Insecticide Use Practice and Occurrence of Insecticide Resistance in Tomato Leaf Miner in the Central Rift Valley

Abiy Fekadu[1], Ferdu Azerefegne[2], and Gashawbeza Ayalew[1]
[1]Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center, POB 436, Adama, Ethiopia. E-mail: abiyfekadu13@gmail.com; [2] Hawassa University, College of Agriculture, Department of Plant and Horticultural Science, POB 770, Hawassa, Ethiopia

Abstract

The tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a major insect pest of tomato in the Central Rift Valley (CRV) areas of Ethiopia. Tomato growers complain on the decline in efficacy of the insecticide registered for its control after the detection of the pest in the CRV in 2013. This decline in efficacy of the registered insecticides was hypothesized to be due to insecticide resistance development. Studies were conducted to understand the pesticide use practices against *T. absoluta* and to assess the occurrence of resistance in *T. absoluta* population. A survey in two kebeles each of five districts namely Lumme, Bora, Dugda and Adamitulu jido kombolcha of East Shewa zone and Hawassa Zuriya district of Sidama zone was conducted in April, 2017. A total of 44 farmers were interviewed using a structured questionnaire and information was gathered on different aspects of insecticide use. A leaf dip bioassay method was used to assess the occurrence of insecticide resistance using strains of *T. absoluta* collected from Hawassa, Meki, Awash Melkassa and Ziway areas. Bioassays were performed using insecticides from three classes namely Coragen 200 SC (chlorantraniliprole), Belt 480 SC (flubendiamide) and Radiant 120 SC (spinetoram) in six dilution rates including the recommended rate. Descriptive statistics were used to summarize the survey data. The bioassay data were analyzed using a probit model. Survey results showed that pesticides were generally applied at a higher rate and more frequently than recommended. The level of resistance to the three insecticides was observed to vary with the strains of *T. absoluta*. The level of resistance for chlorantraniliprole and flubediamide was higher than for Spinetoram. The LC_{50} values of all strains were far higher than the field rate for all the insecticides tested. Pesticide misuse and abuse were observed to be a common phenomenon in the study area. Higher LC_{50} values than the recommended field rates and higher resistance ratios suggest that the *T. absoluta* population in Ethiopia has developed resistance to the insecticides registered for its control. Efforts should be made in developing an Insecticide Resistance Management (IRM) strategy for effective and sustainable resistance management in the chemical control of *T. absoluta*.

Keywords: Pesticide use, insecticide resistance, chlorantraniliprole, flubendiamide, spinetoram

Pest Mgt. J. Eth. 23: 1–18 (2020)
https://doi.org/10.20372/pmjoe.2020.v23.n1.a1

Introduction

In Ethiopia, vegetable crop production has increased through the years in area coverage and amount of produce. Tomato, which is a very important vegetable crop in the country, ranks fifth in terms of area coverage and production [Central Statistical Agency (CSA), 2021]. Tomato production and productivity is highly constrained by both abiotic and biotic factors. The polyphagous insect pest, African bollworm (*Helicoverpa armigera*) in warm and wet environments and the oligophagous, potato tuber moth (*Phthorimaea operculella*) in hot and dry environments were reportedly the most commonly encountered and economical arthropod pests of tomato in Ethiopia (Tsedeke and Gashawbeza, 1997). The tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera, Gelechiidae) detected in the Central Rift Valley Region (CRV) of Ethiopia in early 2013, has become one of the major arthropod pests of tomato in Ethiopia (Gashawbeza, 2015).

The tomato leaf miner is a serious pest of both outdoor and greenhouse tomatoes. It is originated in South America, and reported since the early 1980s from Argentina, Brazil and Bolivia (Mohamed and Lobna, 2012). It has become the major insect pest of tomato throughout the Mediterranean basin since its first occurrence in 2006-2007 in Spain (Roditakis *et al*., 2013). Several management methods were recommended and are being used against *T. absoluta*. Among these, chemical control using synthetic insecticides has been considered the main method to manage the insect (Haddi, 2011). In Ethiopia, following its occurrence, insecticides from diamide and spinosyns classes were registered for chemical control of the pest (Gashawbeza, 2015).

Insecticide resistance development has been a major problem in chemical control of *T. absoluta* (Haddi, 2011). Several cases of insecticide resistance development in *T. absoluta* population were reported from different parts of the world (Melis *et al*., 2015). Therefore, to avoid the selection of resistant biotypes, a systematic utilization of insecticides with frequent changes of active ingredients is desirable (Mohamed and Lobna, 2012).

A decline in efficacy of some of the registered insecticides for the control of *T. absoluta* in Ethiopia is being reported from tomato growing areas in the central rift valley (CRV) which could be an insecticide resistance problem (first author observation). Therefore, knowledge of insecticide use practices for the control of *T. absoluta* and the presence of insecticide resistance in *T. absoluta* population is useful for judicious use of insecticides and insecticide resistance management.

