

Original Research Article

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

Comment [L1]: Pesticides and neem seed kernel extract on blights and *Tuta absoluta* at different phenological stages of tomato in Hamelmalo Agricultural College, Eritrea

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] 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. T₁₁ showed highest control of DI, DS and reduced the larval population of *T. absoluta* per plot and minimized the damage level. Among all the treatments, T₁₁ and T₉ were the most effective to reduce the damage of plants and minimizing the larvae of *T. absoluta* at fruiting stage. Neem extract had least effect than all treatments. Mancozeb (T₁) and combinations of Mancozeb + Dimethoate + NSE (T₁₁) gave significantly higher marketable yield than other treatments. The overall Cost-Benefit Ratio (BCR) was similar for all treatments during the two crop seasons, but the average CBR was higher for T₁₁ whereas, it was least for T₃.

Comment [L2]: Neem seed kernel

Comment [L3]: Incidence

Comment [L4]: Disease severity

Comment [L5]: CBR?

Comment [L6]: Seasons;

Comment [L7]: Whereas it was ..

Key words: Benefit-Cost ratio, Disease incidence, Pesticides, Severity, *Tuta absoluta*, Tomato.

1. INTRODUCTION

Most vegetables in Eritrea are damaged due to a number of pathogens and insect pests. Tomato (*Lycopersicon esculentum* 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 is 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

Comment [L8]: The number of pathogens

36 to the Geneva-based International Trade Centre. In most parts of Africa, tomato is mainly produced
37 by small-scale farmers who have limited access to inputs such as good seeds, fertilizers and
38 pesticides. The crop is grown in many areas under natural rainfall, which makes the harvests
39 unpredictable and inconsistent. According to [2] tomato production can improve the livelihoods of
40 subsistence farmers by creating jobs and serving as source of income for both rural and per urban
41 dwellers.

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

46 According to the Ministry of Agriculture's Report for 2003 [5] , annually there is 25% yield loss of
47 tomato production because of insect pest and diseases, although sometime this loss can reach up to
48 40-50%. Diseases include late blight (*Phytophthora infestans*), early blight (*Alternaria alternata*) white
49 or grey mold (*Botrytis cinerea*), *Verticillium* and *Fusarium* wilts, damping off (*Pythium* spp.), bacterial
50 leaf spot (*Xanthomonas vesicatora*), mosaic and curly top viral diseases. Other pest are nematodes
51 (*Meloidogyne* spp.), African bollworm (*Helicoverpa armigera*), leaf worm (*Spodoptera lituralis*), aphids
52 (*Aphis gossypii*), whitefly (*Bemisia tabaci*), and very recently *Tuta absoluta* [Lepidoptera:Gelechiidae]
53 an invasive pest of tomato [6], [7a] and [7b]. In addition, adverse environmental conditions and the
54 deficit of nutrients also can cause 'cat-faced tomato', cracking, sun scald and blossom-end rot
55 (caused by water stress). *Tuta absoluta* Meyrick which arrived from South America via Spain in 2008
56 has spread across at last 15 African countries. This Lepidoptera is also known as tomato-leaf miner,
57 which kill plants as The larvae burrow into leaves, fruits and stems and in warm climates it can have
58 as many as 12 generations annually, with each female laying an average of 260 eggs. In Africa, the
59 majority of farmers still depend on indigenous pest management [8]. In Eritrea (Fig.1), this pest is
60 invasive, causing damage on tomato crops in various parts of the country.

Comment [L9]: sometimes

Comment [L10]: pests

Comment [L11]: kills

Comment [L12]: the larvae

Comment [L13]: where is the figure 1

61 1.1 Application of Pesticides

62 Pesticides have made great contributions in plant protection of this pest; but have also raised a
63 number of ecological and medical problems [9]. Nevertheless, the indiscriminate use of pesticide has
64 resulted in the development of resistance by pests (insects, weeds, etc), build-up resurgence and
65 outbreak of new pests. In general, pesticides are toxic to non-target organisms and have hazardous
66 effects on the environment which is dangerous to the sustainability of ecosystems [10].

Comment [L14]: pesticides

67 1.2 Botanicals

68 Plant Extract Insecticides (PEI), such as neem extracts (*Azadirachta indica* A. Juss) has long been
69 recognized as a source of environment-friendly bio-pesticide. *A. indica* has been recommended for
70 many Integrated Pest Management (IPM) programs [11]. Azadirachtin is one of the main botanical
71 pesticides in use and has potential as an alternative to conventional insecticides for such use.

