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Studies on Diversity of Major Insect Pests and Coccinellid Predators on Mustard Crop Ecosystem in Relation to Abiotic Factors

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ABSTRACT

The present experiment was conducted to record the occurrence of insect pests and coccinellid predators on mustard crop ecosystem during *rabi* season 2021-22 and 2022-23 at Technological Park, Sardar Vallabh Bhai Patel University of Agriculture and Technology, Modi Puram, Uttar Pradesh. Total five major insect pests and different species of coccinellids were found associated with the mustard crop. Mustard sawfly, Painted bugs, Green stink bugs appeared during the early stages (48^{th} SW to till 5^{th} SW) and disappeared in the later part of the crop period. Cabbage butterfly was observed in the middle of the crop period (3^{rd} to 11 SW). Mustard aphid and coccinellids were associated largely with the mustard crop i.e, from 48^{th} SW to till harvest of the crop. Correlation studies revealed that the temperature and relative humidity are the two most important weather parameters that influence the insect pests and coccinellid population of mustard crop ecosystem.

Keywords Mustard crop, Insect pests, Coccinellids, Weather parameters, Correlation.

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INTRODUCTION

Indian mustard (*Brassica juncea* L.) is the most widely grown oilseed crop in India explicitly in north India and it is a *rabi* season crop cultivated majorly in states like Uttar Pradesh, Haryana, Madhya Pradesh, Rajasthan and some Gujarat regions. In India, the area under mustard cultivation is 87.44 lakh hectares with the production of 109.5 lakh tonnes and with the productivity of 1270 kg/ha (COOIT). Compared to other countries, the average yields of mustard are very low in India and the main constraint responsible for low yields were insect pests and weather parameters.

The mustard crop is more vulnerable to variety of insect pests from sowing till harvest than other oil seed crops. The insect pests of economic importance are, mustard aphid, *Lipaphis erysimi,* cabbage aphid, *Brevicoryne brassica* (L.), (Kalt.), mustard sawfly, *Athalia lugens proxima* (Klug), cabbage butterfly, *Pieris brassicae* (Linn), Painted bug *Bagrada picta* (K), Mustard leaf eater, *Spodoptera litura* (F), leafminer, *Chromatomyia horticola* (Goureau), Thrips, *Thrips tabaci* and Whitefly, *Bemesia tabaci* (Gennedius). (Verma 2016). These insect-pests can be grouped as key pest, major pest and minor pest on the basis of their economic importance. Forty-three insect pests are known to be associated with different growth stages of rapeseed-mustard (Bakhetia and Sekhon 1989).

Moreover, weather factors viz., temperature, relative humidity and rainfall greatly influence the insect pest population (Kisimoto and Dyck 1976). Hence an experiment was conducted to know the occurrence of different insect pests, their dispersal and subsequent population build-up in mustard crop ecosystem in relation to abiotic factors.

MATERIALS AND METHODS

An experiment was conducted at Technological Park, SVPUA and T, Meerut, UP during *rabi* season 2021-2022 and 2022-2023 for which mustard variety Laxmi-2 was sown in 5*4 plots on October 25th by following all the agronomic practices and strictly avoiding plant protection measures. Ten plants were randomly selected and tagged for recording data from each plot. Population counts of insect pests and coccinellids was taken from early stages of the crop on weekly intervals. Mode of observation include no. of larvae / plant for sawfly, no of nymphs or adults / plant for painted bug, no. of aphids per top 10 cm central twig/ plant for aphid, no. of larvae or caterpillar/ plant for cabbage butterfly and for coccinellids, no. of grubs and adults / plant was considered. Later the data was subjected to correlation and multiple regression with various weather parameters viz., minimum and maximum temperature, morning and evening relative humidity, bright sunshine hours, rainfall, which was collected from GMSK in charge, Dept of Soil Science and Agricultural Chemistry, SVPUA and T.

RESULTS AND DISCUSSION

The insect pests and coccinellid population data

Table 1. Occurrence of major insect pests and coccinellid population on mustard crop ecosystem during *rabi* season 2021-22.

