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Population Dynamics of Natural Enemies in Okra Agro-ecosystem in Relation to Abiotic Factors

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Authors' contributions

This work was carried out in collaboration between both the authors. Both the author together designed the study. However, the statistical analysis was performed by author RK, protocol and first draft of the manuscript was also written by him. Author PPS supervised and managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The present experiment was carried out to access the relationship between population fluctuation of natural enemies and abiotic factors in okra agro-ecosystem at the Research Farm, Tirhut College of Agriculture, Dholi, Muzaffarpur (Bihar). From pooled data of two consecutive *Kharif* seasons i.e. 2018 and 2019 it was inferred that the highest coccinellids population was registered during 35th standard week (4.56 coccinellids/ 5 plant). Thereafter, the population gradually decreases and reached to 1.19 coccinellids/ 5 plant during 41st standard week i.e. end of the crop. Correlation studies of coccinellids population with abiotic factors indicated that the maximum temperature had positive and highly significant effect on coccinellids. While, minimum temperature and relative humidity at 7 hrs showed positive but non-significant effect on coccinellids. The relative humidity at 14 hrs and rainfall had negative and non-significant correlation with coccinellids population. All the weather parameters together governed 49.90 per cent to the coccinellids population build up (R^2 = 0.4990). In case of spider, incidence commenced in 27th standard week however, the maximum population (3.94 spiders/ 5 plant) was observed in 35th standard week. Correlation analysis of spider population with abiotic factors exhibited that the maximum temperature had highly significant and

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positive effect on spider population. Unlike it, minimum temperature and relative humidity at 7 hrs indicated positive and non-significant effect on spider population. However, the effect of relative humidity at 14 hrs and rainfall on spider population was found negative and non-significant. However, all the prevailing weather parameters together contributed 48.23 per cent towards spider incidence (R^2 = 0.4823).

Keywords: Okra; natural enemies; population fluctuation; abiotic factors.

1. INTRODUCTION

Okra, *Abelmoschus esculentus* is an important vegetable crop belongs to family Malvaceae [1]. The crop is attacked by 72 species of insect pests [2], while many species of mite belonging to the genus *Tetranychus* also infests okra [3]. The excessive use of non-recommended chemical insecticides has been noticed for controlling the pest of okra by farming community which causes many serious problems to the environment, animals, human being and natural enemies [4]. The recent trends of agriculture are mainly focused on sustainable crop production and optimizing chemicals use, thus promoting the natural pest control agents by conservation of natural enemies [5]. Population of natural enemies are influenced by both host availability and abiotic factors. Among natural enemies spiders, ants and coccinellids are main predators that causes reduction of insect pests of okra [5]. Spiders are present in all agro-ecosystems and have significant influence on the pests of different crops [4] while in okra agro-ecosystem coccinellids are also found to play vital role in minimizing the pest population especially sucking pests [1]. Despite their crucial role in maintaining the integrity of natural ecosystem, natural enemies have largely been ignored in conservation studies [6]. According to Intergovernmental Panel on Climate Change global mean surface temperatures have increased for 0.6 ºC since the late 19th century and it is estimated that by 2050 increase in temperature ranges from 0.8 ºC to 2.6 ºC whereas, by the end of 21st century it reaches up to 5.8 ºC. Rise in temperature perturbing the earth's energy balance by altering the properties of the atmosphere and the surface. Since, insects and spiders are poikilothermic in nature global warming could pose a greater risk to them [7]. The work done on this aspect seems to be very little in Bihar. Hence, an attempt was made to recognize the relationship between natural enemies population and abiotic factors in okra agro-ecosystem.

2. MATERIALS AND METHODS

In order to study the population dynamics of natural enemies of okra, a fixed plot survey was carried out by growing Kashi Pragati as a test variety. The crop was sown during two consecutive *Kharif* seasons i.e. 2018 and 2019, respectively. The row to row and plant to plant spacing was 50 cm and 20 cm, respectively. The whole plot was divided into 4 small sub-plots each measuring 5×5 m^2. Manurial and cultural practices were adopted as per recommended package of practices except insecticidal application. The population of natural enemies in okra agro-ecosystem was recorded on ten randomly selected plants in each sub-plot at weekly interval and average population per five plant was worked out. Sampling methods employed for the collection of spiders and coccinellids include visual searching and hand picking methods. Hand collection of the spiders and coccinellids was done by walking diagonally in the field. The collected samples were kept in polythene bag for further studies. Weekly data of different abiotic factors viz. maximum temperature (ºC), minimum temperature (ºC), relative humidity (7 hrs. & 14 hrs) and rainfall (mm) were simultaneously recorded from meteorological observatory, TCA Dholi and were finally subjected to correlation studies.

