Pheromonal Trapping of *Chilo partellus* (SWINHOE) (Lepidoptera: Pyralidae) Moths in Relation to Male Population Density and Competition with Females

Gopalan Chandran UNNITHAN and Kailash Narain SAXENA

*The International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, Nairobi, Kenya*

(Received December 9, 1989; Accepted October 2, 1990)

The numbers of laboratory-reared males of *Chilo partellus* (SWINHOE) which were released, both in a screenhouse and in the field, and recaptured in virgin female-baited traps were positively correlated. Pheromone trap catches were reduced by 75–100% when 18 or 36 virgin females were placed in two concentric circles of radii 10 m and 20 m occupying an area of 1,257 sq m. around the trap. Mated females surrounding the trap did not cause a significant decrease in the trap catch. Tethered virgin females surrounding a virgin female-baited trap competed successfully among themselves and with the trap for receptive males, the percentage of the tethered mated females being 30–66% and the catch in the trap reducing by 78–86% compared with that in the control. Thus, although catches of males in pheromone traps increased with the increase in their population density, the efficiency of the trap decreased due to competition with increasing number of calling females in the trap vicinity. The disruption in the catch was not accompanied by a corresponding reduction in mating. The results also demonstrated competition among pheromone traps.

**Key words:** Chilo, pheromone, trapping

**INTRODUCTION**

The efficiency of pheromone traps for lepidopterous insects has been shown to be influenced by several factors, including the population density of the male and female moths, their age and mating status, and competition between the trap and native populations of calling females (RIEDEL et al., 1976; CARDÉ, 1979; CROFT et al., 1986). Trap catch has been shown to decline with increasing population density due to competition for males between pheromone traps and the native females (MILLER and McDougall, 1973; HOWELL, 1974; CARDÉ, 1979; HARTSTACK and WITZ, 1981; ELKINTON and CARDÉ, 1984; CARDÉ and ELKINTON, 1984; WALL, 1984). Models of such competition have been proposed by HOWELL (1974), NAKAMURA and OYAMA (1978) and NAKAMURA (1982). Recently, KNIGHT and CROFT (1987) have shown how competition between female moths and pheromone traps can affect the temporal pattern of the catch. Trap efficiency can also be affected by competition among traps (WALL and PERRY, 1978).

In our efforts to develop a pheromonal monitoring system for the stem-borer
Chilo partellus (Swinhoe), a major pest of maize (Zea mays Linnaeus) and sorghum (Sorghum bicolor [Linnaeus] Moench) in Asia and Africa, we have investigated certain factors that could affect the performance of the pheromone trap (Unnithan and Saxena, 1990). These studies showed that the attractancy of females to males and responsiveness of males to pheromone traps (or calling females) declined after mating. The present study investigated the relationship of the pheromone trap catch with the male population density, the influence of virgin females in the vicinity of the pheromone trap on the catch, and the competition between females and pheromone traps. These have been studied by releasing males and recapturing them in pheromone traps, and by using caged and tethered females placed in the field surrounding the pheromone trap. Since pheromone components of C. partellus (Nesbitt et al., 1979) were not found to be effective in attracting males in Kenya (Unnithan and Saxena, 1990), we have used the virgin females as the attractant bait for this study.

MATERIALS AND METHODS

This study was conducted during the long cropping seasons (March–July) in the years 1987–1989 at the ICIPE Field Station at Mbita on the shores of Lake Victoria in western Kenya.

Insects. Chilo partellus moths used in this study were drawn from the insectary culture maintained at 25 ± 2°C on an artificial diet which contained, among other ingredients, sorghum leaf powder (Ochieng et al., 1985). They were maintained under a natural photoperiod regime of approximately 12 hr light : 12 hr dark phase. Pupae were isolated from the diet and kept individually in 25 ml plastic cups until eclosion when the adults were taken for tests.

