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# Seasonal incidence of major insect pests and their natural enemies on Cauliflower (*Brassica oleracea* var. *botrytis*) in relation to weather parameters

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**ABSTRACT:** A field experiment was conducted to study the population dynamics of major insect pests and their natural enemies in cauli flower eco system in two consecutive cropping seasons *i.e.,* winter 2021-22 and 22-23 at experimental farm of Dr Rajendra Prasad Central Agricultural University, Pusa, Bihar. In cropping season 2021-22, the incidence was at its peak of the pests: Aphids (123.72), Diamondback Moth (12.83), Tobacco caterpillar (1.02), Leaf webber (2.83), and Flea beetle (2.56) per plant were recorded on $12^{th}$SMW, $11^{th}$SMW, $12^{th}$SMW, $9^{th}$SMW, and $12^{th}$SMW, respectively. Similarly, on $11^{th}$SMW, $12^{th}$SMW, $12^{th}$SMW, $10^{th}$SMW, and $12^{th}$SMW of cropping season 2022-23 maximum incidence of aphids (147.2), DBM (17.47), tobacco caterpillar (1.65), leaf webber (1.43) and flea beetle (2.53) per plant were recorded, respectively. Maximum population of *Cotesia plutellae* were 3.86 and 5.43*, Oomyzus* sp. were 1.01 and 1.21, *Aphidius colimani* 13.48 and 15.83, Coccinellids were 5.13 and 9.56, and Syrphids were 2.12 and 2.16 recorded during the cropping season 2021-22 and 2022-23, respectively. The correlation between population of insect pests and natural enemies in relation to weather parameters shown significant positive correlation with temperature (maximum and minimum), rainfall and sunshine while negative and significant correlation to relative humidity (morning - evening) during both the cropping season.The coefficient of determination (adjusted $R^2$) value and regression equations obtained after subjecting insect population data in multiple linear regression analysis in relation to weather parameters indicates significant influence of weather parameter on population build-up of insect pests and related natural enemies.

**Keywords:** Aphids, *Aphidius, colimani,* cauliflower, coccinellids, *Cotesia plutellae,* diamondback moth, weather parameters

## INTRODUCTION

India is the second largest producer of fruit and vegetables with production of 108.34 and 212.91 million tonnes, respectively ($2^{nd}$ Advance Estimate for the year 2022-23 resealed by Ministry of Agriculture and Farmers Welfare). Cole crops are the most important group of vegetable grown in winter months in sub-tropical plains to temperate hilly regions of the country. Among them, cauliflower is most important crop, cultivated in 4.90 lakh hectares which produces 95.21 lakh metric ton with productivity of 19.42 metric ton per hectare (2022-23-$2^{nd}$ Advance Estimate, India state Agri). Major cauliflower growing states includes Uttar Pradesh, Orissa, Bihar, West Bengal, Assam, Karnataka, Maharashtra, Madhya Pradesh and Tamil Nadu. Bihar is the third largest producer of cauliflower with an area and production of 0.68 lakh hectares and 1.11metric ton, respectively (2022-23-$2^{nd}$ Advance Estimate, India state Agri).

Production of cauliflower is constrained by number of factors like fluctuating weather factors, lack of knowledge about improved varieties for different season, diseases and pest incidence, inappropriate their management techniques. Across the world, insect pests and diseases causing annually 40 per cent of total crop loss while 35 per cent in India (Annual Report-2020, FAO). Major insect pests causing potential damage to cauliflower in the referred region includes Diamondback moth, *Plutella xylostella*; Head borer, *Hellula undalis*; Leaf webber, *Crosidolomia binotalis*; Aphids, *Brevicoryne brassicae*; Cabbage butter fly, *Pieris rapae*, Tobacco caterpillar, *Spodoptera litura* and painted bugs, *Bagrada cruciferarum etc* (Sahu *et al.,* 2019). In India, diamondback moth is one of the limiting factors in successful production of good quality marketable cauliflower due to its higher damage potential ranging from 14 to 84 per cent (Abhijith *et al.,* 2019; Gautam *et al.,* 2018) causing 30 to 100 per cent of quality yield loss (Lingappa *et al.,* 2004). *Spodoptera litura* is a polyphagous pest reported on about 112 cultivated plants, also considered as a major pest on early crucifers. It is responsible to cause economic loss ranging 25 to cent per cent (Sahu *et al.,* 2020a). Aphids is also one of the serious pest among the sucking pests has potential to cause considerable damage to the crop by its presence and sucking plant juice resulting leaf yellowing and curling, plant stunting and wilting.

Natural enemies play vital role in regulation of population of arthropod pests. In cauliflower ecosystem, the predators like lady bird beetle, mantids, green lace wings, ants and syrphids are more common and abundant. Hymenopteran parasitoids *viz*., *Aphidius*sp, *Aphilinus*sp, *Encarsia* spare nymphal parasitoid on aphids, *Cotesia plutellae* a larval parasitoid on DBM, *Oomyzus*sp a larval-pupal parasitoid on DBM and *Bracon* sp a larval parasitoid on *S. lituraetc*., are the potential biocontrol agents. Pagore *et al.* (2021) reported the significant parasitizing potential of biocontrol agent ranging from 10 per cent to 80 per cent based on their reproductive capacity, host preference and climatic factors.

