Journal of Experimental Agriculture International

41(5): 1-12, 2019; Article no.JEAI.52510
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Pesticides and Neem Seed Kernel Extract on Blights and *Tuta absoluta* at Different Phenological Stages of Tomato in Hamelmalo Agricultural College, Eritrea

Syed Danish Yaseen Naqvi[1], Sethumadhava Rao[1*], Adugna Haile[1], Belay Teweldemedhin[2] and Aggrey Bernard Nyende[3]

[1]Department of Plant Protection, Hamelmalo Agricultural College, Eritrea.
[2]Department of Horticulture, Hamelmalo Agricultural College, Eritrea.
[3]Jommo Kenyata University of Agriculture and Technology, Kenya.

Authors' contributions

This work was carried out in collaboration among all authors. Author SDYN performed the study. Author SR designed the study, managed the literature review and wrote the first draft of the manuscript. Authors BT and ABN worked on the statistical analysis. Author AH managed the analyses of the study and reviewed the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v41i530416
Editor(s):
(1) Dr. Slawomir Borek, Associate Professor, Department of Plant Physiology, Adam Mickiewicz University, Poland.
(2) Dr. Hab. Mariusz Cycoń, Department and Institute of Microbiology and Virology, School of Pharmacy with the Division of laboratory Medicine, Medical University of Silesia, Poland.
(3) Prof. Mohamed Fadel, Microbial Chemistry Department, Gene tic Engineering and Biotechnology Division, National Research Center, El-Behos Street, Dokki, Giza, Egypt.
Reviewers:
(1) Nuto Yaovi, University of Lomé, Togo.
(2) Mohamed Ahmed Gesraha, National Research Centre, Egypt.
Complete Peer review History: http://www.sdiarticle4.com/review-history/52510

Original Research Article

Received 15 September 2019
Accepted 19 November 2019
Published 26 November 2019

ABSTRACT

Tomato in Eritrea is affected by nearly 30 diseases and insect pests among which blight, leaf curl virus, root-knot nematodes, powdery mildew, *Tuta absoluta, Helicoverpa armigera,* aphids, whitefly and red spider mites are the most important. In the field, experiments were conducted in Hamelmalo Agricultural College for two consecutive seasons (2015 and 2016) in a Randomized Complete Block Design with three replications. Treatments used were pesticides (mancozeb, dimethoate, deltamethrin) and aqueous Neem seed kernel extract and their combinations. Disease incidence (DI), Disease severity (DS) of blights and infestations of *Tuta absoluta* [Lepidoptera:Gelechiidae]

**Corresponding author: E-mail: sethumadhava.g@gmail.com;*

were assessed at different phenological stages of the crop. Mancozeb alone was not so effective to reduce either DI or DS or damage of plants but it causes declining the number of larvae of *T. absoluta* at flowering stage. T_{11} showed the highest control of DI, DS and reduced the larval population of *T. absoluta* per plot and minimized the damage level. Among all the treatments, T_{11} and T_9 were the most effective to reduce the damage of plants and minimizing the larvae of *T. absoluta* at fruiting stage. Neem extract had the least effect than all treatments. Mancozeb (T_1) and combinations of Mancozeb + Dimethoate + NSE (T_{11}) gave significantly higher marketable yield than other treatments. The overall Cost-Benefit Ratio (CBR) was similar for all treatments during the two crop seasons, but the average CBR was higher for T_{11} whereas it was least for T_3.

Keywords: Benefit-cost ratio; disease incidence; pesticides; severity; Tuta absoluta; tomato.

1. INTRODUCTION

Most vegetables in Eritrea are damaged due to the number of pathogens and insect pests. Tomato (*Lycopersicon escculentum L.*) is an important and popular horticultural commodity in the world and it ranks third in global production after potatoes and sweet potatoes [1]. In Africa, the total tomato production for 2012 was 17.938 million tons with Egypt being the leading in the continent producing 8.625 million tons whereas the average yields of tomato in Eritrea are 12-16 tons ha^{-1} only. Africa exported almost $800 million worth of tomatoes in 2015, or about 10% of the world's total, according to the Geneva-based International Trade Centre. In most parts of Africa, tomato is mainly produced by small-scale farmers who have limited access to inputs such as good seeds, fertilizers and pesticides. The crop is grown in many areas under natural rainfall, which makes the harvests unpredictable and inconsistent. According to [2] tomato production can improve the livelihoods of subsistence farmers by creating jobs and serving as a source of income for both rural and per urban dwellers.

In Eritrea, tomato is grown mostly under irrigation and sometimes under rainfed conditions, but the average yield of tomato (12-16 tons ha^{-1}) has remained low, compared with an average of 27.2 tons ha^{-1} globally [3] and [4]. This low yield level needs to be improved through research by identifying the status, constraints and opportunities of tomato production in Africa as well as in Eritrea.

