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MONITORING OF CODLING MOTH (*C. Pomonella, Lepidoptera: Tortricidae*) USING PHEROMONE TRAPS

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ABSTRACT

Monitoring codling moth, *Cydia pomonella* L., in farmer's orchard by installing sex pheromone traps is a key prerequisite for its effective management. For mass trapping of *C. pomonella*, sex pheromones were installed to evaluate their performance in apple orchard of Loralai district of Balochistan. Four different pheromone traps were installed in randomized complete block design (RCBD). Each trap was replicated three times with experimental units of twelve traps in an area of 43560 square feet. The results revealed significantly different at (P<0.05) and observed that *C. pomonella* moths captured maximum in the month of May (25.29±1.39), followed by June (22.54±0.64) and lowest in July (11.36±0.57). Turning the findings into weeks, the numbers of trapped adult *C. pomonella* fluctuated, and the highest overall population of *C. pomonella* moths (34.75±0.12) were captured on very first week of observation when newly sex pheromone traps were installed in apple orchard, followed by third week (30.39±0.59) when lures were changed fortnightly. After the third week, the captured population of moths remained in twenties from fourth week till eight week of observation and trapped population ranged (20.68±0.49 to 25.36±0.2) overall. Later, as the temperature increased in last weeks of observation, the number of moths remained less or more in installed sex pheromone traps and ranged (10.89±1.07 to 17.04±0.39) from week nine to twelfth week. The weekly moths trapped results further observed that the lowest number of moths captured (6.14±0.59) in overall traps of the studied apple orchard. The flying ethology of *C. pomonella* showed statistically different and executed that maximum number of *C. pomonella* moths were trapped at night (27.46±1.72), followed by evening (11.72±1.51), morning (3.58±0.45), and the lowest in afternoon (2.28±0.08). Furthermore, populations of *C. pomonella* moths trapped overall were correlated with temperature and relative humidity and results for correlation show that moths captured showed positive but least correlation and not significant (r=0.175, F =113.79, P < 0.651), while trapped moths population showed

negative but highest correlation with relative humidity and highly significant (r=-0.984, F =113.79, P < 0.0000) at 0.05 probability level.

INTRODUCTION

Due to its delectable flavour and value as a vitamin for human health, apples are one of the fruits that are grown most worldwide. With more than 7500 identified varieties, it has been grown for millennia in both Europe and Asia. The saying " A daily apple keeps the doctor away " is often used to describe this fruit because of its high potassium and phosphorus content and low salt content (Na). In fact, eating foods high in K helps to avoid heart disease. Low intakes of sodium protect kidneys from harm and help manage blood pressure. Also, it contains vitamin B complex, which is beneficial for one's health once again. (Philips & John, 2013; USDA, 2013).

Many pests damage the apple crop, but the codling moth The most harmful one is *Cydia pomonella* (L.), a significant internal apple pest that is present across the world. (Arthurs *et al.,* 2015) traps that are lured with sex pheromones can normally be used to monitor adult populations in commercial orchards (Balazs *et al.,* 2014). If not regulated, its average degree of damage is up to 20–90%, which could cause the farmers to suffer significant economic losses. (Bradley *et al.,* 2009) and the farmers are controlling it with 4-5 sprays of dangerous insecticides. In turn, this led to the buildup of pesticide residues in the produce and the emergence of pest resistance. In addition to apple, this insect also harms pear, walnut, quince, and several stone fruits, which reduces the amount of fruit that is produced. (Maciej *et al.,* 2014; Eduardo *et al.,* 2017).

