Field Efficacy of Various Insecticides and Trichogramma Chilonis (Ishii) Against Tomato Fruit Borer Helicoverpa Armigera (Hubner) (Lepidoptera: Notctuidae)

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Abstract

The present study investigated the comparative efficacy of botanical extracts (Neem 2 and 3%), commercial insecticide (Radiant) and bio-agent (Trichogramma chilonis) against tomato fruit borer Helicoverpa armigera in tomato crop under field conditions, Agriculture Research Institute (ARI) Tarnab Peshawar, 2019. The experiment was laid out under randomized complete block design (RCBD) with factorial arrangement having five treatments (Radiant, Neem (2 and 3%) and Trichogramma chilonis) replicated three times. Pre spray data was recorded before 24hrs of treatment application while post spray data was recorded after different time intervals (24hrs, 48hrs, 72hrs, 5 days, 7days, 10 days and 15 days) of each treatment application. Data regarding infestation showed that highest percent reduction over control was recorded in Radiant treated plots followed by Neem 3% and Trichogramma treated plots. The efficacy of each treatment was recorded at peak after 7 days then gradually declined and was found minimum after 15 days interval. However, highest larval and eggs infestation were recorded in control plots throughout the experimental period. Statistical analysis of the data also revealed that botanical extracts (Neem 2 and 3%), commercial insecticide (Radiant) and bio agent (Trichogramma chilonis) significantly reduced percent fruit damage. Highest percent reduction in comparison with control was recorded in the plots treated with commercial insecticide Radiant. Data further revealed that each treatment application significantly increased total tomato yield and total marketable tomato yield. Highest tomato total marketable yield (9583 kg ha-1) with 80% increase over control was recorded in the Radiant treated plots. It can be concluded that Radiant, Trichocards and Neem 3% comparatively have a high potential in reduction of fruit infestation which as a result gives higher yield with high percentage of marketable fruits and with highest cost benefit ratio.

Introduction

Tomato (*Lycopersicon esculentum* Mill) belongs to family Solanacea, is the most popular and widely cultivated vegetable in the world. It can be used in fresh or in processed form, while it is also a good source of vitamins A, B and C and aids in wound healing due to its antibiotic properties (Baloch 1994). According to the Food and Agriculture Organization corporate statistical data base, In 2017 production of tomato in the world was 182,301,395 metric tons. The largest producer country was China accounting 33% of total world production followed by India, USA and Turkey (FAOSTAT 2018). Statistics of 2015–2016 shows that the total area under cultivation of tomato in Pakistan was 4542 ha produce total of 142462 tons tomato, while in Khyber Pakhtunkhwa the total production of tomato was 43931 tons from the area of 3708 ha. (MNFSR 2016-17).

As compared to other countries the production of tomato is low in Pakistan due to several reasons while insect pests cause huge losses. Thus the quality and quantity of tomato is damaged at different level by different insect pests such as Aphids, jassids, whitefly and fruit worms (Hoffmann 2007). The important insect pest of tomato are fruit worm, *Helicoverpa armigera* (Hubner), and is the most serious agricultural insect pests worldwide (Atwal 1976).
In Pakistan, among other insect pests *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) is one of the important pests of many cultivated plants like tomato, chick pea, cotton, pigeon pea and are regularly the victims of *H. armigera* in various areas of the country. Tomato fruit borer feeds gregariously at the larval stages and due to this feeding habit causes huge loses in production of fruit. Adult of the borer usually can be seen from April to May and lays its eggs on the leaves. The immature larva feeds on the leaves, flowers and tomato fruits and finishes its developmental stages in the fruit. Larvae have almost 6 instars, all levels of larvae damage tomato fruit. In the process of maturation, larvae can comes out and move to another tomato fruit. The last instar of larvae falls to the ground from tomato fruit and pupates beneath the soil. Approximately 12 fruits of tomato can be damaged by one caterpillar, reduce market value, and ultimately cause a great deal of financial damage to farmers (Hussain and Bilal 2007).

To deal with this potential and notorious pest, 85% of the world use insecticide to manage this pest (Shaheen 2008). However, incredible use of synthetic insecticide has led to the problem of pest resurgence, insecticidal resistance in insects, environmental pollution, health problems, decimation of useful fauna and the increased cost of pest controls as well (Hussain 1993). In order to address all these issues, it has become imperative to explore the substitutes of these toxic insecticides to keep the *H. armigera* population below injury level and have no harmful effect on bio control agents (Hassan 1992).

Biological control is becoming a promising pest control method with many advantages over insecticides such as host-specific, non-toxic benefit to mammals and organisms, less insect-resistant, readily biodegradable and cheaper as well (Wink 1993). Similarly, there has been great interest in the development of environmental friendly botanical formulations (Schmutterer 1990). These include neem (*Azadirachta indica*), Ageratum, Chrysanthemum and Karanj, which have been used to control *Helicoverpa* pest generations. It has become the most powerful source of botanical pesticides (Schmutterer 1990).

*Trichogramma* is an ovarian parasite species most frequently used in a large-scale biological surveillance program against lepidopteran pests. Adult of *T. chilonis* (Hymenoptera: Trichogrammatidae) are small wasps that kills a host's eggs by letting one or more of its eggs into much larger Lepidopteran eggs. Different species of *Trichogramma* are maximally used insects in the world because of their ease of mass production and application against many pests (Ayvaz et al. 2008).

People use different type of pesticides to combat these pests and save crops. However, the continued and widespread use of similar insecticide groups causes problems with pesticide residues and other environmental pollution. This has highlighted the need to develop new, safer and easily degradable pesticides that can be viable and effective for pest control. Spinosad is one of those new substances derived from the soil actinomycete fermentation soup *Saccharopolyspora spinosa*, which comprise of spinosyn A and spinosyn D. Spinosad have faster contact and ingestion activity in insects that helps in causing excitation of the nervous system, leading to paralysis and cessation of feeding (Amalendu et al. 2009).
The economic importance of agricultural products has forced farmers to use pesticides almost daily, sometimes as much as twice according to the recommended dose. The indispensable use of synthetic pesticides to control this pest has led to the formation of harmful pesticides and fruit residues (Armes et al. 1994).

