Mitigation of Insecticide Resistance in Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae) by Conjunctive Use of Trap Crops, Neem and Trichogramma chilonis Ishii in Cotton

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Abstract: Push-pull strategy with conjunctive use of trap crops, neem and Trichogramma chilonis Ishii was evaluated against cotton bollworm, Helicoverpa armigera (Hubner) under field conditions. Neem seed kernel extract (NSKE) was applied on cotton crop leaving trap crops (okra and pigeonpea) commencing from 46 DAS at weekly interval to increase the pushing of H. armigera away from cotton. Application of NSKE on cotton improved the oviposition preference ratio from 1:1.35 to 1:1.40 to 1:3.02 and 1:2.43 on cotton:okra and cotton:pigeonpea, respectively. Egg parasitoid, T. chilonis cards were tagged after each application of NSKE on the trap crops. The percent parasitism of eggs of H. armigera on cotton sole crop system ranged from 14.8 to 16.4% and that on trap crops was 10.4 to 12.0 and 14.5 to 15.5% on okra and pigeonpea respectively. Cotton (treated with NSKE) + Trap crops (Trichogramma released) system recorded the lowest mean egg, larval population and fruiting bodies, boil and locule damage. The synthetic pyrethroids resistance in field survived H. armigera at the end of the season was reduced from 85.3-94.0 to 84.8-92.1%.

Key words: Insecticide resistance management, Helicoverpa armigera, neem, Trichogramma chilonis, cotton

INTRODUCTION

Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae) is a serious polyphagous pest, which has emerged as the dominant pest of a wide variety of crops in recent years in India. In earlier days, the management practices included cultural methods and the use of neem products as pesticides. These practices have virtually disappeared and chemical pesticides have taken precedence. Indiscriminate use of pyrethroids had virtually replaced all other insecticides on cotton in South India by 1985. Severe outbreaks of H. armigera in Central and Southern regions of India in 1984-85 and in 1987 were attributed to the overuse of pyrethroids. Regular monitoring of field populations since 1993 confirmed high to very high level of resistance (>90%) to synthetic pyrethroids. The removal of selection pressure of pesticides to H. armigera by using botanicals and biocontrol agents was found to increase the susceptibility of H. armigera to the insecticides. The exclusive use of biocontrol agents viz., HaNPV, Bt and Trichogramma chilonis Ishii were found to be less effective compared to IPM approach in controlling H. armigera. The low dispersing ability of egg parasitoid, Trichogramma is the major constraint in cotton ecosystem. The increasing problems due to continual usage of pesticides and failure of any individual component to check the pest population in cotton have made the adoption of IPM/TRM an imperative and has given urgency to the need to develop ecologically viable and economically feasible alternative technologies. Hence, the possibility of effective utilization of T. chilonis through trap crops and use of neem products on cotton to diversify the pest to trap crops was explored.

MATERIALS AND METHODS

A field experiment was conducted on cotton at Agricultural Research Station, Vaigad, Tamil Nadu Agricultural University, Tamil Nadu during Summer, 2003 (March–July) with trap crops okra (Arka Anamika) and pigeonpea (APK 1). It was laid out in a Randomized Block Design (10x10 m plot size) with twelve treatments each with three replications. A cotton variety MCU5 was sown (75x30 cm) on one side of the ridge. In each plot having 10 rows of cotton, fifth row was substituted with trap crops, which was sown simultaneously on the other side of the ridge without any loss to cotton cropped area. The trap cropping systems were compared with the cotton sole crop with 10 rows of cotton in each plot. All the plots received recommended agronomic practices of the region except the treatment operations. NSKE 5% was

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applied on cotton leaving trap crops to diversify the pests to trap crops before each release of *T. chilonis* commencing from 46 days after sowing (DAS) at weekly interval upto maturity phase (81 DAS). The release of *T. chilonis* on trap crops (@ 0.625 cc ha⁻¹/cotton sole crop (@ 6.25 cc ha⁻¹) was commenced from one week after the application of NSKE spray (53 DAS) at weekly interval upto the maturity of the trap crop.

