Trends in Research on Arthropod Pests of Vegetables in Ethiopia

Gashawbeza Ayalew[1] and Ferdu Azerefegne[2]*
[1]Melkassa Agricultural Research Center, EIAR, P.O. Box 436, Adama, Ethiopia
[2]School of Plant and Horticultural Sciences, Hawassa University, Hawassa, Ethiopia
[*]Corresponding Author Email: azeref@gmail.com; Cell phone: +251 911876563

Abstract

Vegetables such as cabbage, pepper, onion, and tomato are widely cultivated and consumed in Ethiopia. They form an important part of the diet and play key roles in diversifying the economy of rural farmers and the agriculture sector in general. Several residents and invasive arthropod pests currently constitute the highest challenge in the production of vegetables in Ethiopia. Due to the absence of periodic surveys, the number of species associated with vegetables is not fully known. New introductions are usually recognized after heavy infestation occurred. A good example is the tomato leaf miner, *Tuta absoluta*, believed to be introduced in 2012. Earlier published works show the occurrence of over 25, 7, 22, and 25 arthropod species associated with, cabbage, onion, pepper, and tomato, respectively. According to Horizon scanning tools of CABI, 300, 72, 316, and 251species are mentioned as dangers to cabbage, onion, pepper and tomato, respectively, for Ethiopia. Of these 21, 11, 18, and 14, respectively are worked out to be quarantine pests for Ethiopia using EPPO global database, CABI distribution map, and literature search on published insect pests list of the four vegetable crops in Ethiopia. Several studies on ecology and management including cultural, biological, and chemical methods have been made on one or more key insect pests of the major vegetables produced. However, chemical control continues to be the most preferred and primary management tactic by producers. About three dozen of insecticides have been registered for the control of some key major arthropod pests on vegetables. However, a couple of insecticides appear to give good level of control. Misuse and abuses of insecticides have resulted in fast efficacy decline of insecticides. A good example is the diamide insecticide Coragen (Chlorantraniliprole) registered for the control of the tomato leaf miner (*Tuta absoluta*). The level of tomato fruit infestation in fields treated with Coragen was about 5% compared to up to 100% in the untreated when it was registered in 2013. Currently, the level of Tuta control achieved with the use of Coragen is nearly nil in most areas of the Central Rift valley (CRV) region probably because of the development of resistance. Similar trends in efficacy decline of the formerly effective insecticides like lambda cyhalothrin has been observed on onion thrips in the CRV region probably because of resistance development and or a mixed infestation of *Thrips tabaci* and *Frankliniella occidentalis*. The nonchemical control options developed for the control of some arthropod pests have not been utilized by the vegetable producers for several reasons. The only exception is the implementation of classical bio-control of Diamondback moth, *Plutella xylostella*, using the larval parasitoid *Diadegma semiclausum* (Hymenoptera: Ichneumonidae) in the cabbage production area of Kofele highland where pesticide use for pest control is minimal. Unavailability of the products in the market such as bio-pesticides and attractants can be mentioned as reasons for the non-adoption of the non-chemical control methods by the vegetable growers. Efforts are currently underway to reassess the efficacy of the registered insecticides against key insect pests of major crops to develop a pesticide resistance management program in the CRV. Initiatives also exist in demonstrating rational use of effective insecticides along with some nonchemical control approaches on farmers' fields in the CRV. Responding to pesticide-related problems in vegetable

production along with strengthening IPM deserves attention by all stakeholders. The paper also outlines future directions of vegetable pest management in Ethiopia.

Keywords: Biocontrol, Chemical control, IPM, Quarantine pests

Introduction

A large number of insect and mite species are found associated with a variety of vegetable crops cultivated in different agro-ecologies both in irrigated and rainfed production systems in Ethiopia. Tsedeke (1988) and Gashawbeza *et al.* (2009) provide lists of insect and mite species recorded on vegetable crops in Ethiopia. Although a large number of arthropod pest species are found associated with major vegetable species, only a few are economically important. New insect and mite species are being added yearly to this list into the country because of human movement with agricultural products among others. A good example is the recent introduction of the leaf-mining and fruit boring moth of tomato, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Newly introduced species often spread fast as they are introduced without their natural enemies from countries of their origin. The occurrence of a new invasive species is noticed in several countries with weak quarantine facilities after the damage is inflicted by the introduced pest. The absence of a periodically updated pest list has contributed to this problem. The Center for Agriculture and Bioscience International (CABI) has recently launched a tool called invasive species Horizon Scanning Tool, a decision support aid to help users identify potential invasive species threats to a country, state or province. This helps to identify dangerous pest species to a country anywhere in the world. A quarantine pest list can be developed by using this along with the European Plant Protection Organization (EPPO) global database, CABI distribution map, and literature search on published insect pests list of the target country and crop species (Table 1).