METHODS AND MATERIALS

Location

The study regarding field efficacy of botanical, commercial insecticide and *Trichogramma chilonis* against tomato fruit borer *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) was conducted in the field of Entomology section, Agriculture Research institute (ARI) Tarnab Peshawar, from April to August 2019.

Field Layout, Preparation and Transplantation

The experiment was laid out under Randomized Complete Block Design (RCBD) with five treatments replicated three times. The whole field was divided into three equal parts considered as Blocks or Replicates. Then each block was further divided into five subplots 3x4 meter each by leaving 1 meter space/distance between these subplots to act as buffer zone, to avoid mixing or drift of the tested treatments. All standard agronomic practices required for vegetable growing before nursery transplantation also including recommended dose of NPK fertilizer application was applied at the time of field preparation. Before plantation five ridges were prepared in each subplot with row to row distance of 75 cm. When the nursery of tomato plants acquired the desired width, that is common pencil size and with 5–6 inch height, during March it was transplanted. Plant to plant distance was kept 30 cm throughout the replications. In order to avoid possible movement of *T. chilonis*, plots treated with *T. chilonis* were covered with green house net having height of 1.5 meter throughout the experiment.

Treatments

Selected treatments shown in the following tables were used against tomato fruit borer (*H. armigera*). Treatments were prepared on the basis of recommended dose.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Common name</th>
<th>Trade name</th>
<th>Active ingredient</th>
<th>Recommended dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spinetoram</td>
<td>Radiant</td>
<td>Spinetoram</td>
<td>0.8ml/L</td>
</tr>
<tr>
<td>2</td>
<td>Neem oil</td>
<td>Neem oil 2%</td>
<td><em>Azadiricha indica</em></td>
<td>20ml/L</td>
</tr>
<tr>
<td>3</td>
<td>Neem oil</td>
<td>Neem oil 3%</td>
<td><em>Azadiricha indica</em></td>
<td>30ml/L</td>
</tr>
<tr>
<td>4</td>
<td><em>Trichogramma</em></td>
<td><em>Trichogramma chilonis</em></td>
<td>————</td>
<td>5 cards/12m²</td>
</tr>
</tbody>
</table>
1. **Trichogramma chilonis (Ishii) egg cards**

Trichocards each containing 50 numbers of parasitized eggs of *T. chilonis* was acquired from the laboratory of entomology ARI, Tarnab, Peshawar. Trichocards were taken in the plastic jar and staple with randomized selected plants in each plot before the initiation of flowering stage.

2. **Neem Oil**

Neem oil was purchased from the local market and was applied at 2% and 3% concentration respectively.

3. **Radiant 120SC**

Radiant is the main product of Arysta life sciences, having spinetoram as active ingredient was purchased from the local market of Khyber Pakhtunkhwa, Peshawar, Pakistan.

4. **Control**

Only water was sprayed on control plots and they was remained untreated as well.

**Application of the Treatments**

Trichocards each having 50 numbers of parasitized eggs at pupal stage of *Trichogramma* was installed in the field. Trichocards containing more emergence potential in less time was acquired from the laboratory. Five Trichocards, each containing 50 number of parasitized eggs was counted and was applied/stapled before initiation of flowering stage with the tomato leaves in per plot.

Application of botanical and chemical insecticide were started as soon as the pest infestation appeared and reached to ETL (1 larvae/plant) till the end of the crop. When the first symptoms of the pests was seen at the beginning of flowering, botanical (neem oil) and insecticide (radiant) treatments were used, followed by a second and third application at an interval of 15 days. Spray of each treatment was applied during normal weather conditions particularly not during just afternoon and windstorm so that to avoid drift.

**Parameters**

The data was recorded on the basis of following parameters.

1. **Larval population count**

The number of larvae per plant was observed separately, by using the forceps, soft camel hair brush and petri dishes or direct count method. Pre spray data was recorded 24hr before the spray application and then after spray application at the interval of 24 hours, 48 hours, 5th day, 7th day, 10th day and 15th day for each plant. Samples were taken in polyethylene bags to bring laboratory and examined by
stereomicroscope. All preserved specimens were identified at Plant Protection Department, with taxonomic keys. The infestation for each replicated plot was averaged and presented in the Table.

2. Pest population count

The pest population including larval density and egg counts on each leaf of the plant was recorded through magnifying lens. Eggs infestation data was recorded before 24 hrs of spray application and then after spray application at interval of 24 hours, 48 hours, 5th day, 7th day, 10th day and 15th day.

3. Percent fruit damage per treatment

3.1 Percent fruit damage by weight

The percent fruit damage by weight was calculated before and after spray application separately and then the damage fruits were added and converted by applying the following formula.

\[
\text{Fruit damage by weight} = \frac{\text{weight of damaged fruit}}{\text{total weight of fruit}} \times 100
\]

3.2 Percent fruit damage by number

The percent of damage fruit by its number was noted down distinctly and then converted all the damage fruit into percent by the following applied formula.

\[
\text{Fruit damage by number} = \frac{\text{number of damage fruits}}{\text{total number of fruits}} \times 100
\]

4. Effect of each treatment on yield of tomato

The effect of each treatment on the yield of tomato was determined by adding the total tomato fruit picked in replicated plots for each treatment as per the following formula.

\[
\text{Yield (kg/ha)} = \frac{\text{Yield plot}^{-1} \times 10000}{\text{Plot size (m}^2\text{)}}
\]

5. Cost Benefits Ratio Analysis:

Cost benefit ratio shows the utmost economic control measure for management of different pest in various crops. The cost benefit ratio for all treatments was calculated by the following formula.

\[
\text{Cost benefit ratio} = \frac{\text{Total income}}{\text{Total cost}}
\]

Statistical analysis
All the data was subjected to analysis of variance (ANOVA) under RCBD to evaluate the infestation of *H. armigera* larval and egg population. Means were separated using LSD tested at 0.05% level of significance using statistix 8.1 package (Steel and Torrie, (1980)).