Materials and Methods

Survey on insecticide use practices

The survey was carried out in selected vegetable growing districts of the CRV of Ethiopia in April 2017 (Fig. 1). Districts included in the survey were selected based on the results obtained from a former study on the occurrence and associated natural enemies of *T. absoluta* in tomato and other solanaceous crops conducted by the Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center in 2016 (unpublished data). A total of five districts along the main road from Modjo to Hawassa, were considered. The districts were Lumme, Bora, Dugda, and Adamitulu Jido Kombolcha from the East Shoa zone and Hawassa Zuriya from Sidama zone. Two kebeles from a district known for growing tomato and five farmers from each kebele who cultivated tomato for one or more years in the previous five years were selected for the interview. Limited numbers of tomato growers with required years of tomato growing experience were found in selected kebeles of Hawassa Zuriya district of Sidama zone, and as a result, only four farmers who met the requirements were interviewed. Thus, a total of 44 farmers were interviewed during the survey. Kebeles and farmers were sampled purposively based on a set of criteria and information provided by agricultural experts and development agents (DAs) at the district bureau of agriculture in each district.

Inquiries on the type and class of insecticides commonly used for *T. absoluta* control, application rate and frequency, methods of pesticide application, farmers’ assessment of the efficacy of insecticides, perception of side effects of pesticides and knowledge and use of other non-chemical control methods, source of pesticides and other related issues were presented to selected farmers using a structured questionnaire and responses were recorded.

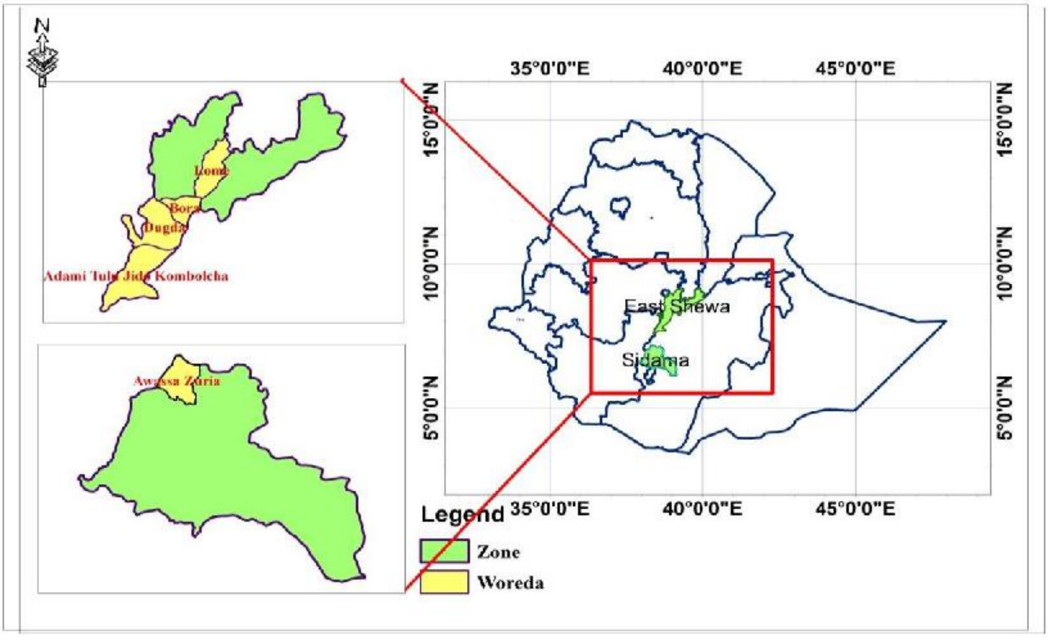

Figure 1. Map of survey locations for pesticide use practices against *Tuta absoluta* in CRV of Ethiopia, 2017

The sensitivity bioassay

The bioassay was carried out in the entomology laboratory of Melkassa Agricultural Research Center (MARC) between July and August 2017.

Insect collection and rearing

Tuta absoluta larvae were collected from infested tomato fields in four localities of the CRV of Ethiopia (Table 1). Tomato fields with variable insecticide use practices for *T. absoluta* control were considered for collecting the insect. Leaves with larvae (third and fourth instar) were brought to the laboratory using plastic cages and reared separately (for respective fields/localities) to obtain F1 generation for the subsequent bioassay test. Larvae were fed on tomato leaves during rearing. Pupae were then collected separately (i.e. for each location) and placed inside rearing cages containing potted tomato seedlings of the variety Gelilema for laying eggs by emerged adults.

Table 1. Locations considered for *T. absoluta* larvae (strains) collection

Name of the location/ locality	Geographic position		Region/ Zone/ district
	Latitude	Longitude	
Awash Melkassa/ MARC	8.2^0 N	39.4^0 E	Oromiya/ East Shoa/ Adama
Shubi Gemo/ Meki	8.0^0 N	38.5^0 E	Oromiya/ East Shoa/ Dugda
Eddo Gojola/ Ziway	7.5^0 N	38.4^0 E	Oromiya/ East Shoa/ Adamitulu Jido Kombolcha
Loke/ Hawassa	7.0^0 N	38.2^0 E	SNNP/ Sidama/ Hawassa Zuriya

Insecticides

Three insecticides from two different chemical classes (mode of action group) were used; the insecticides chlorantraniliprole and flubendiamide from diamide class and spinetoram from spinosyn class. Six dilution rates including label recommended rates were considered for each test insecticide (Table 2). Insecticide dilutions were based on active ingredient content (g or ml a.i.).