**Assessment of pests:** The bollworm incidence was assessed on the basis of egg, larval population and percent damage on fruiting bodies (squares, flowers and bolls), open bolls, locules and inter locules. Eggs and larvae were counted on 10 randomly selected tagged plants per plot. The total number of fruiting bodies and those damaged by bollworms were counted at ten randomly selected plants per replication. The total number of bolls collected from ten randomly selected plants per plot at each picking was assessed for number of damaged bolls, number of locules damaged, inter locule boring and percentage was worked out. Kapas were picked out at ten days interval from each plot and the yield was expressed in terms of q ha⁻¹.

**Preference ratio:** The preference ratio of pests on cotton and trap crops were worked out by using the following formula:

\[
PR = \frac{\text{Population of pests on trap crop}}{\text{Population of pests on cotton}}
\]

**Assessment of effectiveness of *T. chilonis* on trap crops/cotton:** The *Trichogramma* cards were tied to the bottom of the leaves by stapling randomly on trap crops/cotton. On fourth day after each release, 20 eggs of *H. armigera* were collected from each plot and brought to the laboratory for observing the emergence of parasitoid and the percentage of parasitisation was calculated.

**Monitoring of resistance frequency in the field population of *H. armigera*:** The resistance frequency of *H. armigera* before first spray and *F₁* field survival population at the end of the crop to synthetic pyrethroids was monitored using Discriminating Dose (DD) assays and the per cent resistance was calculated by using the formula given by Regupathy and Dhamu[9].

**RESULTS AND DISCUSSION**

**Effectiveness of push-pull strategy with conjunctive use of trap crops, neem and *T. chilonis* against *H. armigera* in cotton:** The most robust crop-protection package was obtained when trap cropping, neem on cotton and restricted release of *T. chilonis* on trap crops were combined (Table 1). In cotton sole crop (untreated check), the mean egg and larval population was 27.4 and 24.6 per ten plants, respectively and percent damage was 29.9, 38.7 and 36.5 on fruiting bodies, boll and locule basis respectively. Conjunctive use of trap crops, NSKE application on cotton and release of *T. chilonis* on trap crops reduced the incidence of *H. armigera* in cotton. Cotton (NSKE treated) + pigeonpea (*T. chilonis* released) treatment was superior and effected 43.1 and 54.9% reduction of eggs and larvae and 56.5, 64.1 and 72.3% reduction of fruiting bodies, boll and locule damage respectively. It recorded a maximum yield of 14.4 q ha⁻¹ compared to 6.3 q ha⁻¹ in cotton sole crop (untreated). This was on par with cotton (NSKE treated) +okra (*T. chilonis* released) treatment, in which the percent reduction of eggs and larvae was 47.5 and 50.8, respectively and 55.9, 63.3 and 70.4% reduction of fruiting bodies, boll and locule damage, respectively.

The other treatments when arranged in descending order according to efficacy followed as cotton (NSKE treated) + pigeonpea (*T. chilonis* unreleased) > cotton (NSKE treated) + okra (*T. chilonis* unreleased) > cotton sole crop (NSKE treated and *T. chilonis* released) > cotton sole crop (NSKE treated) > cotton (NSKE untreated) + pigeonpea (*T. chilonis* released) > cotton (NSKE untreated) + pigeonpea (*T. chilonis* unreleased) > cotton (NSKE untreated) + okra (*T. chilonis* released) > cotton sole crop (*T. chilonis* released) > cotton sole crop (untreated).

The trap cropping, NSKE application on cotton and release of *T. chilonis* on trap crops did not bring about any impact on the inter locule damage, but inter locule damage was considerably reduced in all the NSKE treated plots irrespective of cropping system and release of *T. chilonis* on trap crops. Application of NSKE on cotton resulted in 43.5 to 58.5% reduction in inter locule damage compared to cotton sole crop (untreated check).

**Diversification of *H. armigera* by restricted application of NSKE on cotton towards trap crops:** Application of NSKE on cotton diversified the *H. armigera* towards untreated trap crops. The egg and larval preference of *H. armigera* on cotton:okra increased from 1.135 to 1.302 and 1:1.12 to 1:2.45 towards okra, respectively. The egg and larval preference on cotton: pigeonpea increased from 1:1.40 to 1:2.43 and 1:1.27 to 1:2.64 towards pigeonpea, respectively (Table 2).