Pheromone trap. For trapping C. partellus males, a water trap (Unnithan and Saxena, 1990) was used in all the experiments. Each trap was set about 0.5 m above ground and baited with two 1-day-old virgin females because this number was found to attract the highest number of males in our earlier study (Unnithan and Saxena, 1990). The females were placed in a 3 cm dia. × 5 cm wire-net cylindrical cage with both its ends covered with nylon net. The cage was suspended from the roof of the trap which was set in the evening.

Relation between male population density and pheromone trap catch. This was studied by releasing different numbers of 1-day-old unmated males in a screenhouse or in the field and determining the proportion of the males recaptured in the pheromone trap during the first night. The screenhouse was 11 m long, 7 m wide, 4.3 m high in the middle with a sloping glass-roof on each side and nylon net side walls which were 2.7 m high. For the screenhouse studies, 10, 20, 30, 40 and 50 males were placed in separate wire-mesh cylindrical cages (9 cm dia. × 9 cm), both ends covered with plastic petridishes as the lids. In the evening, each of the four cages was placed about 1 m from each corner of the screenhouse and its lids were removed so that the males could come out and fly around freely. A pheromone trap was placed in the centre of the screenhouse. Next morning, the number of captured males was recorded. Each experiment was replicated 8 times. The tests were repeated at 3-day intervals by releasing fresh males but the trap was set daily to make sure that all the surviving males were caught before the next release.

In the field, the pheromone trap was set in the centre of a sorghum plot with a
high natural infestation of *C. partellus*. The males were marked with a felt-tip marker pen on their forewings and 10, 20, or 60 individuals were released from the cages placed one each at 20 m east, north, west and south of the trap. On the following morning, the number of marked as well as unmarked males caught in the trap was recorded. Males were released every third day, each time marking with a different colour and tests with each number of the released males were replicated four times.

The relationships of the numbers of the males released with the numbers as well as percentages of those recaptured were examined on the basis of regression analysis. The mean values for the numbers and percentages of recaptured males were compared for different numbers of released males on the basis of analysis of variance (ANOVA) followed by DUNCAN's (1955) Multiple Range Test (DMRT).

Effect of female population density and mating status on pheromone trap catches. In the first experiment, single 1-day old virgin females were enclosed in cylindrical cages (5 cm dia. × 7 cm) of wire-net (7 mesh/cm) and each cage was suspended from a 0.5 m high wooden stake. The cages were then arranged at equal intervals along the circumferences of two concentric circles, an inner with a radius of 10 cm and an outer with 20 cm radius (Fig. 1). The area occupied by the circles was 1257 sq cm. At the centre of the circles was placed a pheromone trap baited with two 1-day old virgin females. The control trap was located in the adjacent plot at a distance of 110 m from the first trap in a direction perpendicular to the direction of the prevailing wind and was not surrounded by the female-bearing cages. The numbers of these cages around the first trap varied to represent three population densities in separate tests: (i) 9 caged females, 3 on the inner and 6 on the outer circle, (ii) 18 females, 6 on the inner and 12 on the outer circle, and (iii) 36 females, 12 on the inner and 24 on the outer circle. Each test was set up in the evening and concluded next morning when the numbers of males from the natural populations caught in the two traps were recorded. Test with each female density was replicated 8–10 times on successive days. The test with 36 females surrounding the trap was also conducted with a modification in which five 1-day old unmated males were released at 25 m each on the east, west, north and south

![Diagram](image)

Fig. 1. Arrangement of wire-net cages, each enclosing one 1-day old virgin female of *C. partellus*, placed along two concentric circles around a pheromone trap baited with two 1-day old virgin females.
direction of the experimental as well as the control trap to supplement the field populations of the males. This test was replicated 6 times on successive days.

