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Effect of weather parameters on the incidence of diamondback moth, *Plutella xylostella* (L.) in cabbage

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ABSTRACT: Studies were conducted to understand the effect of weather parameters on the incidence of diamondback moth, *Plutella xylostella* (L.) on cabbage at Horticulture Farm, Rajasthan College of Agriculture, Udaipur, India during r*abi,* 2019-20 and 2020-21. In both the seasons, a markedly high population of diamondback moth larvae was recorded (9.18 larvae/ plant) during the 2nd week of March, 2020 and 10.15 larvae/plant during the 3rd week of March, 2021, respectively. Similarly, the peak populations of diamondback moth pupae were noticed during the 4th week of February (6.45 pupae/ plant) and the 1st week of March (7.08 pupae/ plant). DBM larval and pupal populations had a significant positive correlation with maximum atmospheric temperature and sunshine hours while a significant negative correlation was observed with mean relative humidity during both years. The coefficient of multiple determination (R^2=0.705) and (R^2 = 0.591) indicated that 70.50 and 59.10 per cent of variation in the larval populations during 2019-20 and 2020-21 respectively. Similarly, DBM pupal population directed a collective influence of 56.60 per cent (R^2=0.566) and 50.00 per cent (R^2 = 0.500) during 2019-20 and 2020-21, respectively.

Keywords: Diamondback moth, cabbage, seasonal incidence, weather parameters

INTRODUCTION

Cabbage (*Brassica oleracea* Var. *Capitata* L.) is a leafy vegetable grown for its edible enlarged terminal bud. It is cultivated widely in the tropical and temperate regions of the world. Many limiting factors have been attributed to low production; among them, the chief constraint is damage caused by the insect pest complex soon after germination till the harvesting. In India, a total of 37 insect pests have been reported to feed on cabbage (Lal, 1975). Among them, diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is recognised as the most prominent pest and considered as the most devastating insect pest of cruciferous crops worldwide. Diamondback moth, hereafter "DBM", is a dominant pest in more than 100 countries across the globe. DBM considered to be one of the most devastative pests of cabbage and other Brassica crops worldwide (Talekar and Shelton, 1993; Shelton and Badenes-perez, 2006). It influences cruciferous plants, peculiarly *Brassica* crops in particular cabbage, cauliflower, broccoli, brussels sprout, kale and turnip (Talekar, 1992; Alam, 1992). DBM manifests a marked preference for cabbage and cauliflower as these crops equip olfactory and gustatory stimuli for successful selection and colonization with fleshy and succulent leaves. It destructs the crop by feeding on the foliage and infests by multitudes of larvae which hinders the growth of the plant leading to a notable reduction in yield. The yield loss is evaluated to vary from 31 to 100 per cent (Abraham and Padmanabhan, 1968) and 52 per cent to 100 per cent (Anuradha, 1997; Cardleron and Hare*,* 1986).

The modifying cropping pattern, monoculture, intensive cultivation of high yielding varieties, negligence of crop rotation, non-adoption of summer ploughing besides negation of other cultural practices and injudicious use of insecticides have aggravated this pest problem in cruciferous vegetables. Commercial consideration of cabbage crop has compelled the growers to go for frequent and injudicious use of insecticides for better marketable yield. As a result, DBM has developed resistance to most commonly used insecticides (Atumurirava *et al.,* 2011; Zhou *et al.,* 2011) and was reported as the first species to develop resistance to some toxins of *Bacillus thuringiensis* (Tabashnik and Cushing, 1987; Talekar and Shelton, 1993). To reduce yield losses caused by DBM, farmers routinely follow chemical control, due to the lack of reliable alternatives and the availability of relatively cheaper insecticides (Talekar and Shelton, 1993). Furthermore, it has led to several problems *viz.,* multiple resistance to commonly used insecticides (Ribeiro *et al.,* 2014), pesticide resurgence (Nemato *et al.*, 1984), residue problems, in-efficiency of natural enemies and environmental pollution, etc. In current estimation, the area, production and productivity of cabbage in Rajasthan have declined rapidly from 1.29 lakh ha, 19.66 lakh metric tonnes and 15.27 metric tonnes per ha, respectively in the year 2016-17 to 1.20 lakh ha, 11.69 lakh metric tonnes and 9.74 metric tonnes per ha, respectively in the year 2017-18 and numerous farmers abandoned the cultivation of cabbage in the state (Anonymous, 2018). Weather conditions play important role in managing DBM, therefore, the weather parameters are studied in the present study to understand their influence on DBM larval and pupal populations.