**Parasitization of *H. armigera* by *T. chilonis* on trap crops and cotton:** The percent parasitization of eggs of *H. armigera* by *T. chilonis* on okra and pigeonpea ranged
Table 1: Effect of push-pull strategy with competitive use of trap crops, neem and *T. chilonis* on biocontrol incidence (Vajpaidia, Summer 2003)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1*</th>
<th>2*</th>
<th>3*</th>
<th>4*</th>
<th>5*</th>
<th>6*</th>
<th>7*</th>
<th>8*</th>
<th>9*</th>
<th>10*</th>
<th>11*</th>
<th>12*</th>
<th>13*</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1, Cotton (NSKE treated)+</td>
<td>14.4</td>
<td>47.5</td>
<td>12.1</td>
<td>50.8</td>
<td>13.2</td>
<td>55.9</td>
<td>14.2</td>
<td>63.3</td>
<td>10.8</td>
<td>70.4</td>
<td>10.1</td>
<td>47.1</td>
<td>14.1</td>
</tr>
<tr>
<td>okra (<em>T. chilonis</em> released)</td>
<td>(3.8)*</td>
<td>(43.5)*</td>
<td>(3.5)*</td>
<td>(45.4)*</td>
<td>(21.2)*</td>
<td>(48.3)*</td>
<td>(22.1)*</td>
<td>(52.7)*</td>
<td>(19.1)*</td>
<td>(57.6)*</td>
<td>(18.4)*</td>
<td>(43.3)*</td>
<td></td>
</tr>
<tr>
<td>T2, Cotton (NSKE treated)+</td>
<td>13.8</td>
<td>49.6</td>
<td>13.3</td>
<td>45.9</td>
<td>15.3</td>
<td>48.8</td>
<td>16.1</td>
<td>56.4</td>
<td>12.4</td>
<td>66.0</td>
<td>9.5</td>
<td>50.3</td>
<td>13.7</td>
</tr>
<tr>
<td>okra (<em>T. chilonis</em> released)</td>
<td>(3.7)*</td>
<td>(44.7)*</td>
<td>(3.7)*</td>
<td>(42.6)*</td>
<td>(22.9)*</td>
<td>(44.3)*</td>
<td>(23.0)*</td>
<td>(49.0)*</td>
<td>(20.6)*</td>
<td>(54.3)*</td>
<td>(17.0)*</td>
<td>(45.1)*</td>
<td></td>
</tr>
<tr>
<td>T3, Cotton (NSKE untreated)+</td>
<td>23.8</td>
<td>33.1</td>
<td>19.7</td>
<td>19.9</td>
<td>22.2</td>
<td>25.7</td>
<td>27.3</td>
<td>29.5</td>
<td>26.1</td>
<td>28.5</td>
<td>17.9</td>
<td>6.3</td>
<td>8.4*</td>
</tr>
<tr>
<td>okra (<em>T. chilonis</em> released)</td>
<td>(4.9)*</td>
<td>(21.2)*</td>
<td>(4.4)*</td>
<td>(26.4)*</td>
<td>(28.0)*</td>
<td>(30.4)*</td>
<td>(31.4)*</td>
<td>(32.8)*</td>
<td>(30.7)*</td>
<td>(32.2)*</td>
<td>(25.0)*</td>
<td>(14.4)*</td>
<td></td>
</tr>
<tr>
<td>T4, Cotton (NSKE untreated)+</td>
<td>24.2</td>
<td>11.7</td>
<td>21.9</td>
<td>10.9</td>
<td>25.1</td>
<td>16.1</td>
<td>33.4</td>
<td>13.7</td>
<td>30.0</td>
<td>17.8</td>
<td>18.1</td>
<td>5.2</td>
<td>8.2*</td>
</tr>
<tr>
<td>okra (<em>T. chilonis</em> released)</td>
<td>(4.9)*</td>
<td>(19.9)*</td>
<td>(4.7)*</td>
<td>(19.3)*</td>
<td>(30.9)*</td>
<td>(23.6)*</td>
<td>(35.3)*</td>
<td>(31.7)*</td>
<td>(33.1)*</td>
<td>(24.9)*</td>
<td>(25.1)*</td>
<td>(13.3)*</td>
<td></td>
</tr>
<tr>
<td>T5, Cotton (NSKE treated)+</td>
<td>15.6</td>
<td>43.1</td>
<td>11.4</td>
<td>34.9</td>
<td>13.0</td>
<td>56.5</td>
<td>13.9</td>
<td>64.1</td>
<td>10.1</td>
<td>72.3</td>
<td>7.9</td>
<td>58.5</td>
<td>14.4</td>
</tr>
<tr>
<td>okra (<em>T. chilonis</em> released)</td>
<td>(3.9)*</td>
<td>(41.0)*</td>
<td>(3.3)*</td>
<td>(47.3)*</td>
<td>(21.1)*</td>
<td>(48.7)*</td>
<td>(21.9)*</td>
<td>(53.2)*</td>
<td>(16.4)*</td>
<td>(58.7)*</td>
<td>(16.2)*</td>
<td>(49.9)*</td>
<td></td>
</tr>
<tr>
<td>T6, Cotton (NSKE treated)+</td>
<td>15.0</td>
<td>45.3</td>
<td>11.6</td>
<td>52.9</td>
<td>14.2</td>
<td>52.5</td>
<td>15.8</td>
<td>59.2</td>
<td>12.8</td>
<td>65.0</td>
<td>8.2</td>
<td>57.1</td>
<td>12.5*</td>
</tr>
</tbody>
</table>