The second experiment was similar to the first except for the arrangement and number of caged females around the pheromone trap. The wire-net cages, each enclosing two 1-day old virgin females, were arranged at equal intervals along the circumferences of 3 concentric circles with radii of 2, 4 and 6 m (Fig. 2). The area occupied by the circles was 113 sq cm. The number of cages was 4 in the inner, 8 in the middle and 12 in the outer circle, the total number of the females being 48. The control trap was located in the adjacent plot at 110 m from the first trap. The experiment was replicated 10 times on successive days.

The third experiment was set up exactly like the first one except that: (i) the number of wire-net cages containing 1 virgin female each was 18 which were arranged in two concentric circles, 6 in the inner and 12 in the outer, at radial distances of 10 and 20 m, respectively, from the centre (Fig. 3); (ii) the pheromone trap was placed outside the outer circle at a distance of 10 m in the upwind (East) direction; (iii) the control trap was placed in the adjacent plot at a distance of 100 m from the 1st trap.

The fourth experiment was also similar to the first except that the caged females were mated and their number was 18, 6 in the inner and 12 in the outer circle.

In all the above four experiments, the numbers of males caught in the control trap (B) were compared with those in the experimental trap (A) using the Student's t-test. The percentage reduction in the catch in the experimental trap was calculated as \[
\frac{(B-A)}{B} \times 100.
\]

**Competition between the pheromone trap and calling females around the trap.** Two experiments were conducted to investigate this competition, using tethered virgin females. In the first, the fore-wing and hind-wing of one side of 1-day old virgin females were tied with a cotton thread and they were tethered to a 5 cm dia. \( \times \) 7 cm wire-net cylindrical cage, both ends of which were open. The cages with one tethered female each were suspended from 0.5 m wooden stakes at equal distances along concentric circles around a pheromonal trap as follows: (i) 36 females arranged in two circles: 12 at 10 m and 24 at 20 m radial distance from the trap; (ii) 60 females in 4 circles: 6 at 5 m, 12 at 10 m, 18 at 15 m and 24 at 20 m radial distance. The field population

![Fig. 2. Arrangement of wire-net cages, each enclosing two 1-day old virgin females of C. partellus, placed along three concentric circles around a pheromone trap.](image-url)
of *C. partellus* males was supplemented by releasing forty 1-day old unmated males for the 1st level of the female population density and 60 for the 2nd. These males were released in equal numbers on the east, north, west and south side of the trap at a distance of 25 m. The experiment was set up in the evening and on the following morning the number of males caught in the pheromone trap was recorded. The tethered females were dissected to ascertain their mating status. Presence of a spermatophore in the bursa copulatrix indicated that the female had mated. The experiment with each female density was repeated on six alternate days and on the intervening days, the pheromone trap alone was set to serve as a control.

In the second experiment, competition between calling females was also studied, using pheromone traps in two densities: one and seven. For the first, a single pheromone trap was set up in the centre of a harvested sorghum field and the number of males caught was recorded. For the second, seven pheromone traps were set, 1 trap being in the centre surrounded by 6 traps at equal intervals in a circle at a radius of 5 m. The tests with the two densities of traps were repeated on alternate days for 5 and 6 days, respectively. The daily catch of males in each trap was recorded. In both the above experiments, the numbers of males caught per day for the two different trap densities were compared using the Student's *t*-test.

**RESULTS**

*Relation between male population density and pheromone trap catches*

Table 1 and Fig. 4 show the results of the screenhouse experiments while Table 2 and Fig. 5 those for the field experiments. In both the test arenas, the numbers as well as the percentages of the recaptured *C. partellus* males showed a positive, significant, linear regression on the numbers of the males released (Figs. 4, 5). However, $R^2$
Table 1. Relation between the number of *Chilo partellus* males released and recaptured in the pheromone trap in the screenhouse

<table>
<thead>
<tr>
<th>No. of males released</th>
<th>No. of males recaptured (mean±S.E.)</th>
<th>% males recaptured (mean±S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.5±0.27d</td>
<td>15.0±2.67a</td>
</tr>
<tr>
<td>20</td>
<td>4.0±1.16c</td>
<td>20.0±6.82a</td>
</tr>
<tr>
<td>30</td>
<td>5.6±0.89c</td>
<td>18.7±2.95a</td>
</tr>
<tr>
<td>40</td>
<td>9.5±1.05b</td>
<td>23.8±2.63a</td>
</tr>
<tr>
<td>50</td>
<td>12.3±0.65a</td>
<td>24.5±1.29a</td>
</tr>
</tbody>
</table>

Mean values followed by the same letters in a column are not significantly different \((p>0.05)\) by ANOVA/DMRT.