The optimum sampling equipment for flying adult insects, especially *Cydia pomonella*, is provided by pheromone traps. Sex pheromones have just recently been used to track insect infestations. Some workers have observed that it is highly helpful for determining the seasonal activity of pest species (Mihaela *et al.,* 2015). Models to forecast the seasonal pest incidence can be developed using data from pheromone trap collections in any location. Building an efficient monitoring system for the codling moth, *Cydia pomonella* L., is crucial since the environment has a big impact on how much is caught in traps by changing both insect activity and the relative efficiency of the traps (Mitchell *et al.,* 2013). Muhammad *et al.,* (2014) examined how climatic factors affected lepidopterous pest catches in pheromone traps, including the potato cutworm Spodoptera litura Fabricius, the diamondback moth (DBM) *Plutella xylostella* (L.), the brinjal shoot and fruit borer (BSFB) Leucinodes orbonalis Guenee, and the okra shoot and fruit borer Earias insulana Boisduval. They also learn that the sum of all the meteorological variables selected for analysis affected tomato worm captures to the tune of 97 percent. The codling moth pupates in the spring after spending the winter in a cocoon beneath loose bark or in the ground close to the host tree. Depending on the temperature, adult emergence typically begins in mid- to late spring. The male emerges up to two weeks earlier than the female in the spring because he develops more quickly. Adult flight takes place around dusk, typically when the temperature is between 10 and 20 °C (Mitchell *et al.,* 2013). Just 40% of the eggs mature when the temperature is below the average of 15°C, despite oviposition being recorded to occur at average temperatures as low as

12.3°C in Norway. Typically, the female begins to lay her eggs two days after emerging (Witold *et al.,* 2017). with common locations for oviposition being on leaves and twigs close the fruit as well as on the fruit itself. (Arthurs *et al.,* 2015) in the parts of the tree that are shielded from the wind and rain. The damage caused by the larva eating its way into the fruit's centre and feeding on the seeds might cause the fruit to fall off, mature too soon, or encourage the growth of harmful fungus like *Monilinia fructigena*. The larva also typically leaves behind a tunnel that is packed with frass. Targeting the egg or larva in pest management is crucial because it prevents the pest from escaping to the protected interior of the host fruit. However, if the pesticide is applied too early, the apple's growth and the pesticide's natural degradation could reduce the amount of sprayed surface and the concentration. While the codling moth only has one generation annually in Norway, it frequently has multiple, more harmful generations in warmer nations (Blomefield & Giliomee 2014). Karuppaiah and Sujayanad (2012) discovered that an increase in the world's The presence of a changing climate is indicated by changes in average temperature, rainfall patterns, and extreme weather occurrences. These short-term and seasonal variations would influence the fauna, vegetation, and population dynamics of insect pests. It is well recognised that the abiotic factors directly affect the dynamics of insect populations by altering the rates of development, survival, fecundity, voltinism, and dispersal. Temperature is a significant component in climatic conditions. Insect pest population dynamics would therefore shift because of climate change.

Since the 1970s, sex pheromone-baited monitoring traps have proven crucial in insect pest management by identifying the many pests that when they are active and present in a crop (Witzgall *et al.* 2010). Furthermore, there has been important developments in the evolution (Miller *et al.* 2015) and validation (Adams *et al.,* 2017) of methods from the quantity of insects caught in pheromone-baited traps, one can determine the absolute density of pests, a crucial factor in developing economic thresholds meant to optimise management decisions. It is becoming more and more evident that pheromone-hunting insects move using biological random walks (*Miller et al.* 2015, Adams *et al.,* 2017), and that captures come about because of random collisions between movers travelling great distances and tiny plumes from monitoring traps. For instance, while searching for pheromone over a complicated a route that causes a net displacement that is rarely greater than 300 m, male codling moths, *Cydia pomonella* (L.), frequently move an estimated total distance of 3 km (Adams *et al.,* 2017).

In many regions of the world, the codling moth (*Cydia pomonella*) is a major insect pest of apples. In temperate regions of all the major continents, a striking amount of fruit damage (80%) has been recorded because of the insect (Arthurs & Lacey, 2015). Although being an economically significant apple pest globally, apple growers only have a very small tolerance (1%) for its harm (Saethre & Hofsvang, 2015). As a result, various control measures, including regular spraying of broad-spectrum insecticides during the fruiting period, have been required. Around three times a year, a few insecticides are sprayed on most apple orchards, and the same substances are also used to disinfect the soil before planting to protect against pests (Arthurs *et al*. 2013; Harold, 2016). As a result, the following goals were set for this research study, which was designed to use pheromone traps to monitor the adult population of the codling moth, *Cydia pomonella*, in a farmer's orchard in the district of Loralai in Balochistan, Pakistan.