Table 2. Treatment details of the insecticide bioassay experiment

Trade name	Common name (active ingredient)	Dilution rates (a.i. / ha)		
		Lower rates*	Recommended rate	Higher rates*
Coragen 200 SC	chlorantranliprole 200 g/L	25g, 37.5g	50g	75g, 87.5g, 100g
Belt 480 SC	flubendiamide	28.8ml, 43.2ml	57.6ml	86.4ml, 100.8ml, 115.2ml
Radiant 120 SC	spinetoram	7.8ml, 11.7ml	15.6ml	23.4ml, 27.3ml, 31.2ml

* = All the lower and higher rates of dilution (in a.i./ha basis) were calculated considering a 25 and 50 percent decrease and a 50, 75 and 100 percent increase in the a.i./ha from the label recommended rates respectively.

Bioassay

The bioassay was conducted according to Insecticide Resistance Action Committee (IRAC) susceptibility test method series, version 3 method number 022. The method is a leaf-dip bioassay to be performed preferably on F1 second instar (L2) larvae (IRAC, 2012). The method has been validated by several researchers in South America and Europe (Haddi, 2011). Sufficient quantity of non-infested and untreated tomato leaves (tender and young) that are uniform in size were collected from open field tomato plants.

Leaflets were then individually dipped in the test liquids for three seconds with gentle agitation. The leaflets were air dried with their upper surface facing skyward. Since the standard bioassay cell unit specified in the method was not available in the country, 90 mm diameter Petri dishes were used for the bioassay. The bottom of each petri dish was covered with slightly moistened filter paper to keep the treated leaflets turgid throughout the bioassay period.

Second instar larvae (4-5mm length) were transferred to the Petri dishes using a fine soft brush and incubated at 25 ± 2°C and 60-70% RH. Ten Petri dishes each with single leaflet and one larva inside were assigned for each dilution rate of the test insecticides and corresponding strains. Similarly, ten Petri dishes with untreated leaflets and a larva inside were included as a control (untreated check) for each test insecticide and respective strain. The bioassay was arranged in three replications.

Performance evaluation was made after 72 hours of exposure. The numbers of live and dead larvae were recorded. Percent mortality was determined using Abbott’s formula (Abbott, 1925) for corrected mortality. The mortality data were used to perform a Probit analysis and plotted along with concentrations on a logit scale for dose-response analysis to provide LC_{50} and LC_{90} estimates for each insecticide and insect population tested and also for calculating the regression line and the slope. The most susceptible strain and recommended field rates were used to make comparisons and compute resistance ratios. A strain with a lower LC_{50} value was assumed as susceptible strain since there is no known standard susceptible strain available for the insect in the country (Haddi, 2011; Melis et al., 2015).

$$\text{Corrected mortality}= \left(1- \frac{\text{n in T after treatment}}{\text{n in Co after treatment}}\right) \times 100$$

Where n in T = Population in the treated plot after treatment; n in Co = Population in control after treatment

Data analysis

Survey on insecticide use practices

Analysis of the survey data was done using the SAS system version 9.0 and descriptive statistics was used to summarize responses given by respondents. Similarly, the Probit analysis was done using the SAS system version 9.0.

Results and Discussion

Survey on insecticide use practices

Preference, purchase and type of insecticides used

Farmers decided on the type of insecticides to purchase for controlling the pest based on the information they got from their neighbors (farmer-to-farmer communication), pesticide retailers, researchers/agricultural professionals and pesticide companies. The information from neighbors accounted for 59% followed by pesticide retailers (34%). The percentage of respondents who used information from researchers/agricultural professionals and pesticide companies was very small (Table 3). Belay *et al.* (2015) reported that farmers hardly relied on information and recommendations from extension agents and/or experts to select and use pesticides.

Eighty-six percent of the respondents purchased insecticides from pesticide retailers and the remaining respondents were from local cooperatives, companies' branches, and other farmers (Table 3). Studies by Belay *et al.* (2015) and Tebkew and Getachew (2015) showed that vegetable growers in the CRV of Ethiopia are largely dependent on the local pesticide retailers, some of which are uncertified and unlicensed for the supply of pesticides.

