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Review of Entomological Research on Root and Tuber Crops in Ethiopia

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Introduction

Root and tuber crops are very important in Ethiopia supporting large number of the population. The most important root and tuber crops include enset (*Ensete ventricosum*), potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), taro (*Colocassia esculenta*), yam (*Dioscorea* spp.), Ethiopian dinich (*Coleus* spp.), anchote (*Coccinia abyssinica*), cassava (*Manihot esculenta*). Insect pests are considered as an important factor contributing to the low amount of yield and deterioration of products in the store. Within the last 20 years, the focus of entomological research has been mainly on potato, sweet potato and slightly on enset. Relatively more research results were obtained on sweet potato butterfly, sweet potato weevil, root mealybug and potato tuber moth.

Potato is one of the very important food and cash crops in Ethiopia, especially in the high and mid-altitude areas. Potato was introduced to Ethiopia first by Schimper, a German botanist, in 1858 (Horton, 1987 and Pankhurst, 1964 cited by Gebremedhin *et al*., 2006). The national average yield did not change much, about 9 t/ha, which is much lower than the world average, 15 tons/ha (FAO, 2001). Since mid 1970s, the land under potato production has been increasing and reached more than 160,000 ha (Gebremedhin *et al*., 2006). The production is both under rain-fed and small-scale irrigation. The most important factors responsible for the low productivity of potato are the low yielder potato cultivars currently under use and susceptibility to the major disease and insect pests. During the last two decades, the status of potato insect pests did not change from what was reported by Bayeh and Tadesse in 1992.

Sweet potato is one of the most important root crops supporting a considerable portion of the population as a source of food and feed in Ethiopia. It has been cultivated as food crop for several years and over 95% of the crop produced in the country is grown in the South, South-western and Eastern parts, where it has remained for centuries as an important co-staple for the community (Terefe, 1987). In the Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia sweet potato is the second most important root crop next to enset in area coverage and production (Assefa *et al.*, 2004 unpublished). In 1993/94, it occupied 49,000 ha with a total production of 343,573 tons. In 1999, the total area of sweet potato in SNNPR reached 52,021.71 ha with a total production of 379,758.48 tons (CSA, 1994; 1999). The national average yield of sweet potato was 7 t/ha in 1999 and increased to 7.3 t/ha in 2006/2007. The yield of sweet potato could increase dramatically to 30-50 t/ha by using improved varieties and the available technologies (Assefa *et al*., 2004 unpublished). There are a number of biophysical and socio-economical constraints that have been hindering the increase in the productivity of sweet potato under farmers' circumstances. Lack of high yielding varieties and pest damage has been cited as the most important limiting factors.

Enset-based farming systems play an important role in food security of Ethiopia. The human carrying capacity of enset and enset based farming system is high and is likely to be greater than any other crop and cropping systems for the same agro ecology and inputs (Almaz, 2001). According to CSA (1997), the total area covered with enset is 224,400 ha. About 15 million (20%) of the Ethiopian population depends on enset as staple and co-staple food source. Enset grows in a wide range of altitudes. It grows below 500 masl (Omo Ratae) under irrigation and at 3200 masl as rain-fed crop. It grows luxuriously in elevations between 2000 and 2750 masl under rain fed conditions (Huffnagil, 1961 and Westphal, 1975). There is no national data on the current level of enset production.

Research findings

Potato

Insect pests recorded

For the last two decades, the major insect pests of potato did not differ and include: cutworms (*Agrotis* spp. and *Exigua* spp.), red ants (*Dorylus* sp.), potato epilachna (*Epilachna hirta),* metallic leaf beetle (*Lagria vilosa*), potato aphid (*Macrosiphum euphorbiae*), green peach aphid (*Myzus persicae)* and the potato tuber moth (*Phthorimaea operculella*) (Bayeh and Tadesse, 1992). Among these insects, the potato tuber moth (PTM) received more attention than all the other potato insect pests combined. Lately, the red ants and aphids have received some attention. Hence, the review focuses on PTM, red ants and aphids.

Table 1. Insect pests recorded on Irish potato in Ethiopia.

Scientific name	Common name	Status	References
Heteroptera			
Pentatomidae			
Eurydem ornate (L.)	Cabbage bug	Unknown	31, 65
Homoptera			
Aleyrodidae			
Bemisia tabaci (Gennadius)	Tobacco whitefly	Minor	31, 65
Aphididae			
Aphis gossypii Glover	Cotton aphid	Minor	31, 65
Aulacorthum solani (Kaltenbach)	Potato aphid	Minor	
Macrosiphum euphorobiae (Thomas)	Pepper aphid	Minor	31, 65
Myzus persicae (Sulzer)	Peach aphid	Minor	31, 65
Thysanoptera			
Thripidae			
Aelothrips sp.? *linaricus* Priesner	Silver banded thrips	Unknown	65
Lepidoptera			
Gelechiidae			
Phthorimaea operculella (Zeller)	Potato tuber moth	Major	9,23,24,25,31, 44,46,56, 65
Pyralidae			
Lecucinodes orbonalis Guenee	Egg plant fruit borer	Unknown	65
Noctuidae			
Agrotis segetum (Schiff.)	Southern cut worm	Minor	31, 65
Diachrysia orichalcea (Fabricius)	Golden plusia	Minor	65
Sphingidae			
Acheronita atropos (Linnaeus)	Death's hawk moth	Minor	31, 65
Hymenoptera			
Tenthredinidae			
Athalia spp.	Sawfly	Unknown	65
Formicidae			
Dorylus sp. nr *brevinodosus* Mayr	Gojam red ant	Minor	9, 31, 44, 65
Coleoptera			
Apionidae			
Apion spp.	Black pod weevil	Unknown	65
Coccinellidae			
Chnootriba simlis (Thnb.)	Tef epilachna	Unknown	31, 65
Epilachna fulvosignata	Egg plant epilachna	Minor	31, 65
Epilachna hirta (Thunberg)	Potato epilachna	Minor	31, 65
Henosepilachna elaterii (Rossi)	Spotted melon beetle	Unknown	31, 65
Tenebrionidae			
Gonocephalum simplex (Fabricius)	Dusty brown beetle	Minor	31, 65
Lagriidae			
Lagria villosa Fabricius	Metallic beetle	Minor	31, 65
Meloidae			
Mylabris flavoguttata Reiche	Pollen beetle	Unknown	31, 65

Potato tuber moth (*Phthorimaea operculella*)

Basic studies

The potato tuber moth originated in the eastern Andes (S. America) where its main solanaceous hosts, potato and tobacco, are thought to have originated (Finney *et al.*, 1947; Rothschild, 1986). It is distributed throughout the world following the spread of potato and is presently regarded as a major pest of potato in almost all tropical and subtropical regions (Finney *et al.*, 1947). In Ethiopia, it has established itself as an important pest in major potato growing areas. The importance of the pest is expected to increase because of the long distance movement of seed tubers to many places across the country from limited source locations mainly in the cool highlands of North and West Shoa.

The activities of male-adults of PTM were monitored using sex pheromone baited traps at Holetta both in seed tuber stores and in production fields (Bayeh and Tadesse, 1992). The field results showed that PTM activity peaked up during January to February and in June. The two peaks in January and June were mainly attributed to the population that had been multiplying on left over tubers in fields from the main season and irrigated potato harvests, respectively. The catches in February were more important because the off-season planted potato was young in the field and liable for PTM attack. On the other hand, the populations of PTM in the seed tuber stores never showed obvious peaks whereby the number of adults caught remained low all year round. In contrast to this observation, higher population of PTM was recorded in the seed tubers from irrigated fields which stayed longer in the field in one of the monitoring years. These observations showed that prompt harvesting plays significant role in reducing the population of PTM. The usual high population in fields had not been contributing much for infestations that occurred in seed tuber stores. One possible reason for this might be the proper timing of vine killing, which might contribute for the reduction in the movement of more larvae into the soil to infest developing tubers (Bayeh and Tadesse, 1992). Similar studies of monitoring the activity of the male PTM were conducted in the major potato growing areas of the West Amhara from 1998 to 2000 during the potato-growing seasons. Data were recorded at a weekly interval. In Tilili, PTM was present throughout the year because of the practice of growing potato three times per year. Whereas at Adet the diffused light store present nearby to the seed multiplication farms was suspected to have contributed for year round activity of PTM in the field. At Adet, the peak period was between June and October in 1998, July to August in 1999 and only in September in 2000. In Tilili the population peaked from July to September in 1998, July to October in 1999 and after August in 2000. In another study at Melkassa Research Center, the field activity of male PTM adults showed an increase towards the end of the crop maturity period (Fig. 1).

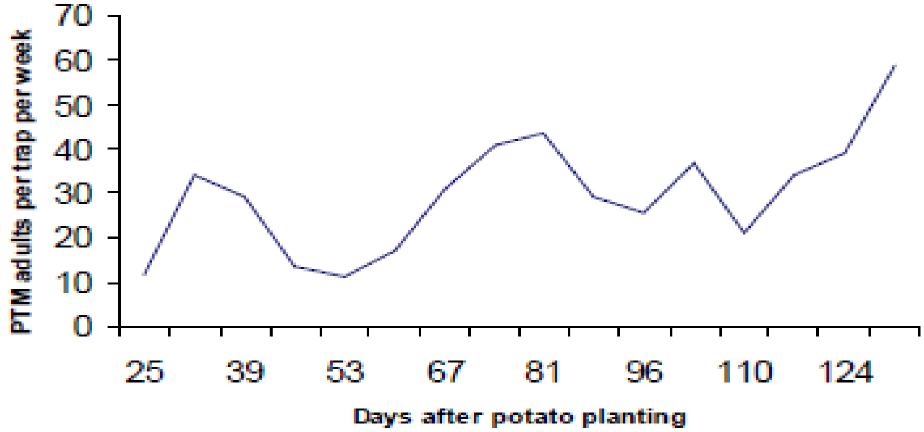


Fig. 1. Sex pheromone baited trap based monitoring of PTM in potato field at Melkassa in 2000/2001 (Bayeh, 2003).

Potato tuber moth larval populations were monitored weekly at the Melkassa Research Center on potato leaves (Bayeh, 2003). Larval population and the number of damaged leaves were recorded on randomly sampled 25 potato plants per plot. Both larval population and the leaf damage they caused increased with time and started to decline when most of the potato leaves entered senescence (Fig. 2).

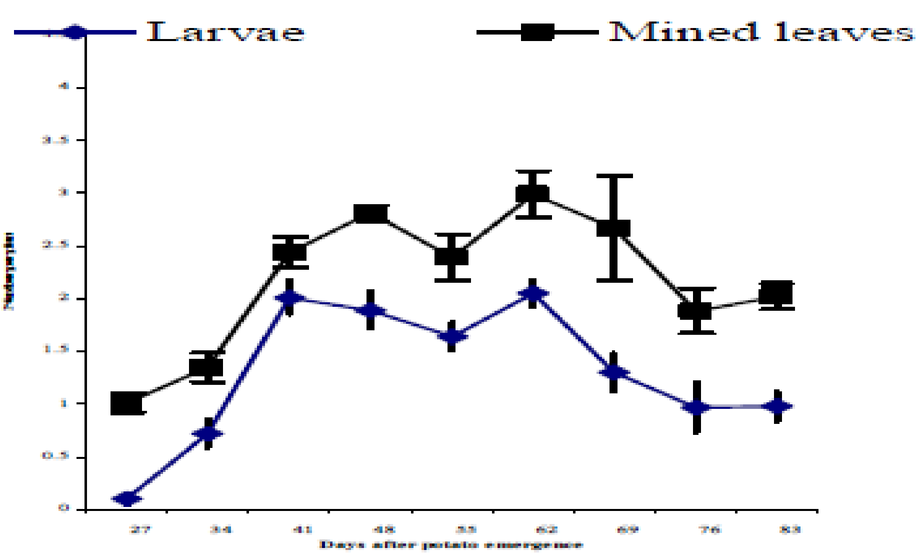


Fig. 2. Monitoring of PTM larval population and leaf damage on potato in 2000/2001 at Melkassa (Bayeh, 2003).

The population of PTM that build upon potato foliage has a direct aftermath on the level of infestation that may occur on developing tubers in the rhizosphere. When potato leaves start senescing, the larvae that develop in leaves find their way down to developing tubers by passing through cracks in the soil. Field infested tubers in turn serve as the nucleus for the multiplication of PTM in stores and for the subsequent carry over of the insect back to the field during the next cropping season. All these depend on the survival and development of PTM larvae in the foliage of potato plants. The survival and development of PTM larvae in potato foliage was studied in controlled growth chamber. Newly hatched larvae were transferred singly into individual Petri dishes containing undamaged leaves taken from potato plants at the pre-blossom and blossom stage. Data were collected on the survival and development of the larvae (n = 80) for the two crop stages. In general, larvae survived better on leaves of potato at blossom stage (Fig. 3). The finding compliments the earlier field observations (Fig. 2) where the larval population and the damage caused on potato leaves were higher during blossoming period. It was found that PTM had significantly longer larval and larva-adult development time on potato foliages at the pre-blossom stage than at the blossom stage (Fig. 4).

