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Investigations on population dynamics of diamondback moth, *Plutella xylostella* Linn. and natural enemies on cabbage, *Brassica oleracea* var. *capitata* Linn

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Abstract
The study on population dynamics of diamondback moth larvae on cabbage variety, Golden Acre revealed the commencement of pest in 50th SMW and maximum larval population on 1st SMW. The larval population showed highly significant negative correlation with maximum, minimum and average temperature. Wind speed had significant positive correlation with the larval population. Coccinellid predators *viz*., *Coccinella transversalis* Fabricius and *Cheilomenes sexmaculata* (Fabricius) were noticed in cabbage ecosystem. The initial occurrence of coccinellids were noted during 50th SMW and the population increased gradually in successive weekly counts and reached a peak in 3rd SMW. The minimum and average temperature and the evening relative humidity had significant negative effect on the population of coccinellid beetles. Wind speed had highly significant positive influence on coccinellid population. Regression studies revealed 76.90 and 80.70 per cent association of *P. xylostella* larval population and coccinellids with significant weather parameters, respectively.

Keywords: Diamondback moth, cabbage, coccinellids, abiotic factors

Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the cool season herbaceous green leafy vegetables belonging to the family Brassicaceae grown worldwide due to its palatability and taste in addition to antioxidant, anti-inflammatory and antibacterial properties. Cabbage was introduced in India and has adapted to grow all over the country. In India, cabbage is grown in an area of 406.86 thousand hectares with a production of 8970.53 thousand metric tonnes during 2016-17 [4]. One of the major constrains in achieving maximum productivity is incidence of pests and diseases. The per cent yield loss in cabbage due to insect pests ranged from 19.24 to 30.30 per cent with an average of 25.80 per cent [11]. Lepidopteran insects that cause serious damage to cabbage are diamondback moth, *Plutella xylostella* (L.), cabbage borer, *Hellula undalis* Fab, leaf webber *Crocidolomia pavonana* (F.), gram pod borer, *Helicoverpa armigera* Hubner, semilooper, *Plusia* sp., tobacco caterpillar, *Spodoptera litura* (F.) and cabbage butterfly, *Pieris brassicae* (L.) [20]. Among lepidopterous pests, *P. xylostella* is a serious pest of cabbage during the vegetative stage [16]. It is the most destructive pest of crucifers worldwide and about 1 billion dollars of losses occurred annually due to its larval damage [18]. Yield loss of 90 – 92 per cent was reported when cabbage was left unprotected [12]. The study on the influence of abiotic factors on population dynamics of diamondback moth is essential to adopt an efficient management strategy against the pest without causing economic losses.

Materials and methods
The present investigation was carried out at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat during November – February, 2018-19. Navsari is geographically situated at 20°57' N latitude and 72°54' E longitude with an altitude of about 12m above MSL on the western coastal belt of India with deep black soil. According to agro-climatic conditions of Gujarat, Navsari falls under South Gujarat Heavy Rainfall Zone, AES-III. The weather is tropical with an average relative humidity above 68.27 per cent throughout the year. The average maximum and minimum temperature varies from 20-30 °C and 12.0-28.1 °C, respectively. Winter is very mild and sets in towards end of October.

The meteorological data on temperature (maximum, minimum and average), relative humidity (morning, evening and average), rainfall, wind speed, evaporation and sunshine hours prevailing during the period of experiment were obtained from Department of Meteorology, N.M College of Agriculture, Navsari Agricultural University (N.A.U.), Navsari. The experiment was laid out in a plot of size 19.80 × 20.25 m^2. Twenty five days old seedlings of cabbage variety, Golden Acre raised in the vegetable nursery of Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, N.A.U, Navsari were transplanted in the main field at a spacing of 60 × 45 cm. The transplanting was done on 19th November during *Rabi*, 2018-19 in the morning followed by irrigation. Agronomic practices as per the recommendations were followed to raise the crop during the experimental period. In order to study the abundance of diamondback moth infesting cabbage, direct visual counting method was adopted. Twenty plants were randomly selected and tagged from net plot area. The observation on larval population of diamondback moth was recorded after transplanting by counting larvae on whole plants at weekly intervals and continued till harvest. Similarly, natural enemies noted in cabbage ecosystem were also recorded.

