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Assessment of spatial distribution of *Plutella xylostella* on Cabbage (*Brassica oleracea* var. *capitata*)

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ABSTRACT

The present investigation aimed to study the distribution pattern of larvae and pupae of diamondback moth (DMB) on cabbage (*Brassica oleracea* var. *capitata* L.). The experiment was laid out in randomized block design at the Horticulture farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan during *rabi* 2019–20 and 2020–21. The present study was carried out to understand the pattern and behaviour of the spatial distribution of DBM in cabbage. The prevalence of DBM incidence was recorded in terms of the number of larvae and pupae per plant on ten randomly selected plants in each replication at weekly intervals. The various indices, viz. variance to mean ratio, exponent–K, patchiness index, clumping index, mean colony size, mean clump size, Iwao's patchiness regression and Taylor's power law were analyzed to test the dispersion behaviour of diamondback moth. The value of various indices exceeded unity in most of the weekly observations indicating clumped type of distribution of diamondback moth larvae and pupae on cabbage. Clumped distribution behaviour of DBM population can aid the understanding of the pest ecology and its management.

Keywords: Cabbage, Clumped distribution, Diamondback moth, *Plutella xylostella*, Population, Spatial distribution

Cole crops are one of the most abundantly consumed vegetables all over the world. They belong to the genus *Brassica* of the family Brassicaceae. Cabbage (*Brassica oleracea* var. *capitata* L.) is a leafy vegetable grown for its edible enlarged terminal bud. Several limiting factors have been attributed to its low production. Among them, the chief constraint is the damage caused by the insect pests right from germination till the harvesting stage. Diamondback moth (DBM) [*Plutella xylostella* (L.) (Lepidoptera: Plutellidae)] is ranked as the most important and destructive insect pest of cruciferous crops worldwide. DBM exhibits a marked preference to cabbage and cauliflower as these crops with fleshy and succulent leaves provide necessary olfactory and gustatory stimuli for successful selection and colonization (Dubey and Chand 1977). It destructs the crop by feeding on the foliage leading to a notable reduction in yield. The yield losses vary from 31–100% (Abraham and Padmanabhan 1968) and 52–100% (Anuradha 1997, Cardleron and Hare 1986).

The changing cropping pattern, monoculture, intensive cultivation of high yielding varieties, negligence to crop rotation, non-adoption of summer ploughing, negation of other cultural practices and injudicious use of insecticides have aggravated 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. Due to this, DBM has developed resistance to most commonly used insecticides (Sun *et al.* 1986, Zhou *et al.* 2011). The knowledge of the behaviour pattern of DBM is of major importance for the development of strategies to manage this pest. The study on the spatial distribution of DBM in cabbage cultivation is essential to develop a plan for integrated pest management, thereby, ensuring the optimization of sampling and control strategies. Therefore, the present investigation was undertaken to understand the pattern and behaviour of the spatial distribution of DBM in cabbage field at Udaipur, Rajasthan.

MATERIALS AND METHODS

The experiment was conducted at the Horticulture farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan during *rabi* 2019–20 and 2020–21. The layout for each experiment was designed with six uniform replications with plot size 4.5 m × 4.5 m, laid out in randomized block

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design. The seedlings of cabbage were transplanted in the last week of October, 2019–20 and the first week of November, 2020–21 to examine the spatial distribution of DBM larval and pupal stages. The crop was not sprayed by any of the insecticides and all other intercultural operations like hoeing, weeding, fertilizer application were performed as per the package of practices by MPUA&T, Udaipur, Rajasthan. The crop was kept under vigil for the appearance of DBM larvae and pupae in the course of each sampling. The observation of DBM larvae per plant on cabbage was recorded at weekly intervals during morning hours between 6:30 a.m. to 8.00 a.m. when pest activity was less active. The prevalence of DBM infestation was recorded in terms of the number of larvae and pupae per plant on ten randomly selected plants in each replication at weekly intervals.