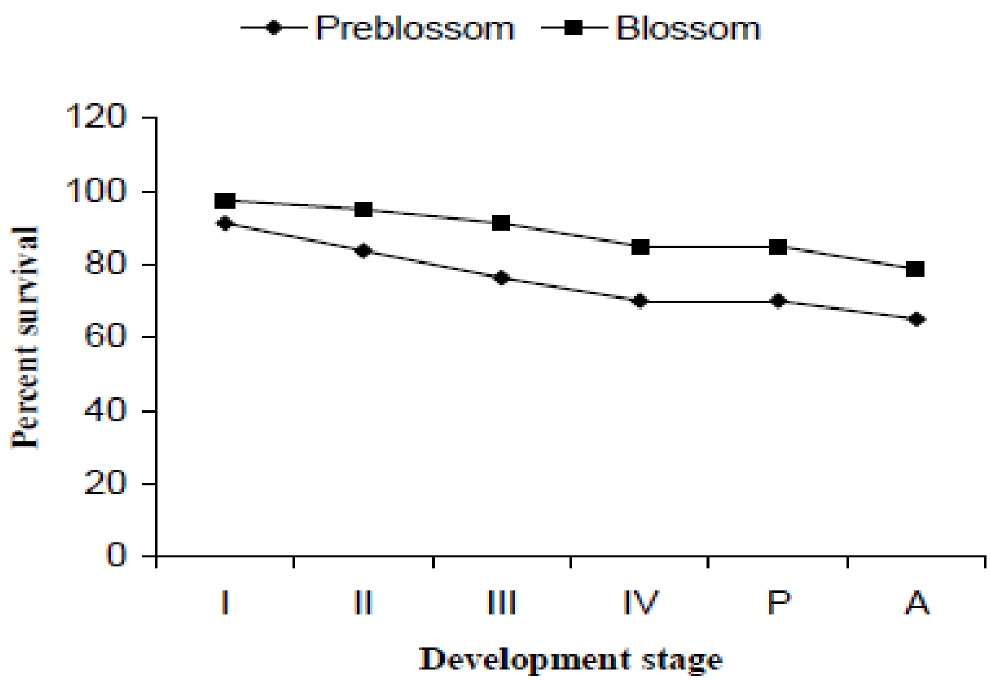


Fig. 3. Mean percentage survival of potato tuber moth larval instars (I-IV), pupae (P) and adults (A) in the leaves of potato plants sampled during pre-blossom and blossom stages (Bayeh, 2003).

Fig. 4. Larval and larva to adult development time (days) of PTM on the leaves of potato taken at pre-blossom and blossom stages (Bayeh, 2003).

Improved storage of seed potato tuber in diffused light stores (DLS) has been demonstrated and introduced in various potato growing areas. However, DLS can never guard off insect pests like PTM. The major source of infestation often comes from tubers transported to DLS. There is always high accumulation of seed tuber per unit area in DLS than in an open field, thus the loss of tubers to the PTM is correspondingly high. The population of PTM in DLS was monitored at Holetta Research Center for three years (1988-91) using sex pheromone baited traps. The insect was found to be active and common all the year round. However, the count in July was significantly higher than in the other months. This was due to the length of storage period whereby the tubers in DLS were kept for about six months after harvest (Bayeh and Tadesse, 1992). The observation also showed that DLS stores with infested seed tubers are potential source of infestation of PTM for the next crop season.

Seed potato production by smallholder farmers has been well adopted and gaining importance in West and North West Shoa. The increase in production of seed tubers might have created an ideal environment for the multiplication and further spread of PTM to the surrounding areas. As a result, there are reports of the insect in places where it has never been reported before. Monitoring was carried out in DLS constructed by small farmers in the Dandi, Degem, Jeldu, and Walmera Woredas that have become the major sources of seed potato for the country at large. Data were collected fortnightly on the number of healthy and damaged sprouts per tuber on ten randomly selected tubers per shelf of the DLS. Each shelf was considered as a replication. The infestation of seed tubers by

PTM was found to be significantly higher in Walmera followed by Jeldu, while no damaged was observed in Dandi and Dagem (Fig. 5). Seed tuber production has longer history, about 15 to 16 years, in Walmera and Jeldu, while it is recent in Dandi and Degem. In general, these results indicated that PTM could become a threat in DLS following the increase in the production of seed tubers and number of DLS put up by farmers.

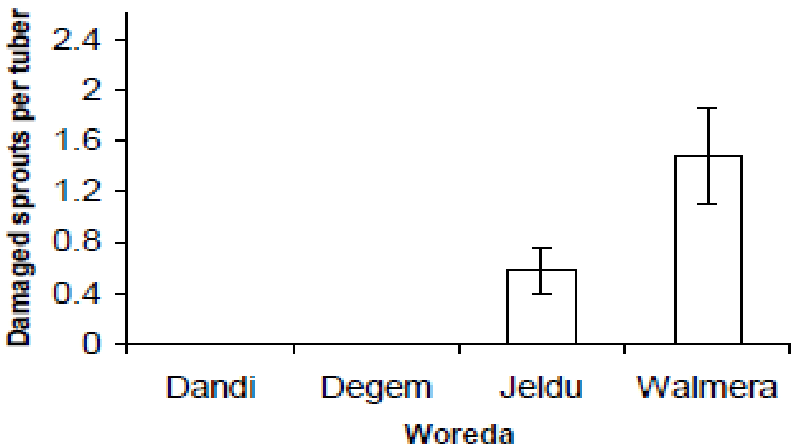


Fig. 5. Mean number of PTM damaged sprouts per tuber in DLS in four Woredas of West and North West Shoa (Bayeh, 2004).

The relative rates of tuber damage due to PTM were assessed in 30 different genotypes of potato grown at Alemaya, eastern Ethiopia (Sileshi and Teriessa, 2001). Field infestation in tubers ranged from 6-62% and significant differences were observed between genotypes in the degree of damage. Over 42% of the tubers were exposed to tuber moth infestation. Tuber infestation and rotting were found to be positively correlated with exposure. There was an overall increase by 93.2% in infestation and 96.3% in rotting in the exposed tubers over the covered ones. On average, 8.7% of the potato tubers were lost due to field infestation.

PTM parasitism

A survey was conducted in potato production fields in the rift valley by deliberately exposing PTM larvae *in situ* in potato plants to natural enemies (Bayeh, 2003). Five parasitoid morphotypes were reared from PTM larvae recovered from mines in potato leaves. The most common parasitoid was the ichneumonid, *Diadegma mollipla* (Hlmgr), which accounted for about 66.2% of the recovered parasitoids. On the other hand, the level of parasitism was not significantly different among the two plant stages and the unspecified plant stage of potato in farmers' fields (Fig. 6).

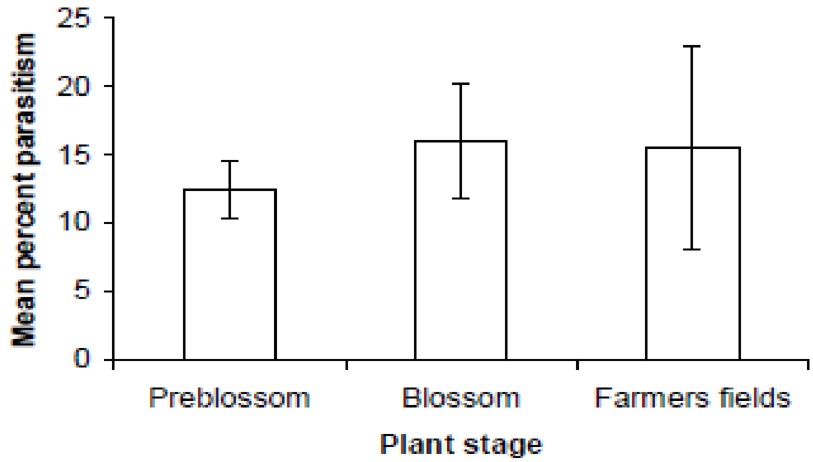


Fig. 6. Percentage parasitism of PTM larvae in the foliage of potato plants at pre-blossom, blossom and unspecified stages (after Bayeh, 2003).

Control measures for PTM

Screening of botanicals

Different botanicals were screened for the control of PTM in DLS at Holetta Research Center (HARC, 1997). Fifty potato tubers of the variety Wechecha were placed in a plastic box and replicated three times for each treatment. Powdered flowers of pyrethrum, *Chrysanthemum cineraraefolium* and leaf powder of all the other tested plants were dusted on potato tubers at 35 g/50 tubers. Uniform coating of all the tubers was ensured by thoroughly shaking them with dust in a plastic box. Aqueous neem seed extract was prepared from 500 g dried and crushed seed that was suspended in a bucket of water tied in a cloth. After 12 hours, the seed materials were removed and squeezed and the solution was taken up to 10 litters. The neem (*Azadirachta indica)* seed extract at 5% concentration and diazinon 60% EC (5 ml in 10 litres of water) solution were prepared and the test tubers were dipped for about one minute before storage. All the treated tubers were exposed to natural PTM infestation. Evaluations made after 120 days showed that the powders from neem seeds, endod seeds and pyrethrum flowers significantly reduced ($P<0.05$) tuber damage when compared with the untreated check and the standard insecticide, diazinon 60% EC (Table 2).

Table 2. Control of PTM with botanical powders in DLS at Holetta (HARC, 1997).

Treatment (botanical powders)		**Percentage damage after 4 months**	
Common ame	**Scientific name**	**Sprouts damaged**	**Tubers damaged**
Pyrethrum-flower	*Chrysanthemum* sp.	0.31.b	3.3ab
Endod-Seed	*Phytolacca dodecandra*	1.62ab	8.0ab
Endod-Leaf	*Phytolacca dodecandra*	8.23ab	3.3ab
Yewof kolo-leaf	*Lantana camara*	2.36ab	3.3ab
Neem-seed	*Azadirachta indica*	0.57ab	1.3b
Neem-leaf	*Azadirachta indica*	5.41ab	1.3b
Nech Beharzaf-leaf	*Eucalyptus globules*	8.83a	2.0b
Bisana-leaf	*Croton macrostachys*	2.69ab	4.7ab
Pepper-leaf	*Piper capense*	2.85ab	4.0ab
Mexican marigold-leaf	*Tagetus minuta* L	2.85ab	4.0ab
Basudin (diazinon) 60% EC		3.86ab	4.7ab
Control		5.02ab	7.3a
CV%		55.3	34.4

Means followed by different letters within a column are significantly different from each other ($P < 0.05$).

In the years 2000/01 and 2001/02, a number of botanicals and Bt *(Bacillus thuringiensis* Kurstaki) were evaluated for the control of PTM both in the field and store. The trials were carried out at Holetta Research Centre and at Shashemene (HARC, 2003). The storage experiments started in November in both locations, the time farmers start storing tubers for seeds (October/ November to June). Neem seed, neem leaf and pyrethrum flower were crushed and water extracted for 24 hours before application. The concentrations of the dipping solutions in water were: Basudin 60% EC solution at 5 ml /10 litres of water, 500 g powder of neem seeds in 10 litres of water, 70 g powder of pyrethrum flower in 10 litres of water, 70 g powder of neem leaf in 10 litres of water, Bt solution at 5 g/ 10 litres of water. Tubers without any sign of PTM damage were dipped in the different solutions for 10 min. Treated tubers were put in separate plastic boxes and stored in DLS. The results from the experiments conducted in 2000/01 are reported here. Dipping of potato tubers in aqueous solutions of pyrethrum flower or neem leaf powder were found to be effective in significantly reducing sprout damage by the PTM in both places. In general, pyrethrum flower gave the best protection to the seed tubers (Fig. 7). Similar procedures were followed to evaluate the efficacy of the botanicals and *Bt* against PTM in the field. Extracts were prepared from neem seed, pyrethrum flower and neem leaf and solutions of Basudin 60% EC and *Bacillus thuringiensis* Kurstaki. The aqueous solutions were applied after making a pre-spray count. Post-spray counts were made after 96 hr. In 2002, the post-spray counts made after 96 hrs showed that diazinon 60% EC treated plots had the lowest population of PTM (Fig. 8).

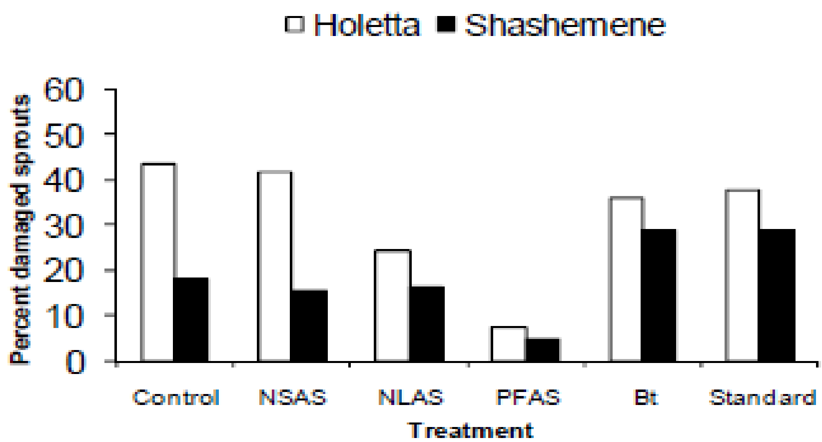


Fig. 7. Mean percentage PTM damaged sprouts of potato tubers treated with different botanicals and Bt. in DLS at Holetta and Shashemene in 2001/02. (NSAS = neem seed aqueous solution; NLAS = neem leaf aqueous solution; PFAS = pyrethrum flower aqueous solution; Bt = *Bacillus thuringiensis;* standard = diazinon 60% EC) (after HARC, 2003).