As the world is moving towards sustainable agriculture production system with the objective of successful management of pest through eco-friendly, economically feasible and socially acceptable techniques. Integrated Pest Management (IPM) is an effective strategy to attain it. Chemical management of pests using insecticide may leads to various environmental and health hazards. The knowledge of the seasonal incidence of insect pests at different growth stages of cauliflower crop may be helpful in evolving proper management. For the sustainable management of pests under IPM, the knowledge on seasonal incidence, and its relation with metrological variables are the key attributes for early prediction of its incidence, identification of critical stage of pest and to schedule of management practices in advance. Keeping above facts in mind this insect pest management in cauliflower was planned and the experiment was conducted.

## MATERIALS AND METHODS

Field experiments on population dynamics of major insect pests and their natural enemies in cauliflower ecosystem were carried out in two consecutive cropping seasons *i.e.,* winter 2021-22 and 22-23 in experimental farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. About thirty days old locally suitable and popular variety (Pusa snowball) cauliflower seedlings were transplanted in the prepared experimental plots in the evening hoursat 60 cm x 60 cm plant spacing to 10 x 5 m plots in second fortnight of December. Crop were grown by following standard package of practice recommended by Dr. RPCAU, Pusa, Bihar to get proper crop stand to get suitable yield except pest management practices which were applied as per the proposed experimental plan.

Observations were recorded to know the abundance of major insect pests and their natural enemies in cauliflower ecosystem since their appearance get on plants to till harvesting. To know the population of diamond back moth, tobacco caterpillar, leaf webber and aphid, absolute counting method were used on randomly selected and tagged 10 plants which were tagged after ten days of planting. Among the natural enemies, predators like coccinellids (grub+pupa+adult) and syrphids (only adult) were counted on per plot basis. Mummified aphids were observed which were parasitized by *Encarsia* sp. which was easily differentiable with healthy aphids, pupal cases of *Cotesia* sp protruding from the DBM larvae are prominent milky white color were recorded as observation (Gaikwad *et al.,* 2018; Bhagat *et al.,* 2018). The observations were recorded since inception of the pest till the harvesting.

The weather data *viz.*, maximum and minimum temperature, relative humidity, rainfall, wind velocity and bright sunshine hours was obtained from the university meteorological observatory of the cropping seasons. These meteorological observations were utilized to correlate with observed population fluctuations. Multiple linear regression analysis was carried to find out the influence of weather parameters on population dynamics of insect pest using SPSS software.

## RESULTS AND DISCUSSION

The observations of current study revealed that the incidence of insect pests *viz*., aphids, diamond back moth (DBM), tobacco caterpillar, leaf webber, flea beetle and the natural enemies *viz*., *Cotesia plutellae, Oomyzus* sp., *Aphidius colimani*, Coccinellids and *Syrphid* spp. The observations recorded in both cropping seasons *i.e.,*2021-22 and 2022-23 were presented in Table- 1 and 2, respectively.

### Status of insect pests during winter, 2021-22 and 2022-23

**Diamondback moth:** During cropping season 20221-22, initial incidence of DBM were recorded on 8$^{th}$ SMW with mean population of 0.92 larvae per plant which gradually increased and reached at its peak in 12$^{th}$ SMW (12.83 larvae per plant), there after population were gradually declined up to 3.68 larvae per plant at the harvesting of the crop (15$^{th}$ SMW). Similarly, during cropping season 2022-23, the incidence was recorded from 8$^{th}$ SMW (1.83 larvae plant) and observed till the harvest of the crop (15$^{th}$ SMW with 7.73 larvae/plant) with peak incidence of 17.74 larvae per plant in 12$^{th}$ SMW.

**Aphid:** During the cropping period 2021-22, first incidence was recorded on 6$^{th}$ SMW with 1.21 aphids per plant and it continue till the harvest (15$^{th}$ SMW) (23.84 per plant). The maximum incidence of 123.72 aphid per plant was observed on 12$^{th}$ SMW during winter 2021-22. Similar trend of aphids infestation were again observed in the consecutive cropping season i.e. 2022-23, with primary incidence of 5.30 aphids per plant in 6$^{th}$ SMW with peak incidence of 147.20 aphids per plant in 11$^{th}$ SMW. Crop was observed was observed till the harvest of the crop with steady decease in population up to 18.84 per plant(15$^{th}$ SMW).