Results and discussions

Seasonal abundance of diamondback moth, *P. xylostella*

The data on seasonal abundance of diamondback moth during 2018-19 *rabi* season are depicted in Table. 1. The study revealed that the incidence of pest occurred from second week of December (3.60 larvae/plant) *i.e.*, 4 weeks after transplanting. Larval population gradually increased to peak during first week of January (5.75 larvae/plant) thereafter decreased to 4.35 larvae/plant in third week of January. Later an increase in population was observed during fourth week of January (5 larvae/plant) and decreased gradually to 0.70 larvae/plant at the end of the crop growth period in third week of February. These findings of population trend are in conformity with the findings of Patel (2002) [13] at Raipur and Shukla (2002) [16] at Udaipur. The initial occurrence of pest was noted between 21-28 days after transplanting during 50th Standard Week. Similarly, Alam (2015) [2] also observed initial occurrence of larvae nearly about 18-22 days after transplanting or in 49th Standard Week at Varanasi. However, Bhagat *et al*. (2018) [6] recorded the incidence after one month of transplanting. The initial incidence of diamondback moth were determined by the termination of diapause, immigration, presence of alternate hosts or a combination of these factors, in addition to the planting date (Andaloro *et al*., 1982) [3]. The peak population was reported by Bana *et al*. (2012) [5] in the first week of January at Jaipur and this lay support with the present findings. Further, Gaikwad *et al*. (2018) [8] recorded maximum diamondback moth larval population of 7.82 larvae/plant in 2nd Standard Meteorological Week in cauliflower at Parbhani. However, Goud *et al*. (2006) [9] found out the peak population during the last week of January *i.e.* at 85 days after transplanting at Hyderabad. The least population of diamondback moth might be due to the non-availability of hosts at the end of crop season or when the adult moths emerged they were not attracted to cabbage as it reached harvesting maturity.

Table 1: Seasonal abundance of *P. xylostella* on cabbage

Observation period	WAT	SMW	Mean larvae/plant
19 - 25 Nov	1	47	0
26 Nov - 2 Dec	2	48	0
03 - 09 Dec	3	49	0
10 - 16 Dec	4	50	3.60
17 - 23 Dec	5	51	4.80
24 - 30 Dec	6	52	5.15
31 Dec - 6 Jan	7	1	5.75
07 - 13 Jan	8	2	4.55
14 - 20 Jan	9	3	4.35
21 - 27 Jan	10	4	5.00
28 Jan - 3 Feb	11	5	3.85
04 - 10 Feb	12	6	2.50
11 - 17 Feb	13	7	1.80
18 - 24 Feb	14	8	0.70

Effect of weather parameters on the incidence of diamondback moth

In the studies conducted to find out the influence of weather parameters on the incidence of diamondback moth, weekly counts of larval population were correlated with temperature (maximum, minimum and average), relative humidity (morning, evening and average), wind speed, sunshine hours and evaporation recorded in the preceding week. Their correlation coefficients are presented in Table 2.

Table 2: Effect of weather parameters on *P. xylostella* in cabbage ecosystem

Weather parameter	Correlation coefficient (r)
Maximum temperature (°C)	–0.693**
Minimum temperature (°C)	–0.825**
Average temperature (°C)	–0.817**
Morning relative humidity (%)	–0.287
Evening relative humidity (%)	–0.224
Average relative humidity (%)	–0.312
Wind speed (km/hr)	0.646*
Sunshine hours (hrs/day)	0.245
Evaporation	–0.330

* Significant at 5 per cent level of significance
**Significant at 1 per cent level of significance

Diamondback moth population exhibited highly significant negative correlation with maximum temperature (r = –0.693), minimum temperature (r = –0.825) and average temperature (r = –0.817). The morning (r = –0.287), evening (r = –0.224) and average relative humidity (r = –0.312) and evaporation (r = –0.330) showed negative non-significant effect, while sunshine hours (r = 0.245) showed positive non-significant effect on the incidence of the diamondback moth. However, wind speed (r = 0.646) had significant positive correlation with the larval population. The absence of rain during crop growing season excluded the correlation of larval population with total rainfall. The present results regarding the correlation of larval population with weather parameters are in confirmity with the findings of Shukla (2002) [16], Bana *et al*. (2012) [5], Jaishree (2017) [10] and Sharma *et al*. (2017) [15]. Similar to the present results, Usha *et al*. (1997) [19] recorded negative correlation with maximum and minimum temperature.

Combined effect of significant weather parameters on the incidence of diamondback moth larval population

The result of regression analysis carried out to understand the combined effect and the combination of each significant weather parameters on the incidence of diamondback moth larval population are represented in Table 3. Regression studies for the effect of abiotic factors on the build-up of *P. xylostella* population revealed that it was significantly influenced by weather factors like maximum temperature, minimum temperature and wind speed with their contribution being 76.90 per cent.

Table 3: Cumulative effect of significant weather parameters on *P. xylostella*

Season	Constant	Multiple Correlation Coefficient (R)	Coefficient of determination (R^2)
2018-19	5.650	0.877	0.769

Regression equation: $\hat{Y}= 5.650 + 0.083\ X_1 – 0.645\ X_2 + 0.855\ X_7$

Where,

$\hat{Y}$ - *P. xylostella* larvae, X_1 - Maximum temperature, X_2 - Minimum temperature, X_7 - Wind speed

The research results of Sonika *et al*. (2017) [17] and Ahmad *et al*. (2015) [1] revealed that the *P. xylostella* population was significantly influenced by weather factors with their contribution being 77.60 and 90 - 98 per cent, respectively.