Table 3. Responses of tomato growers on issues related with purchase of pesticides for pest control

Points raised on purchase of pesticides	Percent respondents (n=44)
Sources of information on the choice of pesticides for purchase	
Neighbors (farmer to farmer communication)	59%
Pesticide retailers	34%
Researchers/agricultural professionals	5%
Pesticide companies	2%
Sources of pesticides for purchase	
Pesticide retailers	86%
Local cooperatives	7%
Companies' branch	5%
Other farmers	2%

A total of nine insecticides were recorded in use for *T. absoluta* control by tomato growers in the surveyed area (Table 4). The insecticides belonged to four insecticide classes (3 Pyrroles, 2 Diamides, 1 Oxadiazine, and 2 Spinosyns) and one mixture (Diamides + Pyrethroids). The majority (55%) of the respondents used insecticides from all classes of insecticides mentioned above, whereas 30% and 15% of the respondents used insecticides from a mixture of diamides and spinosyns; and diamides, respectively.

Table 4. Insecticides used by tomato growers for *T. absoluta* control in CRV of Ethiopia, 2017

No.	Trade name	Common name / active ingredient	Chemical group / class	Approved use *
1	Ampligo 150 ZC	chlorantraniliprole + lambda-cyhalothrin	Diamides + Pyrethroids	For the control of tomato leaf miner and fruit borer (*T. absoluta*) on tomato
2	Avaunt 150 SC	indoxacarb	Oxadiazine	For the control of stalk borer on maize, sweet potato butterfly on sweet potato, caterpillars on flowers and African boll worm on cotton
3	Belt SC 480	flubendiamide	Diamides	For the control of tomato leaf miner and fruit borer (*T. absoluta*) on tomato
4	Best field 360 SC**	chlorfenapyr	Pyrroles	For the control of onion thrips (*Thrips tabaci*) on onion and *T. absoluta* on tomato
5	Coragen 200 SC	chlorantraniliprole	Diamides	For the control of African bollworm (*H. armigera*) on cotton and *Tuta absoluta* on tomato
6	Radiant 120 SC	spinetoram	Spinosyns	For the control of onion thrips (*T/ tabaci*) on onion and *T. absoluta* on tomato
7	Secure 24% SC	chlorfenapyr	Pyrroles	For the control of tomato leaf miner and fruit borer (*T. absoluta*) on tomato
8	Tracer 480 SC	spinosad	Spinosyns	For the control of thrips and leaf miners on flowers, African bollworm on cotton and *T. absoluta* on tomato
9	Tutan***	chlorfenapyr	Pyrroles	For the control of African boll worm on cotton

*Source, MOANR (Ministry of Agriculture and Natural Resources) pesticide registration list (August, 2016)
**Not registered until October, 2017 (MOANR pesticide registration list)
***Not registered until May, 2018 (MOANR pesticide registration list)

Among the insecticides used by the respondents to control *T. absoluta*, insecticides from the diamide class had been used most frequently (43%) followed by insecticides from both diamide and spinosyn classes (32%) (Fig. 2). Seventy-three percent of the respondents used these insecticides for more than two years, 23% for two years, and 5% for one year.

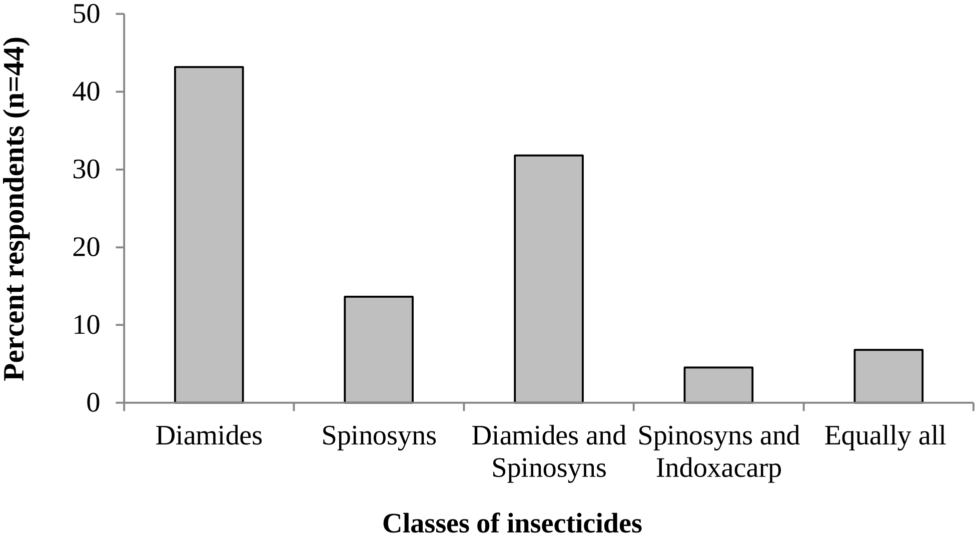

Figure 2. Classes of insecticides most frequently used to control *T. absoluta* in CRV of Ethiopia, 2017

The use of unregistered pesticides for the control of vegetable pests by vegetable growers has been reported in the central rift valley of Ethiopia (Belay *et al*., 2015; Tebkew and Getachew, 2015). In agreement with this, the respondents in this study used two insecticides namely Best field 360 SC and Tutan 36% SC which were not registered for use in the country at the time of this survey (Table 4) (MOANR, 2016).