**RESULTS**

Field efficacy of botanicals, synthetic insecticide and bio control agent were tested against tomato fruit borer (*Helicoverpa armigera*) on tomato crop. Data were obtained for various parameters including cost benefit ratio and presented in Tables 1–9 with their ANOVA given in Appendix I-I0. Results recorded are described below.

**First Spray**

**1. Effect on eggs infestation**

Effect of botanical, commercial insecticides and *Trichogramma* on mean eggs infestation of fruit borer *H. armigera* after 1st spray at different time intervals was recorded. The mean data after 1st spray are presented in Table 1.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>24 hrs</th>
<th>48 hrs</th>
<th>72 hrs</th>
<th>5 days</th>
<th>7 days</th>
<th>10 days</th>
<th>15 days</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>3.97e</td>
<td>3.86f</td>
<td>3.77ijkl</td>
<td>3.67mno</td>
<td>3.56r</td>
<td>3.58qr</td>
<td>3.61opqr</td>
<td>3.72c</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>3.96e</td>
<td>3.89f</td>
<td>3.79hjik</td>
<td>3.72lm</td>
<td>3.60qr</td>
<td>3.62opqr</td>
<td>3.64nopq</td>
<td>3.75b</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>3.90f</td>
<td>3.88f</td>
<td>3.82ghi</td>
<td>3.74kl</td>
<td>3.61pqr</td>
<td>3.63nopq</td>
<td>3.66nop</td>
<td>3.75b</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>3.86fg</td>
<td>3.79hjik</td>
<td>3.80hij</td>
<td>3.76ijkl</td>
<td>3.64nopq</td>
<td>3.66nop</td>
<td>3.68nn</td>
<td>3.74b</td>
</tr>
<tr>
<td>Control</td>
<td>3.84fg</td>
<td>3.90f</td>
<td>3.98de</td>
<td>4.04d</td>
<td>4.10c</td>
<td>4.32b</td>
<td>4.57a</td>
<td>4.11a</td>
</tr>
<tr>
<td>Mean</td>
<td>3.91a</td>
<td>3.86b</td>
<td>3.83c</td>
<td>3.79d</td>
<td>3.70e</td>
<td>3.76d</td>
<td>3.83c</td>
<td></td>
</tr>
</tbody>
</table>

*Means in rows and columns followed by different letters are significantly different at P-value ≤ 0.05

LSD value (P ≤ 0.05) for treatment = 0.022

LSD value (P ≤ 0.05) for time = 0.026

LSD value (P ≤ 0.05) for treatment× time intervals = 0.057

Statistical analysis of the data revealed that both botanical, commercial insecticides and *Trichogramma* significantly (P ≤ 0.05 and F-value = 56.87) reduced the eggs population of *H. armigera*. Lowest eggs population (3.72 eggs/plant) was recorded in the plots treated with commercial insecticide Radiant, followed by eggs population (3.75 eggs/plant) was recorded in the plots treated with botanical insecticide.
Neem (3%). The eggs population (3.75 eggs/plant) was noted in the plots treated with biological agent (*Trichogramma*). Highest eggs population (4.11 eggs/plant) was observed in control treatment.

Different time intervals also significantly (P ≤ 0.05 and F-value = 468.97) reduced the eggs population of *H. armigera*. Lowest eggs population (4.11 eggs/plant) was observed in control treatment.

Interaction effect of time interval and treatments were also found significant (P ≤ 0.05 and F-value = 65.46). Lowest eggs population (3.70 eggs/plant) was recorded after 7 days, followed by the eggs population (3.76 eggs/plant) was recorded after 10 days. Highest eggs population (3.91 eggs/plant) was recorded after 24 hours.

2. Effect on larval infestation

The mean data regarding larval population density of *H. armigera* after application of first spray are presented in Table 2.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>24 hrs</th>
<th>48 hrs</th>
<th>72 hrs</th>
<th>5 days</th>
<th>7 days</th>
<th>10 days</th>
<th>15 days</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>2.12e</td>
<td>2.01f</td>
<td>1.92ijkl</td>
<td>1.82mno</td>
<td>1.71r</td>
<td>1.73qr</td>
<td>1.76opqr</td>
<td>1.87c</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>2.11e</td>
<td>2.04f</td>
<td>1.94hijk</td>
<td>1.87lm</td>
<td>1.75qr</td>
<td>1.77opqr</td>
<td>1.79nopq</td>
<td>1.90b</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>2.05f</td>
<td>2.03f</td>
<td>1.97ghi</td>
<td>1.89kl</td>
<td>1.76pqr</td>
<td>1.78nopq</td>
<td>1.81nop</td>
<td>1.90b</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>2.01fg</td>
<td>1.94hijk</td>
<td>1.95hij</td>
<td>1.91jkl</td>
<td>1.79nopq</td>
<td>1.81nop</td>
<td>1.83mn</td>
<td>1.89b</td>
</tr>
<tr>
<td>Control</td>
<td>1.99fg</td>
<td>2.05f</td>
<td>2.13de</td>
<td>2.19d</td>
<td>2.25c</td>
<td>2.47b</td>
<td>2.72a</td>
<td>2.26a</td>
</tr>
<tr>
<td>Mean</td>
<td>2.06a</td>
<td>2.01b</td>
<td>1.98c</td>
<td>1.94d</td>
<td>1.85e</td>
<td>1.91d</td>
<td>1.98c</td>
<td></td>
</tr>
</tbody>
</table>