**Tobacco caterpillar**: This pest was not serious during

**Table 1. Seasonal incidence of major insect pests and their natural enemies in cauliflower ecosystem during late winter, 2021-22**

| SMW | Date | Crop stage | Mean Number of Insect pest and natural enemies per plant with their stage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Aphid | Diamond back moth | Tobacco caterpillar | Leaf Webber | Flea Beetle | *Cotesia plutellae* | *Oomyzus sp.* | *Aphidius colimani* | Coccinellids | *Syrphid* sp. |
| | | | Nymphs & adults | Larvae & pupae | Larvae | Larvae | Adult | Pupae | Parasitoid of DBM pupae | Mummified aphid | Grubs, pupae & adults | Larvae, pupae & adult |
| 3 | 15-Jan-22 | Vegetative stage 1-49 DAT | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 22-Jan-22 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 29-Jan-22 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 05-Feb-22 | | 1.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.00 |
| 7 | 12-Feb-22 | | 2.05 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 |
| 8 | 19-Feb-22 | Curd Initiation and Development 50-78 DAT | 12.67 | 0.92 | 0.00 | 1.92 | 0.35 | 0.00 | 0.00 | 0.00 | 0.81 | 0.75 |
| 9 | 26-Feb-22 | | 25.82 | 2.86 | 0.00 | 2.83 | 0.73 | 0.09 | 0.00 | 1.06 | 1.25 | 1.14 |
| 10 | 05-Mar-22 | | 68.93 | 5.32 | 0.00 | 2.32 | 1.26 | 0.35 | 0.00 | 4.89 | 3.34 | 1.67 |
| 11 | 12-Mar-22 | | 110.73 | 12.83 | 0.02 | 1.02 | 2.06 | 1.94 | 0.04 | 7.82 | 4.22 | 2.12 |
| 12 | 19-Mar-22 | Maturation and harvesting of curd 79-101 DAT | 123.72 | 9.83 | 1.02 | 0.00 | 2.56 | 3.86 | 0.39 | 12.78 | 5.13 | 1.87 |
| 13 | 26-Mar-22 | | 90.73 | 8.96 | 0.65 | 0.00 | 1.97 | 2.84 | 1.01 | 13.48 | 4.93 | 0.93 |
| 14 | 02-Apr-22 | | 57.94 | 4.61 | 0.34 | 0.00 | 1.03 | 1.05 | 0.67 | 9.23 | 3.43 | 0.47 |
| 15 | 09-Apr-22 | | 23.84 | 3.68 | 0.00 | 0.00 | 0.78 | 0.58 | 0.32 | 5.07 | 1.92 | 0.16 |

**SMW-Standard meteorological week; DAT-Days after transplanting; DBM- Diamondback moth;**

**Table 2. Seasonal incidence of major insect pests and their natural enemies in cauliflower ecosystem during late winter, 2022-23**

| SMW | Date | Crop stage | Mean Number of Insect pests and natural enemies per plant with their stage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Aphid | Diamond back moth | Tobacco leaf eating caterpillar | Leaf Webber | Flea Beetle | *Cotesia plutellae* | *Oomyzus sp.* | *Aphidius colimani* | Coccinellids | Syrphid sp |
| | | | Nymphs & adults | Larvae & pupae | Larvae | Larvae | Adult | Pupae | Parasitoid DBM pupae | Mummified aphid | Grubs & adults | Larvae and pupae |
| 3 | 15-Jan-23 | Vegetative stage 1-49 DAT | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 |
| 4 | 22- Jan-23 | | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 |
| 5 | 29- Jan-23 | | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 |
| 6 | 05-Feb-23 | | 5.3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.2 | 0.00 |
| 7 | 12-Feb-23 | | 23.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.54 | 0.21 |
| 8 | 19-Feb-23 | Curd Initiation 50-78 DAT | 37.3 | 1.83 | 0.00 | 0.32 | 0.10 | 0.00 | 0.00 | 0.00 | 0.86 | 0.52 |
| 9 | 26-Feb-23 | | 77.1 | 3.72 | 0.00 | 0.79 | 0.23 | 0.19 | 0.00 | 1.84 | 1.65 | 0.83 |
| 10 | 05-Mar-23 | | 123.7 | 7.00 | 0.03 | 1.43 | 0.67 | 1.45 | 0.05 | 6.83 | 3.65 | 1.08 |
| 11 | 12-Mar-23 | | 147.2 | 14.33 | 0.16 | 1.07 | 1.92 | 3.26 | 0.64 | 9.64 | 6.94 | 1.67 |
| 12 | 19-Mar-23 | Maturation and harvesting of curd 79-101 DAT | 128.83 | 17.47 | 1.65 | 0.25 | 2.53 | 5.43 | 0.89 | 15.83 | 9.56 | 2.16 |
| 13 | 26-Mar-23 | | 80.42 | 13.82 | 1.47 | 0.00 | 3.04 | 4.96 | 1.01 | 13.94 | 8.43 | 1.48 |
| 14 | 02-Apr-23 | | 43.56 | 11.73 | 0.56 | 0.00 | 1.93 | 2.63 | 0.71 | 8.93 | 6.93 | 0.95 |
| 15 | 09-Apr-23 | | 18.84 | 7.73 | 0.00 | 0.00 | 0.78 | 1.85 | 0.00 | 3.85 | 4.93 | 0.43 |

**SMW-Standard meteorological week; DAT-Days after transplanting; DBM- Diamondback moth;**

the time of experimentation which was observed as minor population with its peak in 12th SMW (1.02 and 1.65 per plant) in both the year of experimentation, respectively. With population fluctuation from 11th to 14th SMW in both the cropping season.