Application rate and frequency

It was found that 57% of the respondents used application rates specified on the labels of insecticides, while 34% of the respondents applied insecticides either below or above the rate indicated on the labels. Nine percent of the respondents applied insecticides based on their personal experiences, and the rates varied with the growth stages of the crop. Tebkew and Getachew (2015) reported that vegetable growers determined rates of applications mainly based on information on the labels of pesticides and their personal experiences. Moreover, Belay *et al*. (2015) mentioned that vegetable growers in CRV of Ethiopia generally use a higher dose of pesticides than recommended, with a wrong perception that a higher dose ensures successful pest control.

Fifty-two percent of the respondents applied insecticides twice weekly; 27% and 9% on a weekly and biweekly basis, respectively, while the rest applied conditionally (Fig. 3). Vegetable farmers regularly treated their vegetables with insecticides either at a weekly or bi-weekly interval (Tebkew and Getachew, 2015).

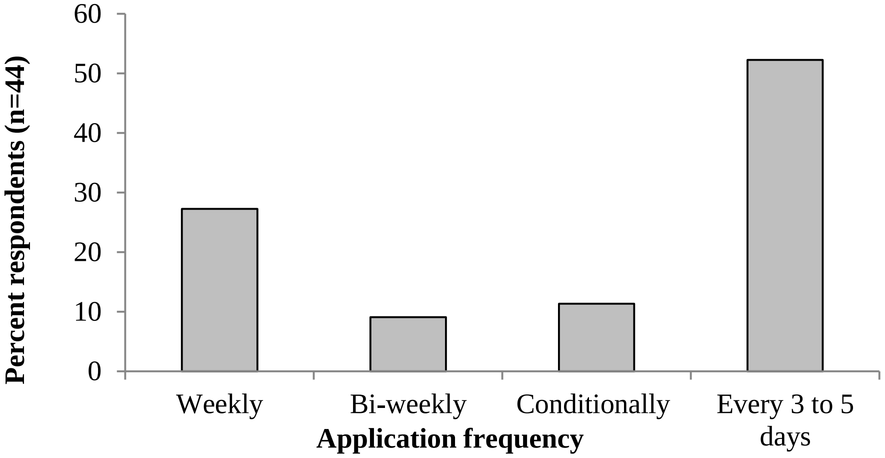

Figure 3. Insecticides application frequencies practiced by tomato growers in CRV of Ethiopia, 2017

Even though the majority of the respondents determined the frequency of insecticides application based on their personal experiences, some sought advice from agricultural experts (DAs and other professionals), insecticide providers (retailers and companies) and fellow tomato growers (Fig. 4).

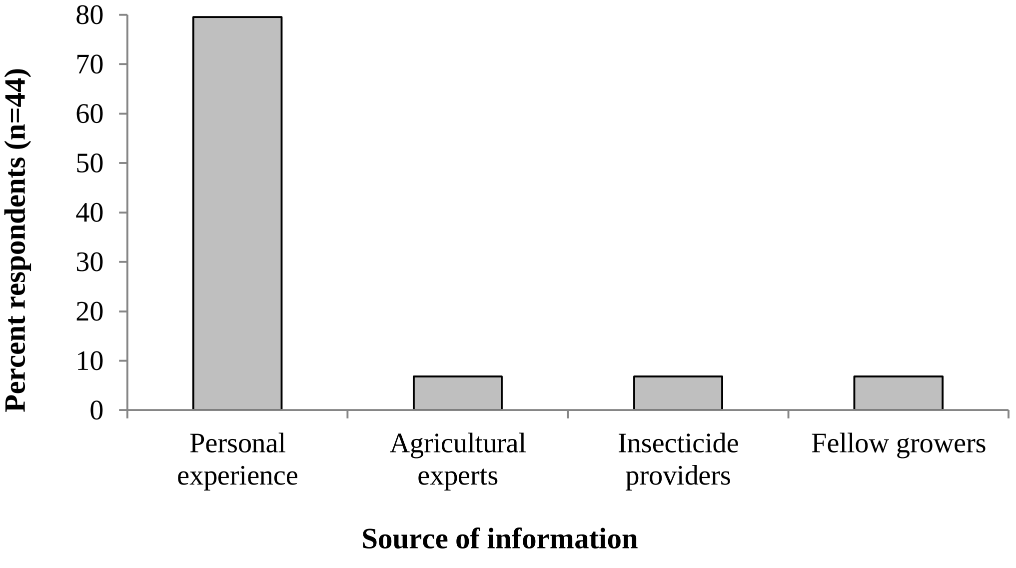

Figure 4. Source of information on insecticides application frequency in CRV of Ethiopia, 2017

Method of pesticides application

Sixty-one percent of the respondents preferred mixing two or more pesticides. However, the number of pesticides mixed during application varied among respondents (Table 5). Eighty-nine percent of the respondents mixed insecticides targeted for the control of *T. absoluta* with fungicides and/or bactericides. The major reason (56 % of the respondents) given for mixing different pesticides was the desire to control different pests at the same time (Table 5).

