INTRODUCTION

Peach is an important fruit crop of Punjab occupying 1.53 thousand hectare area (Anonymous, 2011) but fruit flies are the major limiting factors in the successful cultivation of this fruit. From economic point of view; Oriental fruit fly, *Bactrocera dorsalis* (Hendel); guava fruit fly, *Bactrocera correcta* (Bezzi) and peach fruit fly, *Bactrocera zonata* (Saunders) are very important pests of fruit crops and are recognized worldwide as the most important threat to horticulture (Ekesi & Mohamed, 2011). Besides the direct damage to fruits, indirect loss is also associated with quarantine restrictions. Important fruits flies damaging fruit crops in Punjab include *B. dorsalis*, *B. zonata* and *ber* fruit fly, *Carpomyia vesuviana* Costa (Atwal & Dhaliwal, 2007) but *B. dorsalis* was reported to cause about 78 per cent damage in peach (Mann, 1980) where the population starts building up from April and continues upto October on different fruit crops (Sharma et al., 2011b).

The fruit flies are very difficult to manage due to the fact that they are polyphagous, multivoltine, adults have high mobility and fecundity, and all the developmental stages are unexposed. Only adults are exposed while eggs and maggots remain protected in the host tissues and most of insecticidal treatments are ineffective (Sharma et al., 2011a).

Application of insecticides further disrupts the ecosystem and causes numerous hazards, which in the present scenario warrants the need of integrated approach for fruit fly management (Verghese et al., 2012). Among the various alternate strategies available for the management of fruit flies, the use of methyl eugenol traps stands as the most outstanding alternative. Methyl eugenol, when used together with an insecticide impregnated into a suitable substrate, forms the basis of male annihilation technique (MAT). Methyl eugenol specially attracts the males of *B. dorsalis, B. correcta* and *B. zonata* (Verghese et al., 2006a). Singh and Sharma (2011) compared the trapping efficiency of different types of methyl eugenol based traps in Kinnow mandarin in Punjab and found that mineral water bottle traps were more efficient as compared to McPhail trap and Nomate trap in September. MAT was also found very effective in monitoring and management of *Bactrocera* spp. on different fruit crops (Vargas et al., 2010a and Singh & Sharma 2011). These traps also have high specificity and low cost (Vargas et al., 2010a).

In the past, though much work had been done on various management components (Stonehouse et al., 2007, Anonymous, 2010 and Vargas et al., 2010a)
2010b) including cultural practices, MAT, BAT and chemical control but very less control of fruit flies was achieved by applying the individual control approach. Thus, keeping in view the importance of fruit flies on peach crop, the present investigations were undertaken to study the carryover, abundance and management of fruit flies on peach in Punjab.

**MATERIAL AND METHODS**

Studies on carryover, abundance and management of fruit flies were carried out during 2010 and 2011 in the peach orchard of University Seed Farm, Ladhowal, Ludhiana by using methyl eugenol based MAT in mineral water bottle traps. One litre capacity mineral water bottle traps developed at Indian Institute of Horticultural Research (IIHR), Bengaluru (Verghese et al., 2006b) and further modified at Punjab Agricultural University, Ludhiana were used in this experiment. The trap consisted of a plywood dispenser, suspended vertically inside the bottle, aligning with the four vents that allow entry of fruit flies inside the bottle. The traps used in MAT technique consisted of immersing water absorbable plywood blocks (5 x 5 x 1 cm) in a solution of ethyl alcohol, methyl eugenol (98%) and malathion mixed in a glass jar in the ratio of 6:4:1 (v/v) for 72 hrs so that this solution was properly absorbed in the plywood blocks. A hole in the block was made with the help of a drill to put wire for hanging on tree. Four holes were made with the help of a hot iron rod on the upper side of bottle for entry of fruit flies. Bottles were cut from bottom side with knife and plywood piece was hanged inside the bottle with two sides of wire coming out from the top of bottle. Four random holes of 3-4 mm diameter were made at the bottom with hot needles to drain the water that may get collected in the bottles. The wire was twisted to make a loop.