According to the Ministry of Agriculture's Report for 2003 [5], annually there is 25% yield loss of tomato production because of insect pest and diseases, although sometimes this loss can reach up to 40-50%. Diseases include late blight *(Phytophthora infestans)*, early blight *(Alternaria alternata)* white or grey mould *(Botrytis cinerea)*, *Verticillium* and *Fusarium* wilts, damping-off *(Pythium* spp.*)*, bacterial leaf spot *(Xanthomonas vesicatora)*, mosaic and curly top viral diseases. Other pests are nematodes (*Meloidogyne* spp.), African bollworm (*Helicoverpa armigera*), leafworm (*Spodoptera lituralis)*, aphids *(Aphis gossypii)*, whitefly *(Bemicia tabaci),* and very recently *Tuta absoluta* [Lepidoptera:Gelechiidae] an invasive pest of tomato [6,7,8]. Also, adverse environmental conditions and the deficit of nutrients can cause 'cat-faced tomato', cracking, sunscald and blossom-end rot (caused by water stress). *Tuta absoluta* Meyrick which arrived from South America via Spain in 2008 has spread across at last 15 African countries. This Lepidoptera is also known as a tomato-leaf miner, which kills plants as the larvae burrow into leaves, fruits and stems and in warm climates, it can have as many as 12 generations annually, with each female laying an average of 260 eggs. In Africa, the majority of farmers still depend on indigenous pest management [9]. In Eritrea (Fig. 1), this pest is invasive, causing damage to tomato crops in various parts of the country.

1.1 Application of Pesticides

Pesticides have made great contributions in plant protection of this pest, but have also raised several ecological and medical problems [10]. Nevertheless, the indiscriminate use of pesticides has resulted in the development of resistance by pests (insects, weeds, etc), build-up resurgence and outbreak of new pests. In general, pesticides are toxic to non-target organisms and have hazardous effects on the environment which is dangerous to the sustainability of ecosystems [11].

1.2 Botanicals

Plant Extract Insecticides (PEI), such as neem extracts (*Azadirachta indica* A. Juss) have long been recognized as a source of environment-

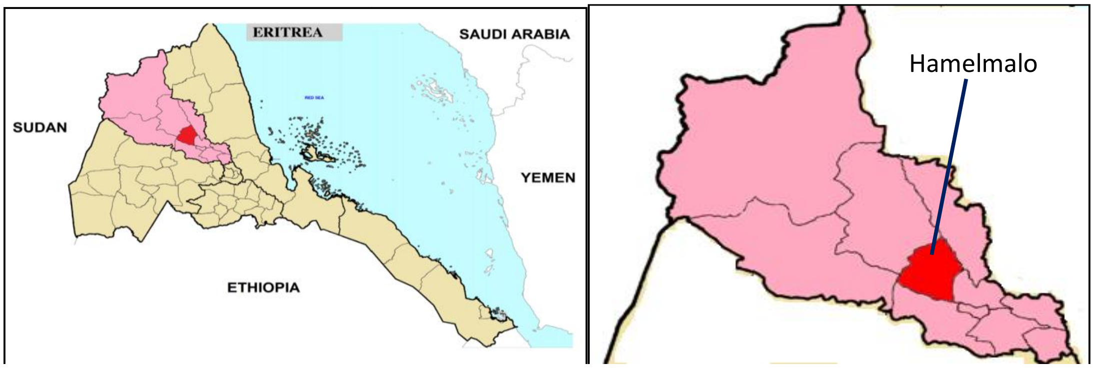

Fig. 1. Anseba region, one of the six zobas of the State of Eritrea; Hamelmalo subzone is shown in red colour in Anseba region

friendly biopesticides. *A. indica* has been recommended for many Integrated Pest Management (IPM) programs [12]. Azadirachtin is one of the main botanical pesticides in use and has potential as an alternative to conventional insecticides for such use. However, the effects of azadirachtin on the tomato leaf miner have been little studied and very little is known of their sub-lethal behavioural effects on this pest species [13]. Azadirachtin caused mortality in insect larvae (2.5–3.5%) at the recommended field-concentration (i.e., 27 mg/L) with negligible difference between the populations tested. Azadirachtin also caused egg-laying avoidance and affected walking by larvae, but not leaf-mining [13].

1.3 Objectives

The general objective of this study was to examine the efficacy of reduced risk pesticides for control of blight diseases and *T. absoluta*. The specific objective of this study was mainly to understand the effect of neem seed kernel extract, pesticides and their combinations on control of blights and *Tuta* and to evaluate the 'yield loss of tomato due to pests and assess Cost-Benefit Ratio (CBR) of the treatments.

2. MATERIALS AND METHODS

2.1 Location

Field trials were conducted, for two consecutive seasons (2015 – 2016) in Hamelmalo Agricultural College which is located northeast of Keren (15° 54.16'' N and 38°27'' E) at an altitude of 1286 m above the sea level. It has a semi-arid climate with an annual mean rainfall of 436 mm and temperature of 7°C in winter and 42°C in summer.