*LSD value (P ≤ 0.05) for treatment = 0.022

*LSD value (P ≤ 0.05) for time = 0.026

*LSD value (P ≤ 0.05) for treatment× time intervals = 0.057

Statistical analysis of the data revealed that both botanical, commercial insecticides and *Trichogramma* significantly (P ≤ 0.05 and F-value = 56.87) reduced the larval population of *H. armigera*. Lowest larval population (1.87 larvae/plant) was recorded in the plots treated with commercial insecticide Radiant,
followed by larval population (1.90 larvae/plant) was recorded in the plots treated with botanical insecticide Neem (3%). The larval population (1.90 larvae/plant) was noted in the plots treated with bio control agent (Trichogramma). Highest larval population (2.26 larvae/plant) was observed in control treatment.

Different time intervals also significantly (P ≤ 0.05 and F-value = 468.97) reduced the larval population of H. armigera. Lowest larval population (1.85 larvae/plant) was recorded after 7 days, followed by the larval population (1.91 larvae/plant) was recorded after 10 days. Highest larval population (2.06 larvae/plant) was recorded after 24 hours.

Interaction effect of time interval and treatments were also found significant (P ≤ 0.05 and F-value = 65.46). Lowest larval population (1.71 larvae/plant) was recorded after 7 days in the plots treated with commercial insecticide Radiant, followed by the larval population (1.73 larvae/plant) was recorded after 10 days in the plots treated with Radiant. Highest larval population (2.72 larvae/plant) was recorded after 15 days in control plots.

Second spray

1. Effect on eggs infestation

Effect of botanical, commercial insecticides and Trichogramma on mean eggs infestation of fruit borer (H. armigera) after 2nd spray at different time intervals was recorded. The mean data after 2nd spray are presented in Table 3.
Table 3
Effect of botanical, commercial insecticides and *Trichogramma* on eggs infestation of *H. armigera* after 2nd spray at different time intervals

<table>
<thead>
<tr>
<th>Treatments</th>
<th>24 hrs</th>
<th>48 hrs</th>
<th>72 hrs</th>
<th>5 days</th>
<th>7 days</th>
<th>10 days</th>
<th>15 days</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>3.58</td>
<td>3.50</td>
<td>3.37</td>
<td>3.30</td>
<td>3.16</td>
<td>3.20</td>
<td>3.24</td>
<td>3.34</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>3.62</td>
<td>3.54</td>
<td>3.37</td>
<td>3.29</td>
<td>3.20</td>
<td>3.23</td>
<td>3.26</td>
<td>3.36</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>3.64</td>
<td>3.58</td>
<td>3.46</td>
<td>3.37</td>
<td>3.24</td>
<td>3.28</td>
<td>3.31</td>
<td>3.41</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>3.67</td>
<td>3.61</td>
<td>3.50</td>
<td>3.42</td>
<td>3.30</td>
<td>3.33</td>
<td>3.36</td>
<td>3.46</td>
</tr>
<tr>
<td>Control</td>
<td>4.66</td>
<td>4.76</td>
<td>4.84</td>
<td>4.96</td>
<td>5.06</td>
<td>5.14</td>
<td>5.18</td>
<td>4.94</td>
</tr>
<tr>
<td>Mean</td>
<td>3.83</td>
<td>3.80</td>
<td>3.71</td>
<td>3.67</td>
<td>3.59</td>
<td>3.64</td>
<td>3.67</td>
<td>3.67</td>
</tr>
</tbody>
</table>

*Means in rows and columns followed by different letters are significantly different at p-value ≤ 0.05*

LSD value (P ≤ 0.05) for treatment = 0.016

LSD value (P ≤ 0.05) for time = 0.019

LSD value (P ≤ 0.05) for treatment× time intervals = 0.042

Statistical analysis of the data revealed that both botanical, commercial insecticides and *Trichogramma* significantly (P ≤ 0.05 and F-value = 172.40) reduced the eggs population of *H. armigera*. Lowest eggs population (3.34 eggs/plant) was recorded in the plots treated with commercial insecticide Radiant, followed by eggs population (3.36 eggs/plant) was recorded in the plots treated with botanical insecticide Neem (3%). The eggs population (3.41 eggs/plant) was noted in the plots treated with biological agent (*Trichogramma*). Highest eggs population (4.94 eggs/plant) was observed in control treatment.

Different time intervals also significantly (P ≤ 0.05 and F-value = 15290.7) reduced the eggs population of *H. armigera*. Lowest eggs population (3.59 eggs/plant) was recorded after 7 days, followed by the eggs population (3.64 eggs/plant) was recorded after 10 days. Highest eggs population (3.83 eggs/plant) was recorded after 24 hours.

Interaction effect of time interval and treatments were also found significant (P ≤ 0.05 and F-value = 108.65). Lowest eggs population (3.16 eggs/plant) was recorded after 7 days in the plots treated with commercial insecticide Radiant, followed by the eggs population (3.20 eggs/plant) was recorded after 10 days in the plots treated with Radiant. Highest eggs population (5.18 eggs/plant) was recorded after 15 days in control plots.

**2. Effect on larval infestation**

Effect of botanical, commercial insecticides and *Trichogramma* on mean larval population count of fruit borer (*H. armigera*) after 2nd spray at different time intervals was recorded. The mean data after 2nd
spray are presented in Table 4.