MATERIALS AND METHODS

In order to study the weather parameters and their multiple corrections on DBM larval and pupal populations, the experiment was laid out at the Horticulture Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur. Udaipur region comes under the agro-climatic zone, "Sub-humid Southern Plain and Aravalli Hills of Rajasthan", which is situated at an altitude of 582.17 meters above mean sea level, at 24°35' N latitude and 74°42' E longitude. The region is characterized by a sub-tropical climate with typical winters and summers. The average annual rainfall ranges from 592.5 mm to 620 mm. The maximum rainfall is received from mid-June to September with scanty showers during the winter season.

Table 1. Seasonal incidence of diamondback moth on cabbage during *Rabi,* 2019-20

SMW	Atmospheric Temperature (°C)			Relative Humidity (%)			Sunshine (Hrs.)	Mean / plant		
	Max.	Min.	Mean	Morning	Evening	Mean		Larvae	Pupae	Infestation (%)
48	26.30	13.30	19.80	88.90	58.00	73.45	3.80	0.62	0.00	1.67
49	24.00	8.10	16.05	86.10	31.40	58.75	5.60	0.88	0.00	2.50
50	24.30	7.50	15.90	88.00	37.70	62.85	6.50	1.13	0.00	5.83
51	23.50	6.60	15.05	82.40	40.10	61.25	7.20	2.05	0.00	8.33
52	21.50	4.70	13.10	82.60	39.40	61.00	5.80	2.62	0.17	12.50
1	21.20	6.80	14.00	86.70	49.30	68.00	5.10	3.52	0.27	20.83
2	22.10	5.20	13.65	81.70	40.40	61.05	7.10	4.17	0.43	25.00
3	21.00	6.40	13.70	86.40	42.00	64.20	5.60	4.65	0.73	27.50
4	24.70	7.90	16.30	82.70	31.30	57.00	8.60	5.48	1.53	30.83
5	22.30	4.50	13.40	85.00	36.30	60.65	8.60	6.27	2.07	42.50
6	23.00	4.40	13.70	80.30	34.40	57.35	8.60	6.72	2.67	38.33
7	28.50	7.70	18.10	77.40	21.90	49.65	8.60	7.30	4.23	39.17
8	28.10	9.00	18.55	76.00	29.00	52.50	7.90	8.20	6.45	45.83
9	30.20	10.90	20.55	73.40	26.60	50.00	7.60	8.65	2.03	48.33
10	26.60	10.20	18.40	71.90	34.40	53.15	9.00	9.18	1.03	54.17
Coefficient of correlation (r) between population and atm. temp.							Maximum Temp.	0.50	0.55*	-
							Minimum Temp.	0.05	0.04	
							Mean Temp.	0.31	0.34	
Coefficient of correlation (r) between population and relative humidity							Morning RH	-0.85*	-0.57*	
							Evening RH	-0.62*	-0.62*	
							Mean	-0.77*	-0.65*	
Coefficient of correlation (r) between population and sunshine								0.78*	0.57*	

SMW = Standard Meteorological Week; *Significant at 5% level

Table 2. Seasonal incidence of diamondback moth on cabbage during *Rabi,* 2020-21

