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Field study of pheromone trap catches of codling moth *Cydia pomonella* (L) (Lepidoptera; Tortricidae) in relation to weather parameters at Madyan Swat Pakistan

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Abstract
Study was carried out to investigate population dynamics and impact of abiotic factors (Temperature, relative humidity and rainfall) on trap catches of apple codling moth (*Cydia pomonella*) at Madyan Swat in an unmanaged orchard during the year 2012-13. Results revealed that the first peak population (11.0±1.03 moths/trap) of *C. pomonella* was observed in 27th standard meteorological week (SMW), whilst the second peak population 10.25±0.9 moths/trap was in 33rd SMW. During the year 2013, the first and second peak population at Madyan was10.25±0.81 &9.00±0.70 moths/trap in 29th and 35th SMW respectively. Correlation matrix revealed that *C. pomonella* showed statistically highly significant ($p<0.01$) positive correlation both with maximum (r = 0.857&0.824) and minimum temperature (r = 0.739& 0.755), whilst non-significant negative relation with percent relative humidity (morning and evening). Nonetheless, *C. pomonella* also showed non-significant negative correlation with total rainfall (mm). Multiple regression models explained 72.34 to 83.42% variability due to meteorological factors in the population dynamics of *C. pomonella* during the year 2012 and 2013. It was concluded that meteorological factors have a profound impact on the population dynamics of *C. pomonella* through pheromone trap catches at Madyan Swat.

Keywords: Pheromone trap, Population dynamics, *Cydia pomonella*, Weather parameters, Correlation

1. Introduction
Swat valley is located at 34^0 34' to 35^0 55' of latitude North and 72^0 08' to 72^0 50' of longitude East in the North West of Khyber Pakhtunkhwa at an altitude of 1136 meters from the sea level. The annual rainfall is 1000-1200 mm and temperature ranges from -2 to 37 ^{0}C [1].
Apple is cultivated on an area of 45000 ha with annual production 600000 tons in Pakistan [2]. *Cydia pomonella* is the serious insect pest of apple fruit in different parts of the world. A remarkable fruit damage (80%) has been observed due to the insect attack in temperate parts of all major continents [3]. While being an economically important pest of the apple worldwide, the growers have a low tolerance (<1%) for its injury [4]. This has necessitated the adoption of different control strategies especially frequent applications of broad-spectrum insecticides throughout the fruiting period. The damage is caused by the larvae, which burrow into the fruit to feed on the flesh and seeds. A small red-ringed cavity hole filled with dry frass is an indication for larval penetration [5].
Adult male population of this pest in commercial orchards can be typically monitored with traps baited with sex pheromone lures [6]. On the average its extent of damage is up to 20-90% and resulting in huge economic losses to the farmers if not controlled [7] and the farmers are applying 4-5 sprays of hazardous insecticides for its control [8]. This results in accumulation of pesticide residues in the produce on one hand and development of pest resistance on the other hand [9].
Pheromone traps offer one of the best sampling tools for flying adult insect especially *C. pomonella*. The use of sex pheromones for monitoring insect pests is of recent origin. It has been reported to be very useful for determining seasonal activity of pest species by several workers [10-12]. Information obtained from pheromone trap collections in any area can be used for development of models to predict the seasonal incidence of pest. Environment greatly affects size of the trap catch by influencing both the activity of the insects as well as the relative performance of the traps and optimal standardized trap design is vital in developing a useful monitoring system for *C. pomonella* [13]. The interpretation of the trap catch data is

often difficult because of the confounding effects of the environment and interaction between insect activity and trap performance. Trap catches may provide meaningful index for estimating population densities of the pests. Trap catches in relation to field infestation and environmental factors such temperature, relative humidity and rainfall are crucially important for decision making process. If a consistent relationship exists among weather parameters and *C. pomonella* population, the pheromone traps could be used to indicate when the field should be scored with insecticides application for the effective management and control of the pest for determining IPM measures [14].