2.2 Cultural Methods

Application of decomposed farmyard manure at the rate of 15 tons per hectare were incorporated and ploughed in the field before planting. Besides, nitrogen and phosphorus in the forms of urea, DAP and potash were applied at recommended doses. Plots were weeded at 20 to 25 days after transplanting and the second weeding was 20 days later. The crop was irrigated at 4 to 5-day intervals for optimum plant growth and development.

2.3 Treatments

The treatments used were mancozeb, dimethoate, deltamethrin and aqueous extract of neem seed kernel (NSE) and their combinations at the rate of 2.5 g L^{-1} for mancozeb, 2 mL L^{-1} for dimethoate, 2 mL L^{-1} for deltamethrin, and 5 mL L^{-1} for aqueous neem leaf extract.

2.4 Design and Analysis

The field trials were carried out in a Randomized Complete Block Design (RCBD) with three replications. The gross plot sizes were 3 m x 3.75 m (11.25 m^2). The data were analyzed using GENSTAT software at 0.5 and 0.1% test of significance.

2.5 Data Collection

Disease incidence (DI), disease severity (DS) of early blights and infestations of *T. absoluta* at flowering Stage, fruiting stage and harvesting stages were assessed by the following formulae:

2.5.1 Disease incidence

$$\text{Percentage of disease incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plants}} \text{ X } 100$$

2.5.2 Disease severity

Disease Severity (DS) with the preformed disease index were recorded and assessed as the following formula:

$$\text{Disease Index} = \frac{\text{Sum of all disease ratings}}{\text{Total No. of plants counted}} \text{ X } \frac{100}{\text{Maximum rating value}}$$

The disease severity was calculated by using a 0-5 scale of [14].

$$\text{\% of Disease Severity} = \frac{\Sigma(\text{nxr1}) - (\text{nxr5})}{5\text{N}} \text{X } 100$$

n = Number of infected leaves
r1 – r5 = Category number
N = Total examined leaves

Disease percentage of *Tuta absoluta* was done by counting the number of leaves/ plants or fruits damaged by the insect.

2.6 Other Parameters

Incidence of other diseases such as Fusarium wilt and root rots were evaluated based on the observed symptoms of the disease and also on the identified pathogens after isolation; days to flowering was determined on the basis of 50% flowering after transplanting; similarly days to fruiting was recorded when mustard size fruits were observed on 50% plants after planting; Total yield (kg/ha) was determined at the time of harvesting which was done from mature green to red ripe stage. Fruit grading was determined as marketable and unmarketable.

3. RESULTS AND DISCUSSION

Effects of 11 treatments on disease incidence, the severity of blights and *T. absoluta* infestations at the flowering stage are given in (Table 1). Data on disease incidence, disease severity and the number of plants damaged by *T. absoluta* were collected before and after spray of treatments.

The disease incidence (DI) in all the pre-spray plots was ranging from 4.45 to 18.89. However, this DI was decreased in the post spray assessment of the disease situation. During the post, spray count the disease decrease significantly in all the mancozeb and their combinations. The highest post spray counts were recorded in treatments T_2, T_3, T_4, T_5, T_9 and T_{10}. The reason for this high DI was due to all these treatments were insecticides and control plot.

Disease Severity (DS) assessment was high like that of DI in the pre-spray counts ranging from 2.53 to 8.87 per cent. However, the DS was reduced in the post spray of mancozeb and its combinations. The post spray assessments were lower in treatments (T_1), mancozeb + dimethoate (T_6), mancozeb + dimethoate + neem kernel extract (NSE) (T_7) and mancozeb + dimethoate + NSE (T_{11}). This result revealed that mancozeb and mancozeb combinations were effective to reduce the DS of bight on tomato crops.

The pre-spray larval count did not show a significant difference among the treatments, the larval count ranged from 3.33 to 6.67 per plot. Post-spray assessment of larval count showed a significant difference among the treatments at $P<0.05$. Mancozeb and control plot had significantly higher larval count with 9.17 and 17.67 larvae per plot (Table 1). There was no significant difference in larval count in all the remaining insecticides and neem extract sprayed plots. Treatments T_{10} and T_{11} had lowest *T. absoluta* larvae count with 0.87 and 0.67 larva/plot, respectively. This result is similar to the report of [15] where he got lower larval count and tomato plant damage with insecticide sprays. He also reported that insecticides were more effective when applied at the egg stage of the pest.

The efficacy of treatments on DI, DS for blights, and the number of larvae of *T. absoluta* and damaged plant at the fruiting stage of the crop is given in Table 2. The DI of blight in the pre-spray at fruiting stage was high ranging from 17.5 to 28.9; there was no significant difference among the treatments. After the post spray, the DI was significantly reduced in all plots treated with mancozeb and mancozeb combine treatments. The highest DI was recorded in the control plot (47.8%) followed by sole insecticides treatments (Table 2).

