



## Assessment of spatial distribution of aphidophagous natural enemies on cabbage ecosystem

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### Abstract

The present investigation aimed to study the distribution pattern of aphidophagous natural enemies on cabbage ecosystem at Udaipur, Rajasthan. The coccinellid adult and syrphid maggot populations were recorded on 60 randomly selected plants at weekly interval. 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 analysed to test the dispersion behaviour. The result revealed that clumped or uniform or random distribution of coccinellid adults and syrphid maggots in cabbage field.

**Keywords:** spatial distribution, cabbage, coccinellid, syrphid and distribution pattern

### Introduction

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. It provides minerals such as P, K, Ca, Fe and also contains high percentage of vitamin A, B and C. The total area under cabbage cultivation in India is 3.99 lac ha with an annual production of 90.37 lac metric tonnes with 22.7 metric tonnes of an average productivity per ha, while in Rajasthan the total area and annual production is 1.20 lac ha and 11.69 lac metric tonnes with 9.74 metric tonnes productivity per ha, in the year 2017-18, respectively (Anonymous, 2018) [1]. Coccinellids are important and the most abundant predators of aphids in many agroecosystems (Rakhshani *et al.* 2010) [11]. The maggots of many syrphid flies are important natural enemies in different agro-ecosystem (Tenhumberg, 1995) [15]. The effective use of coccinellids and syrphids in pest management, therefore, depends on an understanding of how they move and distribute in the ecosystem. A fuller knowledge of the effect of habitat heterogeneity on the distribution of natural enemies is vital for the development of field augmentation strategies (Powell *et al.* 1995) [10]. Therefore, present investigation was taken to understand the pattern and behaviour of spatial distribution of coccinellids and syrphids in cabbage field at Udaipur, Rajasthan.

### Materials and Methods

The experiment was laid out during *Rabi*, 2019-20 and 2020-21 at the Horticulture farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur which is located at South Eastern part of Rajasthan. The seedlings of cabbage variety (Golden acre) were raised on a well-prepared nursery bed. The layout for each experiment was designed on the prepared field, with uniform six replications with plots sized of 4.5 m x 4.5 m laid out in randomized block design. The seedlings

of cabbage were transplanted in the last week of October, 2019-20 and first week of November, 2020-21 to examine the spatial distribution of coccinellid adult and syrphid maggot. All intercultural operations like hoeing, weeding, fertilizer application, irrigation, except insecticide application were performed as per the package of practices by MPUA & T, Udaipur, Rajasthan. The observation on coccinellid adult beetle and syrphid maggot per plant on cabbage was recorded at weekly intervals during morning hours between 6:30 a.m. to 8.00 a.m. The prevalence of coccinellid adult and syrphid maggot were recorded in terms of the number of adult beetles and maggot per plant on 10 randomly selected plants in each replication. Totally 60 plants were observed to estimate the population in weekly intervals.

The data from original counts were arranged in frequency tables for fitting the different statistical parameters. Variance to mean ratio (Southwood, 1978) [12], exponent - K (Lloyd, 1967) [8], patchiness index (Lloyd, 1967) [8], clumping index (David and Moore, 1954) [3], mean colony size (Tanigoshi *et al.* 1975) [13], mean clump size (Arbous and Kerrich, 1951) [2], Iwao's patchiness regression (Iwao, 1968) [6] and Taylor's power law (Taylor, 1961) [14] were analyzed to test the dispersion behaviour of the pest. Alpha ( $\alpha$ ) and beta ( $\beta$ ) 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) [6]. The regression constants 'a' and 'b' of Taylor's power law also indicated the sampling parameter and the aggregation index respectively (Taylor, 1961) [14].

The following formulae were fitted to the analysis of spatial distribution.

1. Dispersion index =

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

Where,  $\bar{x}$  = mean density

$s^2$  = variance

$$3. \quad CV = \frac{\sigma}{\bar{x}} \times 100$$

Where,  $s$  = standard deviation

$\bar{x}$  = mean

$$4. \quad \text{Mean Crowding Index (X)} = \bar{x} + \left(\frac{s^2}{\bar{x}} - 1\right)$$

$$5. \quad \text{Lloyd's Patchiness Index} = \frac{X}{\bar{x}}$$

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

$S^2 = a \cdot x^b$  (Taylor 1961) where 'a' is a constant depending upon experimental conditions and 'b' is the coefficient of contagion.