### Table 4
Effect of botanical, commercial insecticides and *Trichogramma* on larval population count of *H. armigera* after 2nd spray at different time intervals

<table>
<thead>
<tr>
<th>Treatments</th>
<th>24 hrs</th>
<th>48 hrs</th>
<th>72 hrs</th>
<th>5 days</th>
<th>7 days</th>
<th>10 days</th>
<th>15 days</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>1.73&lt;sup&gt;ij&lt;/sup&gt;</td>
<td>1.65&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>1.52&lt;sup&gt;o&lt;/sup&gt;</td>
<td>1.45&lt;sup&gt;pqr&lt;/sup&gt;</td>
<td>1.31&lt;sup&gt;v&lt;/sup&gt;</td>
<td>1.35&lt;sup&gt;uv&lt;/sup&gt;</td>
<td>1.39&lt;sup&gt;stu&lt;/sup&gt;</td>
<td>1.49&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>1.77&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>1.69&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>1.52&lt;sup&gt;o&lt;/sup&gt;</td>
<td>1.44&lt;sup&gt;pqr&lt;/sup&gt;</td>
<td>1.35&lt;sup&gt;uv&lt;/sup&gt;</td>
<td>1.38&lt;sup&gt;tu&lt;/sup&gt;</td>
<td>1.41&lt;sup&gt;rst&lt;/sup&gt;</td>
<td>1.50&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>1.79&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>1.73&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>1.61&lt;sup&gt;mn&lt;/sup&gt;</td>
<td>1.52&lt;sup&gt;o&lt;/sup&gt;</td>
<td>1.39&lt;sup&gt;stu&lt;/sup&gt;</td>
<td>1.43&lt;sup&gt;qrs&lt;/sup&gt;</td>
<td>1.46&lt;sup&gt;pq&lt;/sup&gt;</td>
<td>1.56&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>1.82&lt;sup&gt;g&lt;/sup&gt;</td>
<td>1.76&lt;sup&gt;hij&lt;/sup&gt;</td>
<td>1.65&lt;sup&gt;lm&lt;/sup&gt;</td>
<td>1.57&lt;sup&gt;n&lt;/sup&gt;</td>
<td>1.45&lt;sup&gt;pqr&lt;/sup&gt;</td>
<td>1.48&lt;sup&gt;op&lt;/sup&gt;</td>
<td>1.51&lt;sup&gt;o&lt;/sup&gt;</td>
<td>1.61&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>2.81&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2.91&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.99&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.09&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>1.99&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.95&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.86&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.82&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.74&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.79&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.82&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

*Means in rows and columns followed by different letters are significantly different at p-value ≤ 0.05*

LSD value (P ≤ 0.05) for treatment = 0.016

LSD value (P ≤ 0.05) for time = 0.019

LSD value (P ≤ 0.05) for treatment× time intervals = 0.042

Statistical analysis of the data revealed that both botanical, commercial insecticides and *Trichogramma* significantly (P ≤ 0.05 and F-value = 172.40) reduced the larval population of *H. armigera*. Lowest larval population (1.49 larvae/plant) was recorded in the plots treated with commercial insecticide Radiant, followed by larval population (1.50 larvae/plant) was recorded in the plots treated with botanical insecticide Neem (3%). The larval population (1.56 larvae/plant) was noted in the plots treated with biological agent (*Trichogramma*). Highest larval population (3.09 larvae/plant) was observed in control treatment.

Different time intervals also significantly (P ≤ 0.05 and F-value = 15290.7) reduced the larval population of *H. armigera*. Lowest larval population (1.74 larvae/plant) was recorded after 7 days, followed by the larval population (1.79 larvae/plant) was recorded after 10 days. Highest larval population (1.99 larvae/plant) was recorded after 24 hours.

Interaction effect of time interval and treatments were also found significant (P ≤ 0.05 and F-value = 108.65). Lowest larval population (1.31 larvae/plant) was recorded after 7 days in the plots treated with commercial insecticide Radiant, followed by the larval population (1.35 larvae/plant) was recorded after 10 days in the plots treated with Radiant. Highest larval population (3.33 larvae/plant) was recorded after 15 days in control plots.

**Third spray**
1. Effect on eggs infestation

Effect of botanical, commercial insecticides and *Trichogramma* on mean eggs infestation of fruit borer (*H. armigera*) after 3rd spray at different time intervals was recorded. The mean data after 3rd spray are presented in Table 5.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>24 hrs</th>
<th>48 hrs</th>
<th>72 hrs</th>
<th>5 days</th>
<th>7 days</th>
<th>10 days</th>
<th>15 days</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>3.22</td>
<td>3.00</td>
<td>2.76</td>
<td>2.57</td>
<td>2.41</td>
<td>2.44</td>
<td>2.47</td>
<td>2.70</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>3.27</td>
<td>3.11</td>
<td>3.02</td>
<td>2.90</td>
<td>2.76</td>
<td>2.78</td>
<td>2.80</td>
<td>2.95</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>3.30</td>
<td>3.16</td>
<td>3.10</td>
<td>3.00</td>
<td>2.86</td>
<td>2.88</td>
<td>2.92</td>
<td>3.03</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>3.36</td>
<td>3.27</td>
<td>3.16</td>
<td>3.07</td>
<td>2.96</td>
<td>3.00</td>
<td>3.02</td>
<td>3.12</td>
</tr>
<tr>
<td>Control</td>
<td>5.27</td>
<td>5.42</td>
<td>5.56</td>
<td>5.69</td>
<td>5.74</td>
<td>5.84</td>
<td>5.96</td>
<td>5.64</td>
</tr>
<tr>
<td>Mean</td>
<td>3.68</td>
<td>3.59</td>
<td>3.52</td>
<td>3.45</td>
<td>3.35</td>
<td>3.39</td>
<td>3.43</td>
<td></td>
</tr>
</tbody>
</table>

*Means in rows and columns followed by different letters are significantly different at p-value ≤ 0.05*

LSD value (P ≤ 0.05) for treatment = 0.033

LSD value (P ≤ 0.05) for time = 0.039

LSD value (P ≤ 0.05) for treatment× time intervals = 0.088

Statistical analysis of the data revealed that both botanical, commercial insecticides and *Trichogramma* significantly (P ≤ 0.05 and F-value = 73.24) reduced the eggs population of *H. armigera*. Lowest eggs population (2.70 eggs/plant) was recorded in the plots treated with commercial insecticide Radiant, followed by eggs population (2.95 eggs/plant) was recorded in the plots treated with botanical insecticide Neem (3%). The eggs population (3.03 eggs/plant) was noted in the plots treated with biological agent (*Trichogramma*). Highest eggs population (5.64 eggs/plant) was observed in control treatment.