Objectives

i. To record the population of codling moth in apple orchard using pheromone traps

ii. To record the effect of abiotic factors on the population dynamics of codling moth in apple orchard

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3. MATERIALS AND METHODS

3.1 Study Area

The current research was done at the farmer's apple orchard of district Loralai Balochistan, Pakistan during apple season of 2022 to monitor the adult male population of *Cydia pomonella.*

3.2 Plot size

The apple orchard consisted of an area of 43560 square feet. The plant to plant and row to row distance between apple trees was 18x18 fts.

3.3 Preparation of funnel pheromone traps

The sex pheromones were purchased from Shani Enterprise in Multan, Punjab, Pakistan., and the traps were made locally. Iron wire, plastic lids, empty plastic jars, funnels, tiny metal hooks, tape, and wooden bars were bought from the market and afterwards joined to make the funnel traps. (Figure

3.1)

Figure 3.1 Installation of pheromone traps in Apple orchard

3.4 Sex Pheromone Chemicals and their installation:

The composition of these sex pheromone was (Z)-11- hexadecenal and (Z)-9-hexadecenal in 97:3 ratio. The chemical lures were fixed in aluminum hook and replaced after 15 days. These traps were hung on four randomly selected Apple trees at height of 2.5 meters with adjacent of five trees in randomized complete block design (RCBD).

3.5 Moth catches Observation

The information was gathered by counting the number of moths that were trapped on a weekly and monthly basis, and then the data were connected to determine their association with weather variables (temperature and humidity). According to Rao *et al., 1991* the flying ethology in response

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to pheromone trap was also reported. The captured moths were recorded over a period of seven days throughout each of the four daytime phases (morning, afternoon, evening, and night).

3.6 Statistical analysis

Four treatments (locations) were used in the experiment, each of which was reproduced three times, in a randomized complete block design. The analysis of variance (ANOVA) test was used to statistically examine the data. The collected means were distinguished with a significant difference using least significant difference (LSD) at 0.05 probability level. All statistical calculations were performed using Statistix-8.1 statistical software.

4. RESULTS

The present study was carried out to monitor codling moth (*Cydia pomonella, Lepidoptera: Tortricidae*) by using pheromone traps in farmer's orchard field of apple in District Loralai of Balochistan, Pakistan.

The results obtained are presented as below:

4.1 Month wise population of adult codling moths captured through pheromone traps at four different places.

Sex pheromone traps are very much effective and safe measuring tool concerned to sampling as well as controlling different insect pests as compared to insecticide. Synthetic pheromones can be very handy for monitoring periodic activity of adult insect pests. Moreover, statistically results revealed significant differences ($F = 793.70$, $P < 0.000$) of *C. pomonella* males captured in all three months of observation.

The results regarding moth catches of *C. pomonella* during different months in apple orchard were observed significantly different at ($P<0.05$)

During apple season of 2022, the traps installed to capture adult male population of *C. pomonella* resulted that overall maximum moths were caught in the month of May (25.29±1.39), followed by June (22.54±0.64) and lowest in July (11.36±0.57) (Table 4.1).

Table 4.1 Month wise mean population of *C. pomonella* during apple season 2022

Months	Trap-1	Trap-2	Trap-3	Trap-4	Overall Mean
May	27.40±0.64a	27.97±0.70a	23.07±0.57b	22.70±0.56b	25.29±1.39a
June	22.77±0.61b	21.60±0.32b	23.07±0.57b	22.70±0.56b	22.54±0.64b
July	10.58±0.38c	11.65±0.45c	11.32±0.67c	11.90±0.51c	11.36±0.57c

Means followed by different letters within the same column are significantly different (p <0.05)

4.2 Weekly *C. pomonella* moths captured through pheromone traps at four different places of orchard during apple season, 2022.

The weekly adult moths monitored through sex pheromones showed fluctuation throughout the traps installed in a farmer's apple orchard.