Table 5. Proportion of respondents (n=44) on their pesticide use practices in the CRV of Ethiopia, 2017

Inquiries	Respondents (%)
Method of pesticides application	
Mixing of pesticides during application	61
Apply one pesticide type at a time	39
Number of pesticides mixed during application	
Two	63
Three	22
More than three (mostly four but sometimes five)	15
Reasons given for mixing pesticides during application	
Control different pests at same time	56
Minimize labor cost and save time	30
Increase efficacy of pesticides	7
As a traditional practice	7

Practice of insecticide rotation

Eighty-two percent of the respondents applied insecticides recommended for *T. absoluta* control in rotations. The major reason for applying insecticides in rotation by the tomato growers was to avoid adaptation of insecticides by the insect (89%), while 11% of the respondents rotated insecticides because they believed that it was good for the crop. All respondents who practiced insecticide rotations were found rotating insecticides from different classes in the rotation scheme. However, the number of insecticides used in the rotation varied among the respondents. The majority (53%) of the respondents rotated three insecticides, while 28% and 19% of the respondents used two and more than three (four to five) insecticides in rotation with weekly to monthly rotation frequencies (Fig. 5). For prolonged use of insecticides in chemical pest control, rotation of effective pesticides from different chemical classes with different modes of action is recommended [Insecticide Resistance Action Committee (IIRAC), 2017].

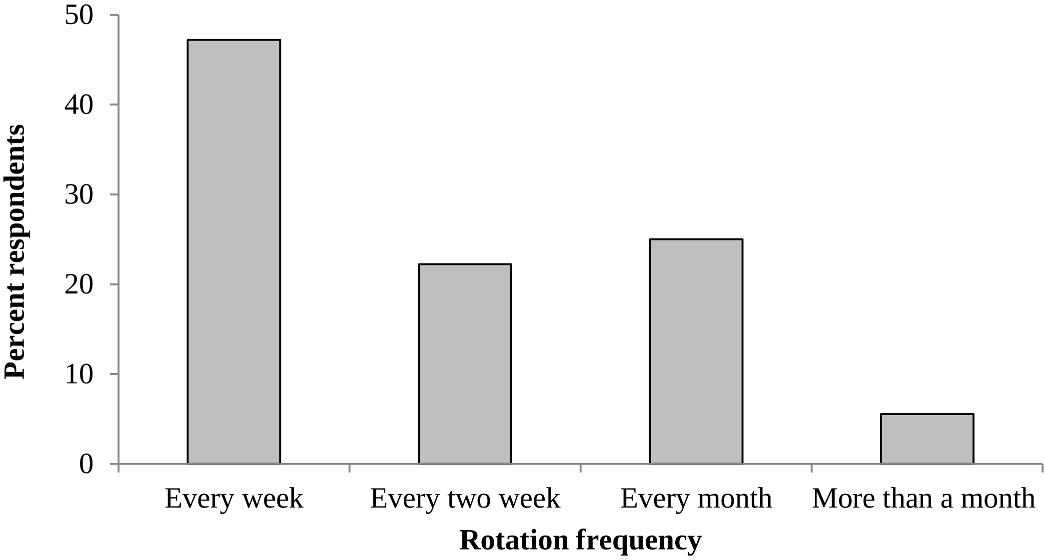

Figure 5. Insecticides rotation frequencies in the CRV of Ethiopia, 2017

Growers' assessment on efficacy of registered insecticides used for *T. absoluta* control

Considering the use of unregistered insecticides by growers for *T. absoluta* control, 57%, 34%, 7%, and 2% of the respondents rated the efficacy of insecticides as very good, excellent, good, and poor, respectively. The decline in efficacy of some of the registered insecticides was mentioned by 82% of the respondents after two to three years of their use for controlling the insect (Fig. 6). The decrease in the proportion of respondents who claimed a decline in efficacy of the registered insecticides in 2017 might be due to the shift from the use of registered insecticides to un-registered as a response to the observed decline in the efficacy of some of the registered insecticides by tomato growers. Victor *et al.* (2015) reported that vegetable farmers take various measures such as increasing the concentration and application frequency of pesticides and/ or changing the types of pesticides to cope with the decline in the efficacy of pesticides.