Zada *et al*. [15] studied the influence of weather parameters on the population fluctuation of *C. pomonella* and reported that temperature and rainfall has a substantial effect on the adult moth catches in the pheromone traps. Prasannakumar *et al*. [16] also investigated the influence of abiotic factors on the pheromone trap catches of tomato fruit borer *Helicoverpa armigera* (Hubner), okra shoot and fruit borer *Earias insulana* Boisduval, Brinjal Shoot and fruit borer (BSFB) *Leucino desorbonalis* Guenee, Potato cutworm *Spodoptera litura* Fabricius and Diamond back moth (DBM) *Plutella xylostella* (L.). They further find out that tomato worm catches were influenced to an extent of 97 percent (R^2) by the combination of all the weather parameters chosen for analysis. Karuppaiah and Sujayanad [17] reported that the occurrence of flare up of pests is evident from increase in global average temperature, changes in the rainfall pattern and extreme climatic events. These seasonal and long term changes would affect the fauna, flora and population dynamics of insect pests. Therefore change in temperature and rainfall pattern would result in changes in the population dynamics of insect pests.

The current study was undertaken to find out the impact of abiotic factors of environment such as temperature, relative humidity and rainfall on the population dynamics of *C. pomonell*a adult male moth catches in the pheromone traps at Madyan Swat.

2. Material and Methods

2.1. Study Area and Parameters

The current studies were conducted at Madyan (35^0 08' 0.00" of latitude North and 72^0 32' 0.00" of longitude East) Swat Pakistan during the year 2012 and 2013, located at an altitude of 1333.84 meters above the sea level. Four synthetic pheromone traps were installed in four apple trees of the "Red Delicious" variety in the farmer's orchard at Madyan Swat valley.

Table 1: Standard Meteorological Weeks (SMW)

SMW#	Dates	SMW#	Dates
1	01 Jan - 07 Jan	27	02 Jul - 08 Jul
2	08 Jan - 14 Jan	28	09 Jul - 15 Jul
3	15 Jan - 21 Jan	29	16 Jul - 22 Jul
4	22 Jan - 28 Jan	30	23 Jul - 29 Jul
5	29 Jan - 04 Feb	31	30 Jul - 05 Aug
6	05 Feb - 11 Feb	32	06 Aug - 12 Aug
7	12 Feb - 18 Feb	33	13 Aug - 19 Aug
8	19 Feb - 25 Feb	34	20 Aug - 26 Aug
9*	26 Feb - 04 Mar	35	27 Aug - 02 Sep
10	05 Mar - 11 Mar	36	03 Sep - 09 Sep
11	12 Mar - 18 Mar	37	10 Sep - 16 Sep
12	19 Mar - 25 Mar	38	17 Sep - 23 Sep
13	26 Mar - 01 Apr	39	24 Sep - 30 Sep
14	02 Apr - 08 Apr	40	01 Oct - 07 Oct
15	09 Apr - 15 Apr	41	08 Oct - 14 Oct
16	16 Apr - 22 Apr	42	15 Oct - 21 Oct
17	23 Apr - 29 Apr	43	22 Oct - 28 Oct
18	30 Apr - 06 May	44	29 Oct - 04 Nov
19	07 May - 13 May	45	05 Nov - 11 Nov
20	14 May - 20 May	46	12 Nov - 18 Nov
21	21 May - 27 May	47	19 Nov - 25 Nov
22	28 May - 03 Jun	48	26 Nov - 02 Dec
23	04 Jun - 10 Jun	49	03 Dec - 09 Dec
24	11 Jun - 17 Jun	50	10 Dec - 16 Dec
25	18 Jun - 24 Jun	51	17 Dec - 23 Dec
26	25 Jun - 01 Jul	52**	24 Dec - 31 Dec

* Week No. 9 will be 8 days during leap year
** Week No. 52 will always have 8 days

The size of the apple orchard was 2.5 ha, comprised 250 apple trees and was 12 years old. The experiment was carried out in randomized complete block design (RCBD) and the adult moth catches replicated four times in both the seasons and each trap treated as replicate. The plant to plant and row to row distance between apple trees were 5.53 x 5.53 square meters. The pheromone traps containing rubber capsule (Septa) with 1 mg of Codlemone the synthetic sex pheromone for *C. pomonella* (Supplied by Shani Enterprise Multan Pakistan), were suspended in the centre of the trap. These traps were hung randomly in the centre of the apple orchard at four sites in field at height of 2.5 meters. Each time as traps were

checked, *C. pomonella* were counted and removed on weekly basis. Pheromone traps were almost species-specific and contamination with other insects was insignificant throughout the season. Codlemone-charged rubber septa were replaced twice within a month with fresh septa to insure maximum attraction. The observations on moth catches, weekly averaged maximum and minimum temperature percent relative humidity (morning, 0300Z and evening 1200Z and total rainfall were taken on weekly basis. For this experiment Reidl and Croft [18] procedures were followed with some minor modification suitable to the prevailing conditions of the apple orchard Madyan Swat.