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

$X^* = \alpha + \beta X$  (Iwao 1968) where 'α' is the index of basic contagion and 'β' is the density contagiousness coefficient.

$$8. \quad \text{Index of Clumping} = \frac{s^2}{\bar{x}} - 1$$

$$9. \quad \text{Mean Colony Size} = 1 + \text{mean crowding}$$

## Results and Discussion

The statistical parameters for testing distribution pattern of coccinellid beetle have been presented in Table 1, 2 and Fig. 1, 2, 3 and 4 during *Rabi*, 2019-20 and 2020-21.

The results showed that the distribution pattern of coccinellids adult was clumped in most sampling. The values of variance to mean ratio exceeded unity in most of the sampling occasions indicating a contagious type of distribution. However, in 50<sup>th</sup>, 2<sup>nd</sup>, 4<sup>th</sup>, 7<sup>th</sup> and 9<sup>th</sup> SMW the distribution pattern was found uniform while in 8<sup>th</sup> SMW the random type of distribution appeared during the *Rabi*, 2019-20 season. Similarly, 50<sup>th</sup> and 4<sup>th</sup> SMW the distribution was recorded uniform, whereas in 5<sup>th</sup>, 7<sup>th</sup>, 8<sup>th</sup> and 9<sup>th</sup> SMW the distribution pattern was random during the *Rabi*, 2020-21 season. The variance to mean ratio greater than unity, but close to 1 have indicated that distribution pattern was close to random. The mean crowding index was ranged from 0.51-11.31 (Table 1) and 0.13 to 13.53 (Table 2) during *Rabi*, 2019-20 and 2020-21, respectively. The Lloyd's index was less than 1.0, near to 1.0 and above 1.0 during both the year that also indicated uniform, random and clumped type of distribution, respectively during the both the year. The Iwao's patchiness regression was computed as  $X^* = 0.53 + 0.9342 \bar{x}$  (Fig. 1) and  $X^* = 0.6135 + 0.9537 \bar{x}$  (Fig. 3) during *rabi*, 2019-20 and 2020-21, respectively. The regression equation based on Taylor's Power law was computed as  $\log S^2 = 0.1287 + 0.8402 \log \bar{x}$  (Fig. 2) and  $S^2 = 0.1528 + 0.9236 \log \bar{x}$  (Fig. 4), respectively. The value of the index of aggregation (b) were less, near to equal and more than unity in both the year, thus confirmed the all type of nature of distribution. The mean crowding index ( $X^*$ ) values were less than mean density, nearly equal to mean density and more than mean density

which showed uniform distribution, random and clumped types of distribution, respectively during the both years. Lloyd's Patchiness index values were less than one, equal to one and more, which also confirmed the all three types of dispersion of coccinellid beetle.

Similarly, the statistical parameters for testing distribution pattern of syrphid maggot have been presented in Table 3, 4 and fig. 5, 6, 7 and 8 during *Rabi*, 2019-20 and 2020-21. The results showed that the distribution pattern of syrphid maggot was clumped in most sampling. The values of variance to mean ratio exceeded unity in most of the sampling occasions indicating a contagious type of distribution. However, in 51<sup>st</sup>, 52<sup>nd</sup> and 4<sup>th</sup> SMW the distribution pattern was found uniform while in 6<sup>th</sup> and 9<sup>th</sup> SMW the random type of distribution appeared during the *Rabi*, 2019-20 season. Likewise, 52<sup>nd</sup>, 4<sup>th</sup>, 9<sup>th</sup> and 10<sup>th</sup> SMW the distribution was recorded uniform, whereas in 7<sup>th</sup> SMW the distribution pattern was found random during the *Rabi*, 2020-21 season. The mean crowding index was ranged from 0.13-12.93 (Table 3) and 0.80 to 18.35 (Table 4) during *Rabi*, 2019-20 and 2020-21, respectively. The Lloyd's index was less than 1.0, near to 1.0 and above 1.0 during both the year that also indicated uniform, random and clumped type of distribution, respectively during the both the year. The Iwao's patchiness regression was computed as  $X^* = 0.1299 + 1.0141 \bar{x}$  (Fig. 5) and  $X^* = 0.5073 + 0.9605 \bar{x}$  (Fig. 7) during *Rabi*, 2019-20 and 2020-21, respectively. The regression equation based on Taylor's Power law was computed as  $\log S^2 = 0.0028 + 1.1064 \log \bar{x}$  (Fig. 6) and  $S^2 = 0.1323 + 0.8526 \log \bar{x}$  (Fig. 8), respectively. The value of the index of aggregation (b) were less, near to equal and more than unity in both the year, thus confirmed the all type of nature of distribution. The mean crowding index ( $X^*$ ) values were less than mean density, nearly equal to mean density and more than mean density which showed uniform distribution, random and clumped types of distribution, respectively during the both years. Lloyd's Patchiness index values were less than one, equal to one and more, which also confirmed the all three types of dispersion of syrphid maggot.