Table 1. Efficacy of treatments on disease incidence (DI), disease severity (DS) of blights and infestations of *Tuta absoluta* at flowering stage, 2015

Treatments	Flowering stage							
	% of Disease Incidence		% of Disease Severity		Number of larvae/plot Pre-spray	Number of larvae/plot post spray	Number of plants damaged pre-spray	Number of plants damaged post spray
	pre spray	post spray	pre spray	post spray				
T_1 mancozeb	8.89	5.35	7.33	2.67	4.33	9.17	9.67	13.33
T_2 dimethoate	6.67	24.25	2.87	3.7	5.67	2.87	10.33	6.33
T_3 Neem Seed Extract (NSE)	8.89	20.01	2.53	3.6	6.67	4.07	11.07	6.33
T_4 control	6.67	27.78	8.87	13.9	5.33	17.67	10.67	16.67
T_5 deltamethrin	8.89	13.33	2.43	3.93	5.67	1.1	11.1	3.67
T_6 mancozeb +dimethoate	17.89	6.78	4.93	1.27	3.16	1.33	9.67	6.17
T_7 mancozeb+ NSE	13.33	4.33	5.2	2.7	3.67	2.67	9.33	6.33
T_8 mancozeb+ deltamethrin	18.89	8.89	4.13	2.1	3.33	1.83	10.33	3.07
T_9 dimethoate+ NSE	6.67	15.56	3.17	3.17	4.17	1.25	9.67	7.9
T_{10} dimethoate+ deltamethrin	4.45	17.78	3.27	4.73	5.33	0.87	11.33	3.33
T_{11} mancozeb+ dimethoate+ NSE	13.67	6.67	4.03	1.47	4.67	0.67	10.33	3.67
SED	4.56	4.48	0.98	1.16	2.38	1.34	1.03	2.13
LSD	9.52	9.34	2.05	2.42	4.96	2.75	2.16	4.45
Level of Significance	NS	NS	NS	S	NS	HS	NS	S

Table 2. Effects of fungicides on Disease Incidence (DI), Severity (DS) of Blights and Insecticides on the infestation of *Tuta absoluta* at Fruiting stage, 2015

Treatments	Fruiting stage							
	% of Disease Incidence		% of Disease Severity		Number of larvae/plot		Number damaged plants	
	pre spray	post spray	pre spray	post spray	Pre-spray	Post spray	Pre-spray	post spry
T_1 mancozeb	19.6	9.1	9.03	4.23	5.67	15.33	6.67	10.33
T_2 dimethoate	17.5	22.2	10.6	19.17	6.67	2.33	7.1	4.33
T_3 Neem Seed Extract (NSE)	19.57	22.2	12.57	18.33	5.67	2.67	6.33	4.33
T_4 control	23.6	47.8	13.73	23.03	7.33	18.33	8.03	16.33
T_5 deltamethrin	24.9	31.1	12.83	27.03	8.67	1.33	6.67	4.67
T_6 mancozeb +dimethoate	21.1	11.1	10.81	6.4	5.67	2.1	7.67	5.33
T_7 mancozeb+ NSE	25.6	13.3	14.97	7.03	5.67	2.67	5.67	4.67
T_8 mancozeb+ deltamethrin	21.1	8.9	9.7	6.23	6.17	1.07	7.67	5.97
T_9 dimethoate+ NSE	18.6	35.6	12.23	19.77	8.17	0.33	5.03	2.33
T_{10} dimethoate+ deltamethrin	28.9	33.3	14.47	24.93	6.33	2.33	7.33	4.33
T_{11} mancozeb+ dimethoate+ NSE	22.8	10.3	12.23	6.03	6.33	1.03	7.33	1.33
SED	6.05	5.28	2.711	3.7	1.75	1.54	1	1.77
LSD	12.62	11.01	5.65	7.71	3.64	3.21	2.1	3.7
Level of Significance	NS	S	NS	S	NS	HS	NS	HS

The disease severity (DS) of blight at the fruiting stage showed that there was no significant difference among the treatments used in the pre-spray assessment. In the post spray assessment, there was a significant difference between the treatments. Plots treated with mancozeb and mancozeb combined treatments had significantly lower DS; whereas, plots treated with sole insecticides and control plot had higher DS per cent. The control plot had DS of 23.037%.

There was no significant larval count per plant among the treatments in the pre-spray count. However, in the post spray count, the number of larvae was significantly higher for insecticide treatments and their combination. The lowest larval counts per plot were recorded in plots treated with dimethoate + NSE and combination of dimethoate + mancozeb + NSE with 0.33 and 1.03 larvae per plant respectively (Table 2).

The larvae of *T. absoluta* cause plant damage at different stages and different parts of tomato crop. There was a significant difference in plant damage among the treatments. Treatments T_{11} and T_9 had the lowest larval damage per plant with 1.33 and 2.33 larvae/plant respectively. The control plot and sole mancozeb sprayed plot gave significantly higher larvae count per plant respectively. In Brazil [13] reported that the *Azadirachtin* caused heavy mortality of larvae allowing only 2.5–3.5% survival at a concentration of 27 mg a.i./L. Neem extract spray also caused egg-laying avoidance and reduced larvae feeding on treated plants.