Table 2: Effect of trap crops and restricted application of NSKE on cotton on the preference of cotton borers (Vajpaidia, Summer 2003)

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>NSKE % spray on cotton</th>
<th>Crops</th>
<th>Eggs</th>
<th>Larvae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton + okra</td>
<td>Cotton untreated with NSKE</td>
<td>Cotton</td>
<td>24.16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Okra</td>
<td>32.66</td>
<td>1:1.35</td>
<td>24.44</td>
</tr>
<tr>
<td>Cotton + pigeonpea</td>
<td>Cotton untreated with NSKE</td>
<td>Cotton</td>
<td>13.85</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Okra</td>
<td>41.88</td>
<td>1:3.02</td>
<td>32.55</td>
</tr>
<tr>
<td>Cotton sole crop</td>
<td>Cotton untreated with NSKE</td>
<td>Cotton</td>
<td>26.16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Pigeonpea</td>
<td>36.80</td>
<td>1:1.40</td>
<td>24.18</td>
</tr>
<tr>
<td></td>
<td>Cotton treated with NSKE</td>
<td>Cotton</td>
<td>15.00</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Pigeonpea</td>
<td>36.50</td>
<td>1:2.43</td>
<td>30.72</td>
</tr>
<tr>
<td></td>
<td>Cotton treated with NSKE</td>
<td>Cotton</td>
<td>27.40</td>
<td>-</td>
</tr>
</tbody>
</table>

H. armigera

Table 2: Effect of trap crops and restricted application of NSKE on cotton on the preference of cotton borers (Vajpaidia, Summer 2003)

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<td>Cotton</td>
<td>24.16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Okra</td>
<td>32.66</td>
<td>1:1.35</td>
<td>24.44</td>
</tr>
<tr>
<td>Cotton + pigeonpea</td>
<td>Cotton untreated with NSKE</td>
<td>Cotton</td>
<td>13.85</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Okra</td>
<td>41.88</td>
<td>1:3.02</td>
<td>32.55</td>
</tr>
<tr>
<td>Cotton sole crop</td>
<td>Cotton untreated with NSKE</td>
<td>Cotton</td>
<td>26.16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Pigeonpea</td>
<td>36.80</td>
<td>1:1.40</td>
<td>24.18</td>
</tr>
<tr>
<td></td>
<td>Cotton treated with NSKE</td>
<td>Cotton</td>
<td>15.00</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Pigeonpea</td>
<td>36.50</td>
<td>1:2.43</td>
<td>30.72</td>
</tr>
<tr>
<td></td>
<td>Cotton treated with NSKE</td>
<td>Cotton</td>
<td>27.40</td>
<td>-</td>
</tr>
</tbody>
</table>

P = Mean population per ten plants
PR = Preference Ratio

from 10.40 to 12.0 and 14.50 to 15.50%, respectively. The percent parasitization of eggs of *H. armigera* on cotton sole crop ranged from 14.80 to 16.40% in the respective *T. chilonis* released plots (Table 3). The movement of the parasitoid on okra fruits was inhibited by long triochrome and wasps were trapped by sticky triochrome exudates. It leads to the lower percentage parasitization on okra fruits compared to cotton and pigeonpea.