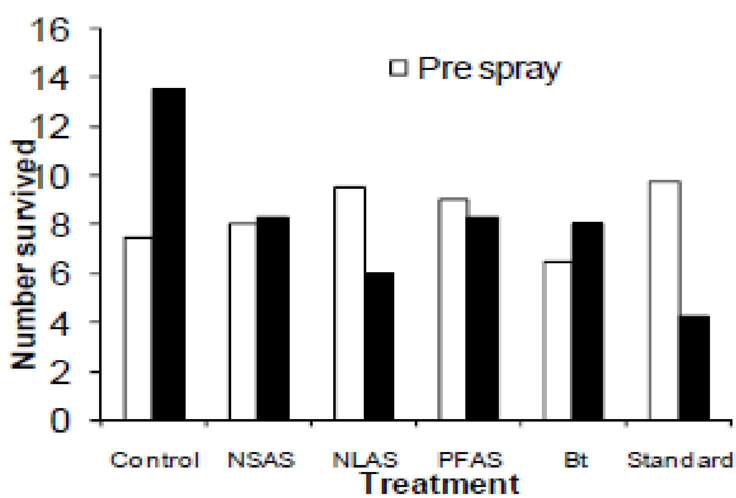


Fig. 8. Effect of spray of different botanicals and Bt on the population of PTM at Holetta during off-season, 2002. (NSAS = neem seed aqueous solution; NLAS = neem leaf aqueous solution; PFAS = pyrethrum flower aqueous solution; Bt = *B. thuringiensis*; standard = diazinon 60% EC) (after HARC, 2003).

Studies on red ants on potato

Crow and Shitaye (1977) and Crow *et al.* (1977) reported that the red ant (*Dorylus* sp.) was a very serious pest on vegetable crops grown at high altitudes. Red ants damage potato plants by scraping the phloem tissues of the roots and destroy root hairs. Such potato plants wilt and die. If the insect appears late in the cropping season, they bore hole and eat out the starch from the developing tubers. Thus, the insect causes direct loss as such kind of damaged tubers are unmarketable. However, the insect has not been reported in major potato growing areas such as Awassa, Shashemene and Shamena, which are situated at altitudes of 1680, 1800 and 2120 masl, respectively. Most of the farmers in Walmera, Degem, Jeldu and Dandi Woredas who were interviewed during a survey responded that the pest is more serious in dry soils. However, most of the farmers in Degem responded that the pest is problematic in wet conditions. About 63% of the farmers responded that the insect is active at any time of the day; 16% said it is active in the morning and another 16% said that it is active in the afternoon, and 5% said it is active in the evenings. Farmers' estimations of the extent of damage on potato by the red ants varied (Table 3). Most of the farmers estimated red ant damage on potato between 0 and 50%. In Degem (North West Shoa) 29% of the farmers claimed up to 100% damage. However, results from sampling of 10 potato plants per field carried out on a total of 8, 8, 17 and 15 farmers' fields in Galessa, Jeldu, Walmera and Dagem, respectively, did not correspond with the farmers' estimations (Fig. 9). The percentage of root damage did not exceed 25% suggesting that farmers overestimated the damage by red ants. The survival of workers of red ants on various parts of potato was studied by offering pieces of potato roots, stem, or tubers to the red ants in plastic Petri dishes covered with tight lids, but ventilated. The control groups were not given any food. The worker ants were collected from active colonies in potato plots and transferred at the rate of 10/ Petri dish. The mortality of the ants was recorded after three days. The least mortality was recorded in the ant groups provided with roots (Fig. 10). The result suggests that control of red ants in potato should focus on delivering the control agent to the root zone of the potato plants.

Table 3. Farmers' estimations of red ant damage on potato plants in 2001 (HARC, 2001).

Damage level (%)	Percentage of respondents			
	Galessa	Jeldu	Walmera	Degem
0	0	0	9.5	22.0
≤25	67.0	54.6	28.6	12.0
26-50	33.0	31.8	23.8	15.0
51-75	0	13.6	28.6	22.0
76-100	0	0	9.5	29.0

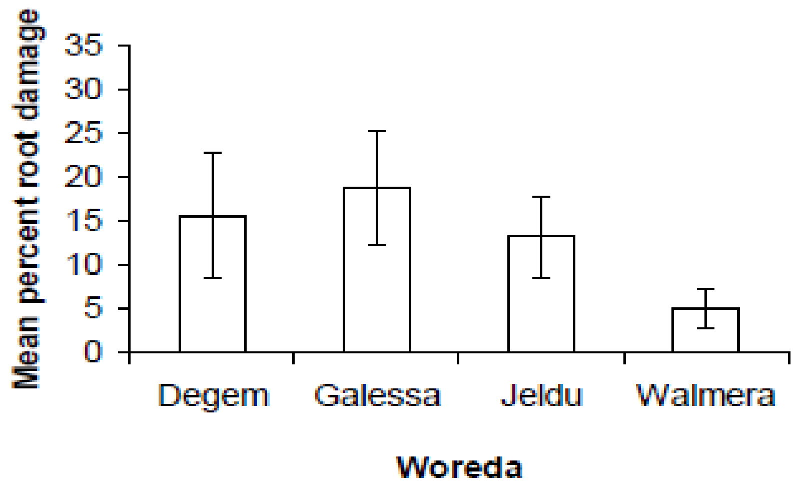


Fig. 9. Percentage damage of potato roots by red ants in four seed potato growing Woredas of the central highlands (after Bayeh, 2006, unpublished).

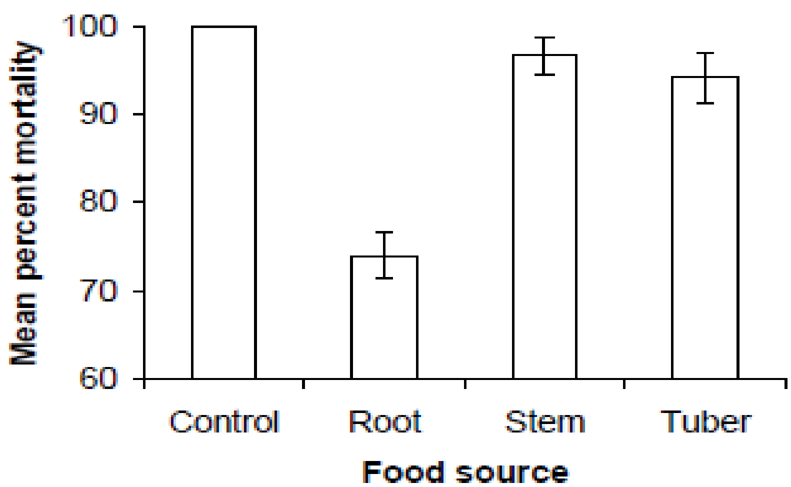


Fig. 10. Percentage mortality of red ant workers provided different parts of potato plant *in vitro* after 3 days (after Bayeh, unpublished).

Aphids on potato

Among the species of aphids known to transmit potato leaf roll virus (PLRV), the most important virus diseases of potato, only the bean aphid (*Aphis fabae*), the potato aphid (*Macrosiphum euphorbiae*) and the green peach aphids (*Myzus persicae*) were commonly recorded in potato fields in Ethiopia. In addition, the

Brassica aphid, *Brevicoryne brassicae*, the rose flower aphid, *Macrosiphum rosae* and *Aphis* spp. are commonly found in and around potato fields. However, the Brassica aphid, which was by far the most common aphid species, was reported not to transmit PLRV (Bayeh and Tadesse, 1992).

Enset

Insect pests recorded

Only a few insects have been recorded attacking enset (Table 4). However, enset root mealybug has become the most important (Tsedeke, 1988; Addis, 2005; Eyob, 2006). The enset root mealybug, *Cataenococcus ensete* William and Matile-Ferrero (Homoptera: Pseudococcidae), is a major pest of enset in the South and southwestern parts of the country (Addis, 2005). It has been collected and reported from Wonago as a new record for Ethiopia (Tsedeke, 1988). *C. ensete* has hitherto been referred to as *Paraputo* sp. which is now sucked as a junior synonym of *Cataenococcus* sp. (Williams and Matile-Ferrero, 1999). *Pentalonia nigrnervosa, Poeicilcarda nigrineervis* and *Planococcus* spp. were frequently found on wilted and healthy plants (Adhanom and Emana, 1987a; 1987b). These insects have been implicated in the transmission of the enset bacterial wilt (Eshetu, 1981). Adhanom and Emana (1987a; 1987b) also reported outbreak of unidentified lepidopterous larvae in Wolaita area especially in the low lands below 1500 masl.

Table 4. Insect pests of enset recorded in Ethiopia.

Scientific name	Common name	Status	References
Homoptera			
Aleyrodidae			
Bemisia tabaci (Gennadius)	Tobacco whitefly	minor	65
Aphididae			
Pentalonia nigrnervosa Coquerel	Banana aphid	minor	9, 10, 40, 65
Diaspididae			
Chrysomphalous aonidium (L.)	Purple scale	minor	65
Cicadellidae			
Poeicilocarda nigrinervis Stal	Black stripped jassid	minor	9, 10, 40
Pseudococcidae			
Catenococus ensete Will. Matile-Ferr.	Enset root mealybug	major	3,4,5,6,7,41, 62,65,67
Planococcus ficus	Root mealybug	unknown	9, 10, 40

Enset root mealybug

Basic studies

Addis (2005) conducted a survey in 163 sites of 25 districts of southern Ethiopia from July 2004 to December 2004 and recorded the root mealybug in Sidama, Gedeo, Gurage, Bench, Kembata Tembaro, Hadyia zones and Amaro and Yem districts. However, the level of infestation was found to be high only in Amaro (100%), Gedeo (66.7%), Sidama (61.5%) and Bench (57.1%). The highest number of mealybugs (81mealybugs/ plant) was recorded in Gedeo zone and the lowest (3.3 mealybugs/ plant) in Yem district. Maji, Gamo Goffa, Sheka, West Shoa, and Jimma were free from enset root mealybugs. The enset root mealybug is known by different local names in different areas; '*Tsete*' in Gedeo, '*Chea*', '*Churcha*' and '*Hufaro*', in Sidama, '*Buno*', '*Osk*', '*Oote*' and '*Dachu*' in Bench languages. Although *C. ensete* was observed at elevations ranging from 1,054-2,977 masl, its infestation was severe between 1,400 and 2,200 masl. The highest level of infestation (53.6%) was recorded between 1,600 and 1,800 masl (Fig. 3); and the lowest above 2,200 masl and below 1,400 masl. The insect attacks enset of all age groups, but it is more serious on 2 to 4 years old enset plants. *C. ensete* was found exclusively on the roots and corm of enset and infested plants have less number of roots, retarded growth, and lack of vigor and subsequently die especially when there is moisture stress. Early infestation by *C. ensete* can be easily overlooked because effects on the above ground part appear lately after extensive damage on the roots and corm had occurred. On the other hand, varying levels of mealybug infestations were recorded on 211 different farmers' enset cultivars (Addis, 2005).

Biology of enset root mealybug

The enset root mealybug has different development stages: (1) bright-orange to yellow-orange colored "crawlers" or rapidly moving first-instar, (2) the settled first-instars that secrete wax that gives the body a whitish appearance, (3) second and third instars that begin to develop distinct lateral and posterior cerarii, increase in body size, and start to produce large amounts of honeydew and (4) the pre-ovipositing adult female. Males are unknown for *C. ensete* and none were observed during this study too. The viviparous females produced 253 ± 17.4 nymphs/ female. The average daily fecundity was six nymphs (Addis, 2005). The average duration of the first, second and third instar nymphs was 16.2 ± 0.5, 18.2 ± 0.7 and 19.8 ± 0.5 days, respectively (Addis, 2005). The average life span of the adult female was 49.95 ± 0.5 days with a range of 47 to 53 days. Thus, the estimated generation time of the enset root mealybug was 94-113 days with estimated three generations per year. The body size of the different nymphal stages ranged from 0.5-2.7 mm long (Table 5). The body size of the adult mealybug ranged from 2.9-4.0 mm in length. According to Addis (2005), the enset root mealybugs encountered in the field were larger in size than those reared in the laboratory. This might be due to the unfavourable environmental conditions in the laboratory compared to their natural habitat. The mealybugs survived well when reared on whole pumpkin and completed their growth to the adult stage. It was observed that adult female mealybugs could not survive for more than three weeks in the soil in absence of plant materials to feed on (Addis, 2005).