SMW	Date	Saw fly	Mustard aphid	Cabbage butterfly	Painted bug	Green stink bug	Cocci-nellids	Max tempe-rature	Min tempe-rature	RH (morning)	RH (evening)	BSS	Rainfall
43	Oct 25-31	0	0	0	0	0	0	30.94	18.00	69.86	49.57	8.10	12.60
44	Nov 1-7	0	0	0	0	0	0	30.06	14.86	72.00	50.14	7.83	0.00
45	Nov 8-14	0	0	0	0	0	0	28.73	12.86	76.86	48.00	6.21	0.00
46	Nov 15-21	0	0	0	0	0	0	29.01	13.86	76.43	49.71	6.50	0.00
47	Nov 22-28	0.1	0	0	0	0	0	28.11	11.00	80.57	46.86	6.31	0.00
48	Nov 29-Dec 5	0.5	0.1	0	0.5	0	0	26.76	9.71	81.57	46.29	5.96	0.00
49	Dec 6- 12	1.6	1.6	0	0.9	0	0.1	23.07	11.64	84.29	48.14	4.21	0.90
50	Dec 13-19	4.7	8.6	0	1.8	0.2	0.8	22.40	9.36	83.43	39.43	5.80	0.00
51	Dec 20-26	3.8	10.2	0	2.9	1	1.2	20.74	7.17	82.43	38.43	6.20	0.00
52	Dec 27-Jan 2	2.1	28.6	0	2.5	1.6	1.1	20.00	6.49	88.63	49.50	4.69	2.50
1	Jan 3-9	0.5	39.4	0	3.1	2.0	1.9	20.6	7.5	84.6	61.1	4.1	9.9
2	Jan 10-16	0	43.5	0	1.6	0.8	2.5	17.7	5.3	91.9	80.6	1.2	67.5
3	Jan 17-23	0	51.6	0	1.2	0.4	2.9	16.2	4.7	92.6	71.1	1.6	3.7
4	Jan 24-30	0	59.8	0.2	0.4	0.1	3.5	16.6	5.3	91.6	67.9	3.2	33.9
5	Jan 31-Feb 6	0	95.0	1.2	0.1	0	3.7	20.1	6.0	88.6	67.0	2.6	18.4
6	Feb7-13	0	108.0	2.8	0	0	4.8	20.5	7.3	85.9	64.1	5.3	4.5
7	Feb 14-20	0	112.8	4.1	0	0	8.4	24.3	8.3	82.6	57.4	6.9	0
8	Feb 21-27	0	124.0	5.9	0	0	9.8	25.9	9.9	82.7	50.3	7.4	0.7
9	Feb 28-Mar 6	0	118.0	1.9	0	0	11.5	26.0	10.5	88.6	53.1	8.3	31.5
10	Mar 7-13	0	60.4	0.1	0	0	12.2	30.3	13.4	76.0	43.0	8.8	0
11	Mar 14-20	0	54.8	0	0	0	10.8	34.2	17.1	71.1	39.6	8.5	0
12	Mar 21-27	0	29.1	0	0	0	4.2	37.5	20.1	67.4	34.3	8.9	0
13	Mar 28-Apr3	0	2.5	0	0	0	2.8	38.7	20.3	58.9	28.4	9.3	0

SMW- Standard Meteorological Week.

Table 2. Occurrence of major insect pests and coccinellid population on mustard crop ecosystem during *rabi* season 2022-23.