Standard agronomic practices were adopted in the apple orchard. It was allowed with *C. pomonella* and no control measures were applied against the pest. The Standard Meteorological Week (SMW) starts from 1st January - 07th January and so on, while the traps were placed in the apple orchard in the 13th SMW (Table-1). The meteorological data from 14th SMW (Start from April) to 38th SMW (end of September) of Tehsil Madyan was taken from Pakistan Meteorological Department Swat and was correlated with the trap catches.

2.2. Statistical Analysis

The data regarding population dynamics of *C. pomonella* catches in the pheromone traps, maximum and minimum temperature, percent relative humidity and rainfall were subjected to correlation Pearson and linear multiple regression analysis by using statistical software Statistix version 8.1. The coefficient of determination (R^2) was also determined through multiple regression models [19].

3. Results and Discussion

3.1. Meteorological parameters and codling moth *C. pomonella* population at Madyan Swat during year 2012 and 2013

The results pertaining to population dynamics of *C. pomonella* revealed that mean population of *C. pomonella* varied significantly in different weeks of cropping season at Madyan in the year 2012 and 2013. The pest population was observed significantly from 17th standard meteorological week (SMW) and increased progressively with sharp rise and fall at the subsequent interval up to 38th (SMW) at Madyan Swat (Tab-2). The data on the mean population of *C. Pomonella* catches in the traps and the prevailing weather factors during the different

Table 2: Weekly averaged weather parameters and *C. pomonella* population in pheromone traps at Madyan during year 2012 & 2013

	2012						2013					
SMW	**Mean CM Catches in Traps (±SE)**	**Max Temp (^{0}C)**	**Min Temp (^{0}C)**	**R.H% (0300Z)**	**R.H% (1200Z)**	**Total R.F (mm)**	**Mean CM Catches in Traps (±SE)**	**Max Temp (^{0}C)**	**Min Temp (^{0}C)**	**R.H% (0300Z)**	**R.H% (1200Z)**	**Total RF (mm)**
14	0.00±0.00	27.29	11.36	62.00	28.5	11.97	0.00±0.00	25.93	12.14	56.00	27.5	11.97
15	0.00±0.00	22.57	9.14	73.57	40.10	9.52	0.00±0.00	24.36	10.86	74.71	39.22	4.48
16	0.00±0.00	23.64	10.57	73.00	51.60	2.03	0.00±0.00	24.21	11.36	74.71	49.37	7.77
17	0.25±0.25	22.29	10.57	79.14	60.10	45.99	0.25±0.25	24.00	11.64	76.29	55.98	26.81
18	0.00±0.00	23.50	11.71	64.71	40.43	6.02	0.00±0.00	25.21	12.93	66.00	41.40	8.19
19	0.50±0.29	26.00	12.93	68.86	39.47	4.97	1.00±0.41	26.36	13.07	65.43	42.44	5.60
20	2.00±0.71	25.91	11.36	67.57	38.08	10.50	2.00±0.81	26.50	12.71	67.29	41.43	4.20
21	2.50±0.63	27.07	12.50	53.29	32.88	3.99	3.00±0.41	26.50	12.29	59.57	33.11	6.30
22	2.25±0.71	29.64	15.36	52.71	29.97	2.10	2.00±1.08	29.29	15.36	53.43	30.89	0.98
23	4.00±0.41	30.45	13.70	50.00	29.32	0.98	2.00±0.81	28.21	14.27	51.14	25.91	1.12
24	6.00±0.63	31.07	16.57	50.71	27.33	0.00	6.00±0.40	29.57	17.36	54.43	30.44	13.23
25	6.25±0.82	30.07	14.00	47.29	28.08	0.98	6.00±0.70	29.86	15.00	48.57	31.09	0.00
26	8.00±1.25	31.36	18.29	49.57	32.66	0.00	8.00±0.40	29.86	17.36	50.29	29.44	1.33
27	11.0±1.03	32.07	19.36	60.86	45.02	1.23	8.00±0.81	32.29	19.86	61.00	47.32	1.28
28	7.25±1.25	30.36	18.21	68.00	47.77	4.66	9.00±0.81	30.07	17.07	71.86	49.97	3.99
29	6.75±0.29	31.43	19.14	64.71	42.21	2.67	10.25±0.8	31.43	18.79	64.43	40.02	1.00
30	5.75±1.41	32.57	21.64	71.00	51.40	7.00	7.25±0.85	31.36	21.14	68.00	48.78	1.67
31	2.50±0.85	28.56	19.36	77.71	59.32	27.79	2.00±0.85	30.71	19.50	78.14	56.34	18.41
32	6.00±0.48	31.00	18.29	73.43	51.76	7.00	5.00±0.81	30.64	19.29	73.14	54.22	18.41
33	10.25±0.9	31.56	20.00	79.29	54.90	2.66	4.75±1.22	29.86	19.43	77.14	53.70	6.51
34	8.75±0.58	29.07	20.00	79.00	67.88	3.01	6.00±1.65	29.21	20.07	80.43	60.2	31.29
35	3.75±0.00	26.98	18.57	70.57	56.71	34.79	9.00±0.70	30.12	18.43	71.14	54.61	3.57
36	1.50±0.00	26.23	17.07	79.14	71.71	67.48	7.00±1.08	27.89	17.36	79.57	69.66	29.47
37	0.00±0.00	24.50	17.50	77.14	68.93	28.77	2.00±1.08	25.43	17.00	76.14	62.89	51.80
38	0.00±0.00	24.86	13.43	74.43	49.53	25.70	0.5±0.70	24.93	14.07	77.86	51.00	25.62