Different time intervals also significantly (P ≤ 0.05 and F-value = 10652.0) reduced the eggs population of *H. armigera*. Lowest eggs population (3.35eggs/plant) was recorded after 7 days, followed by the eggs population (3.39 eggs/plant) was recorded after 10 days. Highest eggs population (3.68 eggs/plant) was recorded after 24 hours.

Interaction effect of time interval and treatments were also found significant (P ≤ 0.05 and F-value = 44.01). Lowest eggs population (2.41 eggs/plant) was recorded after 7 days in the plots treated with
commercial insecticide Radiant, followed by the eggs population (2.44 eggs/plant) was recorded after 10 days in the plots treated with Radiant. Highest eggs population (5.96 eggs/plant) was recorded after 15 days in control plots.

2. Effect on larval infestation

Effect of botanical, commercial insecticides and *Trichogramma* on mean larval population count of fruit borer (*H. armigera*) after 3rd spray at different time intervals was recorded. The mean data after 3rd spray are presented in Table 6.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>24 hrs</th>
<th>48 hrs</th>
<th>72 hrs</th>
<th>5 days</th>
<th>7 days</th>
<th>10 days</th>
<th>15 days</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>1.37&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>1.15&lt;sup&gt;mno&lt;/sup&gt;</td>
<td>0.91&lt;sup&gt;t&lt;/sup&gt;</td>
<td>0.72&lt;sup&gt;u&lt;/sup&gt;</td>
<td>0.56&lt;sup&gt;v&lt;/sup&gt;</td>
<td>0.59&lt;sup&gt;v&lt;/sup&gt;</td>
<td>0.62&lt;sup&gt;v&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>1.42&lt;sup&gt;h&lt;/sup&gt;</td>
<td>1.26&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>1.17&lt;sup&gt;lmn&lt;/sup&gt;</td>
<td>1.05&lt;sup&gt;pq&lt;/sup&gt;</td>
<td>0.91&lt;sup&gt;t&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;st&lt;/sup&gt;</td>
<td>0.95&lt;sup&gt;rst&lt;/sup&gt;</td>
<td>1.10&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>1.45&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>1.31&lt;sup&gt;ij&lt;/sup&gt;</td>
<td>1.25&lt;sup&gt;kl&lt;/sup&gt;</td>
<td>1.15&lt;sup&gt;mno&lt;/sup&gt;</td>
<td>1.01&lt;sup&gt;qrs&lt;/sup&gt;</td>
<td>1.03&lt;sup&gt;pqr&lt;/sup&gt;</td>
<td>1.07&lt;sup&gt;opq&lt;/sup&gt;</td>
<td>1.18&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>1.51&lt;sup&gt;g&lt;/sup&gt;</td>
<td>1.42&lt;sup&gt;h&lt;/sup&gt;</td>
<td>1.3&lt;sup&gt;ij&lt;/sup&gt;</td>
<td>1.22&lt;sup&gt;klm&lt;/sup&gt;</td>
<td>1.11&lt;sup&gt;nop&lt;/sup&gt;</td>
<td>1.15&lt;sup&gt;mno&lt;/sup&gt;</td>
<td>1.17&lt;sup&gt;lmn&lt;/sup&gt;</td>
<td>1.27&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>3.42&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.57&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.71&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.84&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.89&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.79&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>1.83&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.74&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.67&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.60&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.50&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.54&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.58&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

*Means in rows and columns followed by different letters are significantly different at p-value ≤ 0.05

LSD value (P ≤ 0.05) for treatment = 0.033

LSD value (P ≤ 0.05) for time = 0.039

LSD value (P ≤ 0.05) for treatment× time intervals = 0.088

Statistical analysis of the data revealed that both botanical, commercial insecticides and *Trichogramma* significantly (P ≤ 0.05 and F-value = 73.24) reduced the larval population of *H. armigera*. Lowest larval population (0.85 larvae/plant) was recorded in the plots treated with commercial insecticide Radiant, followed by larval population (1.10 larvae/plant) was recorded in the plots treated with botanical insecticide Neem (3%). The larval population (1.18 larvae/plant) was noted in the plots treated with biological agent (*Trichogramma*). Highest larval population (3.79 larvae/plant) was observed in control treatment.

Different time intervals also significantly (P ≤ 0.05 and F-value = 10652.0) reduced the larval population of *H. armigera*. Lowest larval population (1.50 larvae/plant) was recorded after 7 days, followed by the larval population (1.54 larvae/plant) was recorded after 10 days. Highest larval population (1.83 larvae/plant) was recorded after 24 hours.
Interaction effect of time interval and treatments were also found significant ($P \leq 0.05$ and $F$-value = 44.01). Lowest larval population (0.56 larvae/plant) was recorded after 7 days in the plots treated with commercial insecticide Radiant, followed by the larval population (0.59 larvae/plant) was recorded after 10 days in the plots treated with Radiant. Highest larval population (4.11 larvae/plant) was recorded after 15 days in control plots.