SMW	Atmospheric Temperature (°C)			Relative Humidity (%)			Sunshine (Hrs)	Mean / plant		
	Max.	Min.	Mean	Morning	Evening	Mean		Larvae	Pupae	Infestation (%)
49	30.40	10.20	20.30	76.10	27.30	51.70	8.80	0.65	0.00	0.83
50	24.50	12.10	18.30	85.40	52.10	68.75	4.10	0.87	0.00	3.33
51	23.30	4.30	13.80	80.90	26.70	53.80	7.90	1.62	0.00	6.67
52	22.50	3.80	13.15	81.90	27.80	54.85	8.30	2.32	0.00	9.17
1	24.00	8.70	16.35	85.70	46.70	66.20	3.40	3.07	0.12	14.17
2	22.80	9.70	16.25	90.60	51.40	71.00	4.30	4.28	0.20	15.83
3	27.30	7.50	17.40	87.90	32.90	60.40	8.30	4.83	0.47	17.50
4	24.50	4.10	14.30	83.10	28.10	55.60	8.80	5.53	1.02	19.17
5	26.10	4.40	15.25	76.10	23.10	49.60	8.60	6.20	1.40	21.67
6	26.60	5.90	16.25	75.60	22.30	48.95	8.70	7.12	2.13	32.50
7	29.00	8.00	18.50	74.40	23.10	48.75	8.30	8.20	1.98	36.67
8	29.60	8.90	19.25	65.40	18.30	41.85	9.30	8.68	4.08	39.17
9	32.30	11.40	21.85	64.90	23.10	44.00	9.60	9.28	7.08	49.17
10	33.10	13.10	23.10	54.40	26.50	40.45	9.50	9.53	3.37	52.50
11	33.30	14.70	24.00	57.40	27.10	42.25	8.50	10.15	1.50	58.33
Coefficient of correlation (r) between population and atm. temp.							Maximum Temp.	0.70*	0.66*	-
							Minimum Temp.	0.35	0.32	
							Mean Temp.	0.58*	0.54*	
Coefficient of correlation (r) between population and relative humidity							Morning RH	-0.76*	-0.68*	
							Evening RH	-0.54*	-0.52*	
							Mean	-0.72*	-0.67*	
Coefficient of correlation (r) between population and sunshine								0.53*	0.54*	

SMW = Standard Meteorological Week; *Significant at 5% level

Seedlings of cabbage variety, Golden acre recommended for the zone was transplanted on prepared field, with uniformly sized plots of 4.5 m x 4.5 m laid out in RBD during the last week of October, 2019-20 and first week of November, 2020-21. Intercultural operations were performed as per the package of practices recommended by the Directorate of Research, MPUA&T, Udaipur, Rajasthan. The population of DBM on cabbage was recorded at weekly intervals for the appearance of DBM larva and pupae in the course of each sampling. The prevalence of DBM infestation was recorded in terms of the number of larvae and pupae per plant on 10 randomly selected plants. The extent of damages by DBM larvae was recorded by sampling randomly selected 20 plants per plot from six plots. Weekly meteorological data of abiotic factors *viz*., atmospheric temperature (maximum and minimum), relative humidity (morning and evening) and sunshine (hrs) were obtained from Agromet observatory, Rajasthan College of Agriculture, Udaipur.

The abiotic factors *viz*., atmospheric temperature (maximum and minimum), relative humidity (morning and evening) and sunshine (hrs) were recorded during the crop season and their simple correlation with the population of insect pests and natural enemies were evaluated by the Karl Pearson formula of correlation coefficient (Fowler *et al*., 1998). The calculated t-value obtained was compared with tabulated t-value 5 per cent level of significance.

