recommended to strengthen local quarantine system, training of farmers, experts and multipliers (Tewodros T. *et al.*, 2011).
Similarly, cultural practices like, cropping system /crop rotation, removal and burning of the infected plant and virus free Seed sources (Abraham A., 2010); it is also have been suggested to clean and distribute virus free planting materials to reduce the present status of the disease and its effect on the resource poor farmers and multipliers (Shiferaw M. *et al.*, 2014; Tesfaye *et al.*, 2013).Application of the combination of all the compatible practices is necessary for sustainable diseases management.

2.5.4 Host Plant resistance

Plant resistance provides a pivotal role in the management of insect pests (Rajasekhara Rao, 2002, 2005). 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.

According to 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. Search for plant resistance in sweet potato to environmental stress is underway in many parts of the world to fulfill the requirements of farmers situated in arid and semi arid tropics (Stathers *et al.*, 2003). Only a limited success has been achieved, because of the inconsistent expression of the resistance (Rajasekhara Rao, 2002).

2.5.5. Varietal Resistance for Sweet Potato

Varieties with immunity or a high level of resistance are not available. Some varieties have low to moderate levels of resistance. Others escape weevil damage because their storage roots are produced deep in the soil or because they mature quickly and can be harvested early. Several researches have verified the presence of variability in sweet potato genotypes for resistance to sweet potato weevil. However, some of the materials reported to be resistant succumb under high weevil population pressure. Emana (1990) evaluated sweet potato varieties for resistance to the weevil from 1987- 1989 and found that 38 % of the varieties to be resistant and remaining were moderately resistant at Areka.

At Awassa however, 55 % of the varieties were reported to be moderately resistant and the rest were susceptible. The study also showed that Koka-26 and Cemsa had deeper roots than the other varieties considered (Temesgen and Tesfaye, 1995b).

2.5.6. Integrated pest Management of Sweet Potato insect

The integration of insecticides, early planting and earthing up three times starting from one month after planting highly reduced the percentage of infestation by the sweet potato weevil and increased root yield of sweet potato (Mesilla *et al.*, 2005).

As indicated in percent infestation by sweet potato weevil significantly affected by planting date and earthing up the lowest percent infestation was recorded from early planting time (July 12), the highest was recorded from late planting time (August 12). By hilling up the soil three times around the root of sweet potato crop the infestation percent was reduced from 21.4 to 17.3 %. The interaction of planting date by earthing up and chemical affected the percent infestation by target pest. Generally, lower percent infestation was recorded from the interaction of early planting by chemical treatment and earthing up as compared to other treatments.

3. CONCULISION

This paper summarizes our current understanding of geographic distribution, symptomatology, pathogen biology, and management of the major sweet potato pests. Pests caused by fungi, bacteria, virus, and some insects can occur at any point in the production cycle, and their prevalence is greatly influenced by the crop system and geographic location. Further research should investigate pests that occur under tropical production systems.

From the insect pests sweet potato weevils are the highest one in both larval and adult life stages for the yield loss and damage in storage and production levels of the crop. Sweet potato weevil, *Cylas*sp is more important since the insect cause's damage both in the field and in storage and as such even in low infestations render the tubers unfit for human or livestock consumption.

Weevils are especially difficult to control, even with insecticides, because they feed inside the roots. Use of weevil-resistant sweet potato cultivars appears to be a practical economical method of control. The apparent inconsistency in resistance among cultivars from season to season or location to location complicates the development of weevil-resistant sweet potato varieties and summarizes the mechanisms of action of weevil on sweet potato and infestation of Sweet potato Feathery Mottle Virus and its management followed by : Cultural practice , Biological control, Chemical controls and discussion on current IPM practices used in the different, including intercropping, entomopathogenic fungi and bacteria, sex pheromones, and pesticides. Weevils (Curculionidae) and Sweet potato Feathery Mottle Virus (SPFMV) were reportedly the most damaging pests and disease where present in crops. Symptoms of scab (caused by the fungus Elisnoe batatus) were the most common folia symptoms and this was the disease of most concern to farmers. The combination of other IPM practices described earlier would prevent the weevil infestation to ensure healthy tubers in nutrition and to sustain programmes involved in anti-hunger and animal feed industries.

❖ Recommendations

-Design and assessment of intercropping options and crop rotations that could extend the supply period. Development of alternatives for conserving planting materials and for having planting material on a timely manner, particularly in drought prone areas.

- Screening new insecticides to control vectors of viruses. Additionally, awareness creation of development workers and farmers on the importance of SPVD through continuous training is very essential. Information on productivity and on suitable soil fertility management practices for sustained crop production for the major soils of Ethiopia is still very limited. There are limited suitable options for improving soil fertility management (which is essential to increase crop and farm productivity) in a crop like sweet potato that is considered a low-input and subsistence crop and where there are few incentives to use labor and resource-intensive technologies.

-Sweet potato comprehensive integrated soil fertility management (ISFM) studies for early, medium and late maturing varieties preferred in seed multiplication and root production schemes for dominant soils found in major agro-ecologies is recommended as future research strategy.

-Drought management is an important factor for increasing sweet potato productivity, given that sweet potato yields can be severely affected by limited water availability. So sweet potato irrigation studies aimed at economizing water use while optimizing vine and root production shall be sought in future.

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