The baited bottles were hanged with the trees at equidistant and there were four treatments consisting of 4, 8, 12 and 16 traps/acre. Each treatment was replicated thrice in each crop. The traps were fixed in the first week of April in the orchard. These traps were kept in the orchard till the fruit harvesting was over. Bottles were fastened to the trees using steel wires at a height of 1-1.5 meter from ground level, depending upon the height of tree, at a place receiving no direct sunlight. Red coloured reflecting tape was tied to the tree on which a trap was fixed for easy accessibility of such trees in the orchards. The lower cut portion of bottle (lid) was removed and all the fruit flies trapped in bottle were collected in carry bag after every 7 days and then again re-fixed with bottle. The carry bags were labelled with the marker and fruit flies trapped/trap were counted when the number was low but when there was large number of fruit flies, the count was made on weight basis. For standardization, average dry weight of 100 adult flies was taken 3 days after collection. The average weight of 100 adult flies was observed to be 450 mg (i.e. 4.5 mg/adult). Average count of fruit flies/gram was 223.

For fruit infestation, a sample of 50 fruits at random/treatment was collected at weekly interval, and infested (based on the oviposition puncture) and healthy fruits were counted. Data were also recorded for number of maggots/fruit by dissecting the fruits. For different species of fruit flies, a random sample of 100 flies was taken and identified for the proportion of different species. Impact of number of traps on the quality of marketable fruits and yield was also assessed by counting number of marketable fruits from 5 trees at full maturity. Average weight of 50 fruits was taken and fruit yield (kg/tree) was calculated. Yield/acre (MT) was also calculated. Trap catches, per cent fruit infestation and number of maggots/fruit were subjected to statistical analysis after suitable conversions of the data. Correlation coefficients with abiotic factors and number of adults trapped/trap/week were also computed.

**RESULTS AND DISCUSSION**

Total fruit fly males of Bactrocera species trapped/week in peach orchard through MAT depicted that 16 traps/acre had significantly more population compared to 4, 8 and 12 traps/acre (Table 1). The studies initiated in 14th standard meteorological week (SMW) had very low population i.e. 14.67 males in 4 traps/acre to 87.0 males in 16 traps/acre. The data recorded at weekly interval till 21st SMW clearly showed that the population of males captured in different traps had a progressive increase and it reached at its maximum in 21st SMW (184.67 in 4 traps to 697.0 in 16 traps). Pooled means showed that total number of fruit fly males trapped/week were significantly high (387.29) in 16 traps/acre compared to 88.83 males in 4 traps/acre.
The mean fruit fly males captured/trap indicated that irrespective of the number of traps/acre, the males captured in 4, 8, 12 and 16 traps/acre were non-significant during different SMW. However, the average number of males captured in different traps showed a progressive increase and reached at its maximum in 21st SMW (43.57 to 46.17 males) (Table 2). Mean fruit fly males trapped/trap/week increased from 3.66 in 4 traps during 14th SMW to 46.17 during 21st SMW. Similarly, there was a significant increase in number of males trapped in 16 traps, which varied from 5.45 to 43.57 over 14th to 21st SMW. Pooled means clearly showed that mean fruit fly males/trap/week were non-significant. The results showed that the concentration of methyl eugenol was equal in all the traps and the males were equally attracted in all the traps. The difference in total number of males captured among traps was only due to the variations in number of traps/acre. The results presented in Figure 1 showed that during the entire crop season of peach (8 weeks), a total number of 710, 1505, 2361 and 3098 males were captured in 4, 8, 12 and 16 traps/acre, respectively. Palam Trap, a lure based mineral water bottle trap was found effective in monitoring and management of 10 species of fruit flies including B. dorsalis and B. zonata in fruits and vegetables in Himachal Pradesh (Mehta et al., 2010) as also found in the present studies. Chandaragi et al. (2012) reported that bottle trap was found effective in monitoring and management of 10 species of fruit flies including B. dorsalis and B. zonata in mango in Karnataka. Sharma (2012) also reported that bottle trap was found to have significantly higher trap catch followed by cylinder trap, when five traps with different designs (bottle trap, cylinder, sphere, PCI trap and open trap) were used to capture fruit flies in mango in Karnataka. Sharma (2012) also reported that bottle trap was found to have significantly higher trap catch followed by cylinder trap, when five traps with different designs (bottle trap, cylinder, sphere, PCI trap and open trap) were used to capture fruit flies in mango in Karnataka.