SMW	Date	Saw fly	Mustard aphid	Cabbage butterfly	Painted bug	Green stink bug	Cocci-nellids	Max tempe-rature	Min tempe-rature	RH (morning)	RH (evening)	BSS	Rainfall
43	Oct 24-30	0	0	0	0	0	0	32.0	17.1	86.9	60.0	6.2	0
44	Oct 31-Nov 6	0	0	0	0	0	0	32.2	16.1	83.9	57.0	5.6	0
45	Nov 7-13	0	0	0	0	0	0	29.6	30.0	81.4	61.0	3.2	0
46	Nov 14-20	0	0	0	0	0	0	28.2	14.5	79.7	64.1	4.0	0.2
47	Nov 21-27	0	0	0	0.2	0	0	27.4	12.1	77.0	64.7	3.8	0
48	Nov 28-Dec 4	0.2	0.3	0	0.6	0	0.2	27.8	10.2	72.6	58.0	4.4	0
49	Dec 5-11	0.8	1.5	0	1.6	0.1	0.9	24.9	8.8	79.7	64.0	2.6	0
50	Dec12-18	1.8	7.9	0	2.6	0.4	1.4	23.4	8.6	88.5	69.2	3.5	0
51	Dec 19-25	4.2	9.6	0	3.4	1.8	1.6	21.8	7.0	95.1	75.0	1.1	0
52	Dec 26-Jan 1	4.6	27.8	0	2.8	2.3	2.4	18.9	6.1	95.7	77.7	0.45	0
1	Jan 2-8	2.1	37.6	0	1.7	1.2	2.8	15.4	4.6	97.9	82.9	0.1	0.0
2	Jan 9-15	0.4	41.7	0	1.1	0.6	3.3	15.6	5.5	94.7	79.7	0.6	0.0
3	Jan 16-22	0	45.8	0.3	0.8	0.4	3.9	17.4	5.1	92.0	71.9	2.4	0.0
4	Jan 23-29	0	51.4	0.6	0.2	0.1	4.6	20.6	6.6	88.1	60.0	2.4	0.2
5	Jan 30-Feb 5	0	68.0	0.9	0.1	0	7.9	21.1	6.0	90.9	59.3	2.9	11.0
6	Feb 6-12	0	95.3	2.6	0	0	9.6	25.1	9.5	83.4	51.1	4.8	0.0
7	Feb 13-19	0	106.3	3.9	0	0	10.9	27.0	11.2	84.4	48.0	5.9	0.0
8	Feb 20-26	0	116.8	4.7	0	0	11.9	29.9	13.0	74.7	44.4	5.7	0.0
9	Feb 27-Mar 5	0	121.5	5.2	0	0	12.6	31.2	14.2	73.0	45.8	6.8	1.0
10	Mar 6-12	0	106.0	1.4	0	0	9.5	32.1	14.9	68.6	43.4	7.6	0.0
11	Mar 13-19	0	51.4	0.4	0	0	3.9	33.0	15.6	61.4	46.0	8.3	2.0
12	Mar 20-26	0	24.1	0	0	0	2.4	24.0	12.6	85.7	68.3	0.3	106.2
13	Mar 27-Apr 2	0	1.8	0	0	0	1.1	29.3	16.6	75.9	45.6	0	37.5

SMW- Standard Meteorological Week.

pertaining to mustard crop was collected at weekly intervals from randomly tagged ten plants during the *rabi* season 2021-22 and 2022-23 and presented in the Tables.1-2, Figs.1-2.

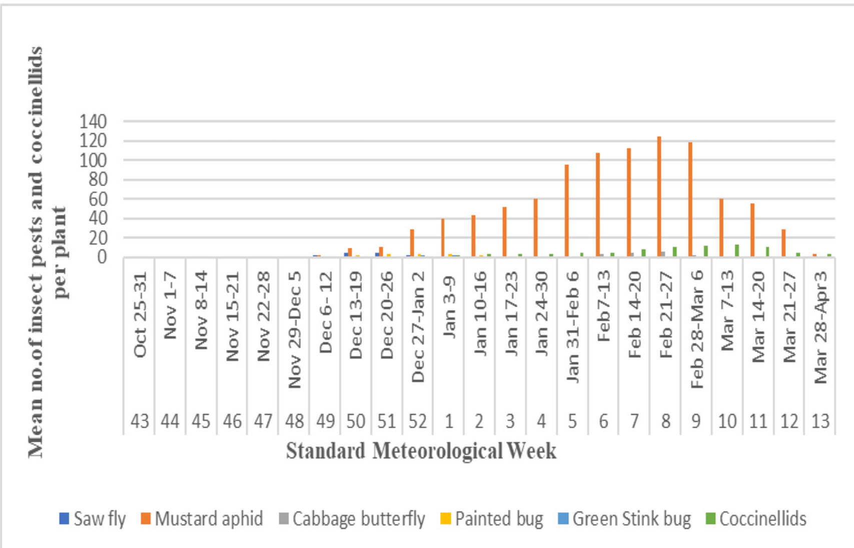

Fig. 1. Seasonal incidence of insect pests and coccinellids on mustard crop during *rabi* 2021-22.