**Leaf webber:** This pest was recorded from 7th SMW (0.22 larvae per plant) to 11th SMW (1.02 larvae per plant) in the cropping season 2021-22 with peak at 9th SMW (2.83 larvae per plant) while from 8th (0.32 larvae per plant) to 12th SMW (0.25 larvae per plant) in cropping season 2022-23 with peak at 10th SMW (1.43 larvae per plant).

**Flea beetle:** Incidence of flea beetle were recorded on cauliflower in both the year of experimentation 2021-22 and 2022-23. Flea beetle incidence was observed between 8th to 15th SMW on the crop with population ranging from 0.35 to peak 2.56 (12th SMW) adults per plant during cropping season 2021-22 thereafter population goes down at faster rate. Similarly, during cropping season 2022-23, incidence was varied between 0.10(8th SMW) to 3.04 (13th SMW) per plant thereafter population decreases very fast and at minimal level of 0.78 in 15th SMW *i.e.,* senescence stage of the crop.

**Status of major natural enemies during cropping period 2021-22 and 2022-23**

**Coccinellids:** The observations of coccinellids were taken at weekly intervals throughout the cropping season which includes grub, pupae and adults absolute population. Although we had recorded the population of coccinellids collectively comprising the species *viz., Coccinella septempunctata*, *Coccinella transversalis*, *Propylea dissecta*, *Micraspis yasumatsui, Menochilus sexmaculata* and *Brumoides suturalis* on cauliflower during cropping season 2021-22. Among the available species *C. septempuctata* was most abundant while *C. transversalis* were second abundant and *B. suturalis* was least. The observed data depicting that the first incidence of coccinellids on 6thSMW with 0.18 per plant which reached at its peak of 5.13 per plant in 12th SMW thereafter gradual decrease in population were observed because the crop was leading to maturity, so aphid population was also decreasing that is why the population of coccinellids decrease accordingly. Similarly in consecutive cropping season *i.e.,*2022-23 the same trends of infestation were recorded other than varying in numerical value.

**Syrphids:** Syrphids (hover fly) are the another most important natural enemies present in the crucifers' ecosystem. The abundance of syrphids are depends on the availability of a stable ecosystem near by the cropping area. More number of species and their abundance was observed during the course of investigation. Each and every individuals were not distinguished species wise but collectively all individuals belonging to syrphid groups are recorded collectively as syrphid adults which mainly comprises *Episyrphus balteatus, Syrphus* sp. *etc.* showed peak incidence of 2.12 and 2.16 per plant on 11th and 12th SMW of 2021-22 and 2022-23, respectively which was available from 8th (0.75, 0.21) to 15th SMW (0.16, 0.43).

**Parasitoids:** Hymenopteran parasitoids *viz.*, *Aphidius* sp., *Aphilinus* sp, *Encarsia* sp. are nymphal parasitoids on aphids, *Cotesia plutellae* a larval parasitoid on DBM, *Oomyzus* sp. a larval-pupal parasitoids on DBM and *Bracon*sp a larval parasitoid on S. *lituraetc.,* are the potential biocontrol agents which were available in the cauliflower ecosystem and it was recorded a potential natural enemy in the cropping system. The parasitoids *viz*., *Cotesia plutellae, Oomyzus* sp. larval parasitoids of DBM and *Aphidius colimani* (a natural enemies of aphid) were found major biocontrol agents with maximum population of 3.86 (12th SMW), 1.01 (13th SMW) and 13.48 (13th SMW) per plant during winter 2021-22; of 5.43 (12th SMW), 1.01 (13th SMW) and 15.83 (12th SMW) per plant during winter 2022-23, respectively.

Experiments revealed that the significantly lower incidence of insect pest were recorded in early growth stage of the crop (52st SMW) due to quick decrease in minimum temperature. Initial incidence of most of the insects were observed from the 5th SMW (February) onwards with gradual rise of temperature except aphids. In 12th SMW (March) peak incidence of insect pest were recorded after that the pest incidence were recorded gradual decrease because crop was leading to its maturity and simultaneously the population of natural enemies also multiplying with faster rate because of suitable growing temperature and abundance in the food. Similar trends of results were also recorded by Mane *et al*. (2021) the peak incidence of diamondback moth and tobacco caterpillar in the month of March in Bihar. Jakhar and Singh 2018 and Jhumar *et al.* (2020) also reported the significant incidence of diamondback moth, aphid, flea beetle and coccinellid predators on 9th to 12th SMW (March).

**Correlation between population dynamics of insect pests and their natural enemies in cauliflower ecosystem with meteorological variables**

The weather factors especially temperature, humidity, sunshine, wind speed and direction are affecting life events of all organisms but the smaller organisms including insects are greatly affected by the climatic variables. Many times, the weather fluctuations affect their life stages, their breeding and developments which are studied under the field of ecological-natural population management. Similarly, the insect pests affecting the crops are also affected by these climatic variables. We had studied these variations under the cauliflower ecosystem during cropping season 2021-22 and 2022-23,where weather factors were significantly affected the population dynamism of insect pest and natural enemies and recorded on experimental crop which is placed in the Table 1 and 2 and Figure- 1 and 2, respectively.