Table 1. Some examples of quarantine pests identified based on CABI Horizon scanning tool for major vegetables cultivated in Ethiopia.

No.	Cabbage	Tomato	Onion
1	*Adoretus sinicus Burmeister*	*Bactrocera aquilonis*	*Acrolepiopsis assectella*
2	*Aleurotrachelus trachoides*	*Bactrocera cucumis*	*Brachycerus albidentatus*
3	*Aleyrodes proletella*	*Bactrocera cucurbitae*	*Brachycerus muricatus*
4	*Cacoecimorpha pronubana*	*Bactrocera latifrons*	*Brachycerus undatus*
5	*Contarinia nasturtii*	*Epitrix tuberis*	*Cacoecimorpha pronubana*
6	*Delia floralis*	*Halyomorpha halys*	*Delia antiqua*
7	*Deroceras reticulatum*	*Helicoverpa zea*	*Liriomyza huidobrensis*
8	*Epitrix cucumeris*	*Heliothis virescens*	*Mamestra brassicae*
9	*Epitrix tuberis*	*Leptinotarsa decemlineata*	*Petrobia latens*
10	*Helicoverpa zea*	*Maconellicoccus hirsutus*	*Scirtothrips dorsalis*

Achievements

Basic/Ecological studies

Onion

Onion thrips (Thrips tabaci)

About 14 species of insects are known to be associated with onion in Ethiopia (source). Of these, the onion thrips, *Thrips tabaci* (Lindeman) has been the major insect pest wherever onion is cultivated in Ethiopia (Gashawbeza *et al*., 2009). Until recently, this species has been regarded as the only thrips species. However, recent studies confirmed the presence of the western flower thrips, *Frankelina occidentalis* together with *T. tabaci*. The presence of onion maggot (*Delia* spp.) and the beet armyworm (*Spodoptera exigua* Hubner) on onion fields in the CRV has been noted although the status and identity need confirmation. Earlier studies on population dynamics of *T. tabaci* showed variation in thrips number between months and seasons with their number peaking during the hot dry periods of February through April and falling during the rainy seasons of June to August (Tsedeke, 1995). A similar trend in population fluctuation of thrips was observed in studies conducted at Melkassa in central Ethiopia recently; their number was higher in plantings made in the hot dry month than in plantings made in the cold dry and wet months. Their number appeared to be influenced by temperature and rainfall (Belete, unpublished data).

Tomato

The tomato leaf miner (Tuta absoluta)

The tomato leaf miner is believed to be introduced into Ethiopia in 2012 although its presence was noted after the pest outbreak in tomato fields of CRV in early 2013 (Gashawbeza and Abiy, 2012). A survey was conducted on the geographic distribution of the pest in the north-western, central, and southern parts of Ethiopia between 2016 and 2017. Out of 11 fields sampled in north-western Ethiopia along the main roads of Gojjam to Northern Gondar of Sanja, it was observed from Andassa/Bahir Dar area only and from all fields sampled in central and southern Ethiopia as far as Arbaminch in 2016. In the following year, the pest was observed in all tomato fields of north western Ethiopia (Gashawbeza, unpublished). It now seems that the pest is wherever tomato is cultivated in the country. A seasonal abundance study carried out at MARC showed the population peaked during hotter months of April and May and lowered in the wet and dry cold months of July to December (Gashawbeza, unpublished).

Other fruit worms (Potato tuber moth, *Phthorimaea operculella*) and African boll worm, *Helicoverpa armigera*)

Before the arrival of *T. absoluta*, the potato tuber moth (PTM) and African bollworm (ABW) were the fruit worm species attacking tomatoes. Until the 1980s, ABW was the major fruit worm species both in irrigated and rain-fed conditions. Studies in the early 1990s showed the increased importance of PTM. Bayeh (2003) showed that the low level of α tomatin contents in some tomato genotypes especially the fresh market group and the provision of enemy-free space by the tomato plants were responsible for the shift in importance from ABW to PTM. Currently, the PTM seems displaced by *T. absoluta*. However, ABW is very common in several tomato fields all over the country.

Whiteflies (*Bemisia tabaci*) and red spider mites (*Teranychus* spp.)