RESULTS AND DISCUSSION

The data on seasonal incidence of DBM on cabbage during *Rabi,* 2019-20 has been presented in Table 1. Multiple correlation analysis presented in Table 3. The DBM larvae started appearing from the 1st week of December, 2019 (48th SMW) and reached its peak of 9.18 larvae/ plant during the 2nd week of March, 2020 (10th SMW). The larval populations endured till the harvest of crop. During the peak incidence, the mean temperature, mean relative humidity and sunshine hrs were 18.40 ℃, 53.15 % and 9.00 hrs, respectively. The extent of damage or per cent plant infestation by the larvae of DBM were ranged from 1.67-54.17 per cent. The larval incidence had a significant positive correlation (r = 0.50) with maximum atmospheric temperature and sunshine hours (r = 0.78). Although, a significant negative correlation (r = - 0.77) was observed with mean relative humidity. Meagre total rainfall of 3.00 mm was documented during the *Rabi,* 2019-20 and hence no significant relations were observed between rainfall and insect populations. The percentage plant infestation by DBM larvae was 1.67 - 54.17 during *Rabi,* 2019-20. Similarly, the DBM pupal population appeared from the 4th week of December, 2019 (52nd SMW) and reached its crest of 6.45 pupae/ plant during the 4th week of February, 2020 (8th SMW) and prevailed till the harvest of crop. At the time of peak, pupae per plant, the mean temperature, mean relative humidity and sunshine were 18.55 ℃, 52.50% and 7.90 hrs, respectively. The pupal population had a significant positive correlation with maximum atmospheric temperature (r = 0.55) and sunshine hours (r = 0.57) whereas significant negative correlation (r = -0.65) was observed with mean relative humidity.

The multiple linear regression analysis directed that atmospheric parameter (mean atmospheric temperature, mean relative humidity and total sunshine) obligated a combined encouragement on DBM larval population. The coefficient of multiple determinations (R^2) was 0.705 indicating that 70.50 per cent of the variation in the larval populations was explained by the explanatory variables. In multiple linear regression equation, the regression coefficient b_1= 0.150 depicts that X_2 (mean relative humidity) and X_3 (total sunshine) constant, with one degree increase in X_1 (mean temperature) commanded on the average to about 0.150 per cent increase in DBM larval populations. In a similar way, b_2= -0.139 means that holding X_1 and X_3, constant and 1 per cent increase in X_2 (mean relative humidity) led from average to about 0.139 per cent decrease in DBM larvae. Likewise, b_3=-0.865 means that holding X_1 and X_2 constant and 1 hr increase in X_3 (sunshine) led average to about 0.865 per cent increase in DBM larvae. Similarly, the multiple linear regression analysis for pupal population directed a collective influence of 56.60 per cent (R^2=0.566) on DBM pupal population. The coefficient of multiple determinations (R^2) was 0.566 indicating that 56.60 per cent of variation in the larval populations was explained by the explanatory variables. The regression coefficient b_1= 0.222 held X_2 (mean relative humidity) and X_3 (total sunshine) constant, with one degree increase in X_1 (mean temperature) directed on the average to about 0.222 per cent increase in DBM pupal population. likewise, b_2= -0.082 which held X_1 and X_3, constant and 1 per cent increase in X_2 (mean relative humidity) led from average to about 0.082 per cent decrease in DBM pupae and b_3=0.520 which held X_1 and X_2 constant and 1 hr increase in X_3 (sunshine) led from average to about 0.520 per cent increase in DBM pupae.

The data on seasonal incidence of DBM on cabbage during *Rabi,* 2020-21 is presented in Table 2. Multiple correlation analysis presented in Table 3. The incidence of DBM larvae initiated in the second week of December (49th SMW, 2020) with count of 0.65 larvae/plant. Afterward, the infestation elevated and reached its peak (10.15 larvae/plant) during the third week of March (11th SMW, 2021), while the prevailing mean atmospheric temperature, mean relative humidity and total sunshine were 24.00 °C, 42.25% and 8.50 hrs, respectively. The extent of damage or per cent plant infestation by the larvae of DBM were ranged from 0.83-58.33 per cent. The DBM larval population exhibited positively significant correlation with mean temperature (r= 0.58) and sunshine (r= 0.53), while negatively non-significant with mean relative humidity (r= -0.72). Meagre total rainfall of 12.60 mm was recorded during the *Rabi,* 2020-21, hence no significant relations were observed between rainfall and insect populations. The percentage plant infestation by DBM larvae was 0.83 - 58.33 during *Rabi,* 2020-21. Likewise, the DBM pupal population noticed from the 1st week of January (1st SMW, 2021) and touched its crest of 7.08 pupae/ plant during the 1st week of March (9th SMW, 2021). During peak pupae per plant, the mean temperature, mean relative humidity and sunshine were 21.85 ℃, 44.00% and 9.60 hrs, respectively. The pupal population had a significant positive correlation with mean atmospheric temperature (r = 0.54) and sunshine hours (r = 0.54). Although, a significant negative correlation (r = -0.67) was observed with mean relative humidity.