### Temperature

**Maximum (14:00 hours LMT) ($T_{max}$):** The impact of climatic parameters were studied on pest during cropping season 2021-22 and 2022-23, the$T_{max}$ showed significant and positive correlation with aphids (r= 0.65 and 0.46), diamondback moth (r= 0.65 and 0.82), tobacco caterpillar (r= 0.35 and 0.57), leaf webber (r= 0.29 and 0.05) and flea beetle (r= 0.68 and 0.79), respectively. Similarly, the natural enemies *viz*., *Cotesia plutellae* (r= 0.48and 0.77), *Oomyzus* sp. (r= 0.47and 0.69), *Aphidius colimani* (r= 0.64and 0.76), Coccinellids (r = 0.72 and 0.86) and *Syrphid* sp. (r= 0.60 and 0.64) showed significant and positive correlation during corresponding years.The present finding also more or less showing similar trends as findings of Jakhar and Singh (2018) who reported positive relation of diamondback moth and *Coccinella septempunctata* with maximum temperature. Similar results were also reported by Gaikwad *et al.* (2018) with respect to diamondback moth, syrphids and mummified aphids, and Mishra *et al.* (2018) and Khan and Talukder (2017) with respect to tobacco caterpillar. Yadav and Agarwal (2018) reported that the positive and significant effect of maximum temperature on incidence of aphids and their natural enemies coccinellid predators *i.e., Coccinella septempunctata*, *Coccinella transversalis* and *Menochilus sexmaculata.*

**Minimum (07:00 hours LMT) ($T_{Min}$):** The impact of minimum temperature were also studied in relation to the associated arthropod fauna in cauliflower ecosystem revealed that the aphids shown correlation coefficient (r) of 0.73 and 0.16, diamondback moth with 0.72 and 0.64, tobacco caterpillar with 0.59 and 0.43, leaf webber with 0.00 and - 0.19 and flea beetle with 0.77 and 0.64 (r) value shown the significant and positive correlation to the minimum temperature during 2021-22 and 2022-23, respectively. The impact of minimum temperature was found highly significant on population buildup of aphid, diamondback moth, flea beetle in 2021-22, while not highly significant in consecutive year, this may be due to annual climatic variation which need further study to know its impact in different years and cause of variations. Likewise for the corresponding years, significant and positive correlation coefficient of 0.68 and 0.61, 0.69 and 0.54,0.82 and 0.57, 0.83 and 0.70, 0.53 and 0.37 were recorded on the natural enemies *viz*., *Cotesia plutellae, Oomyzus* sp., *Aphidius colimani*, Coccinellids and *Syrphid* spp. respectively in corresponding year of experimentation. The current results are more or less similar with the findings of Yadav and Agarwal (2018) in respect to aphids and their natural enemies in cauliflower ecosystem. Lal *et al.,* 2020 also found the positive relation of mean atmospheric temperature with diamondback moth, flea beetle and painted bugs. Similarly, Khan and Talukder (2017) reported positive and highly significant correlation between tobacco caterpillar and minimum temperature.

### Relative Humidity

**Morning (07:00 hours LMT) (%):** A negative and non-significant correlation was observed with relative humidity and all major pests of cauliflower in both the cropping year including aphid(r= -0.38 and -0.40), diamondback moth (r= -0.43 and -0.73), tobacco caterpillar (r= -0.20 and -0.54), and flea beetle (r= -0.41 and -0.70) in respect to morning relative humidity (%) for the corresponding years *i.e.,* 2021-22 and 2022-23while in case of leaf webber we had observed positive and negative non-significant correlations in the corresponding years (r= 0.16 and -0.06).In cropping season 2021-22, the natural enemy population *viz*., *Cotesia plutellae, Aphidius colimani*, Coccinellids and *Syrphid* sp. were shown negative and non-significant correlation with the morning relative humidity with r value of -0.31, -0.55, -0.51 and -0.15, respectively while *Oomyzus* sp. have negative and significant correlation with morning relative humidity (-0.56). But in the consecutive cropping season, the natural enemies shown negative and highly significant correlation with *Cotesia plutellae* (-0.71)*,Aphidius colimani*(-0.73), Coccinellids (-0.78) but Oomyzus sp. having negative and significant correlation and *Syrphid* sp. (-0.55) having negative and non-significant correlation with morning relative humidity. These variations are due to change in weather factors between the corresponding cropping seasons. The similar results were also reported by Yadav and Agarwal (2018) that the morning relative humidity showed negative influence on the incidence of insects. The current results were also supported by the findings of Shigwan *et al.* (2022) and Mishra *et al.* (2018).