**Effect on percent fruit damage**

A gradational decline was found in percent fruit damage by the application of botanical, commercial insecticides and *Trichogramma*. Effect of each treatment on percent fruit damage by number and weight was recorded and presented in Table 7 during the experiment.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>% damaged fruits (No.)</th>
<th>% decrease over control (No.)</th>
<th>% damaged fruits (weight)</th>
<th>% decrease over control (weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>6.13 e</td>
<td>83.03</td>
<td>5.53 e</td>
<td>85.30</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>9.76 d</td>
<td>72.98</td>
<td>8.11 d</td>
<td>78.45</td>
</tr>
<tr>
<td><em>Trichogramma</em></td>
<td>11.53 c</td>
<td>68.08</td>
<td>12.15 c</td>
<td>67.71</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>14.42 b</td>
<td>60.08</td>
<td>15.67 b</td>
<td>58.36</td>
</tr>
<tr>
<td>Control</td>
<td>36.12 a</td>
<td>0.00</td>
<td>37.63 a</td>
<td>0.00</td>
</tr>
<tr>
<td>LSD value</td>
<td>0.70</td>
<td>-</td>
<td>0.40</td>
<td>-</td>
</tr>
</tbody>
</table>

*Means followed by different letters are significantly different at p-value $\leq 0.05$

1. **Percent fruit damage by number**

Analysis of variance of data showed that spray application of botanical, commercial insecticides and *Trichogramma* significantly ($P \leq 0.05$ and $F$-value = 11094.4) reduced percent tomato fruit damage by number. Highest reduction of fruit damage by number (6.13) with 83% decrease over control was recorded in the plots treated with commercial insecticide Radiant, followed by fruit damage by number (9.76) with 73% decrease over control was recorded in the plots treated with botanical insecticide Neem (3%). Reduction of fruit damage (11.53) with 68% decrease over control was noted in the plots treated with *Trichogramma*. Lowest reduction of fruit damage (36.12) was observed in control plots. Commercial insecticide Radiant was found more effective in reduction of fruit damage by number compared to botanical insecticide (Neem 2 and 3%) and *Trichogramma chilonis*.

2. **Percent fruit damage by weight**
Effect of spray application of botanical, commercial insecticides and *Trichogramma chilonis* on percent tomato fruit damage by weight was also found significant (P ≤ 0.05 and F-value = 3058.00). Highest fruit damage by weight (37.63) was recorded in control. Lowest fruit damage by weight (5.53) with 85% decrease over control was recorded in the plots treated with commercial insecticide Radiant, followed by fruit damage by weight (8.11) with 78% decrease over control was recorded in the plots treated with botanical insecticide Neem (3%). Reduction of fruit damage by weight (12.15) with 68% decrease over control was noted in the plots treated with *T. chilonis*. Results clearly indicated that strong positive reduction in percent fruit damage by weight was found in the plots treated with commercial insecticide Radiant compared to all other treatments.

**Effect of each treatment on average yield of tomato (kg)**

The data recorded on average yield per plot and total marketable yield of tomato are presented in Table 8.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (kg) plot⁻¹</th>
<th>Total marketable yield (kg ha⁻¹)</th>
<th>Percent increase over control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>11.5 a</td>
<td>9583 a</td>
<td>79.69</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>10.1 b</td>
<td>8417 b</td>
<td>57.83</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>9.1 c</td>
<td>7583 c</td>
<td>42.19</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>8.6 d</td>
<td>7167 d</td>
<td>34.39</td>
</tr>
<tr>
<td>Control</td>
<td>6.4 e</td>
<td>5333 e</td>
<td>0.00</td>
</tr>
<tr>
<td>LSD value</td>
<td>0.40</td>
<td>334.47</td>
<td>-</td>
</tr>
</tbody>
</table>

*Means followed by different letters are significantly different at P-value ≤ 0.05.*

1. **Yield per plot (kg)**

Statistical analysis of the data indicated that spray application of botanical, commercial insecticides and *Trichogramma chilonis* significantly (P ≤ 0.05 and F-value = 235.58) increased tomato yield per plot. Maximum tomato yield (11.5 kg plot⁻¹) was recorded in the plots treated with commercial insecticide Radiant, followed by the tomato yield (10.1 kg plot⁻¹) was recorded in the plots treated with botanical insecticide Neem (3%). Tomato yield of (9.1 kg plot⁻¹) was noted in the plots treated with *Trichogramma*. Minimum tomato yield (6.4 kg plot⁻¹) was observed in control plots.

2. **Total marketable yield (kg ha)**
Analysis of variance of the data revealed that total marketable yield of tomato was also significantly (P ≤ 0.05 and F-value = 235.86) affected by spray application of botanical, commercial insecticides and \textit{Trichogramma chilonis}. Highest tomato total marketable yield (9583 kg ha\(^{-1}\)) with 80% increase over control was recorded in the plots treated with commercial insecticide Radiant, followed by the tomato total marketable yield (8417 kg ha\(^{-1}\)) with 58% increase over control was recorded in the plots treated with botanical insecticide Neem (3%). Tomato total marketable yield (7583 kg ha\(^{-1}\)) with 42% increase over control was recorded in the plots treated with \textit{T. chilonis}. Lowest tomato total marketable yield (5333 kg ha\(^{-1}\)) was observed in control plots.