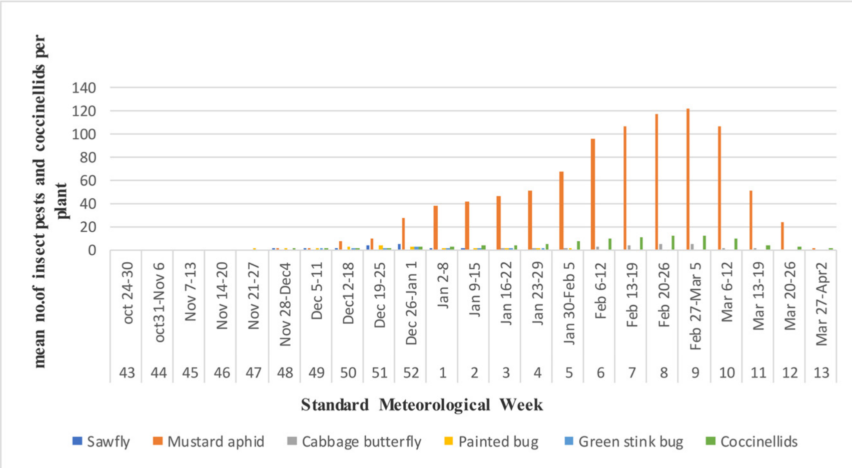

Fig. 2. Seasonal incidence of insect pests and coccinellids on mustard crop during *rabi* 2022-23.

Seasonal incidence (*rabi* 2021-22 and 2022-23) of insect pests and coccinellid population

The incidence of sawfly on mustard was recorded in the early stage of the crop i.e., on 47th standard week (0.1 larvae per plant). Later, it reached its peak (4.7 larvae per plant) during 50th standard week and sharp fall of population was observed during 52nd and 1st standard week. During 48th standard week of 2022-23 *rabi* season, the first incidence of sawfly (0.2 larvae /plant) was observed, reached its peak (4.6 larvae/ plant) in 52nd standard week and later sharp declining trend was noticed (Tables 1-2). These results are in partial agreement with Pal *et al.* (2015) who recorded mustard sawfly population at early stage where peak population recorded with 2.9 larvae/10 plants.

The first appearance of mustard aphid was observed (0.1 aphid) during 48th standard week, later there was gradual increase in aphid population vigorously and reached its peak (124.0 aphid /plant) in 8th standard week. Thereafter, sharp decline of aphid population was observed in succeeding weeks. During 2022-23, almost same trend was noticed for the first time i.e., first time observed in (0.3 aphid/plant) 48th standard week, thereafter the population increased gradually, reached its peak (121.5 aphid/plant) in 9th standard week and further its incidence was reduced (Tables 1-2). Zia and Haseeb (2019) opined that the increasing temperature and decreasing relative humidity are the most important factors governing for the increase of aphid population. Singh *et al.* (1986) reported that the maximum and minimum temperature, morning and evening relative humidity, bright sunshine hours were positively correlated with the aphid population. Kalra (1979) recorded that average temperature had significant negative correlation with mustard aphid population on mustard crop but same influence was not existed at very low temperatures. He also highlighted that the negative correlation exists between relative humidity and *Lipaphis erysimi* population. Tripathi *et al.* (2005), opined that the maximum temperature and relative humidity have shown significant negative and positive effect respectively whereas, rainfall and minimum temperature have shown non-significant effects on aphid population.

During 2021-22, the incidence of cabbage butterfly was noticed in 4th standard week (0.2 larvae/ plant), reached its peak in 8th standard week (5.9 larvae/plant) and then lessening of population was observed and in 2022-23, the larvae were observed initially during 3rd standard week (0.3 larvae/plant), further the population increased gradually, reached its peak (5.2 larvae/plant) in 9th standard week and later the population got reduced rapidly (Tables 1-2).

Table 3. Correlation coefficient (r) between insect pests, coccinellids and weather parameters in mustard crop ecosystem during *rabi* season 2021-2022.