Though many studies on the population dynamics of lady beetles have explained field interactions (Dreistadt and Flint, 1996 [4]; Grez and Prado, 2000 [5]; Wells and McPherson, 1999 [16]; Wright and Laing, 1980 [17]) most studies have focused solely on temporal synchrony lady beetles, assuming they were spatially coincident. Jamie *et al* (2001) [7] recorded that the aggregation of syrphids occurred in the field margin. Park and Obrycki (2004) [9] observed that lady beetle populations were aggregated during the peak population period and randomly distributed early and late in the season.

**Table 1:** Distribution pattern of Coccinellid adult on cabbage during *Rabi*, 2019-20

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)	Lloyd's patchiness index ( $X/\bar{x}$ )	Index of clumping (IDM)	Mean colony size (C)	Pattern of distribution
49	0.50	0.70	1.40	1.25	1.67	0.90	1.80	0.40	1.90	C
50	0.83	0.57	0.68	-2.60	0.90	0.51	0.62	-0.32	1.51	U
51	1.67	2.67	1.60	2.78	0.98	2.27	1.36	0.60	3.27	C

52	2.17	3.77	1.74	2.93	0.90	2.91	1.34	0.74	3.91	C
1	2.83	5.37	1.89	3.17	0.82	3.73	1.32	0.89	4.73	C
2	4.50	3.50	0.78	-20.25	0.42	4.28	0.95	-0.22	5.28	U
3	5.17	8.17	1.58	8.90	0.55	5.75	1.11	0.58	6.75	C
4	7.67	2.67	0.35	-11.76	0.21	7.01	0.91	-0.65	8.01	U
5	6.00	9.20	1.53	11.25	0.51	6.53	1.09	0.53	7.53	C
6	6.33	8.67	1.37	17.19	0.46	6.70	1.06	0.37	7.70	C
7	10.17	8.17	0.80	-51.68	0.28	9.97	0.98	-0.20	10.97	U
8	11.33	11.07	0.98	-481.67	0.29	11.31	1.00	-0.02	12.31	R
9	7.50	5.10	0.68	-23.44	0.30	7.18	0.96	-0.32	8.18	U
10	3.17	4.57	1.44	7.16	0.67	3.61	1.14	0.44	4.61	C

U- Uniform; C- Clumped; R- Random; ( $\bar{x}$ ) mean of 15 plants

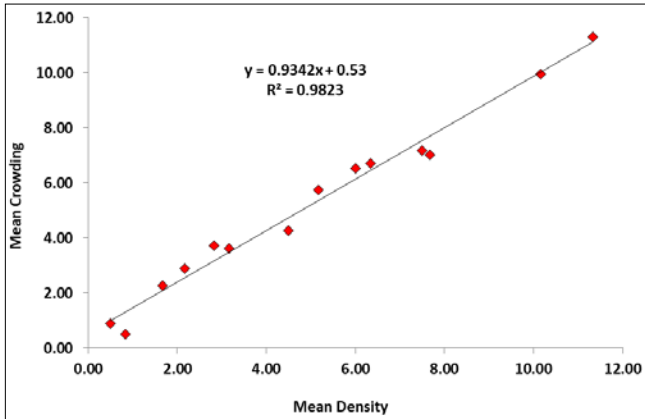


Fig 1: Iwao's Regression for mean crowding and mean density of coccinellid adult on cabbage during Rabi, 2019-20