Whiteflies (*B. tabaci*) and red spider mites (*Teranychus* spp.) are among the major arthropod pests of tomato in Ethiopia particularly in the CRV. However, research emphasis has been very low on these pests. Similar to most arthropod pests, their activity is high during the hotter months of February through June. High incidence of the tomato yellow leaf curl virus (TYLCV) transmitted by the whiteflies on tomato and its high incidence in hotter months had led to avoidance of planting tomato during this period by the upper awash agroindustry enterprise (UAAIE) about a decade ago. However, they are not currently as problematic as they were and year-round production is being made by the farm.

Cabbage

Diamondback moth (Plutella xylostella)

Intensive studies on the bio-ecology of the Diamondback moth including its biology, host suitability, geographic and spatial distribution were conducted in Ethiopia (Gashawbeza, 2003). The life table statistics showed that the head cabbage, *Brassica oleracea* var. capitata L., was the most suitable host for the pest with the shortest development period and the highest reproductive potential (Gashawbeza *et al.*, 2006a). A total of 194 fields of brassica were surveyed in 13 different areas of Ethiopia to assess the occurrence of the pest and indigenous parasitoids associated with it. Higher DBM numbers were associated with pesticide use and higher overall parasitism with intercropping. Eight parasitoid species were recorded of which three species namely *Oomyzus sokolowskii* (Hymenoptera: Eulophidae), *Diadegma* spp. (Hymenoptera: Ichneumonidae) and *Apanteles* spp (Hymenoptera: Braconidae) were important with overall parasitism ranging from 3.6 to 79.5% (Gashawbeza and Ogol, 2006). Studies on population dynamics showed the presence of two to three generations in highland area (Holeta) and three to five generations in the low land area (Melkassa). In the low land site, DBM number fluctuated between 0 and 3.2 insects per plant in December (cold-dry) planted field and between 0 and 8.5 insects in April (hot dry) planted field. In the high land site population fluctuated between 0–15.7 and 0 to 1.7 in December and April planted fields, respectively. Rainfall and maximum temperature significantly influenced DBM activity at the highland site (Gashawbeza *et al.*, 2006b). Studies on the spatial distribution of DBM showed that the pest was confined within its host field. DBM captures were influenced by geographic location and cropping system. In the highland area maximum temperature influenced the aggregation index positively and in the low land rainfall influenced the aggregation index negatively (Gashawbeza *et al.*, 2008).

Mealy cabbage aphid (Brevicoryne brassicae)

The mealy cabbage aphid is widely distributed pest of brassicas in Ethiopia and probably ranks second in importance following DBM (Gashawbeza, 2003). Little information is generated from Ethiopia on the biology and ecology of this pest so far. Field and greenhouse studies showed that *B. brassicae* had longer pre-reproductive, adult longevity, life span, and lower intrinsic rate of increase on *Brassica oleracae* than *B. carinata* (Mezgebe, 2019). Cabbage aphid populations were higher in Ziway, lowland production area, in all production seasons and years than Wetera Resu, highland production area. Higher parasitism rate of *Diaeretiella rapae* (82.7%) and predator population of syrphid larvae (5.4 larvae/leaf) and coccinellid beetle (4 beetles/leaf) were recorded at Ziway. Water stress affected the glucosinolate content of the plant and population density of the aphid. Higher population density of *B. brassicae* was recorded on water-stressed plants which had lower glucosinolate concentration. On the other hand, shorter pre-reproduction period, longer reproduction period and adult longevity were recorded on plants treated with a higher nitrogen rate (150%) (Mezgebe, 2019).

Pepper

African bollworm (ABW), aphids and termites had been regarded as major insect pests of pepper in Ethiopia (Tsedeke, 1995). Although the information on the status of these pests from studies made in recent years is lacking, their importance seems to get lesser. For example, the low level of ABW and aphids damage in the CRV made difficult to evaluate insecticides received for generating efficacy data for the purpose of registration and use against these pests on pepper. Ethiopian Pepper Mottle Virus (EPMV) (genus Potyvirus, family Potiviridae), is an important disease of pepper transmitted by aphids non-persistently. The population dynamics of aphids on pepper and their role in transmitting EPMV were studied in the Central Rift Valley of Ethiopia (Atsbeha *et al.*, 2009). The population density of aphids was higher at Ziway than Awassa. It was found that temperature had less influence than rainfall on seasonal flights and the population buildup of aphids at both locations. The incidences of EPMV were also highly correlated with the population buildup of aphids.