Weather parameter	Correlation coefficients (r)					
	Mustard sawfly	Mustard aphid	Cabbage butterfly	Painted bug	Green bug	Coccinellids
Maximum temperature	-0.285^{NS}	0.296^{NS}	-0.115^{NS}	-0.557**	-0.459*	0.154^{NS}
Minimum temperature	-0.238^{NS}	-0.384^{NS}	-0.211^{NS}	-0.510*	-0.440*	0.053^{NS}
Relative humidity (morning)	0.175^{NS}	0.427*	0.199^{NS}	0.419*	0.350^{NS}	0.020^{NS}
Relative humidity (evening)	-0.321^{NS}	0.429*	0.179^{NS}	0.135^{NS}	0.218^{NS}	-0.014^{NS}
Bright sunshine hours	-0.101^{NS}	-0.075^{NS}	0.126^{NS}	-0.474*	-0.405^{NS}	0.357^{NS}
Rainfall	-0.209^{NS}	0.255^{NS}	-0.046^{NS}	0.121^{NS}	0.167^{NS}	0.078^{NS}

The present results are inline with the observations of Singh *et al*. (2018) who recorded the peak population of cabbage butterfly during 8th standard week.

The first incidence of painted bug (0.5 bugs/ plant) on mustard crop was observed during 48th standard week, thereafter sudden increase and decrease of bug population was during 1st and 2nd standard week (3.1 bugs/plant) (1.6 bugs/plant) respectively whereas in 2022-23, the painted bug (0.2 bugs/plant) infestation was noticed and reached highest (3.4 bugs/ plant) during 47th and 51st standard weeks respectively (Tables 1-2). The present observations are according to the findings of Singh and Lal (2012) who also recorded the infestation of painted bug nearly the same time.

In 2021-22, the green stink bug population (0.2 bugs/plant) was first observed on 50th standard week, increased its peak (2 bugs/plant) in 1st standard week and later there was decline in the population whereas in 2022-23, it was initially noticed (0.1 bug/plant) during 49th standard week, reached its peak (2.3 bugs/ plant) in 52nd standard week and later there was a sharp decline in bug population (Tables 1-2).

The appearance of coccinellid population (0.1 beetle/ plant) was first noticed during 49th standard week in 2021-22, thereafter the population increased gradually and reached its peak (12.2 beetle/plant) during 10th standard week and later, there was declining trend in the coccinellid population but in 2022-23, the coccinellids were (0.2 beetle/plant) first noticed during 48th standard week and the population increased gradually in the succeeding weeks, reached to its peak (12.6 beetle/plant) in 9th standard week and later on, the population was slowly declined (Tables 1-2). The present records are in partial agreement with the findings of Singh *et al*. (2018) who reported mean of 12.40 grubs/plant during (peak period) 11th standard week.

Effect of weather parameters on insect pests and coccinellid population in mustard crop ecosystem during *rabi* 2021-22 and 2022-23

The correlation studies were conducted between the insect pests, coccinellid population and weather parameters of one week interval right from sowing to harvesting of mustard crop during 2021-22 and 2022-23 and were presented in the Tables 3-4.

Table 4. Correlation coefficient (r) between insect pests, coccinellids and weather parameters in mustard crop ecosystem during *rabi* season 2022-2023.

Weather parameter	Correlation coefficients (r)					
	Mustard sawfly	Mustard aphid	Cabbage butterfly	Painted bug	Green stink bug	Coccinellids
Maximum temperature	-0.474*	0.073^{NS}	0.292^{NS}	-0.576**	-0.596**	0.096^{NS}
Minimum temperature	-0.415*	-0.152^{NS}	0.050^{NS}	-0.524*	-0.474*	-0.144^{NS}
Relative humidity (morning)	0.542**	-0.215^{NS}	-0.307^{NS}	0.573**	0.627**	-0.209^{NS}
Relative humidity (evening)	0.600**	-0.511*	-0.608**	0.689**	0.673**	-0.543**
Bright sunshine hours	-0.265^{NS}	-0.054^{NS}	0.045^{NS}	-0.315^{NS}	-0.291^{NS}	-0.011^{NS}
Rainfall	-0.115^{NS}	-0.060^{NS}	-0.113^{NS}	-0.153^{NS}	-0.119^{NS}	-0.055^{NS}

*Significant at 5% level, **Significant at 1% level.

Table 5. Multiple regression analysis between insect pests, coccinellid predators and weather parameters at one week interval in mustard crop ecosystem during *rabi* season 2021-22.