Where:
CM: *Cydia pomonella*
SMW: Standard meteorological week
R.H(0300Z): Relative humidity data taken on 8:00 am (Morning)
R.H(1200Z): Relative humidity data taken on 5:00 pm (Evening)
R.F (mm): Total rainfall of the week.

weeks of the cropping seasons of apple orchard in both the years of study indicated that the first flight of *C. Pomonella* population was observed in 17th SMW sat Madyan during both the years. Mean population of *C. Pomonella* reached to its maximum level during the 27th and 29th SMW (11.00±1.03 and 10.25±0.80 moth/trap) in 2012 and 2013 respectively. Then the mean population fluctuation of *C. Pomonella* again gradually showed decline and reached to their maximum levels again. After sharp rise and fall in the population, maximum population level was observed in adult moth trap was noticed

in 33rd and 35th SMW (10.25±0.92 and 9.00±0.70 moth /trap). The lowest mean population of *C. pomonella* was recorded in 37th and 39th SMW (0.00±0.00 and 1.00±0.40 moth /trap). It may be due to variations in temperature, relative humidity and rainfall during the congenial period of crop growth and pest overlapping generations, which showed that this pest can easily complete two generation in this region. The results are in close corroboration with the findings of Tamhankar *et al*. [10], Singh and Sachan [11] and Patil *et al*. [12] who reported that pheromone traps offer one of the best sampling tools for flying adult insects and can be usefor monitoring insect pests of vegetables and fruit orchard for applying control strategy. Prasannakumar *et al*. [16] also used Standard Meteorological Weeks (SMW) for monitoring the insect pests of tomato, Okra and Eggplant (Brinjal). He reported that the tomato borer attained peak during 47th standard week (7.10 moths/trap), Okra shoot and fruit borer attained its peak population (7.52 moths/trap) in 48th standard week while Brinjal shoot and fruit borer have maximum population (44.13 moths/trap) in 41st standard week. The results disclosed that moth activity increased with the increase in temperature. As the temperature increased the pheromonal compounds might have evaporated and hence, increase moth catches in the traps. Besides female moths oviposit on fruits, maximum male moth coming for the mating with female catches in the traps during peak summer season [20]. The results are not in close concordance with findings of Gedia *et al*. [21], who reported that besides temperature, relative humidity and rainfall, wind speed and dew drops on the plant also have a profound effect on the population dynamics of moths and their oviposition.

3.2. The correlation matrix of codling moth *C. Pomonella* population with weather parameters over a period of time at Madyan Swat during year 2012 and 2013

The study of correlation coefficients were worked out between population build up of *C. pomonella* and mean weather parameters during observations for the data at Madyan during the year 2012 and 2013 (Tab-3). During the current studies of population dynamics of *C. pomonella*, the correlation between *C. Pomonella* population and weather parameters revealed that mean maximum temperature showed significant ($p<0.05$) positive association during both year of studies and population of *C. pomonella* increases with raised in temperature at Madyan, likewise mean minimum

temperature also showed a significant ($p<0.01$) positive relation with *C. pomonella* population build up.These results are in agreement with findings of Agrawal *et al*. [22], who find out that population growth rates of insects may be higher where temperatures are raising. Nevertheless, relative humidity both at morning and evening showed non-significant negative correlation with *C. pomonella* population during the year 2012 and non-significant positive association during the year 2013. Likewise, *C. pomonella* showed non-significant negative correlation with total rainfall during both the years of studies.