Management studies

Onion

Cultural control

Dejene (2006) assessed the effect of mulching on thrips infestation at MARC in 2004/05 and found that mulching onion plots with a white plastic sheet significantly ($P<0.05$) suppressed thrips population and consequently improved bulb yield compared to mulching with a black plastic sheet, tef straw and sawdust. Intercropping onion with other leafy vegetables such as cabbage and lettuce has been reported to significantly reduce thrips number and their damage and increased the activities of predatory thrips *Aeolothrips* spp. (Gebretsadkan *et al.*, 2018).

Botanical control

The potential of ethanol extracts of neem seeds (*Azadirachtha indica*) and pepper tree (*Schinus molle*) and leaves of bersema (*Bersema abyssinica*) in suppressing thrips attacking onion was reported from studies conducted in the mid-90s (Gashawbeza *et al.*, 2009). Similar studies made elsewhere also showed the potential of botanicals in reducing thrips infestation on onion (Gashawbeza *et al.*, 2009). However, onion growers are not using botanicals for thrips control similar to other crop pests in Ethiopia. This is despite efforts made to demonstrate the usefulness of botanicals in the integrated management of thrips on onion (Mohammed *et al.*, 2006).

Chemical control

Pyrethroid insecticides such as cypermethrin and lambdacyhalothrin had been used successfully for several years to reduce thrips damage in the 1980s. In the early 1990s, chemical control failure with the use of pyrethroid insecticides became a common phenomenon wherever they were used for thrips control. Several insecticides from different chemical classes have been screened for registration and use against the onion thrips in recent years. Following the failure of pyrethroid insecticides, the organophosphate insecticide profenofos available in the market with different trade names such as Selecron, Danefos, Girgit-plus, and Golbe have been used. Similarly, failure of profenofos has been observed on several onion fields (Belete *et al*., 2018). Recently registered insecticides namely spinosyn, spinetoram (Radiant), and the neonicotinoid imidacloprid (Fighter) are among the effective insecticides for the control of this pest (Gashawbeza, unpublished).

Tomato

Studies on the IPM of insect pests of tomato mainly fruit worms, African bollworm (*H. armigera*) and potato tuber moth (*P. operculella)* have been compiled by Tsedeke (1995) and Gashawbeza *et al.* (2009). Two fruit worm resistant tomato varieties, Serio (Melka Salasa) and RV 41 (Melka shola), were registered and released (Tsedeke and Gshawbeza, 1997). These are among the common open-pollinated tomato varieties (OPVs) in the production system although the trend of replacing OPVs with hybrids such as Gelile and Shanti is at an increasing rate particularly in the major tomato-producing belt of the central rift valley. The pyrethroids, cypermethrin and deltamethrin, were reported to be effective in reducing damage by the two fruit worms (Ferede, 1988). Other fruit worm management tools such as entomopathogenic bacteria, *Bacillus thuringiensis*, was found less effective compared with pyrethroids (Gashawbeza *et al*., 2009). Early fruiting was reported to be the most important developmental stage of tomato at which control measures should be applied against fruit worms to effectively reduce losses in quality and quantity (Gashawbeza and Lemma, 2004). Current research efforts on insect pests of tomato are focused on the IPM of the recently introduced leaf miner and fruit borer, *Tuta absoluta*. Studies on the management of whiteflies have also been initiated.

Tomato leaf miner (*Tuta absoluta*)

The presence of the tomato leaf miner in Ethiopia was first noted after a heavy incidence of leaf blotching leading to leaf drying was observed in the tomato field of the Ethio-vegfru farm located close to Koka in February 2013 (Gashawbeza and Abiy, 2012). Series of studies towards the IPM of *T. absoluta* have been conducted over the past few years which are highlighted under.

Chemical control

A variety of insecticides available in the market for controlling other vegetable insect and mite pests did not help in reducing the pest damage when the pest out broke in 2013. Hence, pesticides effective for the control of this pest in countries where this pest was established prior to its introduction were screened. These efforts led to the identification of insecticides that can give effective control. These include Coragen (common name Chlorantraniliprole), Ampligo (mixture of Chlorantraniliprole and Lambda-cyhalothrin) Radiant (common name spinetoram) and Tracer (common name spinosad) (Gashawbeza, 2015). More insecticides were screened in the latter years for registration and use against the pest and about a dozen are registered to date (MOAL, 2018). However, due to repeated application, pesticide resistance population particularly to the chlorantraniliprole insecticide has become common in several tomato fields in the CRV (Abiy, 2019). A pesticide resistance management program by the application of effective insecticides in rotation from different chemical classes is currently underway (Gashawbeza, unpublished).