**Effect of trap crops, neem and *T. chilonis* against Resistance Frequency (RF) of *H. armigera* to synthetic pyrethroids**: The extent of resistance before spraying was 94.0, 92.5, 88.2, 90.2 and 85.3% to cypermethrin, fenvalerate, deltamethrin, lambda-cyhalothrin and beta-cyfluthrin, respectively. The resistance of field survived population at the end of the season was 90.4, 89.1, 89.5, 92.1 and 84.8% to cypermethrin, fenvalerate, deltamethrin, lambda-cyhalothrin and beta-cyfluthrin, respectively (Table 4).

Trap cropping is based on the pest's host plant preference and accomplished by providing a plant variety or species that is preferred over the main crop. A pest moving into an area is likely to be attacked by the preferred trap plants and be diverted away from the main crop[9]. The diverse biological effects of neem are repellency, phagodeterrence, growth inhibition, abnormal development[9] and oviposition suppression[10].
Table 3: Mean per cent parasitisation of \( H. \) armigera eggs by \( T. \) chilonis on trap crops and cotton (Valajadum, Summer 2003)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Trap crop/ cotton</th>
<th>Percent of parasitisation on trap crops/cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_c ) Cotton (NSKE treated)</td>
<td>Okra</td>
<td>12.0</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE treated)</td>
<td>okra (( T. ) chilonis released)</td>
<td>(20.3)*</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE treated)</td>
<td>Okra</td>
<td>1.2</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>Okra</td>
<td>10.4</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>okra (( T. ) chilonis released)</td>
<td>(18.8)*</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>Okra</td>
<td>3.7</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>okra (( T. ) chilonis released)</td>
<td>(11.6)*</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE treated)</td>
<td>Pigeonpea</td>
<td>14.5</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE treated)</td>
<td>Pigeonpea</td>
<td>2.5</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>Pigeonpea</td>
<td>15.5</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>Pigeonpea</td>
<td>(23.1)*</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>Pigeonpea</td>
<td>1.2</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>Cotton</td>
<td>14.8</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE untreated)</td>
<td>Cotton</td>
<td>(22.6)*</td>
</tr>
<tr>
<td>( T_c ) Cotton (NSKE treated)</td>
<td>Cotton</td>
<td>2.5</td>
</tr>
<tr>
<td>( T_{c0} ) on (( T. ) chilonis released)</td>
<td>Cotton</td>
<td>16.4</td>
</tr>
<tr>
<td>( T_{c0} ) on (( T. ) chilonis released)</td>
<td>Cotton</td>
<td>(23.8)*</td>
</tr>
<tr>
<td>( T_c ) Cotton sole crop (untreated check)</td>
<td>Cotton</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Figures in parentheses are square root transformed values.
Means in a column followed by same letter(s) are not significantly different (\( p \leq 0.05 \)) by DMRT.

Table 4: Effect of push-pull strategy with conjunctive use of trap crops, neem and \( T. \) chilonis against Resistance Frequency (RF) of \( H. \) armigera to synthetic pyrethroids (Valajadum, Summer 2003)

<table>
<thead>
<tr>
<th>Synthetic pyrethroid</th>
<th>DD dose (ppm)</th>
<th>% resistance of ( P_1 ) field before first spray</th>
<th>% resistance of ( P_1 ) field after last spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cypermethrin</td>
<td>0.1000</td>
<td>94.6±3.4</td>
<td>90.4±4.1</td>
</tr>
<tr>
<td>Fenvalerate</td>
<td>0.2000</td>
<td>92.5±3.7</td>
<td>89.1±4.6</td>
</tr>
<tr>
<td>Deltamethrin</td>
<td>0.0125</td>
<td>88.2±4.6</td>
<td>89.5±4.6</td>
</tr>
<tr>
<td>Lambda-cyhalothrin</td>
<td>0.0250</td>
<td>94.9±3.4</td>
<td>92.1±3.5</td>
</tr>
<tr>
<td>Beta-cyfluthrin</td>
<td>0.0200</td>
<td>85.3±5.1</td>
<td>84.8±5.1</td>
</tr>
</tbody>
</table>