The multiple linear regression analysis revealed that atmospheric parameters (mean atmospheric temperature, mean relative humidity and total sunshine) obliged a collective reassurance on DBM larval population. The coefficient of multiple determination (R^2) was 0.591 indicating that 59.10 per cent of variation in the DBM larval populations was explained by the explanatory variables. In multiple linear regression equation, the regression coefficient b_1= 0.205 means that held X_2 (mean relative humidity) and X_3 (total sunshine) constant, with one degree increase in X_1 (mean temperature) directed on average 0.205 per cent increase in DBM larval population. In the same way, b_2= -0.283 means that holds X_1 and X_3, constant and 1 per cent increase in X_2 (mean relative humidity) led from average to about 0.283 per cent decrease in larval populations. Equally, b_3=-0.447 holds X_1 and X_2 constant and 1 hr increase in X_3 (sunshine) led from average to about 0.447 per cent decrease in number of larvae. The multiple linear regression analysis for pupal population had a collective influence on DBM pupal population. The coefficient of multiple determinations (R^2) was 0.500 indicating that 50.00 per cent of variation in the DBM pupal populations was explained by the explanatory variables. The regression coefficient b_1= 0.166 means that held X_2 (mean relative humidity) and X_3 (total sunshine) constant, with one degree increase in X_1 (mean temperature) focused on the average to about 0.166 per cent increase in DBM pupal population. Similarly, b_2= -0.095 means that held X_1 and X_3, constant and 1 per cent increase in X_2 (mean relative humidity) led from average to about 0.095 per cent decrease in DBM pupae and b_3= 0.088 means that held X_1 and X_2 constant and 1 hr increase in X_3 (sunshine) led from average to about 0.088 per cent increase in DBM pupal populations.

Similarly, Mahendran *et al.* (2017) observed that initial larval and pupal populations of *P. xylostella* were seen during the 52nd meteorological week, with a mean density of 1.27 to 1.30 larvae and pupae/ 10 plants and peak populations during 9th SMW with 102.55 to 111.15 larvae and pupae/10 plants. They witnessed that larval and pupal populations were positively significant with sunshine hours as well as maximum and minimum temperature during the first year of the experiment while positive non-significant during the second year, respectively while relative humidity was negatively significant during the first year and negatively non-significant during the second year.

In the present investigation, DBM larval incidence had a significant positive correlation with maximum atmospheric temperature and sunshine hrs whereas, mean relative humidity had a significant negative correlation during both the seasons. Meagre total rainfall of 3.00 mm and 12.60 mm were recorded during the

Table 3. Multiple linear regression for key weather parameters on diamondback moth on cabbage during *Rabi*, 2019-20 and 2020-21

Season	Insect	Regression equation	Regression coefficients			Multiple correlation coefficient (R)	Coefficient of multiple determination (R^2)
			b_1	b_2	b_3		
Rabi, 2019-20	Diamondback moth larvae	$Y = 4.447+(0.150)X_1+(-0.139)X_2+(0.865)X_3$	0.150*	-0.139*	0.865*	0.839	0.705 (70.50%)
Rabi, 2019-20	Diamondback moth pupae	$Y = -0.688+(0.222)X_1+(-0.082)X_2+(0.520)X_3$	0.222*	-0.082*	0.520*	0.752	0.566 (56.60%)
Rabi, 2020-21	Diamondback moth larvae	$Y = 20.399+(0.205)X_1+(-0.283)X_2+(-0.447)X_3$	0.205*	-0.283	-0.447*	0.769	0.591 (59.10%)
Rabi, 2020-21	Diamondback moth pupae	$Y = 2.927+(0.166)X_1+(-0.095)X_2+(0.088)X_3$	0.166*	-0.095*	0.088*	0.707	0.500 (50.00%)