Fig. 4. Regression of the numbers and percentages of *Chilo partellus* males recaptured in pheromone traps on the numbers of males released in the screenhouse.

Fig. 5. Regression of the numbers and percentages of *Chilo partellus* males recaptured in pheromone traps on the numbers of males released in the field.
values for the numbers of recaptured males were higher (0.98, 0.99) than those for the percentages (0.86, 0.76). While the mean values for the numbers of recaptured males differed significantly among different numbers of released males, those for the percentages of the recaptured males were statistically identical, as shown by the analysis of variance followed by Duncan's Multiple Range Test (Tables 1, 2). These observations suggest that differences in the population density of the males determined the number trapped but not the percentage which averaged about 20% in the screenhouse and 10% in the field. In the screenhouse, there were no calling females other than those used as the bait, while it was not so in the field. During the field experiment the nightly catch of wild males in the trap was 12.1 ± 3.1 (mean ± S.E.), indicating the presence of a fairly high natural population of *C. partellus*.

**Effects of female population density and mating status on pheromone trap catches**

Table 3 presents the results of the experiments in which wire-net cages containing one or two virgin or mated females were arranged in different numbers in concentric circles and a pheromone trap was placed at the centre or outside the circle. The pheromone trap catch was not significantly affected by the presence of 9 caged virgin females in two concentric circles of radii 10 and 20 m occupying an area of 1257 sq cm surrounding the trap. But, the catches of the males in the pheromone traps surrounded by 18, 36, or 48 caged virgin females were significantly lower than those in the corresponding control traps, the reduction in the catches being 75–100%. The numbers of males caught in the pheromone trap placed 10 m outside (upwind) of the circle of the caged virgin females were not significantly lower than those in the control trap. Similarly, the pheromone trap catch was not significantly affected by the mated females surrounding the trap.

**Competition between the pheromone trap and calling females around the trap**

The results of the experiments on the competition between the pheromone trap and tethered virgin females surrounding it are presented in Table 4. The number of males caught was significantly reduced by about 78–86% when the trap was surrounded by 36 or 60 tethered virgin females. Of the tethered females recovered, the average percentage of mated females was 58.2 and 65.9, respectively. These observations suggest that the reduction in the male catch in the pheromone trap was due to successful competition by the females for the males.

Competition between the pheromone trap and calling females in the trap vicinity as well as competition among pheromone traps was evident from the results of the

---

**Table 2. Relation between the number of Chilo partellus males released and recaptured in the pheromone trap in the field**

<table>
<thead>
<tr>
<th>No. of males released</th>
<th>No. of males recaptured (mean ± S.E.)</th>
<th>% males recaptured (mean ± S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.75 ± 0.48a</td>
<td>7.5 ± 4.8a</td>
</tr>
<tr>
<td>20</td>
<td>2.00 ± 0.41ab</td>
<td>10.0 ± 2.0a</td>
</tr>
<tr>
<td>60</td>
<td>6.75 ± 2.95b</td>
<td>11.3 ± 4.9a</td>
</tr>
</tbody>
</table>

Means followed by the same letters in a column are not significantly different (p > 0.05) by ANOVA/DMRT.
Table 3. Effect of *Chilo partellus* female population density in the neighbourhood of pheromone traps on catches of males in the field