**Evening (14:00 hours LMT) (%):** In the cropping season 2021-22, the evening relative humidity (%)also shown negative and non-significant correlation in respect to insect pests *viz*., aphids (r= -0.28), diamondback moth (r= -0.35), tobacco caterpillar (r= -0.08), leaf webber (r= -0.39) and flea beetle (r= -0.31)and similar results were also observed in case of the natural enemies population *viz*., *Cotesia plutellae* (-0.06)*, Oomyzus* sp. (-0.28), *Aphidius colimani*(-0.29), Coccinellids (-0.38) and *Syrphid* sp. (-0.31).

In the cropping season 2022-23, the insect pest aphids (-0.72), diamondback moth (-0.84) and flea beetle (-0.73) have negative and highly significant correlation with evening relative humidity while tobacco caterpillar (-0.55) and leaf webber (-0.40) have negative and non-significant correlation with the evening relative humidity

A

| | *Aphid* | *DBM* | *Tobacco caterpillar* | *Leaf webber* | *Flea Beetle* | *Cotesia plutellae* | *Oomyzus* sp. | *Aphidius colimani* | *Coccinellids* | *Syrphids* |
|---|---|---|---|---|---|---|---|---|---|---|
| $T_{max}$(°C) | 0.65* | 0.65* | 0.35 | 0.29 | 0.68* | 0.48 | 0.47 | 0.64* | 0.72** | 0.60* |
| $T_{min}$(°C) | 0.73** | 0.72** | 0.59* | 0.00 | 0.77** | 0.68* | 0.69** | 0.82** | 0.83** | 0.53 |
| $RH_{morn}$(%) | -0.38 | -0.43 | -0.20 | 0.16 | -0.41 | -0.31 | -0.56 | -0.55 | -0.51 | -0.15 |
| $RH_{eve}$(%) | -0.28 | -0.35 | 0.08 | -0.39 | -0.31 | -0.06 | -0.28 | -0.29 | -0.38 | -0.31 |
| Rainfall (mm) | 0.20 | 0.24 | 0.25 | -0.27 | 0.29 | 0.31 | 0.25 | 0.33 | 0.25 | 0.04 |
| Bright sunshine (hr.) | 0.35 | 0.42 | -0.05 | 0.37 | 0.36 | 0.12 | 0.33 | 0.35 | 0.45 | 0.36 |

B

| | *Aphid* | *DBM* | *Tobacco caterpillar* | *Leaf webber* | *Flea Beetle* | *Cotesia plutellae* | *Oomyzus* sp. | *Aphidius colimani* | *Coccinellids* | *Syrphids* |
|---|---|---|---|---|---|---|---|---|---|---|
| $T_{max}$(°C) | 0.46 | 0.82** | 0.57* | 0.05 | 0.79** | 0.77** | 0.69** | 0.76** | 0.86** | 0.64* |
| $T_{min}$(°C) | 0.16 | 0.64* | 0.43 | -0.19 | 0.64* | 0.61* | 0.54* | 0.57* | 0.70** | 0.37 |
| $RH_{morn}$(%) | -0.40 | -0.73** | -0.54 | -0.06 | -0.70** | -0.71** | -0.60* | -0.73** | -0.78** | -0.55 |
| $RH_{eve}$(%) | -0.72** | -0.84** | -0.55 | -0.40 | -0.73** | -0.74** | -0.64* | -0.78** | -0.83** | -0.80** |
| Rainfall (mm) | -0.22 | -0.32 | -0.18 | -0.21 | -0.27 | -0.27 | -0.22 | -0.28 | -0.32 | -0.26 |
| Bright sunshine (hr.) | 0.82** | 0.82** | 0.53 | 0.55 | 0.72** | 0.71** | 0.63* | 0.76** | 0.79** | 0.86** |

Scale: -1 … 0 … 1

$T_{max}$ – Maximum Temperature; $T_{min}$ - Minimum Temperature; $RH_{eve}$ - Evening Relative Humidity; $RH_{morn}$ - Morning Relative Humidity; **- Correlation is significant at the 0.01 level (2-tailed); *-Correlation is significant at the 0.05 level (2-tailed).

**Fig- 1.Comparative map on Correlation co-efficient(r) between meteorological parameters and population of major cauliflower insect pest and their natural enemies whereas, A- during 2021-22; B-during 2022-23**

in the same cropping year. The natural enemies *viz*., *Cotesia plutellae*(-0.74) ,*Aphidius colimani*(-0.78), Coccinellids(-0.83) and *Syrphid*sp(-0.80) were also shown negative and highly significant correlation with evening relative humidity while *Oomyzus* sp.,(-0.64) have negative and significant correlation.The current experimental finding sare also supporting the findings of Gaikwad *et al.,* 2018 that the evening relative humidity has significant negative impact on the incidence of diamondback moth, tobacco caterpillar, leaf webber, aphid and natural enemies (syrphid and mummified aphid).The similar findings are also reported by Bhagat *et al.* (2018), Jakhar and Singh, (2018) and Yadav and Agarwal, (2018).