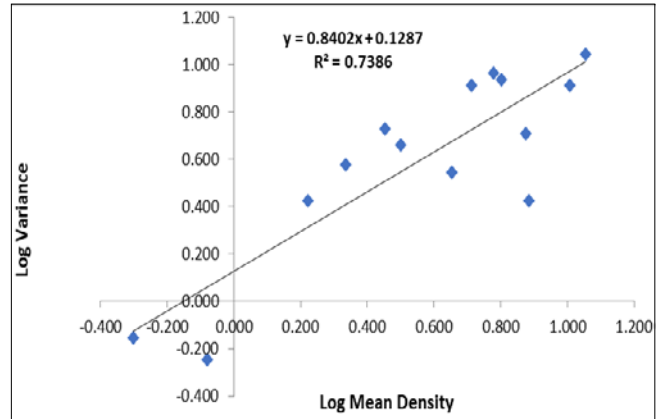


Fig 2: Regression of log variance on log mean density for coccinellid adult on cabbage during Rabi, 2019-20

Table 2: Distribution pattern of Coccinellid adult on cabbage during Rabi, 2020-21

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)	Lloyd's patchiness index ( $X/\bar{x}$ )	Index of clumping (IDM)	Mean colony size (C)	Pattern of distribution
49	0.67	1.47	2.20	0.56	1.82	1.87	2.80	1.20	2.87	C
50	0.33	0.27	0.80	-1.67	1.55	0.13	0.40	-0.20	1.13	U
51	1.33	2.27	1.70	1.90	1.13	2.03	1.53	0.70	3.03	C
52	2.00	3.20	1.60	3.33	0.89	2.60	1.30	0.60	3.60	C
1	2.17	3.37	1.55	3.91	0.85	2.72	1.26	0.55	3.72	C
2	3.00	4.40	1.47	6.43	0.70	3.47	1.16	0.47	4.47	C
3	4.83	8.17	1.69	7.01	0.59	5.52	1.14	0.69	6.52	C
4	6.17	4.57	0.74	-23.77	0.35	5.91	0.96	-0.26	6.91	U
5	8.17	7.37	0.90	-83.37	0.33	8.07	0.99	-0.10	9.07	R
6	7.17	13.37	1.87	8.28	0.51	8.03	1.12	0.87	9.03	C
7	13.50	13.90	1.03	455.63	0.28	13.53	1.00	0.03	14.53	R
8	9.17	8.57	0.93	-140.05	0.32	9.10	0.99	-0.07	10.10	R
9	10.83	10.17	0.94	-176.04	0.29	10.77	0.99	-0.06	11.77	R
10	9.50	15.50	1.63	15.04	0.41	10.13	1.07	0.63	11.13	C
11	4.83	6.17	1.28	17.52	0.51	5.11	1.06	0.28	6.11	C

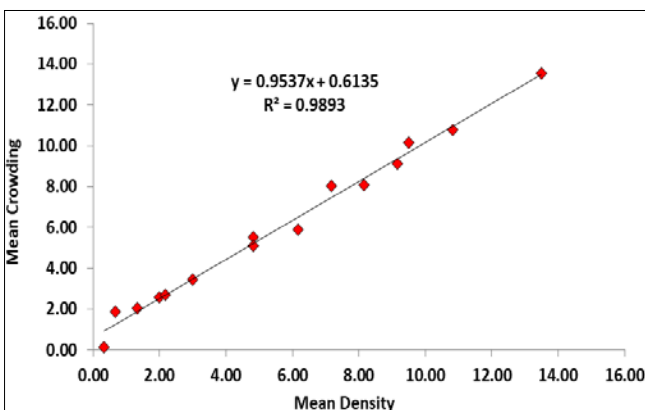


Fig 3: Iwao's Regression for mean crowding and mean density coccinellid adult on cabbage during Rabi, 2020-21