*Significant at 5 per cent level of significance; Observations = 11; Y = Dependent variable; insect populations;

X_1 = Mean Atm. Temperature (°C); X_2 = Mean Relative Humidity (%); X_3 = Mean Sunshine (hour) (mm)

Partial regression coefficient $b_{1:}$ $b_{yx1.x2x3,}$ $b_{2:}$ $b_{yx2.x1x3,}$ $b_{1:}$ $b_{yx3.x1x2}$

Rabi, 2019-20 and 2020-21 seasons, respectively, hence no significant relations were noticed between rainfall and insect populations. The results obtained from the present experiment revealed that the incidence of DBM was significantly affected by temperature and sunshine positively whereas relative humidity negatively Similarly, Venkateswarlu *et al.* (2011) observed DBM larval populations appearance during the 1st week of February and peak incidence (7.9 larvae /plant) during the 1st week of March. They also revealed that maximum temperature among different abiotic factors had a significant positive correlation while mean relative humidity had a significant negative correlation with the population of *P. xylostella.* Patra *et al.* (2013) found that the maximum population of the *P. xylostella* was documented on 1st March and 23rd February of about 13.60 and 14.33 larvae per plant during a couple of seasons, respectively on cabbage crop and the maximum temperature had a significant effect in elevating the population of *P. xylostella*. Similarly, Rahimgul and Sasya (2016), conducted research on the cabbage cultivar Golden acre during *Rabi,* 2015-2016 at Allahabad and reported that DBM larvae commenced from the 2nd week of February with an average 0.25 larvae/plant and reached a peak level of 3.40 larvae/ plant at 4th week of March. Jat *et al.* (2017) also reported the incidence of DBM in the 4th week of January and peak during the 4th week of February (13.10 larvae/five plants). They found that DBM population exhibited a positive significant correlation with temperature and a negative non-significant correlation with relative humidity and rainfall. Similarly, Jat *et al.* (2017) evidenced that infestation of DBM was started during the 2nd week of December during *Rabi,* 2012-13 and 2013-14 and reached its crest with a mean population of 5.40 and 5.20 larvae/plant in the 5th and 6th SMW during both the years, respectively. They found that DBM population exhibited a positive correlation with mean temperature and a negative correlation with mean relative humidity.

During the study period, the larval incidence of DBM on cabbage started from the 1st week of December, 2019 and the second week of December during the *Rabi,* 2019-20 and 2020-21, respectively. During both seasons, a noticeably high population of DBM larvae was recorded as 9.18 larvae/ plant during the 2nd week of March, 2020 and 10.15 larvae/plant during the 3rd week of March, 2021, in the respective crop season. The DBM pupal population was heeded from the 4th week of December and the 1st week of January during both years, respectively. The peak populations were noticed during the 4th week of February (6.45 pupae/ plant) and the 1st week of March (7.08 pupae/ plant). DBM larval and pupal populations had a significant positive correlation with maximum atmospheric temperature and sunshine hrs while a significant negative correlation was observed with mean relative humidity during both years. The coefficient of multiple determination (R^2 =0.705) and (R^2 = 0.591) indicated that 70.50 and 59.10 per cent of variation in the larval populations during 2019-20 and 2020-21 respectively. Similarly, DBM pupal population directed a collective influence of 56.60 per cent (R^2=0.566) and 50.00 per cent (R^2 = 0.500) during 2019-20 and 2020-21, respectively. The information is helpful for developing efficient pest management strategies against DBM populations in Southern Rajasthan and similar agro-ecological regions.

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