**Rainfall (mm)**

A positive and non-significant correlation were observed with respect to aphids, diamondback moth, tobacco caterpillar and flea beetle with correlation (r) value of 0.20, 0.24, 0.25, and 0.29, respectively during cropping season 2021-22 except for leaf webber shown negative and non-significant correlation (-0.27). Similarly, the natural enemies *viz*., *Cotesia plutellae* (r= 0.31)*,Oomyzus* sp. (r= 0.25), *Aphidius colimani* (r= 0.33), Coccinellids (r= 0.25) and *Syrphid*sp (r= 0.04) was also observed positive and non-significant correlation with rainfall during the cropping season 2021-22.

In the cropping season 2022-23, all insect pest namely aphids (-0.22), diamondback moth (-0.32), tobacco caterpillar (-0.18), leaf webber (-0.21) and flea beetle (-0.27) and the natural enemies namely *Cotesia plutellae* (-0.27)*,Oomyzus* sp. (-0.22), *Aphidius colimani* (-0.28), Coccinellids (-0.32) and *Syrphid* sp. (-0.26) were shown negative and non-significant correlation with rainfall. Our findings are at par with Mishra *et al.,* (2018) and Kumar *et al.*(2023), who had also reported that the substantial decrease of population of diamondback moth, tobacco caterpillar, leaf webber and aphid occurrence with increasing rainfall. Rainfall affects negatively the percent parasitisation of aphids and incidence of syrphid predator (Gaikwad, 2018).

**Bright sunshine (hrs.)**

Sunshine hour shown positive but non-significant impact on all pests and natural enemies *viz*., aphids (0.35), diamondback moth (0.42), leaf webber (0.37) and flea beetle (0.36) in the cropping season 2021-22 while tobacco caterpillar (-0.05) shown negative and non-significant correlation. While in case of natural enemies also shown positive and non- significant correlation *viz*.,*Cotesia plutellae* (0.12)*, Aphidius colimani* (0.33), Coccinellids (0.35) and *Syrphid*sp (0.45) while *Oomyzus* sp. (0.36).

Whereas in 2022-23 positive and highly significant correlation were observed with aphids (0.82), diamondback moth (0.81) and flea beetle (0.72) while tobacco caterpillar (0.53) and leaf webber(0.55) have non-significant positive correlation. In same manner all natural enemies have positive and highly significant correlation with bright sunshine namely *Cotesia plutellae* (0.71)*, Aphidius colimani* (0.76), Coccinellids (0.79) and *Syrphid* sp. (0.86) while *Oomyzus* sp. (0.63) have significant and positive correlation.

Current findings are also had similar trends which was observed by Gaikwad *et al.,* (2018). who had reported the positive influence of the sunshine on the diamondback moth, tobacco caterpillar, leaf webber, aphidand natural enemies *i.e.,* syrphids and mummified aphids *etc*. Similarly, Yadav and Agarwal (2018) reported the positive and significant correlation of sunshine with respect to aphid and their predatory coccinellids *i.e., Coccinella septempunctata*, *Coccinella transversalis* and *Menochilus sexmaculata.*

**Multilinear regression equation on seasonal incidence of insect pest and their natural enemies in relation to weather factors**

During 2021-22 and 2022-23 our experiments showing populations were significantly influenced by the weather parameters (Table. 3) with coefficient of determination value ($r^2$) 0.79 and 0.69 for aphid, 0.77 and 0.85 for DBM, 0.49 and 0.78 for tobacco caterpillar, 0.70 and 0.45 for leaf webber and 0.84 and 0.76 for flea beetle, respectively for corresponding cropping seasons. Similarly, the values ($r^2$) for natural enemies *viz*., *Cotesia plutellae* (0.85 and 0.88)*, Oomyzus* sp. (0.68 and 0.69), *Aphidius colimani* (0.83 and 0.82), Coccinellids (0.73 and 0.89) and *Syrphid* sp. (0.83 and 0.82) are obtained showing these also influenced by the weather factors during respective years.

The experimental findings presented here showing significant effects of the weather parameters on the incidence of insect pests of cauliflower and their natural enemies in which the relatively higher temperature, lower relative humidity, reduced rainfall and optimum sunshine are more suitable for the establishment and development of insect pests. Similar trends of findings were also reported by Hemchandra and Singh (2007) revealing such conditions found to be favourable for the growth of the insect pest population. Marchioro and Foerster (2011) also observed the significance of temperature on development and survival of diamondback moth affecting the population dynamics. They also reported the decrease of development time of the immature stages, increase of survival and number of generations per year with increase in temperature within a threshold limit aiding in higher incidence of insect pests. In line with current findings, Soh *et al.* (2018). also reported