There was no sequential population of moths captured in all four traps installed throughout the study for all three months, the numbers of trapped adult *C. pomonella* fluctuated weekly, and the study recorded that relative humidity and temperature affected the number of population trapping. Moreover, statistically results revealed significant differences (F =664.02, P < 0.000) of *C. pomonella* males captured in all weeks of observation.

The results in Table 4.2 show that highest overall population of *C. pomonella* moths (34.75±0.12) were captured on very first week of observation when newly sex pheromone traps were installed in apple orchard, followed by third week (30.39±0.59) when lures were changed fortnightly. After third week, the captured population of moths remained in twenties from fourth week till eight week of observation and trapped population ranged (20.68±0.49 to 25.36±0.2) overall. Later, as the temperature increased in last weeks of observation, the number of moths remained less or more in installed sex pheromone traps and ranged (10.89±1.07 to 17.04±0.39) from week nine to twelfth week. The weekly moths trapped results further observed that the lowest number of moths captured (6.14±0.59) in overall traps of the studied apple orchard (Table 4.2).

Table 4.2 Weekly mean number of *C. pomonella* moths captured during apple season 2022 at farmer's field in Loralai, Balochistan, Pakistan

Weeks	Trap-1	Trap-2	Trap-3	Trap-4	Overall Mean
Week-1	$34.43±0.70^{a}$	$34.86±0.50^{a}$	$35.00±0.58^{a}$	$34.71±0.5^{a}$	$34.75±0.12^{a}$
Week-2	$26.14±0.66^{e}$	$25.71±0.71^{ef}$	$28.14±0.57^{d}$	$29.00±0.58^{cd}$	$27.25±0.79^{c}$
Week-3	$30.29±0.41^{bc}$	$32±0.58^{b}$	$30.14±0.52^{c}$	$29.14±0.52^{cd}$	$30.39±0.59^{b}$
Week-4	$21.14±1.16^{lm}$	$22.00±0.58^{jklm}$	$22.86±0.49^{ijkl}$	$21.14±1.16^{lm}$	$21.75±0.41^{f}$
Week-5	$25.57±0.63^{ef}$	$24.71±1.05^{efgh}$	$25.29±0.33^{efg}$	$25.86±0.63^{ef}$	$25.36±0.25^{d}$
Week-6	$21.43±0.84^{klm}$	$21.00±1.15^{mn}$	$21.43±0.84^{klm}$	$23.00±0.58^{hijk}$	$21.72±0.44^{f}$
Week-7	$24.86±0.63^{efg}$	$23.71±0.40^{ghij}$	$24.14±1.38^{fghi}$	$24.29±1.44^{fghi}$	$24.25±0.24^{e}$
Week-8	$20.71±1.02^{mn}$	$19.29±0.40^{no}$	$21.57±0.93^{klm}$	$21.14±1.16^{lm}$	$20.68±0.49^{g}$

Week-9	18.17±0.88^{op}	16.86±0.30^{p}	16.71±0.60^{p}	16.43±0.78^{pq}	17.04±0.39^{h}
Week-10	14.71±0.26^{pq}	13.71±0.52^{rs}	12.43±0.55^{stuv}	13.43±0.67^{rst}	13.57±0.47^{i}
Week-11	11.00±0.58^{v}	13.00±0.58^{rstu}	11.29±0.55^{uv}	11.86±0.54^{tuv}	11.79±0.44^{j}
Week-12	7.71±0.63^{w}	11.57±0.68^{uv}	12.29±0.49^{stuv}	12.00±0.58^{stuv}	10.89±1.07^{j}
Week-13	5.00±0.88^{x}	5.57±0.32^{x}	6.29±0.47^{wx}	7.71±0.40^{w}	6.14±0.59^{k}

Means followed by different letters within the same column are significantly different ($p <0.05$)

4.3 Flight ethology of *C. pomonella*.

The flight time of *C. pomonella* in response of four different installed pheromones was recorded once for once week during all study periods. To record the flight ethology, the installed traps were observed for four different periods of all day i.e., (morning, afternoon, evening, and night) (Figure 4.1).