<table>
<thead>
<tr>
<th>Experiment No.</th>
<th>Experimental trap position</th>
<th>No. and arrangement of females</th>
<th>Mating status of females</th>
<th>No. males trapped per night (mean±S.E.)</th>
<th>Percentage reduction in male catch in Trap (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Experimental trap (A)</td>
<td>Control trap (B)</td>
</tr>
<tr>
<td>1</td>
<td>Centre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9 in 2 circles&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Virgin</td>
<td>1.6±0.5</td>
<td>1.9±0.6</td>
</tr>
<tr>
<td></td>
<td>Centre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18 in 2 circles&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Virgin</td>
<td>1.0±0.5</td>
<td>5.6±1.4&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Centre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36 in 2 circles&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Virgin</td>
<td>0</td>
<td>2.9±0.4&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Centre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36 in 2 circles&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Virgin</td>
<td>0.5±0.3</td>
<td>6.1±1.5&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>Centre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48 in 3 circles&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Virgin</td>
<td>0.5±0.2</td>
<td>6.6±1.0&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>Outside&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18 in 2 circles</td>
<td>Virgin</td>
<td>1.7±0.8</td>
<td>2.2±0.4</td>
</tr>
<tr>
<td>4</td>
<td>Centre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18 in 2 circles</td>
<td>Mated</td>
<td>2.6±0.2</td>
<td>3.6±0.8</td>
</tr>
</tbody>
</table>

<sup>a</sup> The trap was located at the centre of concentric circles bearing the wire-net cages with females.
<sup>b</sup> The trap was set outside the concentric circles of the female-bearing cages, 10 m upwind.
<sup>c</sup> Wire-net cages, each containing one female, arranged in 2 concentric circles of radii of 10 and 20 m occupying 1257 sq cm area.
<sup>d</sup> Wire-net cages, each with 2 females, arranged in 3 concentric circles of radii of 2, 4 and 6 m occupying 113 sq cm area.
<sup>e</sup> Five 1-day old unmated males released east, west, north and south side of the trap at 25 m distance to supplement the field population.
<sup>*, ***, ***</sup>Significantly different at $p<0.05$ and $p<0.001$, respectively, from the corresponding mean of the experimental trap (A) (Student's t-test).
C. partellus Pheromone Trap Competition with Females

Table 4. Competition between Chilo partellus females and the pheromone trap: mating of tethered females and trap catches of males

<table>
<thead>
<tr>
<th>Tethered females</th>
<th>No. of males caught per night (mean±S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of females placed</td>
</tr>
<tr>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>36</td>
<td>30.7±1.3</td>
</tr>
<tr>
<td>60</td>
<td>51.0±0.7</td>
</tr>
</tbody>
</table>

a,b 40 and 60 unmated 1-day-old males each, respectively, were released to supplement the field population.

experiments using two different pheromone trap densities, i.e. one and seven. Numbers (mean±S.E.) of males caught per trap per night was 3.00±0.84 with one trap per plot and 0.98±0.19 with 7 traps per plot, the former being significantly greater. On the other hand, the total nightly catch of males in one trap (3.00±0.84) did not differ significantly from that of seven traps (6.80±2.10). The results implied that the traps competed among themselves for the available searching males.

DISCUSSION

A previous report (Unnithan and Saxena, 1990) on the factors determining pheromonal trapping of Chilo partellus males revealed no significant difference between laboratory-reared and wild moths in the attraction of the wild males to the females, and in the responsiveness of the males to the pheromone trap. Hence, the results of the present studies using laboratory-reared moths should be relevant although they do not fully represent the field situation.

In the enclosed environment of the screenhouse, and in the field, the numbers of C. partellus males released and recaptured in the female-baited traps showed a significant positive relationship. In the field, it was likely that the free-flying population of calling females could have affected the trap performance, and consequently reduced the proportion of released males recaptured, compared with that in the screenhouse. However, further work under different levels of natural populations is required to define in detail the relationship between C. partellus pheromone trap catches and population density.