**Table 3. Co-efficient of determination ($r^2$) between weather parameters and population of major cauliflower insect pest and their natural enemies during cropping season 2021-22 and 2022-23**

| | Regression Equation 2021-22 | 2022-23 | $r^2$ (2021-22) | $r^2$ (2022-23) |
|---|---|---|---|---|
| Aphid | $Y=369.16+24.22X_1-30.39X_2-6.04X_3+1.00X_4-1.00X_5-6.21X_6$ | $Y=-716.93+11.69X_1-5.13X_2+1.95X_3+3.88X_4+37.10X_5+21.15X_6$ | 0.79 | 0.69 |
| DBM | $Y=1.604+2.69X_1-3.11X_2-0.37X_3+0.22X_4-0.124X_5-0.58X_6$ | $Y=5.48+0.416X_1+0.005X_2-0.51X_3+0.43X_4+5.89X_5+2.22X_6$ | 0.77 | 0.85 |
| Tobacco caterpillar | $Y=0.639+0.23X_1-0.26X_{2-}0.02X_3+0.003X_4-0.01X_5-0.15X_6$ | $Y=0.016-0.14X_1+0.17X_2+0.02X_3-0.018X_4+0.71X_5+0.7X_6$ | 0.49 | 0.78 |
| Leaf webber | $Y=10.72-0.70X_1+0.60X_2-0.04X_3-0.02X_4+0.04X_5+0.81X_6$ | $Y=-8.59+0.16X_1-0.70X_2+0.04X_3+0.02X_4-0.19X_5+0.03X_6$ | 0.70 | 0.45 |
| Flea Beetle | $Y=6.10+0.47X_1-0.57X_2-0.12X_3+0.03X_4-0.02X_5-0.08X_6$ | $Y=-0.404-0.05X_1+0.11X_2-0.07X_3+0.08X_4+0.95X_5+0.51X_6$ | 0.84 | 0.76 |
| *Cotesia plutellae* | $Y=-1.51+1.03X_1-1.16X_2-0.09X_3+0.06X_4-0.05X_5-0.50X_6$ | $Y=0.202-0.04X_1+0.15X_2-0.12X_3+0.14X_4+2.06X_5+0.76X_6$ | 0.65 | 0.84 |
| *Oomyzus* sp. | $Y=-3.55+0.22X_1-0.19X_2+0.001X_3+0.02X_4-0.01X_5-0.11X_6$ | $Y=-0.108+0.002X_1+0.001X_2-0.04X_3+0.05X_4+0.39X_5+0.23X_6$ | 0.68 | 0.69 |
| *Aphidius colimani* | $Y=17.60+3.30X_1-3.54X_2-0.57X_3+0.18X_4-0.14X_5-1.36X_6$ | $Y=-17.19+0.31X_1+0.26X_2-0.29X_3+0.46X_4+5.12X_5+2.19X_6$ | 0.83 | 0.82 |
| Coccinellids | $Y=16.81+0.93X_1-1.11X_2-0.28X_3+0.05X_4-0.02X_5-0.15X_6$ | $Y=7.54+0.05X_1+0.16X_2-0.28X_3+0.21X_4+3.22X_5+1.25X_6$ | 0.85 | 0.88 |
| Syrphids | $Y=9.53+0.11X_1-0.26X_2-0.10X_3+0.005X_4-0.004X_5+0.16X_6$ | $Y=-4.41+0.03X_1+0.04X_2+0.02X_3+0.01X_4+0.78X_5+0.20X_6$ | 0.83 | 0.82 |

**Whereas, $X_1$- Maximum Temperature; $X_2$- Minimum Temperature; X3- Morning Relative Humidity; $X_4$- Evening Relative Humidity; $X_5$-Rainfall and $X_6$-Sunshine Hour; $r^{2=}$ Co-efficient of determination**

significant effects of temperature on *Brevicoryne brassicae* population. Relative humidity influences the biological and behavioural changes in insects. Under heat stress condition, low humidity reduces insect survival (Bubliy *et al.,* 2012). Rainfall also acts as a signal for diapausing insects to resume their life processes. Egg and neonate stages are highly susceptible to the rainfall causes the physical damage, dislodge from the plant and disrupting movement to feeding sites and affects the oviposition sites. It also creates congenial microclimate suitable for entomopathogenic organisms thereby affecting the survival (Rahman *et al.,* 2017). Insects shows characteristic photoperiodism which profoundly influences the geographical distribution, seasonal biology, growth, form, metabolism and behaviour of the insect. Sunshine influence directly and indirectly the insect pest dynamics through regulation of temperature and relative humidity in addition to photoperiodism (Beck, 1980).

## CONCLUSION

From the present findings we can conclude that the infestation of major insect pests (Aphid and Diamondback moth) started from the first fortnight of the February and reached at its peak in the month of early March in both years of experimentation. The natural enemies shown similar trend in which incidence was in parallel with the population of their host pest. The correlation between population of insect pest and their natural enemies against weather parameters showing significant positive correlation with temperature (maximum and minimum), rainfall and sunshine while negative correlation with relative humidity (morning - evening). Multiple linear regression analysis is also indicating that the significant impact on the population dynamics of the insects by weather factors. These findings will help the farmers to plan comprehensive management schedule to supress the developing pest population and reduce the loss caused by them. Although the findings of two different experiments couldn't be compared exactly as in physical and chemical science but the trends of variations in their population could be compared in biological sciences may be recognised as parameters which affecting the life processes either positively or negatively. These types of experimental findings need their validation in corresponding environmental condition before executing at the mass level.

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