Table 3: The correlation matrix of *C. pomonella* population with weather parameters over a period of time at Madyan during year 2012 & 2013.

Weather parameters	Correlation coefficient for *C. pomonella* at Madyan Swat	
	Year 2012	Year 2103
Mean Max Temp (^{0}C)	0.857**	0.824**
Mean Min Temp (^{0}C)	0.739**	0.755**
Mean R.H (%) (0300Z)	-0.197^{NS}	0.125^{NS}
Mean R.H (%) (1200Z)	-0.021^{NS}	0.122^{NS}
Total Rainfall (mm)	-0.441^{NS}	-0.239^{NS}

* = Significant at 5% level of probability.
** = Significant at 1% level of probability.
NS = Non Significant.

The multiple regression models indicated that total rainfall, maximum temperature and relative humidity contributes maximum towards the incidence of *C. pomonella* in the pheromone traps at Madyan. The results further revealed that weather parameters contributed 72.34% to 83.42% variability in the population dynamics of *C. pomonella* at Madyanin the year 2012 and 2013 respectively (Table-4).

Table 4: Multiple regression equations for *C. pomonella* population at Madyan Swat during year 2012 and 2013.

Year	Regression Equations	R^2 Value
2012	Y1= -27.456+1.145X1-0.287X2-0.062X3+0.191X4-0.069X5	83.42%
2013	Y2= -14.135+0.638X1+0.201X2-0.147X3+0.0167X4-0.056X5	72.34%

Where:
Y1 and Y2 – *C. pomonella* population
X1 - Maximum temperature (°C)
X2 - Minimum temperature (°C)
X3 - Relative humidity (%) at 0300 hrs (8.00 am Morning)
X4 - Relative humidity (%) at 1200 hrs (5.00 pm Evening)
X5 - Total Rainfall (mm)

Present findings are comparable with those of Sabir *et al*.[23] who reported that rainfall, average temperature and relative humidity are vital abiotic factors which have noteworthy impact on population fluctuation of insect pests. These results are not in concordance with those of Calora and Ferino [24], who observed no clear-cut relationship between a single climatic factor and the incidence of different lepidopteriouspests, even the populations were generally higher during rainy months and low temperature. Results regarding relative humidity are also not in conformity to those presented by Emura and Kojima [25] who reported that a relative humidity of less than 60% caused high mortality of the larvae of rice pest insect. Conclusively, this aspect needs more comprehensive, elaborative and well spread studies involving different agro-ecological areas of apple orchard.

All abiotic factors particularly temperature contributes significantly toward increasing or decreasing *C. pomonella* trapped with the help of sex attractant pheromone. Positive and highly significant correlation of *Dacus zonatus* incidence with minimum and maximum temperature was recorded earlier by Lui and Yeh [26]. The results are in close conformity with our studies. The results pertaining to the population dynamics of *C. pomonella* are in close agreement with the findings of Hasyim *et al*. [27], who reported that the number of flies and moths captured with pheromones traps correlated positively with all three abiotic factors, i.e. temperature, humidity and rainfall. Similar observations with regard to the influence of meteorological parameters on the incidence of melonfly were also claimed earlier by several workers [28-31].

4. Conclusion and Recommendations

Temperature positively influenced ($p \leq 0.01$) the adults moth catches of *C. pomonella* whilst relative humidity did not expressed any significant effect on adult moth catches in pheromone traps. Nonetheless, rainfall showed non-significant negative relationship in the current studies. Thus such studies may offer an insight on the possible impact of weather parameters on population dynamics of this pest and insecticide applications based on trap captures can significantly reduce the number of sprays needed for *C. pomonella* management. Change in temperature might change population dynamics of insect pests differently in different agro-ecosystem and ecological zones. Nevertheless, further study should be carried out in this perspective to assess the change in the population dynamics of *C. pomonella* due to abiotic factors of environment. Developing prediction models and studying evolutionary changes under modified environment would be useful to face the challenges in near future.

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