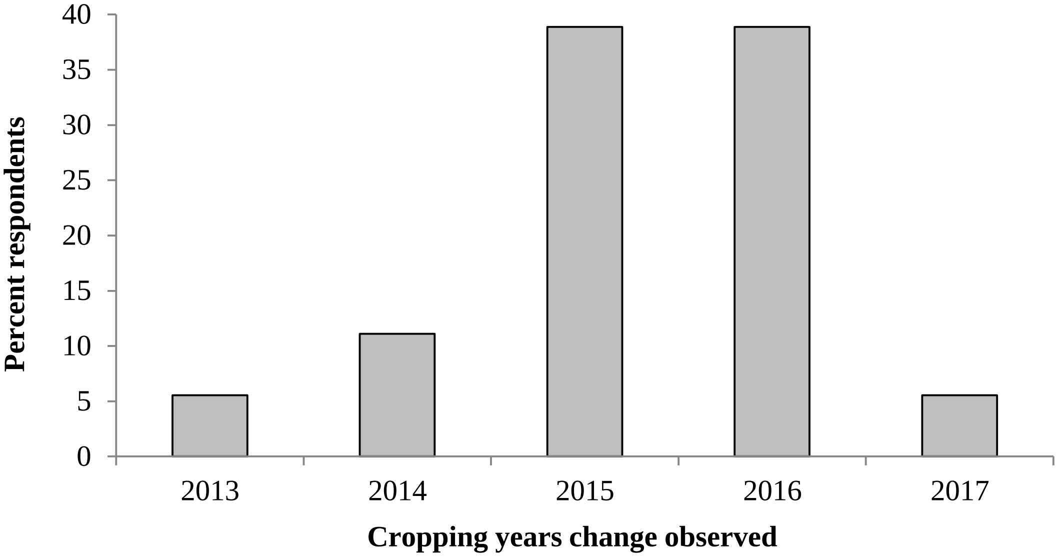

Figure 6. Cropping years which a decline in the efficacy of insecticides used to control *T. absoluta* observed in CRV of Ethiopia, 2017

Detection of occurrence of insecticide resistance in *T. absoluta* population

Sensitivity bioassay

The difference in susceptibility between the four *T. absoluta* strains to the different compounds tested was determined based on the criterion of failure of 95% CL at LC_{50} to overlap. Hence, a significant difference was observed among *T. absoluta* strains of Hawassa and Ziway to flubendiamide only (Table 6). Since a general standard susceptible strain could not be found, the comparisons and resistance ratios (RR) were based on the most susceptible strain (i.e. the strain with a lower LC_{50} value) and recommended field rates on labels of insecticides (Haddi, 2011). Therefore, the strain from MARC was the most susceptible one to chlorantraniliprole. Whereas *T. absoluta* strains from Hawassa and Ziway were found most susceptible, respectively, to flubendiamide and spinetoram.

Table 6. Relative toxicity of chlorantraniliprole, flubendiamide, and spinetoram to *T. absoluta* strains of Hawassa, MARC, Meki and Ziway, 2017

Active ingredient	Strain	N	Slope ± SE	LC$_{50}$ g, ml a.i./ha (Cl 95%)			LC$_{90}$ g, ml a.i./ha (Cl 95%)			χ^2	RR
chloran traniliprole	MARC	210	7.06 ±1.44	96.49	(83.18	121.59)	197.56	(147.17	378.84)	23.94	_
	Ziway	210	6.58 ±1.40	100.78	(85.55	133.01)	217.38	(155.71	470.07)	22.07	1.04
	Hawassa	210	4.25 ±2.86	151.72	_	_	498.72	_	_	2.20	1.57
	Meki	210	5.9 3±1.74	159.42	(114.57	568.89)	407.44	(210.07	7063)	9.62	1.65
flubendiamide	Hawassa	210	4.21 ±1.19	92.67	(70.69	127.19)	307.87	(189.16	1498)	12.63	_
	MARC	210	4.22 ±0.93	98.04	(76.03	139.30)	325.07	(201.99	991.80)	20.81	1.06
	Meki	210	3.72 ±1.56	186.49	(125.18	4600)	727.58	(281.39	9128253)	5.68	2.01
	Ziway	210	3.42 ±1.16	205.48	(129.99	1375)	902.14	(334.43	105724)	8.72	2.22
spinetoram	Ziway	210	5.71 ±1.25	23.29	(18.38	28.23)	56.47	(42.45	106.87)	20.99	_
	Hawassa	210	5.20 ±1.69	25.62	(17.60	31.97)	67.73	(46.56	323.70)	9.40	1.10
	MARC	210	5.96 ±1.13	26.47	(22.36	32.95)	61.84	(45.42	115.99)	27.95	1.14
	Meki	210	5.77 ±1.87	28.28	(23.20	37.80)	67.95	(45.84	364.12)	9.48	1.21

N= number of larvae tested, χ^2 = Chi-square test, RR = resistance ration (LC$_{50}$ resistance/LC$_{50}$ susceptible)

Chlorantraniliprole

The comparison for susceptibility to chlorantraniliprole did not show significant differences among the strains in LC_{50} and LC_{90} values. The highest LC_{50} value was recoded from Meki (159.42 g/ha a.i.) followed by Hawassa (151.72 g/ha a.i.). On the other hand, LC_{50} of MARC was the lowest (96.49 g/ha a.i.). Chlorantraniliprole resistance ratios ranged from 1.04 to 1.65. The recommended field rate for chlorantraniliprole (Coragen 200 SC) is 50 g/ha (a.i.). However, the LC_{50} values of all strains were far higher than the field rate, indicating the presence of resistance.