There was no significant difference in the DI of blight among the treatments used. On the other hand, all mancozeb and mancozeb and insecticide combination sprayed plot had significantly lower DS as compared to insecticides treated plots. Lowest and highest DS were recorded from T_{11} and T_{10} with 7.3 and 30.81% (Table 3).

There was no significant difference in the pre-sprayed larval count per plant among the treatments used. However, the post-spray counts showed that there were significant differences in larval damage per plant among the treatments. The lowest damage was obtained from T_3 and highest damage was recorded from the control plot T_4 with 0.67 and 11.67 larvae per plant respectively. This could be due to the application of crude plant extracts of neem that could result in inhibiting the growth of larvae. Similar results were reported by [16] who worked with neem and garlic extracts and found that neem extract was effective in retarding of larval development and reducing the mycelia growth of *Fusarium oxysporum* f. sp. *lycopersici*.

All the treatments had an effect on DI and DS of blight and infestations of *Tuta absoluta* at the flowering stage during 2016 (Table 4). Except for T_6, T_7, T_8 and T_{11}, the rest of the treatments reduced the percentage of blight incidence and

Table 3. Effects of treatments on disease incidence (DI), severity (DS) of blights and infestations of *Tuta absoluta* at harvesting stage, 2015

Treatments	Percentage of		Number of larvae/plot		Number of fruit damaged /plot	
	DI	DS	Pre-spray	Post-spray	Pre-spray	Post-spray
T_1 mancozeb	16.6	9.97	4.93	9.67	6.33	7.67
T_2 dimethoate	24.4	26.30	2.67	1.67	4.33	2.67
T_3 Neem Seed Extract (NSE)	26.7	27.10	3.21	0.67	2.33	1.33
T_4 control	28.9	30.47	3.03	11.67	3.33	12.33
T_5 deltamethrin	28.9	29.57	3.50	1.10	4.11	1.30
T_6 mancozeb +dimethoate	15.2	11.77	3.37	2.33	3.01	2.67
T_7 mancozeb+ NSE	16.7	12.91	2.67	2.11	6.33	3.67
T_8 mancozeb+ deltamethrin	17.6	12.57	2.33	0.67	3.21	1.53
T_9 dimethoate+ NSE	31.1	27.57	2.13	1.01	4.23	1.67
T_{10} dimethoate+ deltamethrin	31.8	30.81	4.97	2.01	3.05	0.75
T_{11} mancozeb+ dimethoate + NSE	17.8	7.3	3.04	1.02	3.67	0.67
SED	10.88	3.21	0.98	1.65	0.57	1.83
LSD	22.7	6.7	2.05	3.45	1.19	3.81
Level of Significance	NS	S	NS	S	HS	S

Table 4. Effects of fungicides on diseases incidence (DI) and diseases severity (DS) of blight of tomato and insecticides on infestations of *Tuta absoluta* at flowering stage, 2016

Treatments	% of disease incidence		% of disease severity		Number of larvae/plot pre-spray	Number of larvae/plot post-spray	Number of plant damage pre-spray	Number of plant damage post-spray
	Pre-spray	Post-spray	Pre-spray	Post-spray				
T_1 mancozeb	17.8	11.8	2.67	1.17	8.01	10.67	4.33	5.83
T_2 dimethoate	22.2	33.3	3.13	3.77	6.17	3.30	8.07	3.33
T_3 Neem Seed Extract (NSE)	24.4	28.9	2.53	3.67	8.17	5.05	7.33	4.17
T_4 control	26.7	44.4	2.77	6.33	9.03	10.67	8.23	10.17
T_5 deltamethrin	26.7	39.9	2.73	4.67	10.93	3.17	6.33	3.5
T_6 mancozeb +dimethoate	20.1	12.6	2.87	2.01	9.67	3.83	5.07	3.83
T_7 mancozeb+ NSE	22.2	12.2	3.07	2.07	9.33	3.03	4.93	2.83
T_8 mancozeb+ deltamethrin	26.7	13.8	1.83	1.67	10.33	4.97	5.9	2.17
T_9 dimethoate+ NSE	28.9	40.3	2.37	3.67	9.67	3.03	7.17	5.5
T_{10} dimethoate+ deltamethrin	22.2	31.1	3.67	6.07	11.33	3.83	3.17	1.5
T_{11} mancozeb+dimethoate+ NSE	20.1	10.3	1.27	1.1	10.33	2.17	6.17	2.5
SED	8.83	7.32	0.749	1.071	1.06	1.17	1.56	1.58
LSD	18.43	15.27	1.562	2.234	2.2	2.44	3.26	3.27
Level of Significance	NS	S	NS	S	HS	HS	NS	NS

DS during post spray counts. Similarly treatment T_{10} (dimethoate + deltamethrin) and T_{11} (mancozeb + dimethoate + NSE) gave drastic decrease in the number of *T. absoluta* larvae from 11.33% to 3.83% for T_{10} and from 10.33% to 2.17% for T_{11}. High level of plant damage was recorded in T_2 and T_3 with 6.33 and 7.17 percent respectively (Table 4). However, repeated use of pesticides is not recommended in current pest management as the pests develop resistance to pesticides. In Chile [17] reported that *T. absoluta* developed resistance to many pesticides such as deltamethrin, metamidophos, esfenvalerate, lambda-cyhalothrin and mevinphos.