Seasonal abundance of natural enemies in cabbage ecosystem

Among the natural enemies of insect pests of cabbage, the coccinellid predators were found in the field and none of the species were recorded parasitizing the diamondback moth. Coccinellid predators *viz*., *Coccinella transversalis* Fabricius and *Cheilomenes sexmaculata* (Fabricius) were noticed in cabbage ecosystem during the course of study.

Seasonal abundance of coccinellids in cabbage ecosystem

The data represented in Table 4 revealed the absence of predators for first three weeks after transplanting the crop. The study on the seasonal abundance of coccinellids on cabbage recorded the initial incidence of coccinellids on 2nd week of December with an initial population of 0.50 adults/plant. The population increased gradually in successive weekly counts and reached a peak of 1.25 adults/plant on third week of January and thereafter population gradually declined to 0.60 adults/plant during the last week of February. Earlier, Debbarma *et al*. (2017) [7] noticed and recorded the coccinellid predators *viz*., *C. sexmaculata*, *Scymnus* sp., *Coccinella septumpunctata* (Fabricius) and *Brumoides suturalis* (Fabricius) during the survey conducted in Dindigul and Theni districts of Tamil Nadu on cauliflower**.** These results are in conformity with the findings of Patra *et al*. (2013) [14] who noticed the occurrence of coccinellids from seedling stage and continued till harvesting of crop.

Table 4: Seasonal abundance of coccinellids in cabbage ecosystem

Observation period	SMW	Mean adults/plant
19 - 25 Nov	47	0
26 Nov- 2 Dec	48	0
03 - 09 Dec	49	0
10 - 16 Dec	50	0.50
17 - 23 Dec	51	0.65
24 - 30 Dec	52	0.70
31 Dec - 6 Jan	1	0.80
07 - 13 Jan	2	0.95
14 - 20 Jan	3	1.25
21 - 27 Jan	4	1.20
28 Jan-3 Feb	5	1.15
04 - 10 Feb	6	1.00
11 - 17 Feb	7	0.80
18 - 24 Feb	8	0.60

Effect of weather parameters on the incidence of coccinellids in cabbage ecosystem

Correlation worked out between the number of coccinellid predators observed in the field and the weather factors *viz*., temperature (maximum and minimum), relative humidity, evaporation, wind speed and sunshine hours are depicted in Table 5. The correlation study revealed that the maximum temperature had non-significant negative effect (r = –0.524), while minimum temperature (r = –0.626) and average temperature (r = –0.619) had significant negative effect on the population of coccinellid predators. The correlation studies also revealed that the morning (r = –0.035) and average relative humidity (r = –0.240) had non-significant negative effect, while evening relative humidity (r = –0.549) had significant negative influence on the population of coccinellid beetles. However, wind speed (r = 0.747) had highly significant positive influence on population. While, sunshine hours (r = 0.448) and evaporation (r = 0.184) had non-significant positive effect on population trend of coccinellids.

Table 5: Effect of weather parameters on coccinellids in cabbage ecosystem

Weather parameter	Correlation coefficient (r)
Maximum temperature (°C)	–0.524
Minimum temperature (°C)	–0.626*
Average temperature (°C)	–0.619*
Morning relative humidity (%)	–0.035
Evening relative humidity (%)	–0.549*
Average relative humidity (%)	–0.240
Wind speed (km/hr)	0.747**
Sunshine hours (hrs/day)	0.448
Evaporation	0.184

* Significant at 5 per cent level of significance

**Significant at 1 per cent level of significance

Combined effect of significant weather parameters on the incidence of coccinellids in cabbage ecosystem

The regression analysis represented in Table 6 revealed that the abiotic factors like minimum temperature, average temperature, evening relative humidity and wind speed were able to explain 80.70 per cent of the variation in incidence of coccinellids.

Table 6: Cumulative effect of significant weather parameters on coccinellids in cabbage ecosystem

Season	Constant	Multiple Correlation Coefficient (R)	Coefficient of determination (R^2)
2018-19	– 0.464	0.899	0.807

Regression equation

$\hat{Y} = – 0.464 – 0.220\ X_2 + 0.225\ X_3 – 0.042\ X_5 + 0.395\ X_7$

Where,

$\hat{Y}$ – Coccinellids, X_2 – Minimum temperature, X_3 – Average temperature, X_5 – Evening relative humidity, X_7 – Wind speed

Conclusion

The incidence of diamondback moth on cabbage commenced from 50th SMW (3.60 larvae/plant) with peak in 1st SMW (5.75 larvae/plant) then decreased gradually. The correlation studies between the incidence of *P. xylostella* population and weather parameters revealed that the larval population had highly significant negative correlation with maximum, minimum and average temperature. However, the correlation between wind speed and larval population of *P. xylostella* was statistically positive and significant. Regression studies revealed 76.90 per cent association of the *P. xylostella* population with significant weather parameters. Coccinellid predators *viz*., *Coccinella transversalis* Fabricius and *Cheilomenes sexmaculata* (Fabricius) were noticed in cabbage ecosystem during the crop growth period.

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