The observed data from original counts were arranged in frequency tables for fitting the different statistical parameters to test the dispersion behaviour of the pest such as variance to mean ratio (Southwood 1978), exponent–K (Lloyd 1967), patchiness index (Lloyd 1967), clumping index (David and Moore 1954), mean colony size (Tanigoshi *et al.* 1975), mean clump size (Arbous and Kerrich 1951), Iwao's patchiness regression (Iwao's 1968) and Taylor's power law (Taylor 1961). Alpha (α) and beta (β) which were obtained from the regression of the mean crowding against mean density refers to the basic component of dispersion and the pattern of distribution, respectively (Iwao 1968). The regression constants 'a' and 'b' of Taylor's power law also indicate the sampling parameter and the aggregation index, respectively (Taylor 1961). The following formulae were fitted to test the analysis of spatial distribution.

$$\text{Dispersion index} = \frac{\text{variance}}{\text{mean}}$$

$$\text{Dispersion pattern (K)} = \frac{(\bar{x})^2}{s^2 - \bar{x}}$$

where, $\bar{x}$ = mean density; s^2 = variance

$$CV = \frac{\sigma}{\bar{x}} \times 100$$

where, s = standard deviation; $\bar{x}$ = mean

$$\text{Mean Crowding Index (X)} = \bar{x} + \left(\frac{s^2}{\bar{x}} - 1\right)$$

$$\text{Llyod's Patchiness Index} = \frac{X}{\bar{x}}$$

Taylor's power law: This gives a relation between variance and mean.

$$S^2 = a.x^b \text{ (Taylor 1961)}$$

where 'a' is a constant depending upon experimental conditions and 'b' is the coefficient of contagion.

Iwao's patchiness index relates mean crowding (X*) to mean density as:

$$X^* = \alpha + \beta X \text{ (Iwao 1968)}$$

where 'α' is the index of basic contagion and 'β' is the density contagiousness coefficient.

$$\text{Index of clumping} = \frac{s^2}{\bar{x}} - 1$$

Mean Colony Size = 1 + mean crowding

RESULTS AND DISCUSSION

The statistical parameters for testing the distribution pattern of DBM larvae during *rabi* 2019–20 and 2020–21 are presented in Table 1. The data revealed clumped larval distribution. The mean crowding index ranged from 6.82–93.23 and 6.96–103.70 during *rabi* 2019–20 and 2020–21, respectively. The Lloyd's index was 1.0 and above during both the years that also indicated the clumped type of distribution. The Iwao's patchiness regression was computed as X* = 0.4551 + 1.0059 $\bar{x}$ and X* = 0.067 + 1.0108 $\bar{x}$. The index of basic contagion (a) was positive during both the years. The positive values indicated that larval aggregation was in clump rather than individuals. The density contagiousness coefficient was b = 1.005 and 1.010, being greater than unity that suggests that the colonies were over dispersed. The regression equation based on Taylor's Power law was computed as log S^2 = 0.1095 + 1.0773 log $\bar{x}$ and S^2 = 0.3234 + 0.8356 log $\bar{x}$, respectively. The value of the index of the aggregation (b) was more than unity in both the years, thus confirming the aggregate nature of distribution. The clumping index (I_{DM}) values were all positive; mean crowding index (X^*) values were greater than mean density. Lloyd's Patchiness index values were equal to one and more, which confirmed the clumped nature of dispersion of DBM larvae. The mean colony size (C) also increased with the increase in number of DBM larvae.

Similarly, the resultant data on the distribution pattern of DBM pupae during *rabi* 2019–20 and 2020–21 are presented in Table 2. The data showed that the pupal population was observed as clumped larval. The mean crowding index ranged from 2.75 to 11.26 and 1.34 to 15.41 during *rabi* 2019–20 and 2020–21, respectively. The Lloyd's index was above 1.0 during both the years. The Iwao's patchiness regression was computed as X* = 1.2203 + 0.9993 $\bar{x}$ and X* = 0.5782 + 1.0211 $\bar{x}$. The index of basic contagion (a) was positive during both the years and indicated that pupal aggregation was in clump. The density contagiousness coefficient was b = 1.220 and 1.0211, being greater than unity that suggests that the colonies were overdispersed. The regression equation based on Taylor's Power law was computed as log S^2 = 0.3618 + 0.9484 log $\bar{x}$ and S^2 = 0.104 + 1.1541 log $\bar{x}$, respectively. The value of the index of aggregation (b) was more than unity in both the years, thus confirming the aggregate nature of the distribution. The clumping index (I_{DM}) values were all positive; mean crowding index (X^*) values were greater than mean density. Lloyd's Patchiness Index values were more than one, which confirmed the clumped nature of dispersion of DBM pupae.