Biopesticides

The effect of four different rates of *Bacillus thuringiensis* (Bt), (0.5, 1, 1.5, and 2 kg per ha and three application frequencies (7, 14, and 21 days interval) was compared with the registered insecticide Chlorantraniliprole 240 SC (Coragen ®) applied at 250 ml per ha biweekly against the pest. Results showed that plots treated with the highest rate of Bt (2 kg ha^{-1}) at 7 days interval suffered less damage and resulted in higher marketable yield than the rest of Bt treatment suggesting the potential of Bt in reducing the pest damage when applied at higher doses and more frequently (Etsegenet, 2015).

Pheromonal control

Pheromone is a species-specific control mechanism that can be used as a component of IPM. Owing to the pest's ability to develop resistance to pesticides, pheromonal control is a component in the IPM of the pest in several countries. For optimal utilization of pheromone, studies are being conducted at Melkassa Agricultural Research Center (MARC) of the Ethiopian Institute of Agricultural Research (EIAR) to determine the optimum position of traps and lure concentration. Keeping traps 30 cm above crop surface resulted in fewer catches than keeping them on the ground or crop surface. A half mg lure concentration was observed to be as efficient as a 0.8 mg lure in attracting male moths. On-farm demonstration of IPM by integrating judicious use of insecticides (application of effective and registered insecticides from different classes rotationally) and pheromone traps at a density of 20 to 40 traps per ha is being made in selected districts of the eastern Shoa zone in collaboration with SNV (Netherlands Development Organization).

Cabbage

Diamondback moth

Research activities conducted on the management of DBM at MARC have been reported at different times. These include studies on chemical control (Gashawbeza, 2006; Gashawbeza, 2011), botanical and microbial control (Gashawbeza, 2006; Lidet *et al*., 2009), and biological control (Gashawbeza and Hopkins, 2013).

Chemical control

The insect growth regulator Novaluron (Rimon) was found more effective than the pyrethroid lambda cyhalothrin and the organophosphate profenofos with minimal effect on the pest's natural enemies (parasitoids) (Gashawbeza, 2011).

Microbial and Botanical control

The effect of two serotypes of *Bacillus thuringiensis* (Bt), namely, kurstaki and aizawai and water extract of neem (*Azadirachta indica*) seeds at 25 and 50 g per liter of water were compared with the commercial neem formulation nimbecidine and the pyrethroid insecticide lambda cyhalothrin at Melkassa and Wonji in 2005 and 2006. Both the microbials and water extracted neem seeds resulted in less damage and higher marketable yield than nimbecidine and lambda cyhalothrin treatments (Lidet *et al*., 2009). Differences between the two serotypes as well as the doses of water extracted seeds were insignificant except for pest damage between the 25 and 50 g per liter of water rate where pest damage level was higher in 25 g per L water (Lidet *et al*., 2009).

Biological control

Gashawbeza and Ogol (2006) have given an account on the diversity and distribution of the species of parasitoids associated with the diamondback moth in Ethiopia. Their findings showed a low level of parasitism by the indigenous parasitoids in the major cabbage producing regions of the country including the Kofele highland in western Arsi and the need of importing effective parasitoids for classical biological control. Hence, the larval parasitoid *Diadegma semiclausum* (Hymenoptera: Ichneumonidae) was imported and released in head cabbage fields of Kofele highland in June 2008. Before release, DBM numbers fluctuated between 4.2 and 11.2 per plant and parasitism ranged between 6.5 and 24.7%. DBM density declined to 2.8, 0.9, and 0.7 per plant whilst parasitism levels increased successively to 21, 39, and 38% in 2008, 2009, and 2010, respectively (Figure 2). This decline of DBM density following the release of the introduced parasitoid and its establishment ensured the production of *Brassica* spp. without pesticide use against DBM in the affected area (Gashawbeza and Hopkins, 2013).

Mealy cabbage aphid

Chemical control

Quite a large number of insecticides are registered for the control of mealy cabbage aphid in Ethiopia. These include the pyrethroid insecticides deltamethrin and lambda cyhalothrin; the organophosphate malathion and dimethoate; and the sulfoxmines sulfoxaflor (MOAL, 2018). Lidet *et al.* (2008) evaluated the performance of lambda cyhalothrin with nimbecidine (commercial neem formulation) and untreated control at Melkassa and Wonji cabbage fields. Aphid infestation was lower and marketable yield was significantly higher in lambda cyhalothrin treated plots than both treatments.