Distribution of enset root mealybug on enset and the soil

The majority (79%) of the enset root mealybugs inhabited the roots and the remaining (21%) was found on the corms (Addis, 2005). Enset root mealybugs were found up to a soil depth of 60-80 cm away from the corm. However, root density as well as the number of mealybug decreased with increasing soil depth. About 99% of the mealybugs were found in the upper 40 cm soil layer. In addition, about 90% of the mealybugs were collected within a 60 cm radius from the plants. On the other hand, 59% of the mealybugs were found on the upper half of the corm. Most of the enset root mealybugs were found within 20 cm radius from the corm (about 63%). Hence, sampling a 20 x 20 x 20 cm cube of soil and roots adjacent to the corm will capture a large percentage of the total root mealybug population on a plant. The proposed assessment method will provide field technicians and researchers with a simple tool to assess population numbers of the enset root mealybugs. It was found that the relationship between plant growth parameters (plant height, pseudostem circumference, fresh root weight and fresh shoot weights) and the population density of root mealybugs was negative (Fig. 11).

Dissemination of enset root mealybugs to new areas

It was observed that some of the enset nurseries found in southern Ethiopia (Yirgachefe and Wonago districts) were highly infested by mealybugs. Some development organizations (aid and government) have been procuring enset suckers from such sites and distribute to different areas of the country where farmers are trying to adopt enset production. Thus, the use of infested suckers has been the major means of spread for the enset root mealybug to new areas.

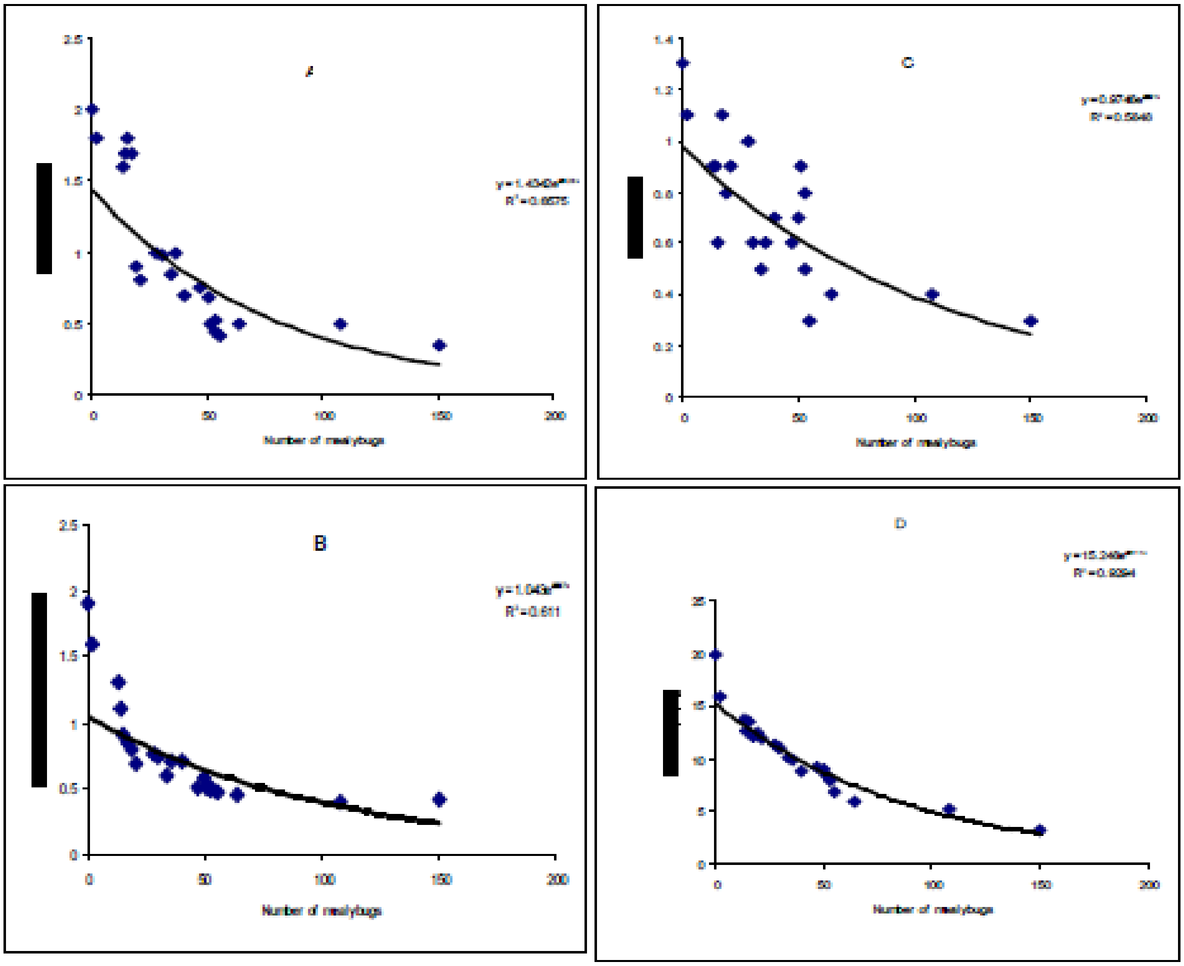


Fig. 11. Relationship between enset root mealybug population and enset plant height (A) and pseudostem circumference measured at soil level (B), enset shoot fresh weight [i.e. leaf + corm + pseudostem fresh weight] (C) and root fresh weight (D). (n=22) (after Addis, 2005).

Table 5. Mean duration and body size of different stages of the enset root mealybug (*Cataenococcus ensete*) (after Addis, 2005).

Insect stage	Mean days	Range	Body length (mm)	Range
First instar	16.2 ± 0.5	13-19	0.79 ± 0.04	0.5-1.2
Second instar	18.2 ± 0.7	13-25	1.71 ± 0.03	1.5-1.9
Third instar	19.8 ± 0.4	16-23	2.46 ± 0.03	2.2-2.7
Adult	50.0 ± 0.5	46-53	3.31 ± 0.07	2.9-4.0
Total duration	103.9 ± 1.1	94-113		

Mean ± standard error

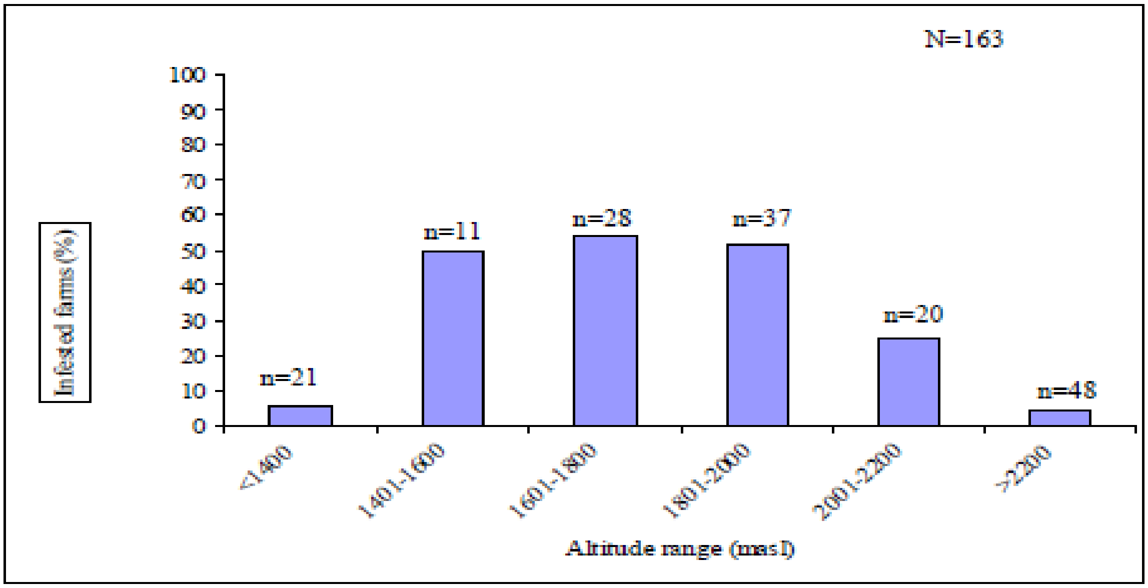


Fig. 12. Incidence of enset root mealybug *(Cataenococcus ensete)* at different altitudes (Addis, 2005).

Table 6. Population density of enset root mealybug in some localities of southern Ethiopia.

Areas surveyed	No. of farms visited	Sites with mealybugs (%)	No. of adult mealybugs/ plant
Gedeo	21	66.7	81.2
Sidama	26	61.5	5.2
Amaro	6	100	9.7
Hadyia	12	9.3	3.5
Bench	7	57.1	1.5
Keffa	7	29.6	9.0
Gurage	12	9.3	9
Kembata Tembaro	12	25	4.7
Yem	6	17.7	3.3

Control measures

Cultural methods

Farm yard manure treatments on infested plants did not reduce the population density of the pest, however, the plants grew and developed better when received the manure which enabled them to withstand the damage by the insect (Addis and Tesfaye, 2002).

Botanicals

The efficacy of seeds of *Azadirachta indica, Melia azedarach*, *Phytolaca dodecandra, Schinus molle,Milletia ferrugenia* and *Maesa lanceolata;* seeds and leaves of *Chenopodium ambrosiodes*, *Tephrosia vogelli, Nicotina tabacum*, and *Maesa lanceolata* were evaluated against the enset root mealybugs in Petri dish and greenhouse experiments (Eyob, 2006). *M. ferruginea* seed-water suspensions extracted at the rate of 10% (w/v) and *Nicotina tabacum* leaf-water suspension extracted at the rate of 30% (w/v) were found to be toxic to the pest under laboratory conditions (Table 7). The LC_{50} and LC_{90} were 40.39 mg and 77.62 mg for *M. ferruginea* and 237 mg/ml and 284.4 mg for *N. tabacum,* respectively. In the pot experiment, drenching the soil around the roots of infested young enset plants with seed water suspensions of 10% *M. ferruginea* caused about 66% mortality. However, *M. ferruginea* was found to be inferior to the synthetic insecticide diazinon. Two applications of *M. ferruginea* improved its efficacy and raised the level of mortality to about 79%. On the other hand, dipping of infested enset seedlings in *M. ferruginea* seed-water suspensions of 10% caused 44% mortality, which is significantly higher ($P<0.05$) than the other botanicals tested and the untreated check. The study indicated that one application of milletia seed water suspension can not satisfactorily control the enset root mealybugs. Combinations of dipping young enset seedlings and repeatedly drenching of the root zone of infested plants with the milletia seed water suspension may be used as part of IPM for the enset root mealybug.

Chemical control

The efficacy of chlorpyrifos, diazinon, dimethoate, endosulfan, fenitrothion and malathion was evaluated against the enset root mealybug under greenhouse and field conditions by drenching the soil (Eyob, 2006). In the greenhouse, diazinon and chlorpyrifos provided 100% and 97% mortality of the pest, respectively (Table 8). The other insecticides were also significantly different from the untreated check, but they caused mortality less than 84%. Chlorpyrifos and diazinon were equally effective on enset root mealybug in the field with >90% mortality of the adult within 14 days after application (Table 9). The percentage mortality increased over time reaching 98% following 45 days after treatment application. Malathion, dimethoate, endosulfan and fenitrothion were less effective. Tesfaye (2003) also indicated that chlorpyrifos 48% EC was effective against the enset root mealybug. However, yellowing of plants was observed in some of the plants treated with chlorpyrifos, diazinon, and malathion (Eyob, 2006). It was suggested that drenching with insecticides should be done on moist soils.

Table 7. Mean mortality of enset root mealybug when treated with water suspensions of different plant materials in Petri dish experiment (Eyob, 2006).

Treatments (4ml/5cm^3 of soil in the Petri dish)	Percentage mortality hours after treatment					
	24 hrs		48 hrs		72 hrs	
	Observed	Corrected	Observed	Corrected	Observed	Corrected
Chenopodium ambrosiodes	6.7^{d}	0.10	13.3^{d}	3.40	19.9^{d}	9.61
Maesa lanceolata (leaf)	10.0^{d}	3.40	13.3^{d}	3.40	23.3^{cd}	13.01
Maesa lanceolata (seed)	16.7^{d}	10.11	23.3^{cd}	13.41	29.9^{cd}	19.62
Azadirachta indica	16.7^{d}	10.11	23.3^{cd}	13.41	29.9^{cd}	19.62
Phytolaca dodecandra	10.0^{d}	3.40	23.3^{cd}	13.41	39.3^{c}	29.03
Melia azedarach	16.6^{d}	10.11	23.3^{cd}	13.41	34.0^{c}	23.72
Schinus molle	13.3^{d}	6.70	36.6^{c}	26.73	43.3^{c}	33.03
Tephrosia vogelli	16.7^{d}	10.11	29.9^{cd}	20.02	53.3^{b}	43.04
Nicotina tabacum	63.4^{c}	56.83	86.6^{b}	76.77	96.6^{a}	85.78
Millettia ferruginea	80.0^{b}	73.42	100.0^{a}	90.02	-	-
Diazinon 60% EC	100.0^{a}	93.45	-	-	-	-
Untreated control	6.6^{d}	-	9.9^{d}	-	10.3^{d}	-
CV (%)	21	-	18.4	-	14.5	-

Means followed by the same letter in the columns are not significantly different from each other according to Tukey's HSD test, $P<0.05$.

Table 8. Mean mortality of enset root mealybug due to synthetic insecticides under greenhouse conditions (after Eyob, 2006).