The distribution pattern of DBM was clumped which corroborated the findings of Goswami and Mukhopadhyay

Table 1 Indices of spatial distribution of Diamondback moth larvae on cabbage

SMW	Mean density ($\bar{x}$)	Variance (s^2)	Variance to mean ratio ($s^2/\bar{x}$)	Dispersion pattern (K)	Co-efficient of variation (CV)	Mean Crowding Index (X^*)	Llyod's Patchiness Index	Clumping Index (I_{DM})	Mean colony size (C)	Pattern of distribution
					Rabi 2019–20					
48	6.17	10.17	1.65	9.51	0.52	6.82	1.11	0.65	7.82	C
49	8.83	12.97	1.47	18.88	0.41	9.30	1.05	0.47	10.30	C
50	11.33	17.47	1.54	20.94	0.37	11.87	1.05	0.54	12.87	C
51	20.50	38.70	1.89	23.09	0.30	21.39	1.04	0.89	22.39	C
52	26.17	38.97	1.49	53.49	0.24	26.66	1.02	0.49	27.66	C
1	35.17	66.17	1.88	39.89	0.23	36.05	1.03	0.88	37.05	C
2	41.67	46.27	1.11	377.42	0.16	41.78	1.00	0.11	42.78	C
3	46.50	81.10	1.74	62.49	0.19	47.24	1.02	0.74	48.24	C
4	54.83	104.17	1.90	60.95	0.19	55.73	1.02	0.90	56.73	C
5	62.67	128.27	2.05	59.86	0.18	63.71	1.02	1.05	64.71	C
6	67.17	79.37	1.18	369.78	0.13	67.35	1.00	0.18	68.35	C
7	73.00	110.80	1.52	140.98	0.14	73.52	1.01	0.52	74.52	C
8	82.00	167.60	2.04	78.55	0.16	83.04	1.01	1.04	84.04	C
9	86.50	186.30	2.15	74.97	0.16	87.65	1.01	1.15	88.65	C
10	91.83	219.77	2.39	65.92	0.16	93.23	1.02	1.39	94.23	C
					Rabi 2020–21					
49	6.50	9.50	1.46	14.08	0.47	6.96	1.07	0.46	7.96	C
50	8.67	9.87	1.14	62.59	0.36	8.81	1.02	0.14	9.81	C
51	16.17	26.17	1.62	26.14	0.32	16.79	1.04	0.62	17.79	C
52	23.17	28.17	1.22	107.34	0.23	23.38	1.01	0.22	24.38	C
1	30.67	52.27	1.70	43.54	0.24	31.37	1.02	0.70	32.37	C
2	42.83	45.37	1.06	724.22	0.16	42.89	1.00	0.06	43.89	C
3	48.33	96.67	2.00	48.33	0.20	49.33	1.02	1.00	50.33	C
4	55.33	72.67	1.31	176.64	0.15	55.65	1.01	0.31	56.65	C
5	62.00	69.60	1.12	505.79	0.13	62.12	1.00	0.12	63.12	C
6	71.17	85.77	1.21	346.90	0.13	71.37	1.00	0.21	72.37	C
7	82.00	157.60	1.92	88.94	0.15	82.92	1.01	0.92	83.92	C
8	86.83	97.37	1.12	715.83	0.11	86.95	1.00	0.12	87.95	C
9	92.83	196.17	2.11	83.40	0.15	93.95	1.01	1.11	94.95	C
10	95.33	256.67	2.69	56.33	0.17	97.03	1.02	1.69	98.03	C
11	101.50	325.10	3.20	46.07	0.18	103.70	1.02	2.20	104.70	C

C, Clumped; ($\bar{x}$) mean of 60 plants.