In the field, the presence of calling C. partellus females around the pheromone trap, in addition to the free-flying natural population, resulted in a significant reduction (75–100%) in the capture of males in the female-baited trap. The pheromone trap catch, however, was not significantly affected when it was surrounded by mated females, instead of virgin females, although mated females were observed to attract males at a lower level (Unnithan and Saxena, 1990). Similarly, the reduction in the pheromone trap catch was not significant when the females were arranged in concentric circles 10 m downwind of the trap. These results clearly demonstrate competition for receptive males between the pheromone trap (or female bait) and calling females in the vicinity. Reduction in the pheromone trap catch due to the addition of virgin females to wild populations was also reported in the case of the gypsy moth (Elkinton and
Cardé, 1984) and in the codling moth (Howell, 1974). A similar reduction in the trap catch of Chilo suppressalis males was considered by Kanno et al. (1980) and Beevor et al. (1977) to be due to the "disruption effect". But, the conditions of the experiments by these workers were quite different from those in the present study, particularly because they used synthetic pheromone(s) or pheromone mimic(s) in concentrations that were much higher than those released by the females in the present work.

From the decreased catch in the pheromone trap surrounded by caged females, it was not clear whether the caged females caused disruption in male-female communication and, thus, in the orientation of the flight of the males to the calling females. But, mating in about 58-66% of the tethered females that surrounded the pheromone trap implied that the densities and spatial distribution used in the experiment did not result in disruption of male-female communication to any great extent, even though the number of males caught in the trap was reduced by 78-86%. The tethered females that mated were able to compete successfully for the available males. This competition effect was further confirmed by the fact that the total number of males caught in the tests with one trap per plot did not differ significantly from the tests with 7 traps per plot. These results also clearly demonstrated the competition among pheromone traps. Besides competition between traps and calling females, the mating status of the males can also affect the trap catch (Unnithan and Saxena, 1990). As C. partellus males usually copulate only once per night (Unnithan, unpublished) they are not likely to be trapped on the same night after mating, as is also suggested in Argyrotaenia citrana (Knight and Croft, 1987).

Decreased catches of males in the pheromone traps with increasing population density have been reported in several insects (Oloumi-Sadeghi et al., 1975; Riedel et al., 1976; Miller and McDougall, 1973; Cardé, 1979; Knight and Croft, 1987). In the codling moth (Laspeyresia pomonella), when laboratory-reared males were released in the field, their recapture in female-baited traps was reduced up to 75% when a low population of free-flying females was present (Howell, 1974). On the other hand, in Heliothis virescens, native females did not appear to affect trap catch until the population was large (Hartstack and Witz, 1981). Such a reduction in pheromone trap catch is regarded as "competition effect" which could be related to various factors like population density, sex ratio, mating status and the searching behaviour of the male (Cardé, 1979). In A. citrana, protandry, cessation of calling by mated females and the receptiveness of mated males regulated competition between pheromone trap and female moth (Knight and Croft, 1987).

In conclusion, our results showed a positive correlation between the numbers of laboratory-reared C. partellus males released, both in the field and screenhouse, and recaptured in pheromone traps. The competition effect of the caged females in the field suggests that trap efficiency would decrease under high female population density. This should be taken into consideration while interpreting the results of pheromone trap catches of C. partellus and using the information for understanding the flight phenology and population density of the pest. Our observations will also be relevant in future attempts to develop mass trapping and mating disruption strategies for the control of this pest.
C. partellus Pheromone Trap Competition with Females

ACKNOWLEDGEMENTS

The authors take great pleasure in thanking Professor Thomas R. Odhiambo, Director, ICPE for helpful suggestions during this work, to Messrs S. O. Paye, P. A. Oreng, G. S. Odhiambo and W. O. Owour for technical assistance and to Dr. R. M. Newson for his critical review of the manuscript. The authors are also grateful to the Swedish Agency for Research Cooperation with Developing Countries (SAREC) for a grant which partially supported this work.

REFERENCES