**Table 9**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Cost of treatments (Rs)</th>
<th>Cost of labor, irrigation (Rs)</th>
<th>Total cost</th>
<th>Total income</th>
<th>Net CBR income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant</td>
<td>10800</td>
<td>3000</td>
<td>13800</td>
<td>191660</td>
<td>177860 (13.89)</td>
</tr>
<tr>
<td>Neem 3%</td>
<td>12960</td>
<td>3000</td>
<td>15960</td>
<td>168340</td>
<td>152380 (10.55)</td>
</tr>
<tr>
<td>Trichocards</td>
<td>4500</td>
<td>3000</td>
<td>7500</td>
<td>151660</td>
<td>144160 (20.22)</td>
</tr>
<tr>
<td>Neem 2%</td>
<td>8641</td>
<td>3000</td>
<td>11641</td>
<td>143340</td>
<td>131699 (12.31)</td>
</tr>
<tr>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Average price of tomato per kg = Rs. 20; Neem oil per liter = Rs. 1200, Radiant 100 ml/hectare = Rs. 3600, cost incurred on trichocards = 1500 per application, cost of spray @ 3000 per spray/hectare

3. **Cost benefit ratio analysis of the treatments**

Economic analysis of the data for efficacy of botanical extracts (Neem 2 and 3%) commercial insecticide Radiant, trichocards for the control of tomato fruit borer \textit{H. armigera} has been presented in Table 9. The highest benefit-cost ratio (BCR) of 20.22 was recorded in \textit{Trichogramma} fallowed by the Radiant which produced BCR of 13.89, next to this treatment. Botanical insecticide (Neem 2%) also gave comparable BCR of 12.31, whereas Neem 3% gave lowest BCR value of 10.55.

**DISCUSSION**

Fruit borer \textit{Helicoverpa armigera} is an important insect pest of tomato in Pakistan. The pest infestation decrease the average tomato yield/ha and also make it unfit for human consumption. Therefore, it’s on time and safe management is essential. The present research investigated the comparative field efficacy of some treatments used against tomato fruit borer. Results showed that among different treatments the lowest pest infestation was recorded in chemical treated plots (Radiant). These results are comparable to
those of some earlier researchers; Babar et al. (2016) recorded equal effect of Radiant against *H. armigera* as our experiment demonstrates. It was recorded 73% decline in *H. armigera* larvae infestation in the plots treated with Radiant and concluded that Radiant prove to be the best against tomato fruit borer. Sohail et al. (2004) experimented different chemicals to control the population density of *H. armigera*. Results depicted that cypermethrin can effectively control the pest and aid in greater yield. Ghosal et al. (2012) applied different chemicals in a tomato field against *H. armigera* and observed that chemical control effectively reduce the infestation of *H. armigera* in the field.

In case of egg infestation the commercial insecticide Radiant gives the best result in comparison with botanical extracts (Neem 2 and 3%) and bio agent (*Trichogramma chilonis*). Radiant proved the maximum ovicidal effect against the *H.armigera* eggs followed by Neem 3% and *T. chilonis* in the reduction of mean number of eggs/plant. Neem 2% showed the lowest ovicidal effect against the *H. armigera* eggs while the maximum eggs infestation was recorded in the control plot. Our results are same with Rizvi and Jaffar (2015) who applied combination of pesticides and plant extracts against *H. armigera* in tomato field. They found that application of insecticides and plant extracts greatly suppress the density of *H. armigera* and increase the production capacity resulting in the wellbeing of farmer. Abbas et al. (2015) examined the infestation variance of *H. armigera* on different crops and reported that *H. armigera* is destructive pest that can result in significant yield losses. To minimize losses from *H. armigera* he suggested that bio-control agents and chemical control should be used. They also reported that radiant is the most appropriate insecticide because of its effectiveness in minimizing *H. armigera* infestation and less persistent in the environment as compared to the other insecticides. Similar results were reported by Visnupriya and Muthukrishnan (2017) who revealed that spinetoram (radiant) has short residual period of 11 days in reference to other treatments.

In case of percent fruit damage by weight and number, the lowest tomato fruit damage was reported in the plots treated with commercial insecticide radiant. In botanical insecticides minimum fruit damage was recorded in the plots treated with Neem 3% followed by the *T. chilonis*. The highest percent fruit damage was observed in control plots. The results are in similarity with Rasheed et al. (2019) who reported that maximum numbers of fruits were damaged in control plots while the lowest number fruits were damaged in the plots treated with radiant. They also reported that plots with lowest larval infestation and less number of damaged fruit results in higher marketable yield. As larvae of *H. armigera* bore into the tomato fruit, eventually the fruit become unhealthy for consumption and losses its value in market. Our results are also comparable with Usman et al. (2018) who reported that higher infestation of larvae results in lower yield.

In case of yield the maximum tomato fruit yield was recorded in the plots treated with commercial insecticide Radiant, followed by the fruit yield obtained from the plots treated with botanical extract Neem 3% and bio agent (*T. chilonis*). Minimum tomato fruit yield was noted in control plots. Our results are in coherence with Utti (2017) who reported that with application of insecticides effectively increase the yield. Kumar et al. (2013) also revealed that management of field with various insecticides can enhance the
production of tomato. Mahla et al. (2017) also reported same impact from application of insecticides with low infestation and high marketable yield from treated plots.

In case of CBR values recorded our results are same with Abbas et al. (2020) and Ullah et al. (2012) who reported the effectiveness of *T. chilonis* against this pest and found similar results. Trichocards do not need any special equipment or skilled person as well as very economical for application.

**CONCLUSION AND RECOMMENDATIONS**

1. It is concluded from the results of the experiment that Radiant (Spinetoram), Trichocards and Neem 3% showed higher larval and eggs population suppression compared to control treatment. Radiant proved best in reduction of larval and eggs population of *H. armigera*.

2. Application of Radiant (Spinetoram), Trichocards and Neem 3% also significantly reduced tomato fruit damage which as a result increased total marketable yield of tomato compared to control.

3. However, bio control treatment incurred low cost of control which resulted with high cost benefit ratio.

4. It was concluded from the current research that Radiant (Spinetoram), Trichocards and Neem 3% comparatively have a maximum potential in reduction of fruit infestation which as a results gives higher yield with high percentage of marketable fruits and with highest cost benefit ratio. It is recommended that that all these effective treatments could be integrated against pest control program of *H. armigera* in tomato crop.

**Declarations**

**Authors Contribution:** Amani Mulk Khan conduct the experiment, Ahmad-Ur-Rahman Saljoqi designed the experiment, technical and language checked, Mehran Ullah analyzed data and wrote the manuscript.

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