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Comment [L16]: bio-pesticides

72 However, the effects of azadirachtin on the tomato leaf miner have been little studied and very little is
73 known of their sub-lethal behavioral effects on this pest species [12]. Azadirachtin caused mortality in
74 insect larvae (2.5–3.5%) at the recommended field-concentration (i.e., 27 mg/L) with negligible
75 difference between the populations tested. Azadirachtin also caused egg-laying avoidance and
76 affected walking by larvae, but not leaf-mining [12].

77 1.3 Objectives

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

Comment [L17]: blights

83 2. MATERIALS AND METHODS

84 2.1 Location

85 Field trials were conducted, for two consecutive seasons (2015 – 2016) in Hamelmalo Agricultural
86 College which is located northeast of Keren (15° 54.16'N and 38° 27'E) at an altitude of 1286 m above
87 the sea level. It has a semi-arid climate with an annual mean rainfall of 436mm and temperature of
88 7°C in winter and 42°C in summer.

89 2.2 Cultural Methods

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

95 2.3 Treatments

96 The treatments used were mancozeb, dimethoate, deltamethrin and aquatic extract of Neem Seed
97 Kernel (NSK) and their combinations at the rate of 2.5 g L⁻¹ for mancozeb, 2 mL L⁻¹ for dimethoate, 2
98 mL L⁻¹ for deltamethrin, and 5 mL L⁻¹ for aqueous neem leaf extract.

Comment [L18]: aqueous extract

Comment [L19]: neem seed kernel

99 2.4 Design and Analysis

100 The field trials were carried out in a Randomized Complete Block Design (RCBD) with three
101 replications. The gross plot sizes were 3 m x 3.75 m (11.25 m²). The data were analyzed using
102 GENSTAT software at 0.5 and 0.1% test of significance.

103 **2.5 Data Collection**

104 **Disease** Incidence (DI), Severity (DS) of Early Blights and Infestations of *T. absoluta* at Flowering
105 Stage, fruiting stage and harvesting stages were assessed by the following formulae:

Comment [L20]: Disease incidence (DI), disease severity (DS) of early blights and infestations of *T. absoluta* at flowering stage, fruiting stage and harvesting stage were

106 **2.5.1 Disease Incidence**

107
$$\text{Percentage of disease incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plants}} \times 100$$

108 **2.5.2 Disease Severity**

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

111
$$\text{Disease Index} = \frac{\text{Sum of all disease ratings}}{\text{Total No. of plants counted}} \times \frac{100}{\text{Maximum rating value}}$$

112 The disease severity was calculated by using 0-5 scale of [13].

113
$$\% \text{ of Disease Severity} = \frac{\sum(nxr1) - (nxr5)}{5N} \times 100$$

114 n = Number of infected leaves

115 r1 – r5 = Category number

116 N = Total examined leaves

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

Comment [L21]: the number of leaves / plant or

119 **2.6 Other Parameters**

120 Incidence of other diseases such as Fusarium wilt and root rots were evaluated based on the
121 observed symptoms of the disease and also on the identified pathogens after isolation; days to
122 flowering was determined on the basis of 50% flowering after transplanting; similarly days to fruiting
123 was recorded when mustard size fruits were observed on 50% plants after planting; Total yield (kg/h)
124 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.

Comment [L22]: (kg/ha)

125 **3. RESULTS AND DISCUSSION**

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

129 The disease incidence (DI) in all the pre-spray plots was ranging from 4.45 to 18.89. However, this
130 DI was decreased in the post spray assessment of the disease situation. During the post spray count
131 the disease decrease significantly in all the mancozeb and their combinations. The highest post spray
132 counts were recorded in treatments of T₂, T₃, T₄, T₅, T₉ and T₁₀. The reason for this high DI was due
133 to all these treatments were insecticides and control plot.

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134 Disease Severity (DS) assessment was high like that of DI in the pre-spray counts ranging from 2.53
135 to 8.87 percent. However, the DS was reduced in the post spray of mancozeb and its combinations.
136 The post spray assessment were lower in treatments of (T₁), mancozeb + dimethoate (T₆), mancozeb
137 + dimethoate + Neem Kernel Extract (NSE) together (T₇) and mancozeb + dimethoate + NSE (T₁₁).
138 This result revealed that mancozeb and mancozeb combinations were effective to reduce the DS of
139 bight on tomato crops.