Table 1. Population of Bactrocera spp. captured in different treatments on peach through male annihilation technique

<table>
<thead>
<tr>
<th>Treatments (Traps/acre)</th>
<th>Total fruit fly males trapped/week*</th>
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<tbody>
<tr>
<td>4</td>
<td>14.67 (3.95)</td>
</tr>
<tr>
<td>8</td>
<td>37.67 (6.21)</td>
</tr>
<tr>
<td>12</td>
<td>68.33 (8.28)</td>
</tr>
<tr>
<td>16</td>
<td>87.0 (9.34)</td>
</tr>
<tr>
<td>CD (p=0.05)</td>
<td>(1.50)</td>
</tr>
</tbody>
</table>

*Mean of 3 replications during 2010 and 2011; **SMW- standard meteorological week; figures in parentheses are √n transformation
found methyl eugenol traps to be effective against *Bactrocera* complex on mango, guava, sapota and peach as observed in the present studies.

To evaluate the impact of males captured in different treatments, infested fruits of peach were recorded in the different treatments (Table 3). The results indicated that the fruit fly adult population appeared about 3 weeks earlier (i.e. 14<sup>th</sup> SMW) (Table 1) than the actual start of fruit infestation and the infested fruits were recorded in 17<sup>th</sup> SMW (Table 3). It was due to the fact that the infestation on fruits was related with the population build up and appropriate fruit maturity for the egg laying. At the beginning (17<sup>th</sup> SMW), the infestation in different treatments i.e. 4 to 16 traps/acre was 2.0 to 2.67 per cent compared to untreated control in which the fruit infestation was 10.0 per cent. With the initiation of colour break stage on fruit and later on with the onset of the maturity of fruits, per cent infested fruits in different treatments also showed a progressive increase. The maximum fruit infestation was observed in 21<sup>st</sup> SMW, which varied from 14.67 per cent in 16 traps/acre to 30.67 per cent in 4 traps/acre. However, the fruit infestation in untreated control was significantly high (93.00%). Pooled means showed that per cent fruit infestation was significantly low (7.20%) in 16 traps/acre compared to 15.73 per cent in 4 traps/acre whereas in untreated control, it was 45.53 per cent. Singh and Mann (2003) reported that population of *B. dorsalis* was maximum in September, declined in July and lowest in February in methyl eugenol baited traps fixed in peach orchard in Punjab. Sharma (2012) observed a low level of fruit fly population in methyl eugenol based trap during hot and dry summer months between 18<sup>th</sup>-24<sup>th</sup> standard weeks, when fixed in mango, guava, sapota and peach orchards at New Delhi. In the present findings, a clear peak was recorded in peach during May-June. A significant positive correlation between trap catches of *B. dorsalis* in mango with maximum and minimum temperature was observed (Agarwal *et al*., 1995), which is also true of case in the current studies. The peak activity of fruit flies in the present studies was found coinciding with the maturity of peach which corroborate the findings of other workers who indicated that the population fluctuation of fruit flies was dependent on the availability of the host crops (Singh & Mann, 2005; Singh, 2008 and
To observe the impact of MAT on mating of females and subsequently on egg laying on fruits, the number of maggots/fruit was recorded in different treatments (Table 4). The results indicated that more the number of males captured, less was the maggots/fruit. Data in Table 4 revealed that 16 traps/acre had significantly less number of maggots/fruit i.e. 4.67 in 19th SMW to 14.03 maggots/fruit in 23rd SMW compared to 4 traps/acre in which 10.33 maggots/fruit were observed in 19th SMW and 21.13 maggots/fruit in 23rd SMW. The number of maggots/fruit in untreated control over SMWs varied from 12.10 to 27.40. Pooled means clearly showed that mean number of maggots/fruit was significantly low (10.88) in 16 traps/acre compared to 16.62 maggots in 4 traps/acre, whereas in untreated control, there were 21.23 maggots/fruit. The proportion of different *Bactrocera* spp. in peach fruits indicated that *B. zonata* (28.00 to 32.67%) was low compared to *B. dorsalis* (67.33-72.00%) (Figure 2). Though the infestation of fruits decreased with the increase in traps/unit area but still some mating occurs. Furthermore, in the present studies, methyl eugenol has been found to be the most powerful male lures usually for the males of *B. dorsalis* and *B. zonata* both for monitoring and management as also reported by other workers (Singh & Sharma, 2011). This technique has been successfully used for the eradication and control of several *Bactrocera* species (Stonehouse et al., 2007 and Vargas et al., 2010b) and could also be found useful in Punjab as the present findings showed a significant impact in reducing the damage and increasing the quality fruit yield. Singh and Sharma (2011) and Singh et

![Fig 2. Proportion of Bactrocera spp. in peach in MAT during 2010 and 2011](image)
al. (2011) reported usefulness of methyl eugenol based mineral water bottle traps in mass trapping of fruit flies, B. zonata and B. dorsalis on Kinnow and pear, respectively in Punjab which corroborate findings of the present studies.