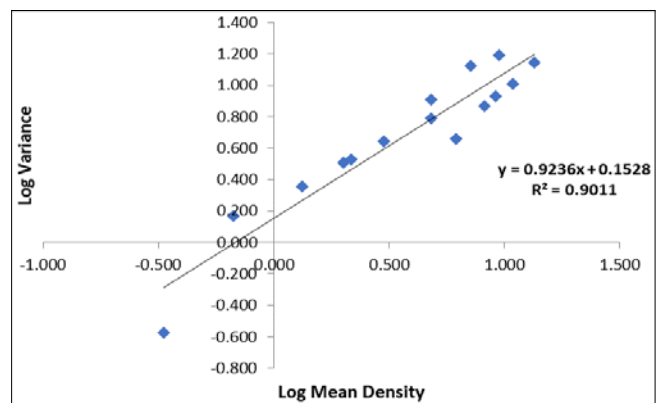
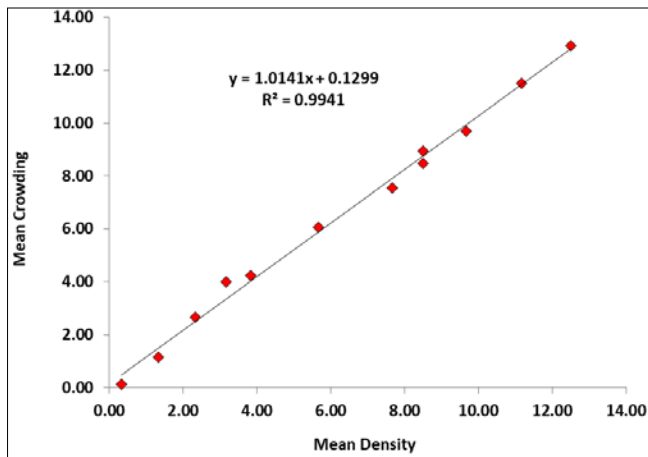


Fig 4: Regression of log variance on log mean density for coccinellid adult on cabbage during Rabi, 2020-21

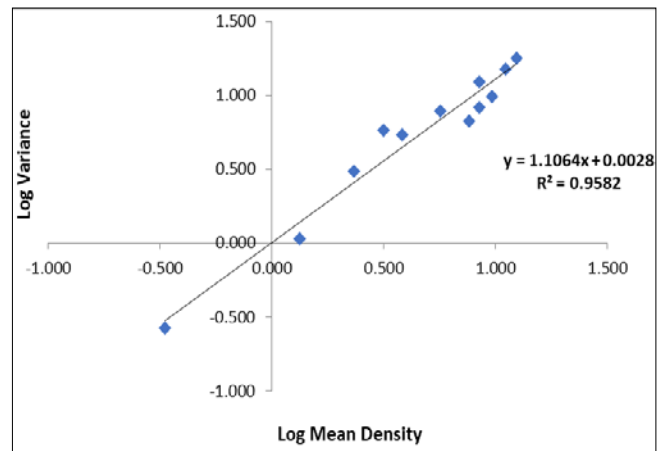
**Table 3:** Distribution pattern of syrphid maggot on cabbage during *Rabi*, 2019-20

SMW	Mean density ( $\bar{X}$ )	Variance (S <sup>2</sup> )	Variance to mean ratio (S <sup>2</sup> / $\bar{X}$ )	Dispersion pattern (K)	Co-efficient of variation (CV)	Mean crowding index (X)	Lloyd's patchiness index (X/ $\bar{X}$ )	Index of clumping (IDM)	Mean colony size (C)	Pattern of distribution
51	0.33	0.27	0.80	-1.67	1.55	0.13	0.40	-0.20	1.13	U
52	1.33	1.07	0.80	-6.67	0.77	1.13	0.85	-0.20	2.13	U
1	2.33	3.07	1.31	7.42	0.75	2.65	1.13	0.31	3.65	C
2	3.83	5.37	1.40	9.58	0.60	4.23	1.10	0.40	5.23	C
3	5.67	7.87	1.39	14.60	0.49	6.05	1.07	0.39	7.05	C
4	7.67	6.67	0.87	-58.78	0.34	7.54	0.98	-0.13	8.54	U
5	8.50	12.30	1.45	19.01	0.41	8.95	1.05	0.45	9.95	C
6	9.67	9.87	1.02	467.22	0.32	9.69	1.00	0.02	10.69	R
7	11.17	14.97	1.34	32.81	0.35	11.51	1.03	0.34	12.51	C
8	12.50	17.90	1.43	28.94	0.34	12.93	1.03	0.43	13.93	C
9	8.50	8.30	0.98	-361.25	0.34	8.48	1.00	-0.02	9.48	R
10	3.17	5.77	1.82	3.86	0.76	3.99	1.26	0.82	4.99	C