(2013). They studied the distribution pattern of larvae of DBM on cabbage under the Gangetic Alluvial condition of West Bengal in three consecutive cabbage seasons (early cabbage, on season cabbage and late cabbage) during 2009–10. Various indices, viz. dispersion parameter 'K', index of dispersion (Id), reciprocal of the exponent–K, Cole's Index, Charlier Coefficient, Lloyd index of mean crowding and Lloyd index of patchiness confirmed that the distribution pattern of the DBM larvae under the study in three crop seasons was aggregative. In similar way, Farias (2001) studied the distribution pattern of *Spodoptera frugiperda* (J. E. Smith) lepidopteran larvae and observed that *S. frugiperda* showed the aggregated distribution for the caterpillars in the field. Subharani and Singh (2009) conducted studies on the spatial distribution of Plume Moth, *Exelastis atomosa* (Wals) infested flower and pods of pigeonpea in the experimental field of the Life Sciences Department, Manipur University. Various indices of dispersion such as variance, variance to mean ratio, Lloyd's index of patchiness, mean crowding, Iwao's regression, and Taylor's power law were evaluated to study the distribution pattern and it was found that the distribution pattern of *E. atomosa* followed contagious behaviour on pigeonpea crop during both the years. Subharani and Singh

Table 2 Indices of spatial distribution of Diamondback moth pupae on cabbage

SMW	Mean density ($\bar{x}$)	Variance (s^2)	Variance to mean ratio ($s^2/\bar{x}$)	Dispersion pattern (K)	Co-efficient of variation (CV)	Mean Crowding Index (X^*)	Llyod's Patchiness Index	Clumping Index (I_{DM})	Mean colony size (C)	Pattern of distribution
					Rabi 2019–20					
52	1.67	3.47	2.08	1.54	1.12	2.75	1.65	1.08	3.75	C
1	2.67	5.87	2.20	2.22	0.91	3.87	1.45	1.20	4.87	C
2	4.33	9.47	2.18	3.66	0.71	5.52	1.27	1.18	6.52	C
3	7.33	9.87	1.35	21.23	0.43	7.68	1.05	0.35	8.68	C
4	15.33	54.27	3.54	6.04	0.48	17.87	1.17	2.54	18.87	C
5	20.67	47.07	2.28	16.18	0.33	21.94	1.06	1.28	22.94	C
6	26.67	71.47	2.68	15.87	0.32	28.35	1.06	1.68	29.35	C
7	42.33	117.47	2.77	23.85	0.26	44.11	1.04	1.77	45.11	C
8	64.50	101.10	1.57	113.67	0.16	65.07	1.01	0.57	66.07	C
9	20.33	34.67	1.70	28.84	0.29	21.04	1.03	0.70	22.04	C
10	10.33	19.87	1.92	11.20	0.43	11.26	1.09	0.92	12.26	C
					Rabi 2020–21					
1	1.17	1.37	1.17	6.81	1.00	1.34	1.15	0.17	2.34	C
2	2.00	4.00	2.00	2.00	1.00	3.00	1.50	1.00	4.00	C
3	4.67	9.47	2.03	4.54	0.66	5.70	1.22	1.03	6.70	C
4	10.17	14.17	1.39	25.84	0.37	10.56	1.04	0.39	11.56	C
5	14.00	16.00	1.14	98.00	0.29	14.14	1.01	0.14	15.14	C
6	21.33	42.27	1.98	21.74	0.30	22.31	1.05	0.98	23.31	C
7	19.83	34.17	1.72	27.44	0.29	20.56	1.04	0.72	21.56	C
8	40.83	103.37	2.53	26.66	0.25	42.36	1.04	1.53	43.36	C
9	70.83	161.37	2.28	55.42	0.18	72.11	1.02	1.28	73.11	C
10	33.67	155.87	4.63	9.28	0.37	37.30	1.11	3.63	38.30	C
11	15.00	21.20	1.41	36.29	0.31	15.41	1.03	0.41	16.41	C

C, Clumped; ($\bar{x}$) mean of 60 plants.

(2011) studied the spatial distribution of pod borer, *Cydia ptychora* (Meyrick) infested flower and pods of pigeonpea in the experimental field of the Department of Life Sciences, Manipur University, Imphal. They found that the distribution pattern of *C. ptychora* followed a contagious behaviour on pigeonpea crops during both the years of the experiment. In another study, Ferdinando *et al.* (2012) studied the spatial distribution of inactive stage (egg pods of the locust), *Dociostaurus maroccanus* (Thunberg) in two Apulian egg bed areas in southern Italy. In both egg bed areas, the variogram models were asymptotic with a small nugget effect and indicated an aggregated distribution of egg pods.

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