Botanical control

Two doses of aqueous extracts of neem seed, 25 and 50 g per L of water, were compared with lambdacyhalothrin and an untreated check. The high rate (50 g per L) resulted in significantly lower aphid infestation and higher marketable yield than the low rate (25 g per L water) and the untreated check. It showed comparable performance with lambda cyhalothrin (Lidet *et al.*, 2008).

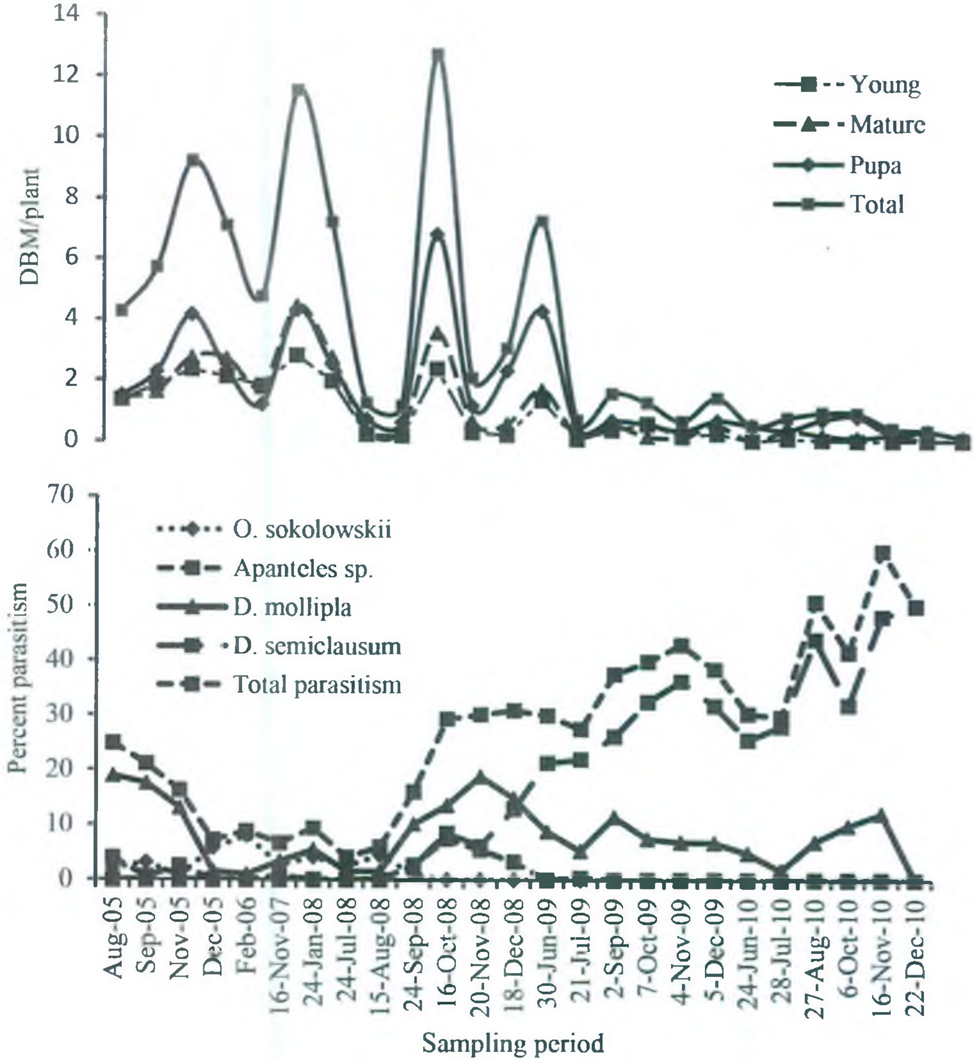

Figure 2. DBM number fluctuation and parasitism level before and after the release of the imported larval parasitoid, *Diadegma semiclausum* in June 2008 at Kofele highland (Gashawbeza and Hopkins, 2013).