Treatments	Observed mortality (%)	Corrected mortality (%)
Diazinon 60% EC	$100. \pm 0.0^{a}$	84.13
Chlorpyrifos 48% EC	97.6 ± 1.0^{a}	80.23
Malathion 50% EC	83.2 ± 1.9^{ab}	67.30
Fenitrothion 50% EC	76.8 ± 2.3^{b}	60.89
Endosulfan 50% EC	74.4 ± 4.1^{b}	58.53
Dimethoate 40% EC	64.8 ± 3.4^{b}	48.87
Control (untreated)	16.0 ± 3.5^{c}	-
CV	16%	

Means followed by the same letter within a column are not significantly different from each other, Tukey, $P<0.05$.

Table 9. Mean mortality and survival of enset root mealybugs on enset seedlings treated with different insecticides under farmers' field conditions (Eyob, 2006).

Treatments	Mean mortality (%)[T]			Mean No. of surviving mealybugs[†]		
	15 days	30 days	45 days	15 days	30 days	45 days
Diazinon 60 %EC	96.5±1.4[a]	97.7±1.2[a]	98.1±1.1[a]	0.9 ± 0.4	0.50±0.3	0.75±0.4
Chlorpyrifos 48%EC	93.7±1.9[a]	95.4±1.3[a]	97.9±1.2[a]	1.1 ± 0.4	1.57±0.5	0.50±0.3
Malathion 50 %EC	75.3±1.6[b]	67.4±2.2[b]	49.7±1.6[c]	4.0 ± 0.5	7.70±1.0	7.90±1.0
Endosulfan 50%EC	61.3±2.7[c]	58.9±1.9[c]	50.8±3.0[c]	7.3 ± 1.8	7.25±1.8	9.60±2.5
Dimethoate 40 %EC	53.5±1.4[c]	60.2±1.9[c]	64.8±2.9[b]	7.1 ± 1.5	8.00±0.8	5.50±1.3
Fenitrothion 50 %EC	61.9±3.7[c]	55.1±1.9[c]	51.0±1.8[c]	7.9 ± 0.9	9.20±2.2	9.20±1.3
Control	-	-	-	34.2 ±5.2	58.9±12.1	53.6±12.6
CV (%)	14.7	8.2	11.5	-	-	-

[†]per sample of soil

Means followed by the same letter within a column are not significantly different; Tukey's HSD test at P <0.05.

Table 10. Mean mortality of enset root mealybugs on enset seedlings treated twice with different insecticides under farmers' field conditions (Eyob, 2006).

Treatment	Mortality %		
	15 days	30 days	45 days
Diazinon 60 % EC	100.0 ± 0.0[a]	100.0 ± 0.0[a]	99.1 ± 0.9[a]
Chlorpyrifos 48 % EC	98.4 ± 1.6[a]	98.9 ± 1.1[a]	99.2 ± 0.8[a]
Malathion 50 % EC	87.1 ± 2.1[b]	78.3 ± 2.6[b]	64.9 ± 4.2[bc]
Endosulfan 50% EC	73.4 ± 0.6[c]	61.0 ± 1.4[c]	52.8 ± 0.7[c]
Fenitrothion 50% EC	71.4 ± 1.6[c]	62.2 ± 3.1[c]	54.1 ± 1.1[c]
Dimethoate 40% EC	67.3 ± 1.0[c]	75.6 ± 1.1[b]	74.7 ± 1.6[b]
Control	-	-	-
CV (%)	9.4	21.0	9.8

Means followed by the same letter within a column are not significantly different; according to Tukey's HSD test at, P<0.05.

In another study, chlorpyrifos, aluminium phosphid (tablets) and malathion 50% EC originating from Admitulu Pesticide Processing Sc. Co. provided better control (Addis and Tesfaye, 1995c).

Sweet potato

Pests recorded

Insect pests recorded on sweet potato in Ethiopia are presented in Table 11. Among these, only the sweet potato weevil (*Cylas puncticollis*) and the sweet potato butterfly (*Acraea acerata)* are the major pests (Crowe *et al.*, 1977; Emana and Adhanom, 1989; Ejigu, 1995; Azerefegne, 1999; Endrias, 2003) which received better research attention.

Table 11. Insect pests recorded on sweet potato in Ethiopia.

Scientific name	Common name	Status	References
Orthoptera			
Acrididae			
Aiolopus simulatrix (Walker)	Clay grasshopper	Unknown	65
Atractomorpha acurtepennis gerasteckeri (I. Boliver)	Sweet potato grasshopper	Unknown	65
Homoptera			
Aleyrodidae			
Bemisia tabaci (Gennadius)	Sweet potato white fly	Unknown	7, 35
Cicadellidae			
Empoasca fascialis (Jacoby)	Cotton leafhopper	Minor	65
Heteroptera			
Corediae			
Cletus fuscescens (Walker)	Cletus bug	Unknown	65
Lygaeidae			
Garptostethus rufus Distant	Red sweet potato bug	Unknown	65
Garptostethus servus (Fabricius)	Red sweet potato bug	Unknown	65
Lygaeus negus Distant	Red sorghum bug	Unknown	65
Miridae			
Helopeltis schoutedeni (Reuter)	Cotton helopeltis	Unknown	65
Taylorilygus simyoni (Reut.)	Sweet potato bug	Unknown	65
Pentatomidae			
Calidea bohemania (Stal)	Blue bug	Unknown	65
Calidea dudecinpunctata (Fabricius)	Blue bug	Unknown	65
Carbula recurva Distant	Carbula bug	Unknown	65
Durmia conjugens (Germar)	Durmia bug	Unknown	65
Macroraphis acuta Dallas	Acute stink bug	Unknown	65
Nezera viridula (Linnaeus)	Green stink bug	Unknown	65
Veteran abyssinica Lethiery	Linseed stink bug	Unknown	65

Table 11. Contd.

Scientific name	Common name	Status	References
Coleoptera			
Curculionidae			
Cylas puncticollis Bohemian	Sweet potato weevil	Major	2,7,8,13,31,35,36,37,38, 39,53,63, 65
Cylas compressus Hartman	Sweet potato weevil	Unknown	31, 65
*Alicidodes dentipes (*Oliver*)*	Striped sweet potato weevil	Unknown	31, 35 ,65
Alicidodes humerous Harold	Striped sweet potato weevil	Unknown	65
Blosyrus rugulosus abyssinicus Aurvillius	Rough sweet potato weevil		31, 65
Blosyrus rugulosus Aurvillius	Rough sweet potato weevil		65
Chrsysomelidae			
Aspidomorpha apicalis (Klug)	Tortoise beetle	Unknown	F
Aspidomorpha areata Klug	Tortoise beetle	Unknown	F
Aspidomorpha areata var nigripennis	Tortoise beetle	Unknown	F
Aspidomorpha cincta Fabricius	Tortoise beetle	Unknown	65
Aspidomorpha quadrimaculata (Oliver)	Tortoise beetle	Minor	65
Aspidomorpha tecta (Beheman)	Sweet potato tortoise beetle	Minor	7, 31, 35, 65
Conchyloctenia hybrida (Beheman)	Conchylo tortoise beetle	Unknown	65
Conchyloctenia illota (Beheman)	Conchylo tortoise beetle	Unknown	65
Conchyloctenia punctata	Conchylo tortoise beetle	Unknown	65
Coccinellidae			
Chnootriba similis (Thnb.)	Tef epilahna	Unknown	65
Lagriidae			
Lagria villosa Fabricius	Metallic beetle	Unknown	7, 31, 35, 65
Chrysolagria cuprina (J. Thompson)	Cuprina beetle	Unknown	65
Sesselia pusilla	Black leaf beetle	Unknown	65
Lepidoptera			
Lyonetiidae			
*Beddelia somnulentella (*Zeller*)*	Sweet potato leaf miner	Sporadic	7, 11, 31, 35, 65
Nymphalidae			
Acarea acerata Hew.	Sweet potato butterfly	Major	1,7,20,21,31, 33,3435, 36, 39,54,64, 65
Sphinigidae			
*Agrius convolvuli (*Linnaeus)	Sweet potato hawk moth	Minor	7, 31, 35, 65

Table 11. Contd.

Scientific name	Common name	Status	References
Hippotion celerio (Linnaeus)	Vine hawk moth	Unknown	65
Hyles lineate (Fabricius)	Silver stripped hawk moth	Unknown	31, 65
Noctuidae			
Diachrysia orichlacea (Fabricius)	Golden plusia	Unknown	65
Spodoptera littoralis Boisduval	Cotton leaf worm	Unknown	65
Ctenoplussia limbirena Guenee	Plusia worm	Unknown	65
Arctidae			
Syntomis Alicia Butler	Tomato tiger moth	Unknown	65
Acarina			
Tetranychidae			
Tetranychus cinnabrinus (Boisduval)	Red spider mites	Unknown	65

F = Ferdu Azerefegne, unpublished.

Sweet potato weevil

The sweet potato weevil was reported to be found in all Woredas surveyed in southern Ethiopia; although there were differences in the extent of stem and tubers damage and weevil population density per plant parts (Ashebir, 2006). High levels of stem and tuber damage and high number of larvae per tuber was recorded in Goffa Zuria, Arba Minch Zuria Woredas (Ashebir, 2006), Nazareth, Werer (Emana, 1987), Awassa, Areka, (Emana and Amanuel, 1992; Adhanom and Tesfaye, 1994) and Humbo (Tesfaye, 2003).

Basic studies

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, 1987; Emana and Amanuel, 1992).

Extent of infestation and loss by sweet potato weevil

Loss assessment experiments conducted between 1984 and 1987 at Nazareth and Werer using various insecticides showed that sweet potato weevil can cause losses of 10-48% (Emana, 1987). The bitterness resulting from sweet potato weevil damage makes even partially damaged tubers unsuitable for human consumption. Because of poor storage technology and planting material preservation, farmers practice piecemeal harvesting which keeps the crop in the field for up to six months. Emana (1990) reported increase in infestation by the weevils from 29% to 68% when harvesting was delayed from five to six months. Moreover, growing sweet potato on the same plot of land for four consecutive years at Awassa resulted in over 70% tuber infestation; whereas under less than 20% infestation was recorded in plots where rotation of crops was practiced (Emana, 1990). The extent of yield loss was high towards the dry season due to low soil moisture, low biomass yield and possibly high soil crack (Ashebir, 2006). The pest is particularly serious under dry conditions because the insect reach the root more easily through the cracks that appear as the soil dries out; therefore, sweet potato root cannot be stored safely in-the ground for long period during the dry season.

Farmers perception on sweet potato weevils

Ashebir (2006) conducted surveys on farmers' perception in major sweet potato growing areas of southern Ethiopia including Arba Minch Zuria, Goffa Zuria, Bolos Sore, Humbo, Dermot Gale, Sodom Zuria, and Kasha Biro in 2005, and found that insect pests were the major constraints of sweet potato production followed by porcupine, mole rat, shortage of land, drought and storage problem in that order. Among insect pests, 63.8% of the farmers perceived sweet potato weevil to be the most important, while 27.6% of the farmers indicated that sweet potato butterfly is important. The rest of the farmers (8.6%) reported leaf miner and vine borer are important. It was observed that the weevil was important in Humbo, Bolos Sore, Goffa and Arba Minch Zuria Woredas, while sweet potato butterfly was important in Damot Gale and Sodo Zuria Woredas. Leaf miner and vine borer were important in Kacha Bira Woreda. The response of farmers suggested that the sweet potato weevil is more important in the lowland and mid-highland areas, while the sweet potato butterfly, leaf miner and vine borer are important in the mid-highland and highland areas.

The majority of farmers (73.3%) recognized the grubs, while about half of them (53.3%) were found to be acquainted with the adult weevil. The recognition of the larvae by many farmers is understandable as it is the stage of the insect encountered in the tubers during harvesting and utilization (Ashebir, 2006).

Control measures

Cultural control

Effect of sowing dates on sweet potato weevil infestation was evaluated at the Awassa and Areka Research Centres in the 1994 cropping season (Adhanom and Tesfaye, 1994). Among the six planting dates extending from June to September, higher tuber infestation was obtained from the late plantings. The highest tuber attack (over 64%) and the lowest yield was obtained from September planted sweet potato followed by the early and late August plantings at Areka (Table

12). The second planting date July 10 gave the highest yield with low weevil infestation. Similarly, higher levels of tuber infestation were recorded from September planting followed by the early and last week of August at Awassa (Table 12). In general, late-planted sweet potato sustained high levels of sweet potato weevil damage at both locations. A similar study conducted in Wolaita indicated that sweet potato planted in August sustained lesser damage than September planted ones (Tesfaye, 2003). Earthling up of soil around the plant three times at monthly intervals starting from the second month after planting significantly reduced infestation of tuberous roots and this practice could enable to delay harvesting for more than six months (Emana, 1990).

Table 12. Effect of sowing date on sweet potato tuber infestation due to sweet potato weevil at Areka and Awassa (after Adhanom and Tesfaye, 1994).