U- Uniform; C- Clumped; R- Random; ( $\bar{X}$ ) mean of 15 plants



**Fig 5:** Iwao's Regression for mean crowding and mean density of syrphid maggot on cabbage during *Rabi*, 2019-20

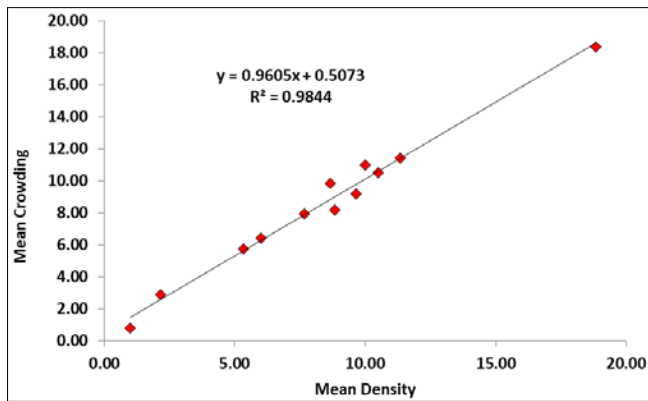


**Fig 6:** Regression of log variance on log mean density for syrphid maggot on cabbage during *Rabi*, 2019-20

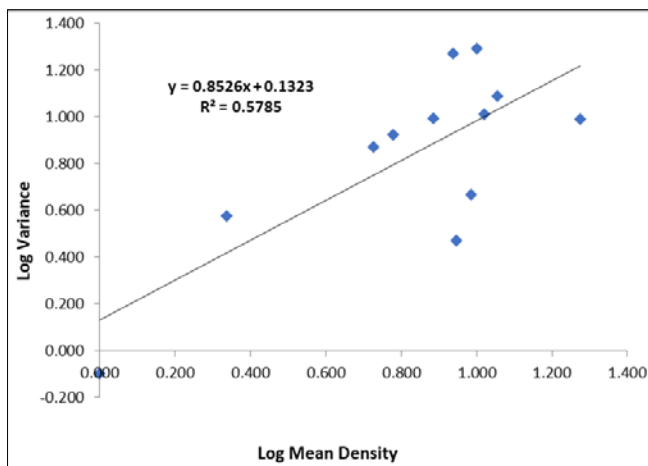
**Table 4:** Distribution pattern of syrphid maggot on cabbage during *Rabi*, 2020-21

SMW	Mean density ( $\bar{X}$ )	Variance (S <sup>2</sup> )	Variance to mean ratio (S <sup>2</sup> / $\bar{X}$ )	Dispersion pattern (K)	Co-efficient of variation (CV)	Mean crowding index (X)	Lloyd's patchiness index (X/ $\bar{X}$ )	Index of clumping (IDM)	Mean colony size (C)	Pattern of distribution
52	1.00	0.80	0.80	-5.00	0.89	0.80	0.80	-0.20	1.80	U
1	2.17	3.77	1.74	2.93	0.90	2.91	1.34	0.74	3.91	C
2	5.33	7.47	1.40	13.33	0.51	5.73	1.08	0.40	6.73	C
3	7.67	9.87	1.29	26.72	0.41	7.95	1.04	0.29	8.95	C
4	9.67	4.67	0.48	-18.69	0.22	9.15	0.95	-0.52	10.15	U
5	8.67	18.67	2.15	7.51	0.50	9.82	1.13	1.15	10.82	C
6	10.00	19.60	1.96	10.42	0.44	10.96	1.10	0.96	11.96	C
7	10.50	10.30	0.98	-551.25	0.31	10.48	1.00	-0.02	11.48	R
8	11.33	12.27	1.08	137.62	0.31	11.42	1.01	0.08	12.42	C
9	18.83	9.77	0.52	-39.12	0.17	18.35	0.97	-0.48	19.35	U
10	8.83	2.97	0.34	-13.30	0.19	8.17	0.92	-0.66	9.17	U
11	6.00	8.40	1.40	15.00	0.48	6.40	1.07	0.40	7.40	C

U- Uniform; C- Clumped; R- Random; ( $\bar{X}$ ) mean of 15 plants



**Fig 7:** Iwao's Regression for mean crowding and mean density syrphid maggot on cabbage during Rabi, 2020-21



**Fig 8:** Regression of log variance on log mean density for syrphid maggot on cabbage during Rabi, 2020-21

### Conclusion

The present investigation aimed to study the distribution pattern of aphidophagous natural enemies on cabbage ecosystem at Udaipur, Rajasthan and the coccinellid adult and syrphid maggot populations revealed that clumped, uniform or random distribution. The knowledge distribution of natural enemies is vital and can be explored for the development of field augmentation strategies.

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### Conflict of Interest Statement

We declare that we have no conflict of interest

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