Maximum disease incidence was recorded from treatments T_5, T_9 and T_{11} with 77.8, 73.3 and 72.6 per cent respectively. There was a decrease in disease incidence in treatment T_1 from 57.8% to 12.6%. The percentage of DS was noticed, before and after spray of treatments, in declining order in T_1 and T_6 with 17.4 and 18.6 per cent respectively. There was no significant difference in the number of larvae/plot and plant damage/plot among the treatments used. The maximum number of plant damage was observed in T_6 (14.01%) and T_4 (14.67%); this was the fact that tomato fruits in this treatment were damaged by rodents and birds (Table 5).

Efficacy of treatments on the number of larvae and fruit damage is shown in Table 6. In the pre-spray count, there was no significant difference among the treatments. However, during the post spray count, dimethoate, deltamethrin and neem extract and their combinations had significantly lower larvae per plot. The highest larval count was recorded from mancozeb and control plot with 9.67 and 14.17larvae/plot respectively. During the study, it was observed that *T. absoluta* caused high tomato fruit damage. The post spray damage assessment also showed that all the plots treated with dimethoate, deltamethrin and neem extracts and their interaction had significantly lower fruit damage per plot. The control and mancozeb treated plots gave higher fruit damage Table 6. Similar results were reported by [18] and [19] in Brazil where cartap and permethrin gave efficient control of the pests but later it was observed that the pest developed resistance to most of the pesticides used.

In both 2015 and 2016 cropping seasons, there was a significant difference in the number of tomato fruits produced per plant. Treatment T_1, T_6 and T_{11} gave the highest number of fruit per plant while the controls plot T_4, T_7, T_8 and T_{10} gave a lower number of fruit per plant (Table 7). There were no significant differences in the number of *T. absoluta* infestation among the treatments in both seasons. However, the highest *T. absoluta* infestation was recorded in the control plot (T_4) as compared to other treatments.

The yield of tomato varies from 105.9 to 250.9 q/ha. The highest yield in both seasons (2015 and 2016), were harvested from T_{11} followed by T_1, T_5 and T_{10}. The control plot gave a significantly lower yield than all the treatments in

Table 5. Effects of fungicides on diseases incidence (DI) and diseases severity (DS) of the blight of tomato and insecticides on infestations of *Tuta absoluta* at Harvesting, 2016

Treatments	% of disease incidence		% of disease severity		Number larvae/ plot	Plant damage/ plot
	Pre-spray	Post-spray	Pre-spray	Post-spray		
T_1 mancozeb	57.8	12.6	29.3	17.4	1	12.33
T_2 dimethoate	71.1	77.8	39.7	45.7	1	10.67
T_3 Neem Seed Extract (NSE)	68.9	75.6	22.6	35.1	0.67	13.67
T_4 control	71.8	87.8	46.3	49.7	1	14.67
T_5 deltamethrin	77.8	69.9	33.7	38.1	1.67	13.67
T_6 mancozeb +dimethoate	37.8	27.8	28.2	18.6	1	14.01
T_7 mancozeb+ NSE	60.01	21.1	24.2	21.2	1.33	12.67
T_8 mancozeb+ deltamethrin	52.21	19.1	23.1	22.2	2	13.5
T_9 dimethoate+ NSE	73.3	64.8	29.6	36.2	0	12.33
T_{10} dimethoate+ deltamethrin	63.3	81.6	32.3	36.2	1.33	12.07
T_{11} mancozeb+dimethoate+ NSE	72.6	15.9	20.6	20.5	1.17	11.67
SED	7.92	7.69	4.93	5.51	0.74	1.92
LSD	16.53	16.04	10.28	11.5	1.55	4.01
Level of Significance	NS	S	NS	S	NS	NS

both years (Table 7). Likewise, the highest marketable yield of tomato was obtained from treatment T_{11} and T_1, whereas the lowest marketable yield was acquired from the control plot. There was no significant difference in the yield of unmarketable tomato among the treatments; however, the highest unmarketable yield was harvested from the control plot.

Cost-benefit ratio (CBR) for tomato pest management during the two years is shown in Table 8. More or less the CBR for the two cropping years is similar, the highest (1.85) CBR was obtained from treatment T_{11} (mancozeb + dimethoate + NSE) followed by treatment T_1 mancozeb with 1.73, whereas, the lowest CBR 0.73 was obtained from T_3 (Neem Seed Extract (NSE) (Table 8). The result showed that a combination of fungicide, insecticides and neem extract are more efficient in the management of tomato pests.