The results showed statistically different flying time of moth ($F =735.17$, $P < 0.0000$) of *C. pomonella* males captured and this execute that the *C. pomonella* adults have crepuscular behavior of flight against pheromone traps.

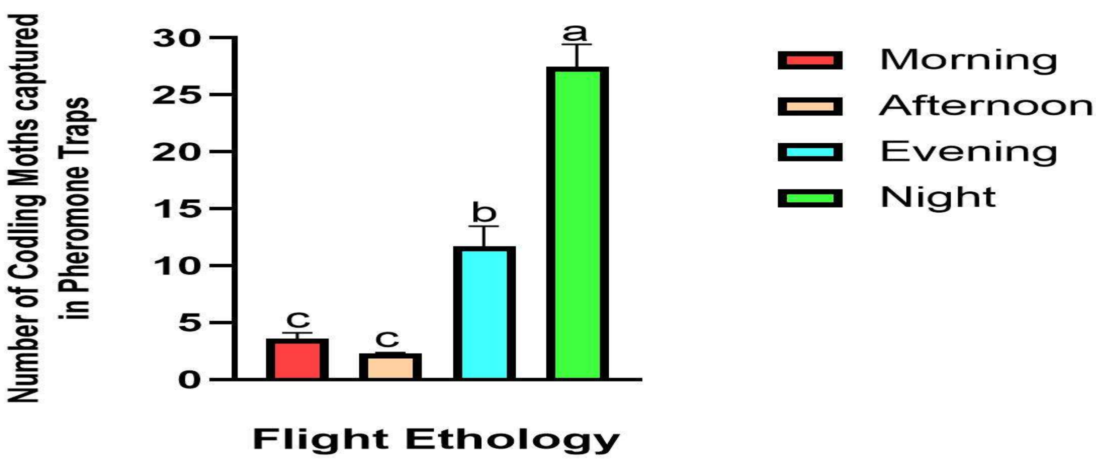

Figure 4.1 Flying ethology of *Cydia pomonella* towards pheromone traps during different phases of the day.

Means followed by different letters in bar diagram are significantly different ($p <0.05$).

The results in figure 4.1 show that maximum number of *C. pomonella* moths were trapped at night (27.46±1.72), followed by evening (11.72±1.51), morning (3.58±0.45), and the lowest in afternoon (2.28±0.08).

4.2 Correlation of *C. pomonella* moths captured with temperature and relative humidity

Furthermore, populations of *C. pomonella* moths trapped overall were correlated with temperature and relative humidity and results for correlation show that moths captured showed positive but least correlation and not significant (r=0.175, F =113.79, P < 0.651), while trapped moths population showed negative but highest correlation with relative humidity and highly significant (r=-0.984, F =113.79, P < 0.0000) at 0.05 probability level (Table 4.3).

Table 4.3 Correlation coefficient measured between population of *C. pomonella* moths and environmental factors.

Abiotic Factors	Moths Trapped
Temperature	0.175*^{NS}
Relative humidity	-0.984**^{HS}

* Shows less/ no correlated

** Shows that correlation is highly correlated

- Shows negative relationship

^{HS} Shows that correlation is highly significant at P< 0.05

^{NS} Shows that correlation is not significant at P< 0.05

DISCUSSION

In many regions of the world, Apple fruit is heavily infested by the codling moth (*Cydia pomonella*). In temperate regions of all the major continents, a striking amount of fruit damage (80%) has been recorded because of the insect (Arthurs & Lacey, 2014). Although being an economically significant apple pest worldwide, apple growers only have a very small tolerance (1%) for its harm. As a result, various control measures have been required, including regular spraying of broad-spectrum insecticides during the fruiting season. Around three times a year, a few insecticides are sprayed on most apple orchards, and the same substances are also used to disinfect the soil before planting to protect against pests (Arthurs *et al.,* 2013).