Insect	Multiple regression equation	Coefficient of determination (R^2)
Mustard sawfly	$Y= 21.085 – 0.392X_1 + 0.104 X_2 – 0.040 X_3 – 0.159 X_4 -- 0.052 X_5 + 0.019 X_6$	0.87
Mustard aphid	$Y= -538.065 + 4.670X_1 – 6.840X_2+ 3.110X_3+3.089X_4+ 20.949X_5 -- 0.201X_6$	0.62
Cabbage butterfly	$Y= -11.434 + 0.109X_1 –0.300X_2 + 0.032 X_3 + 0.106 X_4 + 0.788X_5 –0.026 X_6$	0.49
Painted bug	$Y= 19.999 – 0.237X_1 –0.047 X_2 –0.095 X_3 –0.083 X_4 –0.150 X_5 + 0.019 X_6$	0.65
Green bug	$Y= 9.031 – 0.076 X_1 – 0.069 X_2 – 0.058 X_3 –0.022 X_4 –0.042 X_5 + 0.008 X_6$	0.35
Coccinellids	$Y= -60.337 + 0.621 X_1 – 0.505 X_2 + 0.410 X_3 + 0.159 X_4 + 1.994 X_5 + 0.022 X_6$	0.54

Multiple regression models were developed for the insect pests, coccinellid population and weather parameters during *rabi* season 2021-22 and 2022-23 (one week interval) and were presented in the Tables 5-6.

Mustard sawfly (*Athalia lugens proxima* (Klug)

The correlation studies with weather parameters of one week interval during 2021-22 revealed that the sawfly population did not exhibit significant relation with any of the weather parameters whereas during 2022-23, the sawfly population was negatively correlated with minimum temperature (-0.415*) and maximum temperatures (-0.474*), positively correlated with relative humidity (Morning) (0.542**) and relative humidity (Evening) (0.600**) and no significant relation with bright sunshine hours and rainfall (Tables 3-4). Regression analysis revealed that, all the weather parameters of collectively influenced the sawfly population to the extent of 87% (R^2= 0.87) and 51% (R^2= 0.51) during *rabi* season 2021-22 and 2022-23 respectively on mustard crop ecosystem (Tables 5 - 6).

Multiple regression equation developed for mustard sawfly for the *rabi* season 2021-22 indicated that increase in one unit of minimum temperature and rainfall resulted in the increase of sawfly population by 0.104 and 0.019 respectively and further increase in one unit of maximum temperature, relative humidity (morning), relative humidity (evening) and bright sunshine hours resulted in the decrease of sawfly population by 0.392, 0.040, 0.159, 0.052 respectively on mustard crop ecosystem whereas for the *rabi* season 2022-23 it indicated that increase in one unit of maximum temperature, relative humidity (morning) and relative humidity (evening) resulted in the increase of sawfly population by 0.236, 0.034 and 0.057 respectively. Further increase in one unit of minimum temperature, bright sunshine hours and rainfall resulted in the decrease of sawfly population by 0.120, 0.304 and 0.018 respectively on mustard crop ecosystem (Tables 5-6)

Mustard aphid (*Lipaphis erysimi*)

The correlation studies with weather parameters during 2021-22 revealed that mustard aphid has shown significant positive correlation with relative

Table 6. Multiple regression analysis between insect pests, coccinellid predators and weather parameters at one week interval in mustard crop ecosystem during *rabi* season 2022-23.

Insect	Multiple regression equation	Coefficient of determination (R^2)
Mustard sawfly	$Y= -9.155 + 0.236 X_1 – 0.120 X_2 + 0.034 X_3 + 0.057 X_4 –0.304 X_5 - 0.018 X_6$	0.51
Mustard aphid	$Y= 424.801 – 11.292 X_1 + 1.040 X_2 + 0.938 X_3 – 4.019 X_4 + 15.330 X_5 + 0.383X_6$	0.78
Cabbage butterfly	$Y= 7.411 – 0.184 X_1 + 0.004 X_2 + 0.067X_3 – 0.142 X_4 + 0.322 X_5 + 0.003X_6$	0.58
Painted bug	$Y= -4.991 + 0.151 X_1 - 0.101X_2 + 0.003X_3 + 0.057 X_4 -0.214 X_5 - 0.015X_6$	0.63
Green stink bug	$Y= -2.935 + 0.060 X_1 - 0.038X_2 + 0.013X_3 + 0.023 X_4 -0.109 X_5 - 0.007X_6$	0.56
Coccinellids	$Y= 37.540 - 0.955 X_1 + 0.043X_2 + 0.143X_3 - 0.433 X_4 + 1.261 X_5 + 0.033X_6$	0.77