Table 6. Number of larvae and fruit damage at fruiting stage

Treatments	Number of larvae/plot		Number fruit damaged/plot	
	Pre-spray	Post-spray	Pre-spray	Post-spray
T_1 mancozeb	6.67	9.67	6.07	15.5
T_2 dimethoate	5.33	3.1	6.05	3.67
T_3 Neem Seed Extract (NSE)	1.33	0.23	6.33	4.67
T_4 control	8.5	14.17	9.33	15.67
T_5 deltamethrin	4.97	1.33	5.07	3.67
T_6 mancozeb +dimethoate	4.07	0.12	7.33	4.83
T_7 mancozeb+ NSE	4.73	0.67	6.9	6.17
T_8 mancozeb+ deltamethrin	3.67	0.67	8.33	4.17
T_9 dimethoate+ NSE	2.67	0.23	9.33	5.3
T_{10} dimethoate+ deltamethrin	2.07	1.01	5.17	3.67
T_{11} mancozeb+ dimethoate+ NSE	1.67	0.15	5.33	2.67
SED	1.75	1.43	2.91	2.68
LSD	3.65	2.99	6.06	5.6
Level of Significance	NS	HS	NS	HS

Table 7. Effect of Different pesticides on fruit infestation, total yield and yield attributing parameters of tomato during two years (2015 and 2016)

Treatments	Fruit per plant		Marketable yield (qt/ha)		Unmarketable yield (qt/ ha)		Yield qt/ ha		Total infested fruits/plant	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1 mancozeb	58	59	202.5	203.9	30.6	34.23	233.1	238.1	7.33	8.33
T_2 dimethoate	41.3	43.3	171.7	175	25.7	29.67	197.3	204.7	7	8
T_3 Neem seed extract (NSE)	30	50.3	84.8	97.4	23.6	23.97	108.4	121.4	4.67	6
T_4 control	37.3	31	102.1	86.7	36.9	35.2	105.9	108.2	8.36	8.33
T_5 deltamethrin	44.3	45.7	192.2	212.1	25.8	27.8	211.2	214.9	7.33	8
T_6 mancozeb +dimethoate	46.7	53.7	183.7	191	32.5	34.53	216.2	225.5	7.67	7
T_7 mancozeb+ NSE	37.8	39	167.3	172.3	21.3	23.33	188.6	195.6	5	5
T_8 mancozeb+ deltamethrin	44.7	47.3	175.9	181.2	24.6	26.3	200.6	207.6	6.67	6.67
T_9 dimethoate+ NSE	55	57.3	186.5	194.8	31.6	32.9	218	227.7	6	6.33
T_{10} dimethoate+ deltamethrin	34.3	36.3	211.3	212.7	21.2	20.83	223.2	239.3	4.47	4.67
T_{11} mancozeb+ dimethoate+ NSE	62	61	221.4	218.1	19.5	21.47	250.9	249.6	7.33	5
LSD	10.96*	10.07*	74.01*	72.38*	NS	NS	77.39*	75.72*	NS	NS
SE	6.44	5.91	43.45	42.5	5.031	5.141	45.44	44.46	1.412	1.686
CV%	14.4	12.4	26.3	25.5	18.8	17.8	23.7	22.9	22.5	25.2

Table 8. The cost-benefit ratio of tomato pest management for 2015 and 2016 cropping seasons

Treatments	CBR * for the first trial year 2015	CBR for the second trial year 2016	Average CBR
T_1 mancozeb	1.74	1.72	1.73
T_2 dimethoate	1.47	1.47	1.47
T_3 Neem Seed Extract (NSE)	0.73	0.82	0.78
T_4 control	1.17	0.79	0.98
T_5 deltamethrin	1.48	1.49	1.49
T_6 mancozeb +dimethoate	1.57	1.6	1.59
T_7 mancozeb+ NSE	1.43	1.45	1.44
T_8 mancozeb+ deltamethrin	1.5	1.52	1.51
T_9 dimethoate+ NSE	1.6	1.64	1.62
T_{10} dimethoate+ deltamethrin	1.09	1.11	1.1
T_{11} mancozeb+ dimethoate+NSE	1.88	1.81	1.85

*LSD at P = 0.05; * Cost-benefit ratio*

4. CONCLUSION

In conclusion, mancozeb and the combination of synthetic insecticides such as deltamethrin and dimethoate are efficient for the control of tomato pests like blight and *T. absoluta* in the study area. Blight (early and late) is very severe during the rainy seasons while *T. absoluta* infestation is persistently high throughout the year. All the subsistence farmers in this area commonly practice pesticides for the control of this pest. But pesticides can be harmful, particularly to the environment as they affect non-targeted organisms like bees and they are also dangerous to human beings and the environment at large. Hence their use should be substituted by other safe methods such as cultural practices like sowing time and use of bio-agents.