On-farm Testing and Demonstration of IPM Technologies

A three years project was conducted between 1999 and 2001 by MARC in collaboration with the International Center of Insect Physiology and Ecology (ICIPE) to develop IPM options towards sustainable vegetable cultivation by small-scale vegetable growers in Wonji area close to MARC. The use of fruit worms resistant tomato variety 'Serio' along with the application of recommended insecticides at critical growth stages (early flowering once and early fruiting once) resulted in comparable performance with plots treated with pesticides frequently. Farmers realized the benefit of need-based application of pesticides through, the reduction of pesticide costs (Mohammed *et al.*, 2006). The potential of neem seed extract for reducing thrips infestation on onion and diamondback moth on cabbage was demonstrated. Farmers were made aware of the availability of non-chemical options of pest control and the benefit that can be obtained from the options demonstrated. Similar initiatives are being implemented by MARC in collaboration with SNV (the Netherlands development program) to extend available IPM technologies against the tomato leaf miner in Koka and Meki areas of CRV. These include the use of pheromone traps for mass trapping of adult moths, rational use of insecticides through rotational applications of registered insecticides from different classes and safe disposal of infested fruit aiming at reducing emerging moths by keeping infested fruit in a polythene bag under the sun for at least a week.

Future Prospects

The menace of arthropod pests on crops will continue. Well-coordinated and planned surveys on pests associated with the target crops are required to prioritize pest problems and give the required attention and response they deserve.

Some arthropod pests such as spider mites and whiteflies have become serious pests of tomato produced in hot-dry months between February and June in the CRV. However, detailed studies on different aspects of these pests have been scanty and limited to screening of pesticides for registration and chemical control. Hence, series of basic and management studies towards developing an IPM program are required.

Basic studies on the biology and ecology of key pests are required to develop an IPM program for prioritized key pests.

Too much emphasis on pest management research has been given for pesticide screening. Indeed, some researchers are devoting most of their time generating efficacy data for registration purposes. Research on the non-chemical options including host plant resistance, biological and cultural control should be made to develop an IPM program for the key pests.

Although research results are available for managing a number of key insect pests of crops produced in dryland and irrigated production areas of the country, efforts to create demand for such technologies such as through on-farm demonstration have been very low. The recent initiative on testing and demonstrating IPM against major pests of vegetable crops in the CRV should be strengthened. The required attention should be given to improve the human power and research facilities.

Acknowledgements

Mr Teklu Bayisa, Adama Center Plant Quarantine Head, Ministry of Agriculture, is duly acknowledged for providing information on quarantine pests of Ethiopia.

References

Abiy F. 2019. Studies on insecticide use, occurrence of insecticide resistance and resistance management in the tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Central Rift Valley (CRV) of Ethiopia. MSc Thesis. Hawassa University, Ethiopia.

Atsebeha S, Alemu T, Azerefgne F, Addis T. 2009. Population dynamics of aphids and incidence of Ethiopian Pepper Mottle Virus in the Central Rift Valley of Ethiopia. *Crop Protection*, 28: 443–448.

Bayeh M. 2003. Tritrophic level interactions in Ethiopian tomato systems: effect of plants on potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepid.: Gelechidae) and its parasitoids. PhD Dissertation. The Hebrew University of Jerusalem, Rehovot, Israel. Pp. 103.

Belete N, Ferdu A, Gashawbeza A. 2018. Field evaluation of commonly used synthetic insecticides against thrips (Thysanoptera: Thripidae) on onion in the Central Rift Valley of Ethiopia. *Pest Management Journal of Ethiopia*, 21: 23–34.

Dejene T. 2006. Assessment of species composition of thrips on onion and their management using mulching. MSc Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia. Pp. 66.

Etsegenet H. 2015. Efficacy of *Bacillus* thuringiensis and determination of its rate and frequency of application against South American tomato moth (*Tuta absoluta* Meyrick) (Lepidoptera: Gelechiidae) at Melkassa, Ethiopia. MSc Thesis. Haramaya University, Ethiopia.

Ferede N. 1988. Insecticidal control of fruit worms on tomato. Pp. 22–30. In: Proceedings of the 8th annual meeting of the committee of Ethiopian Entomologists (CEE), CEE, Addis Ababa.

Gashawbeza A. 2015. Efficacy of selected insecticides against the South American Tomato Moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) on tomato in the Central Rift valley of Ethiopia. *African Entomology*, 23(2): 410–417.

Gashawbeza A. 2011. Effect of the insect growth regulator novaluron on diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), and its indigenous parasitoids *Crop Protection*, 30: 1087–1090.

Gashawbeza A. 2006. Comparison of yield loss on cabbage from diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) using two insecticides. *Crop Protection*, 25: 915–919.

Gashawbeza A. 2003 Population Ecology of Diamondback moth, *Plutella xylostella* L. (Lep.: Plutellidae) and its parasitoids in Ethiopia. PhD Thesis. Kenyatta University, Nairobi. Pp. 163.