humidity (morning) (0.427*) and relative humidity (evening) (0.429*) whereas no significant relation with other parameters. During 2022-23, there was significant negative correlation with relative humidity (evening) (-0.511*) and no significant relation with remaining weather parameters (Tables 3-4). Regression analysis revealed that, all the weather parameters collectively influenced the mustard aphid population to the extent of 62% (R^2= 0.62) and 78% (R^2= 0.78) on mustard crop ecosystem during *rabi* season 2021-22 and 2022-23 (Tables 5-6).

Multiple regression equation developed for mustard aphid for the *rabi* season 2021-22 indicated that increase in one unit of maximum temperature, relative humidity (morning), relative humidity (evening) and bright sunshine hours resulted in the increase of sawfly population by 4.670, 3.110, 3.089 and 20.949 respectively. Further increase in one unit of minimum temperature, and rainfall resulted in the decrease of the aphid population by 6.840 and 0.201 respectively and for the *rabi* season 2022-23 it indicated that increase in one unit of minimum temperature, relative humidity (morning), bright sunshine hours and rainfall resulted in the increase of aphid population by 1.040, 0.938, 15.330 and 0.383 respectively. Further increase in one unit of maximum temperature and relative humidity (evening) resulted in the decrease of the aphid population by 11.292 and 4.019 respectively on mustard crop ecosystem (Tables 5-6).

Cabbage butterfly (*Pieris brassicae* (Linn)

The correlation studies with weather parameters during 2021-22 revealed that the cabbage butterfly has shown no significant correlation with any of the weather parameters and during 2022-23 there was negative correlation with relative humidity (evening) (-0.608**) and no correlation with other weather variables (Tables 3-4). Regression analysis revealed that, all the weather parameters of *rabi* season 2021-22 collectively influenced the cabbage butterfly population to the extent of 49% (R^2= 0.49) whereas in 2022-23 it was 58% (R^2= 0.58) on mustard crop ecosystem (Tables 5-6).

Multiple regression equation developed for cabbage butterfly for the *rabi* season 2021-22 indicated that increase in one unit of maximum temperature, relative humidity (morning), relative humidity (evening) and bright sunshine hours resulted in the increase of cabbage butterfly population by 0.109, 0.032, 0.106 and 0.788 respectively and further increase in one unit of minimum temperature and rainfall resulted in the decrease of the cabbage butterfly population by 0.300 and 0.026 respectively whereas for 2022-23, it indicated that increase in one unit of minimum temperature, relative humidity (morning), bright sunshine hours and rainfall resulted in the increase of cabbage butterfly population by 0.004, 0.067, 0.322 and 0.003 respectively and further increase in one unit of maximum temperature and relative humidity (evening) resulted in the decrease of the cabbage butterfly population by 0.184 and 0.142 respectively on mustard crop ecosystem (Tables 5-6).

Painted bug (*Bagrada picta* (K)

The correlation studies between weather parameters and painted bug during 2021-22 revealed that maximum temperature (-0.557**), minimum temperature (-0.510*), bright sunshine hours (-0.474*) exhibited negative correlation but relative humidity (morning) (0.419*) was positive correlated whereas relative humidity (evening) and rainfall did not show any significant effect. During 2022-23, there was significant negative correlation with maximum temperature (-0.576**,) minimum temperature (-0.524*) and significant positive correlation with relative humidity (morning) (0.573**) and relative humidity (evening) (0.689**) and no correlation with bright sunshine hours and rainfall (Tables 3-4). Regression analysis revealed that, all the weather parameters of *rabi* season 2021-22 and 2022-23 collectively influenced the Painted bug population to the extent of 65% (R^2= 0.65) and 63% (R^2= 0.63) respectively on mustard crop ecosystem (Tables 5-6).