ACKNOWLEDGEMENT

The authors are grateful to Department of Plant Protection, Hamelmalo Agricultural College and also thankful to the Jommo Kenyata University of Agriculture and Technology, Nairobi, Kenya and to the JICA (Japan International Cooperation Agency) project for the logistic support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Tan H, Thomas-Ahner JM, Grainger EM, Wan L, Francis DM, Schwartz SJ, Erdman Jr JW, Steven K, Clinton SK. Tomato-based food products for prostate cancer prevention: What have we learned? Cancer Metastasis Reviews. 2010;29:553–568.
2. Isaac Kojo Arah, Ernest Kodzo Kumah, Etornam Kosi Anku, Harrison Amaglo. An overview of post-harvest losses in tomato production in Africa: Causes and possible prevention strategies. Journal of Biology, Agriculture and Healthcare. 2015;5(16). [Accessed Aug 13, 2017] Available:https://www.researchgate.net/publication/283507662_An_Overview_of_Post-Harvest_Losses_in_Tomato_Production_in_Africa_Causes_and_Possible_Preventio Strategies
3. Jones JB. Tomato plant culture, in the field, greenhouse and home garden. CRC Press, Washington, D.C.; 1999.
4. Samuel Asgedom, Paul C. Struik, Ep Heuvelink, Woldeamlak Arai. Opportunities and constraints of tomato production in Eritrea. African Journal of Agricultural Research. 2011;6(4):956-967 [Accessed 18 February, 2011] Available:http://www.academicjournals.org/AJAR.DOI:10.5897/AJAR10.597.Academic.Journals
5. MoA. Report on the crop protection activities. In: Basic agricultural facts of Anseba Region, Keren; 2003. [Accessed on 23 April, 2011] Available:http://www.eritreaembassy-japan.org/data/AgronomyinSpateIrrigatedAreasofEritrea.pdf
6. Syed D, Awet T, Bereket T, Gezae A, Ruta M. Survey on economical important fungal diseases of tomato in Sub-Zoba

Hamemalo of Eritrea. Review of Plant Studies. 2014;1(4):39-48.
7. Syed Danish Yaseen Naqvi, Adugna Haile, Sethumadhava Rao, Belay Teweldemedhin, Virendra Kumar Sharma. Occurrence and prevalence of diseases and insect pests on vegetable crops in Zoba Anseba, Eritrea. Journal of Eco-friendly Agriculture. 2016;12(1):29-40.
8. Syed Danish Yaseen Naqvi, Adugna Haile, Sethumadhava Rao, Belay Teweldemedhin, Virendrakumar Sharma, Aggrey Bernard Nyende. Evaluation of husbandry, insect pests, diseases and management practices of vegetables cultivated in Zoba Anseba, Eritrea. Journal of Eco-friendly Agriculture. 2016;12(1):47-50.
9. Abate TA, van Huis JKO. Annual Review of Entomology. 2000;45:631-659.
10. Varma J, Dubey N. Prospectives of botanical and microbial products as pesticides of tomorrow. Curr. Sci. 1999;76: 172–178.
11. Jeyasankar A, Jesudasan RWA. Insecticidal properties of novel botanicals against a few lepidopteran pests. Pestology. 2005;29:42–44.
12. Schmutterer H. Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. Annu. Rev. Entomol. 1990;35:271–297.
13. Tomé HVV, Martins JC, Corrêa AS, Galdino TVS, Picanço MC, Guedes RNC. Azadirachtin avoidance by larvae and adult females of the tomato leafminer *Tuta absoluta.* Crop Protection. 2013;46:63-69.
14. Mayee CD, Datar VV. Phytopathometery Tech. Bult. 1. Marathwada Agri. Uni. Parbhani India. 1986;90-91.
15. Joel González-Cabrera, Oscar Mollá, Helga Montón, Alberto Urbaneja. Efficacy of *Bacillus thuringiensis* (Berliner) in controlling the tomato borer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). BioControl. 2011;56(1):71–80.
16. Agbenin ON, Marley PS. *In vitro* assay of some plant extracts against *Fusarium oxysporum* fsp. *lycopersici* causal agent of tomato wilt. Journal of Plant Protection Research. 2006;46(3):215-220.
17. Salazar ER, Araya JE. Detección de resistencia a insecticidas en la polilla del tomate. Simiente. 1997;67:8-22.
18. Lietti Marcela MM, Eduardo Botto Raúl, Alzogaray A. Insecticide resistance in Argentine populations of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) Neotrop. Entomol. 2005;34(1). Available:http://dx.doi.org/10.1590/S1519-566X2005000100016
19. Siqueira HÁA, Guedes RNC, Picanço MC. Insecticide resistance in populations of *Tuta absoluta* (Lepidoptera: Gelechiidae). Agricultural and Forest Entomology. 2000;2:147–153. DOI: 10.1046/j.1461-9563.2000.00062

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/52510