SE: Standard error (a)

Biological control in IRM/IPM system is a subject of considerable current interest because of a perceived urgency to develop and adopt safe and efficient methods for managing agricultural pests\(^{[1]}\). The inability of \( Trichogramma \) to disperse in larger areas are the major constraints in cotton ecosystem\(^{[2]}\). However, the above difficulties could be overcome through a concept called push-pull strategy\(^{[3]}\), in which host-masking agents, repellents, antifeedants or oviposition deterrents are deployed to push colonizing insects away from the harvestable crop and also to attract predators or parasitoids into the area. At the same time, the pests are aggregated on a sacrificial or trap crop so that a selective control agents, eg, \( Trichogramma \) sp. can be used directly to reduce the pest population.

Field trial was conducted on push-pull strategy with conjunctive use of three components such as trap crops, neem spray on cotton alone along with restricted release of \( Trichogramma \) on trap crops against \( H. \) armigera. Application of NSKE on cotton in conjunction with restricted release of \( Trichogramma \) on trap crops under trap cropping system in cotton was most effective in controlling \( H. \) armigera and increasing the yield.

In the present study, okra acted as a good trap for \( H. \) armigera and the efficiency of the trap crop was improved by applying NSKE on cotton. Similar observation on noctuid's ovipositional preference to okra than cotton in Punjab was reported by Singh et al\(^{[1]}\), suggested intercropping of okra in cotton for \( H. \) armigera as an useful cultural practices. Similar diversion of \( A. \) devastans, \( B. \) tabaci, \( A. \) gossypii and semi-loopers from cotton to okra\(^{[3]}\) was observed when the Non-edible Oil (NEO) formulations were applied on the main crop.

The percent parasitism on okra, pigeonpea and cotton observed in the present study is very low compared to 37.5\% on okra\(^{[4]}\), 55\% on pigeonpea\(^{[4]}\) and 32 to 96\% on cotton\(^{[5,10]}\). This might be due to the variation in the variety of the crop in relation to trichome characters and environmental conditions of the experimental area.

\( Trichogramma \) eggs parasitism is much influenced by host plants and rarely parasitise eggs on pigeonpea\(^{[6,11]}\). Romeies et al\(^{[12]}\) recorded 2.2\% parasitisation on pigeonpea. However, Duffield\(^{[12]}\) reported high levels of egg parasitisation on short duration pigeonpea, when it was inter cropped with sorghum due to the movement of parasitoids from sorghum to pigeonpea. This is in confirmation with the present study, where the spraying of NSKE forced the parasitoid on the trap crops and increased the percent parasitisation.

The efficiency of \( T. \) chilonis on pigeonpea is dependent on the plant surface structure on which the host eggs were found\(^{[6]}\). Romeies et al\(^{[12]}\) observed the percent egg parasitisation of 3.6, 0.3 and 40.7 on calyces, pods and leaves of pigeonpea, respectively. However, in the present study, lower level of parasitism in pigeonpea was observed though eggs were observed on leaves and petals.

In the conjunctive use of trap crops, NSKE on cotton and \( T. \) chilonis on trap crops, the resistance of the field collected population of \( H. \) armigera to the pyrethroids showed lesser percent survival compared to the survival of the field collected population before spraying. Botanicals may be used to increase the susceptibility of
the target pest. The exposure to a stressor might influence
the susceptibility of the host to an active pathogen. The
biologically active compounds from the plant products
penetrate the gut wall which allows the easy penetration
of the pathogen into the haemocoel[9].

The non-chemical methods used in the present study
in cotton provides scope for relaxation in selection
pressure of H. armigera to certain extent. Use of botanical
pesticides and trap crop are the best choice for the cotton
IPM. Different modes of actions like antifeedant,
antiovipositional, IGR, cidal, antisybiiom and reduction in
reproduction make the insects more vulnerable and
prevent the development of resistance and resurgence.
Plant products are an excellent choice for preservation of
beneficial organisms. This is important in light of today's
expanding IPM programme. Use of these plant derivatives
and biocontrol agents as a component of IRM will go a
long way in the management of insect pests.

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