Flubendiamide

Resistance to flubendiamide was only observed in *T. absoluta* population from Ziway when compared with the most susceptible strain, Hawassa. LC_{50} of the resistance population was 205.48 ml/ha (a.i.) with a resistance ratio of 2.2. The other strains had overlapping confidence intervals. However, all strains showed no significant difference in susceptibility to the insecticide in the LC_{90}. The confidence intervals of the four strains at the LC_{90} were very wide and overlapping. LC_{50} values of Meki and Ziway were approximately four folds higher than the field rate of flubendiamide (i.e 57.6 ml/ha a.i.), Populations of Hawassa and MARC also showed higher LC_{50} of 92.67 and 98.04 ml/ha (a.i.), respectively suggesting that all populations tested had developed resistance to flubendiamide.

Spinetoram

For Spinetoram, the variability observed in the LC_{50} and LC_{90} values among the tested strains were low (under 1.2 times). The highest LC_{50} value of 28.28 ml/ha (a.i.) and LC_{90} value of 67.95 ml/ha (a.i.) were recorded from Meki, while population from Ziway had the lowest LC_{50} of 23.29 ml/ha (a.i.) and LC_{90} of 56.47 ml/ha (a.i.). The confidence intervals of all strains overlapped. The Hawassa and MARC strains showed LC_{50} of 25.62 and 26.47 ml/ha (a.i.), respectively. All strains had LC_{50} values higher than the field rate of Spinetoram 15.6 ml/ha (a.i.) which suggests the existence of resistance.

Tuta absoluta has been reported for developing resistance to insecticides from different classes. Resistance to diamides (chlorantraniliprole and flubendiamide) was observed in *T. absoluta* populations from Greece and Italy (Roditakis *et al.*, 2015). Melis et al. (2015) also reported resistance to chlorantraniliprole in two populations of *T. absoluta* from Turkey. Moreover, *T. absoluta* has shown resistance to spinosad in Brazil, Chile and Turkey (Reyes *et al.*, 2012; Campos *et al.*, 2014; Melis *et al.*, 2015).

Results of the bioassay test conducted on *T. absoluta* strains collected from CRV of Ethiopia suggested that the levels of resistance among *T .absoluta* strains were low for all test insecticides. The lack of a good susceptible standard population can be the reason for underestimating the levels of resistance (resistance ratios) to the compounds (Siqueira *et al*., 2000). The level of resistance to chlorantraniliprole was 1.65 times higher in *T. absoluta* population of Meki than MARC population. Melis *et al*. (2015) also mentioned a 1.84 fold resistance to chlorantraniliprole in *T. absoluta* population of Turkey.

The resistance ratio to flubendiamide (> 2 fold) was higher than that of chlorantraniliprole and Spinetoram. This high level of resistance to flubendiamide may be due to a higher selection pressure provided by the intensive use of this insecticide. However, considering, the time of registration of this insecticide in Ethiopia for *T. absoluta* control compared to chlorantraniliprole, the observed difference is unclear. It is worth mentioning that the sites from where the populations were collected are not far from flower farms which use a range of insecticides including the unregistered ones. It could also be due to cross-resistance following the exposure of the population to chlorantraniliprole. Therefore, there is a possible cross-resistance in *T. absoluta* population of Meki which consistently shows a relatively high level of resistance to both insecticides compared with the respective susceptible reference strains (i.e. 2.01 fold to flubendiamide and 1.65 fold to chlorantraniliprole). Roditakis *et al*. (2015) also reported similar phenomena in two European populations of *T. absoluta*.

In this bioassay, the *T. absoluta* populations exhibited very low levels of resistance (RR < 1.21 folds) to spinetoram. Similarly, low levels of resistance to spinosyns (spinosad) were reported in *T. absoluta* populations of Brazil (Silva *et al*., 2011). Moreover, different studies on the efficacy of insecticides against *T. absoluta* determined that spinosyns provide good control of the insect (Saad *et al*., 2013; Mohamed and Lobna, 2012; Eleonora and Vili, 2014).

Conclusion and Recommendation

The results of the survey clearly showed that misuse and abuse of pesticides in CRV of Ethiopia is rampant. This in turn aggravates the development of insecticide resistant population of arthropod pests of vegetables produced in the region. Hence, efforts need to be made towards judicious use of chemical control in the IPM of the tomato leaf miner.

The results of the sensitivity bioassay suggest that insecticides from spinosyns class still have the potential to control *T. absoluta*. However, to attain a sustainable control of *T. absoluta* using insecticides, registration of more effective insecticides having different modes of action is crucial. Moreover, developing a sound insecticide rotation scheme is important to increase the life span of insecticides for long-term use in an IPM program.

The present study focused on the central rift valley region of Ethiopia where vegetable production is intensive and pesticide use is heavy. Similar studies are required in other vegetable or tomato production areas to have a national picture of pesticide use practices, and to assess the level of sensitivity to insecticides among *T. absoluta* strains in the country. In addition, Efforts should also be made to develop insecticide resistance management strategy for effective and sustainable resistance management in chemical control of *T. absoluta*.

Acknowledgments

The Ethiopian Institute of Agricultural Research is duly acknowledged for financing the study. The crop protection staff of Melkassa Agricultural Research Center supported the execution of the study.

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