The present study was carried out considering the significance of the scenario since sexual pheromone traps offer an ideal sample method and control approach for flying adult insects (Tamhankar *et al.,* 1989; Singh & Sachan, 1991; Patil *et al.,* 1992). The study's methodology involved bulk *C. pomonella* catching using pheromone traps in four separate locations (Tortricidae: Lepidoptera). It has already been widely noted that one important benefit of sex pheromone research is the surveillance of insect populations through the installation of pheromone traps. The use of pheromone-baited traps is useful for determining the pest population so that the schedule of the application of pesticides to control the pests may be planned (Vakenti and Kadsen, 1976). In the same way, sex pheromone lures could be employed in field situations with funnel traps and delta traps. Also, the placement of the traps in relation to the crop canopy may have an impact on the design of the traps that can draw the most insects in different areas (Srinivasan, 2008).

The results of the current investigation revealed that During apple season of 2022, the traps installed to capture adult male population of *C. pomonella* resulted that overall maximum moths were caught in the month of May (25.29±1.39), followed by June (22.54±0.64) and lowest in July (11.36±0.57). There was no sequential population of moths captured in all four traps installed throughout the study for all three months, the numbers of trapped adult *C. pomonella* fluctuated weekly, and the study recorded that relative humidity, and temperature affected the number of population trapping. Moreover, statistically results revealed significant differences (F =664.02, P < 0.000) of *C. pomonella* males captured in all weeks of observation. The results further found that highest overall population of *C. pomonella* moths (34.75±0.12) were captured on very first week of observation when newly sex pheromone traps were installed in apple orchard, followed by third week (30.39±0.59) when lures were changed fortnightly. After the third week, the captured population of moths remained in twenties from fourth week till eight week of observation and trapped population ranged (20.68±0.49 to 25.36±0.2) overall. Later, as the temperature increased in last weeks of observation, the number of moths remained less or more in installed sex pheromone traps and ranged (10.89±1.07 to 17.04±0.39) from week nine to twelfth week. The weekly moths trapped results further observed that the lowest number of moths captured (6.14±0.59) in overall traps of the studied apple orchard. It is consistent with these results Hussain *et al.* (2015) kept track of *Cydia pomonella's* population dynamics in 2009 discovered that all locations' initial capture, maximum catch, and lowest catch dates were on May 21, June 11, and August 13. Although the population was smaller in 2010, the dynamics remained the same. Both years experienced comparable climatic conditions. Hence, effective codling moth monitoring is crucial. In 2009, it was greatest in Hardas and lowest in Gongma, while in 2010, it was highest in Shilikchey and lowest in Poyen.

Additionally, study revealed that most moths were trapped at night. particularly when sun set (27.46±1.72), followed by (11.72±1.51), morning (3.58±0.45). It was discovered that pests fly at night to avoid pheromone traps. Nonetheless, only a small number of moths (2.280.08) were photographed during the day. These findings are corroborated by those of other researchers who studied how lepidopteron moths flew at night and in the evening and found that one of the primary causes was light (Patil and Mamadapur 1996; Shivakumara, 2001). Furthermore, populations of *C. pomonella* moths trapped overall were correlated with temperature and relative humidity and results for correlation show that moths captured showed positive but least correlation and not significant (r=0.175, F =113.79, P < 0.651), while trapped moths population showed negative but highest correlation with relative humidity and highly significant (r=-0.984, F =113.79, P < 0.0000) at 0.05 probability level. Patil *et al.* (1992) described similar outcomes on cotton. According to Satpathy and Mishra (2007) and Mall *et al.* (1992), adults of *H. armigera* are most active in the evening, when the temperature is between 20 and 25 ^{0}C.

It can be inferred from the findings of the present study that mass trapping can be an effective and appropriate pest management strategy given the socioeconomic circumstances of the Loarlai region of Balochistan, Pakistan.

Conclusions

The current research leads to the conclusion that sex pheromone traps in apple orchard fields should be set up to catch the adult population. the codling moth, *Cydia pomonella* of at early stages in the month of March to April of each growing season. In addition, these traps should be installed at evening time before sun sets.

Recommendations

From the present results, it is recommended that pheromone traps should be tested by installing at different heights keeping in view the height of apple tree. Moreover, these traps may also be kept installed at least a month after collecting the apple fruits from orchard.

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