Eradication/suppression campaigns were made by using combination of methyl eugenol and insecticides against B. dorsalis (Vargas et al., 2010a) but the present findings indicated that 16 traps/acre in peach were very effective in reducing fruit fly damage as also reported by Koyama et al. (1984) in Japan and Viraktamath and Ravikumar (2006) in India. In the present study, 16 traps/acre were found far superior to that of 4, 8 and 12 traps/acre but Verghese et al. (2006a) found @ 4 traps/acre very effective in controlling fruit flies in different parts of India in mango and guava.

The correlation between captured males of Bactrocera spp./trap and different abiotic factors on peach (Table 5) indicated that maximum temperature (r = 0.66 to 0.75), minimum temperature (r = 0.75 to 0.77), mean temperature (r = 0.80 to 0.83), wind speed (r = 0.77 to 0.78) and evaporation (r = 0.75 to 0.81) were having significantly high positive correlation with the male population captured in different treatments while relative humidity (r = -0.46 to -0.53), sunshine (r = -0.14 to -0.19), rainfall (r = -0.21 to -0.27) and number of rainy days (r = -0.21 to -0.27) were having a negative impact on male capturing in different treatments. The abundance of B. dorsalis as reflected by catches of males in a trap baited with methyl eugenol was positively correlated with the abundance of fallen fruits of carambolas, but not with rainfall (Vijayasegaran, 1984). High temperatures, which lead to reduced fly activity, have been associated with low trap captures of Ceratitis capitata (Wiedemann) flies (Prokopy et al., 1987). Abiotic factors played an important role in the regulation of B. correcta population, however, in the current findings it was variable. Mean maximum and minimum temperature, day degree, morning relative humidity and rainfall had positive impact while sunshine hours had negative effect on B. correcta population (Rana et al., 1992). Aluja et al. (1996) did not find any relationship between rainfall and fruit fly trap captures in mango orchards in Mexico and results of this study corroborate the present findings at Ludhiana. In Ludhiana, incidence of B. dorsalis was nil in winter (December

<table>
<thead>
<tr>
<th>Table 4. Mean number of maggots of Bactrocera spp. per fruit of peach in male annihilation technique</th>
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<tbody>
<tr>
<td>Treatments (Traps/acre)</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>May 7-13</td>
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<tr>
<td>May 14-20</td>
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<tr>
<td>May 28-June 3</td>
</tr>
<tr>
<td>June 4-10</td>
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<tr>
<td>June 11-17</td>
</tr>
<tr>
<td>Mean</td>
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<tr>
<td>CD (p=0.05)</td>
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</table>

*Mean of 3 replications during 2010 and 2011; **SMW-standard meteorological week; figures in parentheses are √n transformation
to February) when the mean temperature varied 
from 12-16°C (Mann, 1996) but its incidence started 
in second fortnight of March when winter fruiting 
of guava was almost over.

Variation in population count of *B. dorsalis* 
and *B. zonata* during different months/seasons 
on different crops was similar to that in mango 
orchards, which were attributed to variation in 
availability of susceptible host, temperature 
and heavy rainfall (Mann, 1996b). Singh (1996) 
observed that incidence of fruit fly and pupal 
counts/kg fruit increased as the season and 
maturity of fruits advanced which corroborate the 
present findings. Jalaluddin *et al.* (2001) observed 
a distinct peak of *B. correcta* in guava orchards with 
the ripening of fruits from July to August. Weekly 
catch when correlated with weather parameters 
showed significant positive correlation with mean 
maximum temperature, minimum temperature, 
day-degrees, morning relative humidity and rainfall 
which corroborate the observations in Punjab during 
the current studies with peach. The present findings 
also showed some similarity with the findings of 
other workers (Dwivedi *et al.*, 2003 and Sureshbabu 
& Viraktamath, 2003) against different *Bactrocera* 
spp. on different fruit crops in India. The population 
build up was positively correlated with temperature 
and rainfall. As the season advanced, the attack of 
*B. dorsalis* also increased during the fruiting period. 
Singh (2004) reported that guava fruit infestation by 
*B. dorsalis* was positively correlated with rainfall, 
mean temperature and relative humidity while it 
had negative correlation with light intensity but 
in the present study, the male capture showed 
inconsistent correlation over the period of study 
during 2010-2011.