Areka			Awassa		
Planting date	**Yield ton/ha**	**Infestation (%)**	**Planting date**	**Yield ton/ha**	**Infestation (%)**
June 25	6.7	0.57	June 19	17.3	18.96
July 10	14.8	0.54	July 1	17.1	45.51
July 24	4.3	8.40	July 16	16.7	62.87
August 8	12.2	28.46	August2	20.1	81.12
August 22	10.2	23.32	August 16	9.9	70.76
September 6	4.8	64.02	September 3	8.1	87.03
CV%	22.6	21.10	CV%	11.70	23.30
$LSD_{0.05}$	3.93	8.29	$LSD_{0.05}$	3.41	25.85
$LSD_{0.01}$	1.59	11.79	$LSD_{0.05}$	4.85	36.76

Varietal resistance

Several researchers 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 the 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 reason for the variation in the level of resistance at the two locations was attributed to the difference in population density of the pest. Fields at Areka had been cultivated for only three years with sweet potato when the trial was conducted and the pest has not yet established itself. At Awassa sweet potato is repeatedly cultivated for more than a decade in the same field. Some of the varieties like Arba Minch I and II, which seemed to be resistant at Areka, were susceptible at Awassa. However, the low level of infestation at Areka could not be enough to label a variety was resistant or not. Tesfaye (2002) found all of the varieties he tested were damaged by the sweet potato weevil and there was no resistant variety. However, the varieties differed in the degree of damages and infestation levels they sustained. Varieties Koka 26 and Cemsa had the lowest level of infestation and adult weevil density in the field. On the other hand, varieties TIB-1102 and TIB-1-1102 had higher levels of tuber infestations. It is known that varieties with deeper roots suffer less from the attack of sweet potato weevils. The study also showed that Koka 26 and Cemsa had deeper roots than the other varieties considered (Addis and Tesfaye, 1995b).

Chemical control

Emana and Adhanom (1990) evaluated seven insecticides as dipping, foliar sprays and combination of both at Awassa and Areka during the 1987 and 1989 cropping seasons. Spraying began two months after planting and continued up to the fourth month at fortnightly interval. Of the seven insecticides, cypermethrin and pirimiphos-methyl gave best control of the sweet potato weevil which resulted in higher marketable yield (Table 13). In another study, dipping of sweet potato vines used for planting in diazinon 60% E.C improved the yield of sweet potato and reduced the level of weevil infestation (Tesfaye, 2002).

Table 13. Efficacy of insecticides in the control of sweet potato weevil (Emana and Adhanom, 1990).

Insecticide	Areka		Awassa	
	Infestation (%)	Marketable yield (t/ha)	Infestation (%)	Marketable yield (t/ha)
Carbaryl	29.94ab	7.9cd	46.3b	4.4a
Cypermethrin	23.94a	16.5a	36.6a	5.3a
Endosulfan	28.01ab	8.2d	44.48b	5.6.7a
Primiphos methyl	25.01a	13.4abc	32.46a	5.7a
Karate	33.01ab	8.4cd	50.67b	4.5ab
Deltamethrin	23.54ab	11.1bc	48.63b	4.4ab
Diazinon-dipping	28.56ab	6.8d	53.73b	4.7ab
Diazinon-dipping + spray	31.28ab	9.0cd	48.06b	3.8ab
Diazinon spray	31.61ab	6.6d	48.13b	3.6ab
Untreated check	41.13b	5.1d	53.14b	1.3ab

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of probability (DMRT).

Integrated management of sweet potato weevil

The integration of insecticides, early planting and earthling 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 (Messele *et al.*, 2005).

Sweet potato butterfly (*Acraea acerata*)

Sweet potato butterfly has become the most important insect pest of sweet potato in the southern parts of the country (Adhanom and Emana, 1987; Emana and Adhanom, 1989; Emana and Amanuel, 1992; Ejigu, 1995; Tesfaye, 1995; Azerefegne, 1999). It was first noted and reported in 1986 as an outbreak in Gamo Goffa Awraja. Since then it has spread over wide areas of southern Ethiopia (Table 14). It poses a very serious threat to the farmers whose daily diet depends on sweet potato. Complete crop failure is now very common in many areas of the region where sweet potato is intensively cultivated.

Table 14. Status of sweet potato butterfly in some localities of southern Ethiopia (after Emana and Amanuel, 1992).

Survey locations	Status of the pest in different seasons		
	1987	1990	1991
Damot Galle	unknown	major	major
Sodo Zuria	unknown	major	major
Areka	unknown	minor	major
Badessa	unknown	minor	major
Gasuba	unknown	unknown	minor
Selamber	minor	major	major
Sawla	major	major	major
Chanodorga	major	minor	absent
Zefine	minor	minor	absent
Wajifo	minor	absent	absent

Basic studies

Biology of the sweet potato butterfly

Azerefegne (1999) studied the biology of sweet potato butterfly in southern Ethiopia and found that the insect breeds throughout the year with about six discrete generations a year. Females lay their eggs in single layered batches of approximately 160 eggs on the underside of young as well as old sweet potato plants. Most eggs were found on the middle leaves along the vine. Larvae passed through five instars; the first three instars were found to feed gregariously whereas the last two instars dispersed and feed solitarily. Larval development was shorter in males than in females. Pupation took place on the foliage or on the ground. Pupation under clods of soil and in cracks was more frequent during the dry periods. The pupal stage lasted about seven days and adults emerged during the daytime, while mating occurred during afternoons. The adults lived for a short time with a maximum life span of nine days. In the laboratory, total development from egg to adult took 34 days. However, in the field both egg and larval developments were of longer durations resulting in a total development time of 40-50 days from egg to adult. Moreover, larval development was extended by 10 days during the rainy period compared with the dry periods. Adult butterflies are aposomatically coloured with orange and black. There is a less bright colour form which was frequent at all times of the year. Both male and female butterflies were found to feed on flowers of many plants such as *Bidens pilosa, Croton macrostachys, Tagetes minuta, Guizota scabra* and *Solanum tuberosum*.

Host plants of sweet potato butterfly

The association between the sweet potato butterfly and sweet potato is relatively new because sweet potato originated from or near north-western America (Austin, 1988). The plant was introduced to Africa about 500 years ago by European explorers (Yen, 1982). But the butterfly is indigenous to Ethiopia where it feeds on native plants. Larvae have been reported to feed on *I. tenuirostris* Choisy., *I. lilacina* Blume, *I. kentrocarpa* A. Rich., *I. wighiti* Choisy., and *Lepistimone owariense* Hall., all in the family Convolvulaceae (Lefévre, 1948; Matanmi and Hassan,1987; Smit, *et al*., 1997; Subukino, 1997). Claims that larval food plants include Poaceae, Cucuribitaceae and Solanaceae (Larsen, 1991) are suspect because larvae have never been observed feeding on any other species than *Ipomoea* even at times of high population density and food limitation in Ethiopia (Azerefegne, 1999). Larvae of the sweet potato butterfly develop not only on sweet potato but also on various wild *Ipomoea* species in Ethiopia. Larvae fed and developed successfully on two indigenous species, *I. cairica* and *I. tenuirostris*, whereas larvae refused to feed on the abundant indigenous *I. hochstetteri*. Introduced species, *I. indica* and *I. purpurea* were unsuitable for development; larvae refused to feed on the former species and had extremely low survival rates on the latter one. *I. batatas* was a better host plant than both *I. cairica* and *I. tenuirostris*; larvae survived well and pupae were larger and females contained high number of mature eggs resulting in more fecund female butterflies. However, there was no difference between larvae developed on *I. cairica* and *I. tenuirostris*. Nevertheless, in southern Ethiopia, wild populations of the insect were not found on *I. cairica* but only on *I. tenuirostris* and *I. obscura*, a plant on which larval performance was not tested (Azerefegne, 1999).

Natural enemies of sweet potato butterfly

The larva of the sweet potato butterfly is attacked by three parasitoid species viz *Glyptapanteles acraeae* (Wilkinson) (Braconidae), *Charops* species (Ichneumonidae), and *Carcelia* sp. (Tachinidae), and the pathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin (Moniliaceae), whereas pupae are parasitized by *Brachymeria albicrus* (Klug) (Chalcidoidea) (Azerefegne, 1999). *Charops* sp. was also reported from earlier studies (Emana and Adhanom, 1989;

IAR, 1988; 1989). The enemies generally seem to be of little importance in reducing high density host populations (Azerefegne, 2000). At low population levels, however, enemy effects sometimes increase, possibly causing longer and deeper population valleys. *Glyptapanteles acraeae* attacks the young host larva. The host is usually killed (87.8%) in the fourth instar. *Charops* sp. attacked during the second larval instar of the pest and emerged somewhat later than *G. acraeae*, mainly (82.9%) from the fifth instar host larvae. *Carcelia* sp. was found to attack older larvae than the two previously mentioned parasitoids. Some *Carcelia* sp. emerged from the last instar host larvae, but the majority (67.7%) emerged from host pupae. *Brachymeria albicrus* appeared to oviposite only in the pupa of the butterfly as it was never retrieved from rearing of field collected larvae. It also emerged from host pupae. Population densities of *G. acraeae* and *Charops* sp. were low during the entire study period. Mortalities caused by *G. acraeae* never exceeded 6% of young larvae, and *Charops* inflicted mortalities not more than 12% of old larvae (Azerefegne, 1999). Mortalities inflicted on the host population increased briefly when host population density was very low. No direct density dependent effects could be found for these two parasitoid species. *G. acraeae* even showed a weak inverse density dependent effect.

Butterfly larvae infected by the pathogenic fungus *Beauveria bassiana* usually died during the last two instars. The incidence of *B. bassiana* infections was low during most of the time. No density dependent effects of *Beauveria* could be discerned. The combined mortalities of *G. acraeae*, *Charops* sp. and *B. bassiana* did not show a significant density dependent response when regressed against log density of young larvae (Azerefegne, 2000). In a sample of 838 pupae collected over several days during a peak host population period of a generation, 4.1% were killed by emerging *B. albicrus* and 6.7% by *Carcelia* sp. (Azerefegne, 1999).

Generation and population fluctuation

The *A. acerata* population developed with discrete and easily discerned generations, so called generation cycles (Azerefegne, 1999). A total of 21 butterfly generations were observed during three and a half years (October 18, 1994 - April 23, 1998), which means about six generations per year (Fig. 14). There were large variations in population density between generations and years. Generation peaks were relatively high from late 1994 until August 1996 after which density decreased drastically and remained low for about one year.

Looking at generation totals (Fig. 15) the ranges of population fluctuations were over four orders of magnitude. The net reproductive rate usually varied within the range of 0.1-10 (Fig. 16). The population change was thus gradual and there were long periods (up to five generations) of either continuous growth or decline.

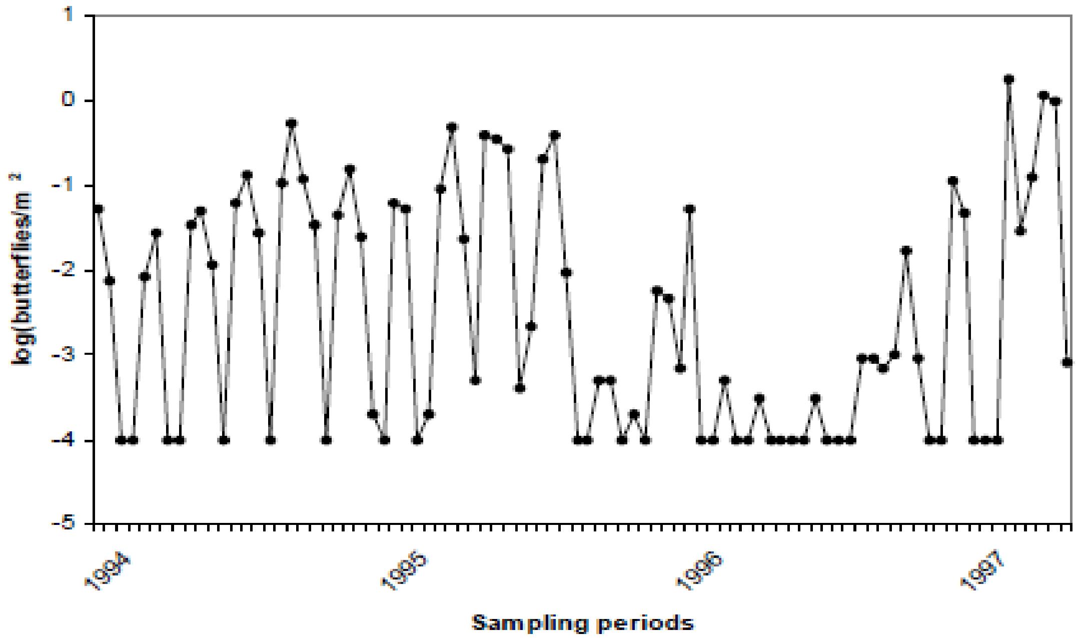


Fig. 14. Population fluctuation of *Acraea acerata* at 15 day interval from December 1994 to April 1998 (Azerefegne, 1999).