Multiple regression equation developed for painted bug for the *rabi* season 2021-22 indicated that increase in one unit of rainfall resulted in the increase of painted bug population by 0.019. Further increase in one unit of maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening) and bright sunshine hours resulted in the decrease of the painted bug population by 0.237, 0.047, 0.095, 0.083 and 0.150 respectively and for the *rabi* season 2022-23 it indicated that increase in one unit of maximum temperature, relative humidity (morning), relative humidity (evening) resulted in the increase of painted bug population by 0.151, 0.003 and 0.057 respectively. Further increase in one unit of minimum temperature, bright sunshine hours and rainfall resulted in the decrease of the painted bug population by 0.101, 0.214 and 0.015 respectively on mustard crop ecosystem (Tables 5-6).

Green stink bug (*Nezara viridula*)

During 2021-22, green stink bug population was negatively correlated with maximum temperature (-0.459*) and minimum temperature (-0.440*) whereas no correlation between relative humidity (morning), relative humidity (evening), bright sunshine hours and rainfall and in 2022-23, significant negative correlation exists between green stink bug and maximum temperature (-0.596**), minimum temperature (-0.474*) and positively correlated with relative humidity (morning) (0.627**), relative humidity (evening) (0.673**) and no relation with bright sunshine hours and rainfall (Table 3-4). Regression analysis revealed that, all the weather parameters collectively influenced the green stink bug population to the extent of 35% (R^2= 0.35) and 56% (R^2= 0.56) for *rabi* season 2021-22 and 2022-23 respectively on mustard crop ecosystem (Tables 5-6).

Multiple regression equation developed for green stink bug for the *rabi* season 2021-22 indicated that increase in one unit of rainfall resulted in the increase of green bug population by 0.008. Further increase in one unit of maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening) and bright sunshine hours resulted in the decrease of the green stink bug population by 0.076, 0.069, 0.058, 0.022 and 0.042 respectively whereas for the *rabi* season 2022-23, it indicated that increase in one unit of maximum temperature, relative humidity (morning), relative humidity (evening) resulted in the increase of green stink bug population by 0.060, 0.013 and 0.023 respectively and further increase in one unit of minimum temperature, bright sunshine hours and rainfall resulted in the decrease of the Green stink bug population by 0.038, 0.109 and 0.007 respectively on mustard crop ecosystem (Tables 5-6).

Coccinellids (*Coccinella* sps.)

No significant relation between weather parameters and coccinellid population was observed during 2021-22 whereas significant negative correlation was observed with relative humidity (evening) (-0.543**) during 2022-23 and rest of the variables hasn't shown any significant relation with coccinellids (Tables 3-4). Regression analysis revealed that, all the weather parameters of *rabi* season 2021-22 and 2022-23 collectively influenced the coccinellid population to the extent of 54% (R^2= 0.54) and 77% (R^2= 0.77) respectively on mustard crop ecosystem (Tables 5-6).

Multiple regression equation developed for coccinellids for the *rabi* season 2021-22 indicated that increase in one unit of maximum temperature, relative humidity (morning), relative humidity (evening), bright sunshine hours and rainfall resulted in the increase of coccinellids population by 0.621, 0.410, 0.159, 1.994 and 0.022 respectively. Further increase in one unit of minimum temperature resulted in the decrease of the coccinellid population by 0.505 and for the *rabi* season 2022-23, it indicates that increase in one unit of minimum temperature, relative humidity (morning), bright sunshine hours and rainfall resulted in the increase of coccinellid population by 0.043, 0.143,1.261 and 0.033 respectively. Further increase in one unit of maximum temperature and relative humidity (evening) resulted in the decrease of the coccinellid population by 0.955 and 0.433 respectively on mustard crop ecosystem (Tables 5-6).

CONCLUSION

Based on the above results, it can be concluded that weather parameters viz., temperature and relative humidity play an utmost important role in the prevalence of insect pests and coccinellid predators in the mustard crop ecosystem. Functional relations between population abundance and weather parameters (i.e., previous weeks weather and pest data) can be useful for taking of any prophylactic/control measures. By using this weather data, we can forewarn the farmers to follow various pest management strategies for the management of insect pests.

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