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Comment [L26]: neem kernel extract (NSE)

Comment [L27]: same as NSK of line 97? Choose one form

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140 The pre-spray larval count did not show a significant difference among the treatments, the larval count
141 ranged from 3.33 to 6.67 per plot. Post-spray assessment larval count showed significant difference
142 among the treatments at P<0.05. Mancozeb and control plot had significantly higher larval count with
143 9.17 and 17.67 larvae per plot (Table 1). There was no significant difference in larval count in all the
144 remaining insecticides and neem extract sprayed plots. Treatments of T₁₀ and T₁₁ had lowest *T.*
145 *absoluta* larvae count with 0.87 and 0.67larva/plot, respectively. This result is similar to the report of
146 [14] where he got lower larval count and tomato plant damage with insecticide sprays. He also
147 reported that insecticides were more effective when applied at egg stage of the pest.

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Table 1. Efficacy of Treatments on Disease Incidence (DI), 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

Comment [L31]: ttreatments

Comment [L32]: diseases

Comment [L33]: incidence

Comment [L34]: disease severity

Comment [L35]: blights

Comment [L36]: infestations

Comment [L37]: flowering

Comment [L38]: stage

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

Comment [L39]: DI was

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

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169 There was no significant larval count per plant among the treatments in the pre spray count. However
170 in the post spray count the number of larvae count was significantly higher for insecticides sprayed
171 and their combination. The lowest larval counts per plot were counted in plots treated with dimethoate
172 + NSE and combination of dimethoate + mancozeb + NSE with 0.33 and 1.03 larvae per plant
173 respectively (Table 2).

Comment [L42]: delete count

Comment [L43]: insecticide treatments

Comment [L44]: to be deleted

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174 The larvae of *T. absoluta* cause plant damage at different stage and different parts of tomato crop.
175 There was a significant difference in plant damage among the treatments. Treatments T₁₁ and T₉ had
176 the lowest larval damage per plant with 1.33 and 2.33 larvae/plant respectively. The control plot and
177 sole mancozeb sprayed plot gave significantly higher larvae count per plant respectively. According to
178 In Brazil [12] reported that the *Azadirachtin* caused heavy mortality of larvae allowing only 2.5–3.5%
179 survival at concentration of 27 mg a.i./L. Neem extract spray also caused egg-laying avoidance and
180 reduced larvae feeding on treated plants.

Comment [L46]: stages

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

Comment [L49]: refer to the remarks relative to table 1.

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 spray
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

182 There was no significant difference in the DI of blight among the treatments used. On the other hand
183 all mancozeb and mancozeb and insecticide combination sprayed plot had significantly lower DS as
184 compared to insecticides treated plots. Lowest and highest DS were recorded from T₁₁ and T₁₀ with
185 7.3 and 30.81% (Table 3).

186 There was no significant difference in the pre-sprayed larval count per plant among the treatments
187 used. However, the post-spray counts showed that there were significant differences in larval damage
188 per plant among the treatments. The lowest damage was obtained from T₃ and highest damage was
189 recorded from the control plot T₄ with 0.67 and 11.67 larvae per plant respectively. This could be due
190 to the application of crude plant extracts of neem that could result in inhibiting the growth of larvae.
191 Similar results were reported by [15] who worked with neem and garlic extraction and found that neem
192 extraction was effective in retarding of larval development and reducing the mycelia growth of
193 *Fusarium oxysporum* f. sp. *lycopersici*.

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UNDER PEER REVIEW

Table 3. Effects of Treatments on Disease Incidence (DI), Severity(DS) of Blights and Infestations of *Tuta absoluta* at Harvesting Stage, 2015

Comment [L52]: See remarks of table 1

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

199 * Disease Incidence

200 # Disease Severity

201 All the treatments had an effect on DI and DS of Blight and infestations of *Tuta absoluta* at flowering
202 stage during 2016 (Table 4). Except for T₆, T₇, T₈ and T₁₁, the rest of the treatments reduced the
203 percentage of blight incidence and DS during post spray counts. Similarly treatment T₁₀ (dimethoate +
204 deltamethrin) and T₁₁ (mancozeb + dimethoate + NSE) gave drastic decrease in the number of *T.*
205 *absoluta* larvae from 11.33% to 3.83% for T₁₀ and from 10.33% to 2.17% for T₁₁. High level of plant
206 damage was recorded in T₂ and T₃ with 6.33 and 7.17 percent respectively (Table 4). However,
207 repeated use of pesticides is not recommended in current pest management as the pests develop
208 resistance to pesticides. [16] in Chile reported that *T. absoluta* developed resistance to many
209 pesticides such as deltamethrin, metamidophos, esfenvalerate, lambda-cyhalothrin and mevinphos.

Comment [L53]: Blight

210 .