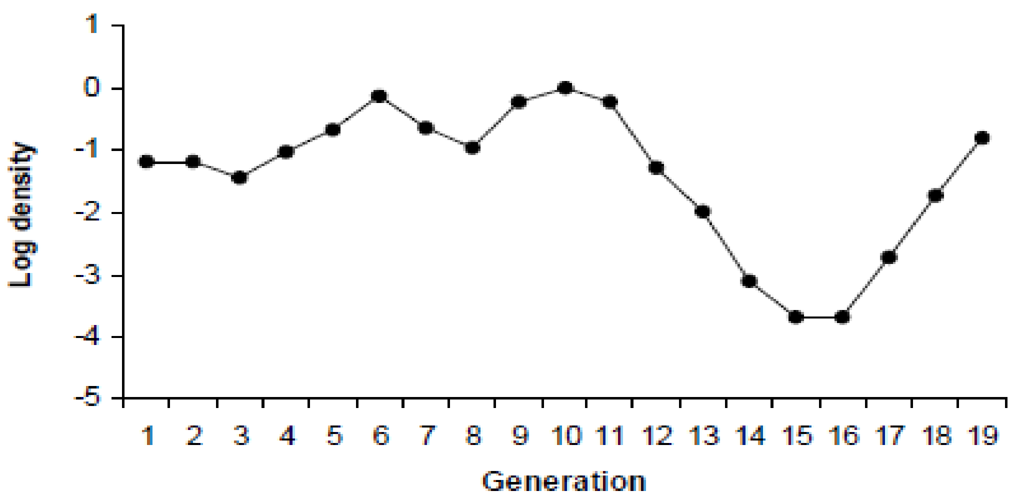


Fig. 15. Generation totals of *Acraea acerata* butterflies (Azerefegne, 2000).

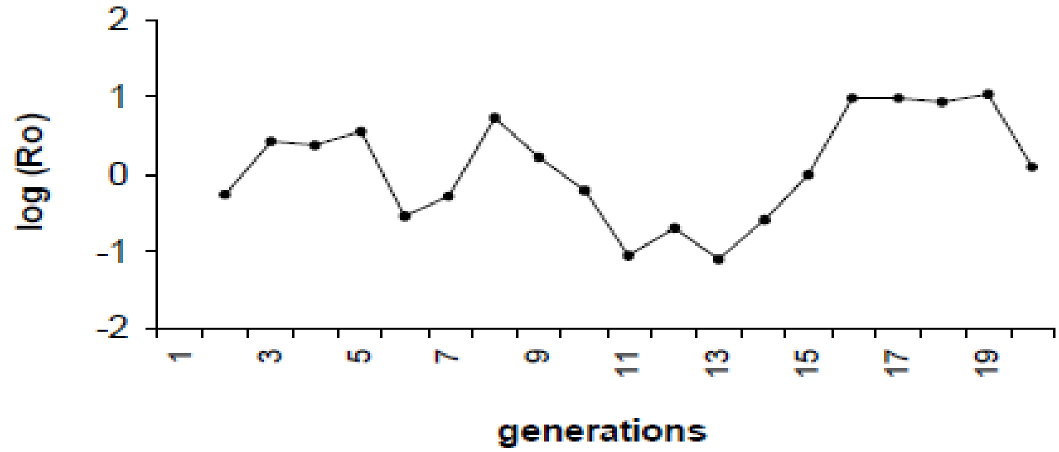


Fig. 16. The net reproductive rate of *Acraea acerata* (Azerefegne, 2000).

Extent of infestation and yield loss

Two peaks of larval density were observed during the five to six month cropping cycle representing two successive insect generations (Azerefegne, 1999). The insect population density varied between the three growing seasons studied. High densities were observed during the 1995/96 (Fig. 17a) and 1997/98 (Fig. 17c, d) cropping seasons, with 7-10 and 6-12 larval tents per square meter, respectively, in the first generation. The 1996/97 season had the lowest number of larvae when compared with the other seasons (< 0.1 larval tents/m^2 at any time) (Fig. 17b).

During the 1995/96 season larvae feeding caused considerable leaf damage as well as reduction in ground cover (Fig. 17a). The difference in the ground cover between the protected and unprotected plots reached a maximum of 28%. While the protected plots reached 100% ground coverage, the unprotected plots did not surpass 90%. About 80% of the leaves on the unprotected plots showed signs of sweet potato butterfly larvae feeding damage.

In the 1996/97 cropping season, there were very few larvae (Fig. 17b) and no differences in ground cover were observed between the sprayed and unsprayed plots. Unlike the other two periods studied, the 1996/97 cropping season was not favourable for growth of sweet potato because of a prolonged dry period. In consequence, complete coverage of the ground was never attained at any time during the growing period.

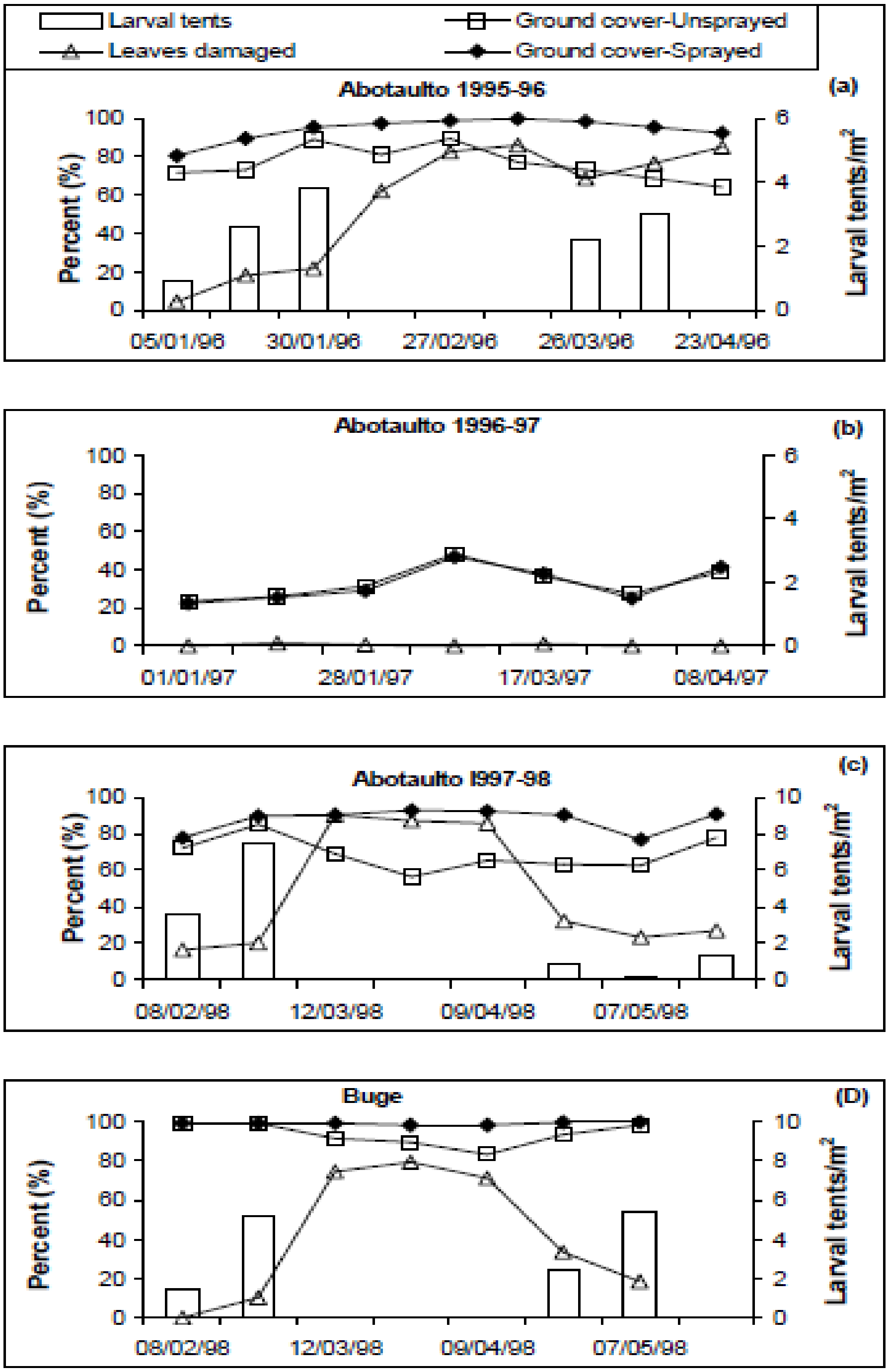


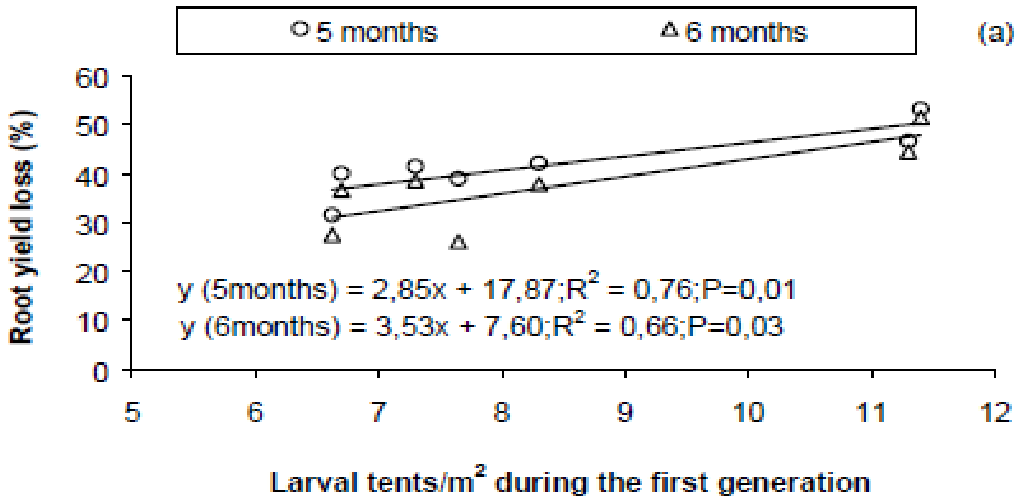
Fig. 17. *A. acerata* larvae density and damage on sweet potato.

In the 1997/98 season, reduction of the ground cover was observed on the unprotected plots compared with protected ones (Fig.17c, d). The reduction ranged from 14 to 53% at the different farms. The proportion of leaves infested ranged from 79-90%.

There was a considerable variation between seasons and locations in crop yield (Table 15). Yield ranges of 5-28 t/ha for five-month harvests and 8-35 t/ha for six month harvests were recorded from the different farms. In the 1995/96 and 1997/98 cropping seasons, the protected plots produced significantly more tuberous roots (Table 15). This significant difference was observed for both five and six month harvests. In the 1996/97, there was no infestation by the insect and thus there was no difference between the sprayed and unsprayed plots. The yield was lower than in the other years of the study due to drought.

Root yield loss of both early and late harvests was strongly correlated with the density of larvae during the first generation (Fig. 18a), explaining about 76 and 66% of the yield reduction in early and late harvests, respectively. The yield loss was not significantly correlated with total larvae density of both generations (Fig. 18b).

The estimated cost of spraying a hectare of land twice during the growing period (316 Eth. birr) showed that there should be a difference of 1.05 t/ha to make insecticide treatments economically profitable. The price of sweet potato at the nearest market was very low (30 birr/100 kg). Nevertheless, the use of insecticides was economically justifiable in all cases of high insect density. The profits ranged from 1119-2669 birr for early harvests and 1684-3126 birr for late harvests. The profit was higher for late harvests (Table 15).



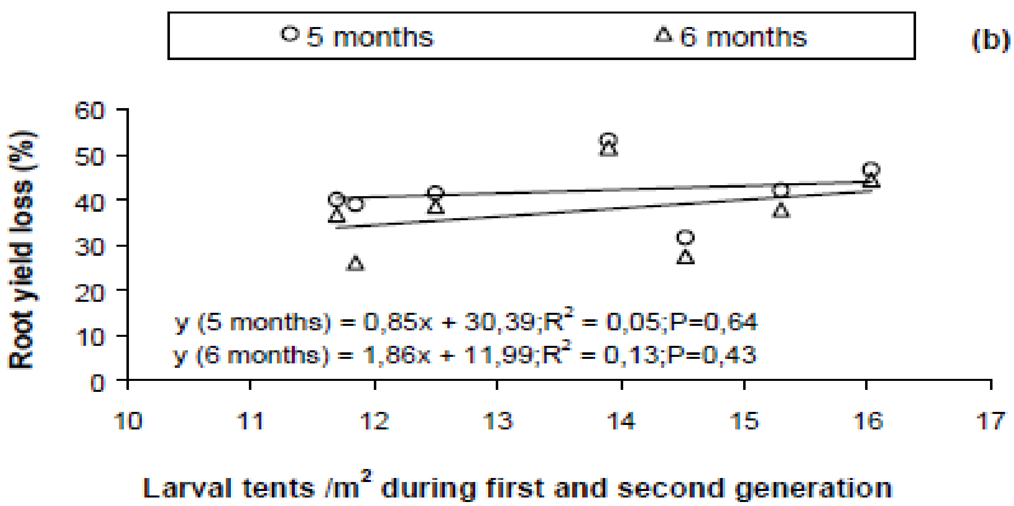


Fig. 18. Relationship between larval density of *Acraea acerata* during a) first generation and b) first and second generation, and tuberous root yield loss (Azerefegne, 1999).