Gashawbeza A, Hopkins R. 2013. Selecting the right parasitoid for the environment in classical biological control programmes: The case of *Diadegma semiclausum* (Hymenoptera: Ichneumonidae) and *Plutella xylostella* (Lepidoptera: Plutellidae) in the Kofele highland of Ethiopia. *Biocontrol Science and Technology*, 23: 1284–1295.

Gashawbeza A, Abiy F. 2012. Occurrence of a new leaf mining and fruit boring moth of tomato, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Ethiopia. *Pest management Journal of Ethiopia*, 16: 57–61.

Gashawbeza A, Bayeh M, Mulugeta N, Yeshitela M, Lidet S, Ahmed I, Tadele T. 2009. Progress in vegetable arthropod insect and mite pest management research between 1985 and 2005. Pp. 47–67. In: Abraham T (ed.), *Increasing Crop Production through Improved Plant Protection, Volume II*. Plant Protection Society of Ethiopia (PPSE). PPSE and EIAR, Addis Ababa Ethiopia.

Gashawbeza A, Sciarretta A, Baumgärtner J, Ogol CKPO, Löhr B. 2008. Spatial distribution of diamondback moth, *Plutella xylostella* L., (Lepidoptera: Plutellidae), at the field and the regional level in Ethiopia. *International Journal of Pest Management*, 54: 31–38.

Gashawbeza A, Ogol CKPO. 2006. Occurrence of the Diamondback moth, *Plutella xylostella* L. and its parasitoids in Ethiopia: Influence of geographical region and agronomic traits. *Journal of Applied Entomology*, 130: 343–348.

Gashawbeza A, Löhr B, Ogol CKPO, Baumgärtner J. 2006a. Suitability of cultivated and wild crucifers for the development of diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae). *Journal of Entomology*, 3: 82–88.

Gashawbeza A, Baumgärtner J, Ogol CKPO, Löhr B. 2006b. Analysis of population dynamics of diamondback moth, (*Plutella xylostella* (L.): (Lepidoptera: Plutellidae) at two sites in central Ethiopia, with particular reference to parasitism. *Biocontrol Science and Technology*, 16: 607–618.

Gebretsadkan Z, Mulatu W, Gashawbeza A. 2018. Role of intercropping on predatory thrips (*Aeolothrips* Spp.) for the management of onion Thrips (*Thrips tabaci* Lind) in Central Zone of Tigray, Ethiopia. *Journal of Science and Sustainable Development*, 6(1): 25–33.

Lidet S, Gashawbeza A, Tadele T. 2008. Effect of neem based insecticides on cabbage aphid (*Brevicoryne brassicae*) and its predator in the central rift valley of Ethiopia. *Pest Management Journal of Ethiopia*, 12:59–66.

Lidet S, Gashawbeza A, Tadele T. 2009. Effect of *Bacillus thuringiensis*, neem and karate on Diamondback moth, *Plutella xylostella* L. damage on head cabbage in the central rift valley of Ethiopia. *East African Journal of sciences*, 3:102–107.

Mezgebe A. 2019. Effect of environmental factors and host plant quality on cabbage aphid (B*revicoryne brassicae* L, Hemiptera: Aphididae) performance. PhD Dissertation. Hawassa University, Ethiopia. Pp. 148.

MOAL. 2018. List of pesticide registered as of March 2018, MOA, Addis Ababa, Ethiopia.

Mohmmed Y, Dessalegne L, Ayalew G, Deressa A, Bekele A, Sitotaw L, Sahele G, Sithanantham S. 2006. Farmers' awareness Building on IPM options of major vegetable pests in Central Rift Valley Region of Ethiopia. Pp. 46–52. In: Bekele E, Azerefegne, F, Abate T. (eds.), *Facilitating the implementation and adoption of IPM in Ethiopia*. Proceedings of a planning workshop, 13–15 October 2003, ASAI/EARO, Nazareth, Ethiopia.

Tsedeke A. 1995a. Pest management in horticulture crops: Progress and prospectus. Pp. 165–173. In: 25 years of research experience in lowland crops. Proceeding of 25th anniversary of Nazareth Research Centre, 22–28 September, 1985, Melkassa, Ethiopia.

Tsedeke A. 1988. Insect and mite pests of horticultural and miscellaneous plants in Ethiopia. Handbook. Addis Ababa, Ethiopia. Pp. 115.

Tsedeke A, Gashawbeza A. 1997. Sources of Resistance in tomato against Fruit worms. *Pest Management Journal of Ethiopia*, 1: 1–7.