UNDER PEER REVIEW

Table 4. Effects of fungicides on Diseases Incidence (DI) and Severity (DS) of Blight of Tomato and insecticides on infestations of *Tuta absoluta* at Flowering Stage, 2016

Comment [L54]: See table 1

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

211 Maximum disease incidence was recorded from treatments of T₅, T₉ and T₁₁ with 77.8, 73.3 and 72.6
 212 percent respectively. There was a decrease in disease incidence in treatment T₁ from 57.8% to
 213 12.6%. The percentage of DS was noticed, before and after spray of treatments, in declining order in
 214 T₁ and T₆ with 17.4 and 18.6 percent respectively. There was no significant difference in number of
 215 larvae/plot and plant damage/plot among the treatments used. The maximum number of plant
 216 damage was observed in T₆ (14.01%) and T₄ (14.67%); this was due to the tomato fruits in this
 217 treatment were damaged by rodents and birds (Table 5).

Comment [L55]: Delete

Comment [L56]: the fact that tomato fruits

Comment [L57]: Refer to table 1

Table 5. Effects of fungicides on Diseases Incidence (DI) and Severity (DS) of 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

218 Efficacy of treatments on number of larvae and fruit damage is shown in Table 6. In the pre spray
 219 count there was no significant difference among the treatments. However, during the post spray
 220 count, dimethoate, deltamethrin and neem extract and their combinations had significantly lower
 221 larvae per plot. The highest larval count was recorded from mancozeb and control plot with 9.67 and
 222 14.17larvae/plot respectively. During the study it was observed that *T. absoluta* caused high tomato
 223 fruit damage. The post spray damage assessment also showed that all the plots treated with
 224 dimethoate, deltamethrin and neem extracts and their interaction had significantly lower fruit damage
 225 per plot. The control and mancozeb treated plots gave higher fruit damage Table 6. Similar results
 226 were reported by [17] and [18] in Brazil where cartap and permethrin gave efficient control of the
 227 pests but later it was observed that the pest developed resistance to most of the pesticides used.

Comment [L58]: interaction

Comment [L59]:

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

Treatments	Number of larvae/plot		Number fruit damage/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

Comment [L60]: Number of fruits damaged/plot

229 In both 2015 and 2016 cropping seasons there was significant difference in the number of tomato fruit
 230 produced per plant. Treatment T₁, T₆ and T₁₁ gave the highest number of fruit per plant while the
 231 controls plot T₄, T₇, T₈ and T₁₀ gave lower number of fruit per plant (Table 7). There were no
 232 significant differences in the number of *T. absoluta* infestation among the treatments in both seasons.
 233 However, the highest *T. absoluta* infestation was recorded in the control plot (T₄) as compared to
 234 other treatments.

Comment [L61]: fruits

235 The yield of tomato varies from 105.9 to 250.9 q/ha. The highest yield in both seasons (2015 and
 236 2016), were harvested from T₁₁ followed by T₁, T₅ and T₁₀. The control plot gave significantly lower
 237 yield than all the treatments in both years (Table 7). Likewise the highest marketable yield of tomato
 238 was obtained from treatment T₁₁ and T₁, whereas the lowest marketable yield was acquired from the
 239 control plot. There was no significant difference in the yield of unmarketable tomato among the
 240 treatments; however the highest unmarketable yield was harvested from the control plot.

Table 7. Effect of Different pesticides on Fruit Infestation, Total Yield and Yield Attributing Parameters of Tomato During Two Years (2015 and 2016)

Comment [L62]: same remarks as table 1

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

241 Cost-benefit ratio (CBR) for tomato pest management during the two years is shown in Table 8. More
 242 or less the CBR for the two cropping years is similar, the highest (1.85) CBR was obtained from
 243 treatment T₁₁ (mancozeb + dimethoate + NSE) followed by treatment T₁ mancozeb with 1.73, whereas,
 244 the lowest CBR 0.73 was obtained from T₃ (Neem Seed Extract (NSE) (Table 8). The result showed
 245 that a combination of fungicide, insecticides and neem extract are more efficient in the management
 246 of tomato pests.

Comment [L63]: table 8

247 **Table 8. Cost-benefit ratio of tomato pest management for 2015 and 2016 cropping seasons**

Treatments	BCR for the first trial year 2015	BCR for the second trial year 2016	Average BCR
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

Comment [L64]: CBR? Must be uniform

Comment [L65]: CBR?

Comment [L66]: CBR?

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

249 4. CONCLUSION

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

Comment [L67]: Delete

Comment [L68]: Human beings

258 CONFLICT OF INTEREST

259 Authors have declared that no competing interests exist.

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