Control of sweet potato butterfly

According to Ashebir (2006), more than 75% of the interviewed farmers in Wolaita did not use any control measure against the sweet potato butterfly, and less than 28% of the farmers applied control methods such as manure, wood ash, irrigation, mulching and a synthetic insecticide (malathion).

Table 15. Yield loss of sweet potato in farmers' fields caused by *A. acerata* (after Azerefegne, 1999).

Season	Location	Treatment	5 months			6 months		
			Tuberous root yield (t/ha)	Loss (%)	Profit (birr)	Tuberous yield (t/ha)	Loss (%)	Profit (birr)
1995-96	Abotaulto	unsprayed sprayed	16.86a 28.78b	41.4	2669	21.97a 35.74b	38.6	3126
1996-97	Abotaulto	unsprayed sprayed	7.61a 7.35a	-	-	9.03a 8.85a	-	-
1997-98	Abotaulto-I	unsprayed sprayed	5.21a 11.12b	53.2	1161	8.28a 17.09b	51.5	1885
	Buge	unsprayed sprayed	12.44a 18.18b	31.6	1119	17.60a 24.26b	27.5	1684

In comparison between sprayed and unsprayed treatments at each site means followed by same letter are not significantly different from each other.

Host plant resistance

Tesfaye (1995) tested six sweet potato cultivars for resistance in terms of preference of adults for oviposition, landing and visiting as well as the level of larval infestation. However, no variation was observed among the varieties evaluated.

Use of botanicals

Mesele et al. (2004) evaluated leaf and seed extracts of *Tephrosia vogelli*, *Datura stramonium*, *Mellia azadirachta*, *Chenopodium album* and *Milleitia ferrugenia*, and leaf of *Calusia abyssinica* and seed of *Azadirchta indica* for their insecticidal activity against the sweet potato butterfly larvae, and found that the botanicals showed differential insecticidal activity with respect to larval mortality and damage to sweet potato. *M. ferrugenia, T. vogelli* and *A. indica* out performed in killing sweet potato butterfly larvae and influenced larval leaf feeding compared to the other botanicals considered (Table 16). Farmers in Wolaita area try different botanicals to control the sweet potato butterfly. There are reports that they make water suspension of crushed fruits of *Solanum incanum* (Embuaye) and sisal leaves and sprinkle over the infested plants with water. However, detailed studies on the level of control are lacking (Ejigu, 1995).

In another study, the efficacy of *Milletia ferrugenia* seed powder aqueous suspensions was evaluated against the sweet potato butterfly larvae under the laboratory and field conditions (Azerefegne, 2006). Dipping tests conducted in the laboratory showed that *M. ferrugenia* can cause high level of mortality on the fourth and fifth instar larvae. Sprays of 5 and 10% of *M. ferrugenia* on the larvae under filed conditions caused more than 90% mortality and there were very few survivors. Survival of the larvae was higher at Sodo zuria where most of the larvae had entered the fifth instar. The result indicated that sprays should be timed at earlier instars of the insect.

Chemical control

Tesfaye (1995) reported that cypermethrin, carbaryl, deltamethrin, diazinon, endosulfan, lamdacyhalothrin and malathion gave satisfactory control when applied at the manufacturers' rates. Addis and Tesfaye (1995) also reported that pirimiphos-methyl, diazinon, carbaryl, deltamethrin and endosulfan were effective against the sweet potato butterfly.

Table 16. Effects of botanicals on percentage morality of sweet potato butterfly larvae and percentage leaf damage of sweet potato (after Mesele *et al.*, 2004).

Treatments	Part used	Days after treatment application (DAT)				Damaged leaves (%)
		1	5	10	15	
Tephrosia vogelli	seed	60bc(7.54)	26.7ab(4.48)	6.67b(1.98)	0a(0.71)	4.6 c (1.58)
T. vogelli	leaf	33.3cd(4.95)	46.7a(6.84)	13.3b(2.59	6.7a(1.98	1.5c(1.32)
Datura stramonium	seed	6.7 de(1.98)	6.7bc(1.98)	0b(0.71)	0a(0.71)	17.2b(4.21)
D. stramonium	leaf	13.3 e(3.72)	0c(0.71)	0b(0.71)	6.7a(1.98)	13.2b(3.82)
Calusia abysinica	leaf	13.3de(3.72)	6.7bc(1.98)	0b(0.71)	0a(0.71)	13.4b(3.71)
Azadrichta indica	seed	6.7 de(1.98)	26.7ab(5.21)	40a(6.22)	0a(0.71)	4.2c(2.16)
Mellia azadirach	leaf	0e(0.71)	20 bc(4.53)	6.7b(1.98)	0a(0.71)	12.4b(3.51)
Chenopodium album	leaf	6.7 de(1.98)	6.7bc(1.98)	6.7b(1.98)	0a(0.71)	16.8b(4.16)
Milletia ferrugenia	seed	80 ab(8.97)	20bc(4.53)	0b(0.71)	0a(0.71)	2.2c(1.52)
M. ferrugenia	leaf	66.7b(8.12)	6.7bc(1.98)	0b(0.71)	0a(0.71)	1.9c(1.45)
Endosulfan E.C	-	100a(10.02)	0c(0.71)	0b(0.71)	0a(0.71)	1.2c(1.16)
Untreated	-	0e(0.71)	0c(0.71)	0b(0.71)	0a(0.71)	26.6a(5.20)

Means followed by the same letter (s) within a column are not significantly different at ($P<0.05$)
Figures within brackets are square root transformed values.

Table 17. Efficacy of insecticides in the control of sweet potato butterfly.

Insecticide treatments	Rate (g a.i./ha)	Infestation (%)	Yield (t/ha)
Endosulfan 35% EC	700	29.68a	19.5
Deltamethrin 2.5% E.C.	12.5	30.80ab	14.6
Primiphos-methyl 50% E.C	500	32.60ab	13.7
Diazinon 60% E.C	1 (litre)	37.00abc	12.9
Carbaryl 25%WP	1500	35.00ab	12.5
Lambda cyhalothrin 5% E.C	12.5	37.00abc	11.3
Untreated check	-	44.40c	9.9
CV%		15.39	

Source: Tesfaye, 1995

Means followed by the same letter(s) within a column are not significantly different from each other at 5% (DMRT).

Insect pests attacking yam and cassava

There are a few records of insect pests on yam (Table 18). Scale insects are reported to cause heavy damage on cassava in Amaro area, southern Ethiopia. However, not much work has been done to date.

Table 18. Insect pests of yam recorded in Ethiopia (after Tsedeke, 1988).

Scientific name	Common name	Status
Homoptera		
Cicadellidae		
Empoasca barbistyla Paoli	Yam leaf hopper	unknown
Poecilocarda nigrinervis Stal	black stripped jassid	unknown
Margarodidae		
Icerya purchasi Maskell	Cottony cushion scale	unknown
Coleoptera		
Chrysomelidae		
Lilioceris livids (Dalman)	Yam beetle	unknown

Conclusion and recommendations

On potato PTM is the most important insect pest in the field and storage. Application of pyrethrum flower powder on stored tubers reduced the damage by PTM. The synthetic insecticide diazinon 60% EC effectively controlled the pest in the field.

Enset root mealybug can be controlled by use of free enset plants. It is important to teach farmers that the chief means of distribution is through planting materials. They should be advised to avoid seedlings coming from infested areas. Some farmers plant seedlings from highlands where infestation is expected to be low. Addition of farmyard manure supports enset plants to grow and develop better and withstand damage by the enset root mealybug, but will not completely eradicate it. Studies are going on on the use of hot water treatment to produce mealybug free planting materials. *M. ferruginea* seed-water suspensions is toxic to enset root mealybugs and caused about 66% mortality in pot experiments. However, one application of *Milletia* cannot satisfactorily control the insect. Two applications of *M. ferruginea* improved its efficacy and raised the level of mealybug mortality to about 79%. Combinations of dipping young enset seedlings and repeatedly drenching of the root zone of infested enset plants with the *Milletia* seed water suspension may be used as part of IPM for the enset root mealybug. The synthetic insecticides chlorpyrifos and diazinon are effective against enset root mealybugs when the root zone of infested enset is drenched with the suspensions of the insecticides.

In southern Ethiopia, sweet potato is grown year round and plots of different ages are always found in a farm. Sweet potato plots belonging to the same farmers or neighbours are located immediately next to the older plots or within 10 m distance, which create conducive conditions for the continuous infestation by the sweet potato weevil. Therefore, neighbouring infested sweet potato fields and leftover infested sweet potato tubers are the most important sources of infestation for newly planted sweet potato plots in the region. Good field sanitation and planting away from weevil-infested fields are the two practices expected to have noticeable effect on weevil management. Farmers of the region are not familiar with the life cycle and dispersal of the sweet potato weevil. They do not usually establish the link between the mobile adult weevil and larva. Therefore, acquainting farmers to the sweet potato weevil life cycle will help in the extension of cultural control methods. The carryover effect of the weevil from an infested crop to a new field can be reduced by careful selection of planting materials by taking the tip of the vine. Vine tip planting is recommended because it produces high yield, and it is likely to be free from prior infestation by the pest. Sweet potato planting at different times of the year encountered varying levels of infestations by the weevil. Therefore, planting at the appropriate time minimizes infestation. Generally, for sweet potato plantings of June to September, the main rainy season, early planting is advised. Those planted late need to be protected with insecticides. There are no resistant varieties for the sweet potato weevil. However, varieties differed in the degree of damage and infestation by the pest. For example, varieties Koka 26 and Cemsa which are characterised by deeper roots had the lowest level of infestations and adult weevil density in the field. Among the insecticides, cypermethrin, pirimiphos-methyl, and diazinon were found to be effective against the weevil.

To get better result farmers should integrate planting less susceptible varieties, use of vines free from infestation by dipping vines in insecticides or using the tip part only, early planting, earthling up three times starting from one month after planting, and insecticide spraying if the area experiences high level of infestations.

Among the botanicals tested, *M. ferrugenia, T. vogelli* and *A. indica* were found to be effective and can be used for the managment of the sweet potato butterfly. On the other hand, the insecticides cypermethrin, carbaryl, deltamethrin, diazinon, endosulfan, lambdacyhalothrin, malathion and pirimiphos-methyl gave satisfactory control when applied at the manufacturers' rates. These insecticides can be used during outbreak periods.

Gaps and challenges

The studies of root and tuber crop pests focused on very important few insects. Most of the studies did not continue for longer durations and similar types of non-detailed studies prevailed in most of the cases. Long term studies encompassing different generations and seasons are lacking. The status of pests of these crops is not known except for those which cause significant crop damage. Research on combination of control methods with the attempt to develop IPM is very few. In addition, economic feasibility of the control methods recommended is not well worked out and the infestation levels, which warrant the use of control measures, are not given. During the period between 1992 and 2003, research activities carried out on potato entomology were limited; comprehensive surveys of insect pests on potato were not conducted. For example, studies on species composition of aphids attacking potato, their distribution and transmission of virus diseases are scarce. From the limited number of studies conducted on potato it can be concluded that there was no new record of insect pests on potato. There are very few recommendations for the management of PTM.

The sweet potato weevil is relatively better studied among the tuber and root crop pests and effort has been made to develop management practices including use of appropriate varieties, insecticides, botanicals, and cultural practices. However, the studies on planting dates and insecticide evaluations are very repetitive. The study on the effect of planting period of sweet potato on the damage by the sweet potato weevil does not cover all the planting periods of sweet potato. Most of the studies compared planting dates conducted from July to October, However, farmers in southern Ethiopia plant sweet potato throughout the year if soil moisture is not limiting.

Sweet potato butterfly has been one of the pests which got research attention. The studies have shown that it can be controlled by some selected botanicals and insecticides. The temporal distribution of the insect is one of the areas which need investigation. Evaluations of insecticides and botanicals were conducted at high population density of the insect. The botanicals recommended are based on laboratory and small-scale field studies. The insecticide recommendations usually did not indicate the volume of spray and economic analyses are not included.

Studies on the enset root mealybug have just started. The effects of the pest on the growth and development of enset, the reaction of the various cultivars of enset to the mealybug; the natural enemies and the alternate hosts of the mealybug are not known.

Prospects

The insects listed as pests of root and tuber crops should be verified and additional data gathered on their distribution and extent of damage. Besides PTM, the red ants have become a consistent menace in the cool highlands of central Ethiopia calling for research attention. The focus of potato entomology should be in developing integrated management strategies to control PTM, the red ant and aphid species vectoring viruses. PTM research should look into the evaluation of new management techniques being used in other countries to give multiple options to users.

Work on sweet potato weevil need to concentrate on cultural practices such as avoidance of adjacent planting of successive sweet potatoes, selection of appropriate barrier crops and appropriate planting dates and practicing field sanitation. Moreover, mulching should be investigated to determine the amount, time and type of mulch materials in relation to weevil control and sweet potato yields. In addition, creating awareness among farmers on the life cycle of the insect and its dispersal is very important.

Techniques of protecting enset planting materials from enset root mealybugs in nurseries and regulating the distribution and exchange of planting materials should be devised. The enset root mealybugs are attended by ants. The association between the ants and the mealybugs, and the role played by ants on the population dynamics of the mealybugs need to be investigated. Emphasis should also be given to those affordable management techniques like cultural methods and use of botanicals.

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