Impact of number of traps/acre on the quality 
marketable fruits and yield of peach crop indicated 
that the number of traps/acre had a direct impact 
on number of quality marketable fruits/tree (Table 
6). The observations showed that there were 709 
healthy fruits in 16 traps/acre compared to 465.00 
in 4 traps/acre, whereas in untreated control, there 
were only 58.20 healthy fruits. The fruit yield (kg/ 
tree) also showed that the number of traps had a 
significant impact on the yield as it is clear that as 
the number of traps increased from 4 to 16, the 
fruit yield also increased from 37.20 to 56.72 kg/ 
tree in 4 and 16 traps, respectively in comparison 
to only 4.66 kg/tree yield in untreated control.

### Table 5. Correlation between captured males of *Bactrocera* spp. per trap and different abiotic factors on peach

<table>
<thead>
<tr>
<th>Treatments (Traps/acre)</th>
<th>Max. temp (°C)</th>
<th>Min. temp (°C)</th>
<th>Mean temp (°C)</th>
<th>RH (%)</th>
<th>Wind speed (km/h)</th>
<th>Sunshine (h)</th>
<th>Rainfall (mm)</th>
<th>Evaporation (mm)</th>
<th>No. of rainy days</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.75*</td>
<td>0.75*</td>
<td>0.83*</td>
<td>0.53</td>
<td>-0.21</td>
<td>-0.14</td>
<td>-0.21</td>
<td>0.81*</td>
<td>-0.21</td>
</tr>
<tr>
<td>8</td>
<td>0.73*</td>
<td>0.77*</td>
<td>0.83*</td>
<td>0.52</td>
<td>-0.23</td>
<td>-0.16</td>
<td>-0.23</td>
<td>0.80*</td>
<td>-0.23</td>
</tr>
<tr>
<td>12</td>
<td>0.75*</td>
<td>0.77*</td>
<td>0.81*</td>
<td>0.46</td>
<td>-0.27</td>
<td>-0.18</td>
<td>-0.27</td>
<td>0.76*</td>
<td>-0.27</td>
</tr>
<tr>
<td>16</td>
<td>0.75*</td>
<td>0.77*</td>
<td>0.80*</td>
<td>0.46</td>
<td>-0.27</td>
<td>-0.19</td>
<td>-0.27</td>
<td>0.75*</td>
<td>-0.27</td>
</tr>
</tbody>
</table>

*Significant at (p = 0.05); critical value of r = 0.71
Yield/acre (MT) varied from 3.35 to 5.10 metric tons, respectively in 4 and 16 traps, whereas only 0.42 metric ton yield was recorded in untreated control.

REFERENCES


<table>
<thead>
<tr>
<th>Treatments (Traps/acre)</th>
<th>No. of marketable fruits/tree*</th>
<th>Fruit yield (kg/tree)*</th>
<th>Yield/acre (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>465.00</td>
<td>37.20</td>
<td>3.35</td>
</tr>
<tr>
<td>8</td>
<td>515.00</td>
<td>41.20</td>
<td>3.71</td>
</tr>
<tr>
<td>12</td>
<td>557.40</td>
<td>44.60</td>
<td>4.01</td>
</tr>
<tr>
<td>16</td>
<td>709.00</td>
<td>56.72</td>
<td>5.10</td>
</tr>
<tr>
<td>Control</td>
<td>58.20</td>
<td>4.66</td>
<td>0.42</td>
</tr>
<tr>
<td>CD (p=0.05)</td>
<td>15.90</td>
<td>1.27</td>
<td>0.11</td>
</tr>
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</table>

*Mean of 5 trees during 2010 and 2011; number of trees/acre=90; average weight of fruit =80
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