3. RESULTS AND DISCUSSION

During *Kharif*, 2018 the coccinellids appearence was first observed during 28th standard week (0.38 coccinellids/ 5 plant) Table 1. Moreover, its peak activity was found during 35th standard week (3.38 coccinellids/ 5 plant) when the prevailing abiotic factors viz. maximum temperature, minimum temperature, relative humidity at 7 hrs and 14 hrs and rainfall were 34.6 ºC, 25.7 ºC, 98.5 %, 76.8 % and 1.4 mm, respectively. Similarly, during *Kharif*, 2019 the number of coccinellids also varied throughout the crop period but the population was found comparatively higher (Table 2). A gradual rise in coccinellids number was observed from 27th to

34th standard week with numerically increased population per five plants (6.25 coccinellids/ 5 plant) in 34th standard week when maximum temperature, minimum temperature, relative humidity at 7 hrs and 14 hrs and rainfall were 34.9 ºC, 27.2 ºC, 98.7 %, 76.2 % and nil, respectively. Thereafter, the gradual decline was noticed in coccinellids population up to end of crop season (1.87 coccinellids/ 5 plant) i.e. 41st standard week. On pooled basis too, the population trend was more or less similar with the highest coccinellids during 35th standard week (4.56 coccinellids/ 5 plant) when maximum temperature, minimum temperature, relative humidity at 7 hrs and 14 hrs and rainfall were 34.2 ºC, 26.5 ºC, 98.5 %, 75.3 % and 0.7 mm, respectively (Table 3). Later, the population exhibited a gradual decrease and reached up to (1.19 coccinellids/ 5 plant) during 41st standard week. The present findings indicate that the population of coccinellids were maximum during high temperature and low rainfall thus it may be inferred that high temperature favours the growth and development of insects.

The present findings are in accordance with findings of [8] who reported that predator, *Chrysoperla carnea* preying on nymph and adult of *Amrasca biguttula biguttula* and the abiotic factors were closely related with pest population. They also concluded a high positive relationship between the pest and parasitoid indicating an important role in suppressing pest population to some extent exists. However, according to [9] the population of natural enemies of insect pests of okra crop habituating in plant with availability of food sources. Further, they reported that the highest population of natural enemies of aphid was recorded in February, i.e. 53.4 lady bird beetle/ plant and 7.02 syrphid/ plant. The peak activity of predator lady bird beetle was reported during second week of September (26 lady bird beetle/ plant), when the population of sucking pests viz. jassid, whitefly and aphid was at its peak [10]. The activity of natural enemies viz. spiders and coccinellids was also studies on okra during *Kharif* season by various workers in different parts of country [11,12].

During *Kharif*, 2018 the values of correlation coefficient (r) between coccinellids and weather parameters were varied remarkably (Table 4). The maximum temperature (r = 0.350), minimum temperature (r = 0.370) showed positive but non-significant correlation with coccinellids population. Further, it is observed that coccinellids population had negative and non-significant correlation with relative humidity at 7 hrs (r = -0.122) and rainfall (r = -0.088) whereas relative humidity at 14 hrs (r = -0.485*) had negative and significant correlation. However, all the weather parameters together contributed 31.57 per cent towards per cent fruit damage (R^2 = 0.3157). During *Kharif*, 2019 the effect of prevailing abiotic factors seems to be more pronounced on coccinellidss population than previous crop season, it might be due to high temperature and low rainfall which favours the pests population build up and thus natural enemies. A perusal of data summarized in Table 5, reveals that maximum temperature (r = 0.565), and relative humidity at 14 hrs (0.495) had positive and significant effect on coccinellids population while minimum temperature (r = 0.389) showed non-significant positive effect. Further, the correlation of coccinellids with relative humidity at 14 hrs (r = -0.275) and rainfall (r = -0.369) was found negative and non-significant. The cumulative effect of all the prevailing weather parameters viz. maximum temperature, minimum temperature, relative humidity at 7 hrs, 14 hrs and rainfall together constitute 75.52 per cent towards coccinellids population (R^2 = 0.7552). The pooled data presented in Table 6 shows more or less similar results comparative to both the years. The data indicated that maximum temperature (r = 0.615) had positive and highly significant effect on coccinellids population. While, minimum temperature and relative humidity at 7 hrs showed positive but non-significant effect on coccinellids population (r = 0.435 and 0.325 respectively). The relative humidity at 14 hrs (r = -0.444) and rainfall (r = -0.433) had negative and non-significant correlation with coccinellids population. While, all the weather parameters together governed 49.90 per cent to the coccinellids population build up (R^2 = 0.4990).

[9] evinced that the population of lady bird beetle were correlated positively but non-significantly with maximum temperature and minimum temperature which provide a good support to the present findings. Unlike it, [1] found that the coccinellids population had negative correlation with maximum and minimum temperature, rainfall and maximum and minimum relative humidity. Additionally, [13] also reported that the coccinellids were negatively correlated with maximum, minimum and mean temperature, rainfall and morning and evening relative humidity which varied from the results of present investigation. [14] revealed that minimum temperature and relative humidity had highly

significant effect on coccinellids population which varied from the present results.

The data pertaining to number of spiders per five plants have been presented in Table 1 reveals that during *Kharif*, 2018 the spider population was commenced during 28th standard week (0.65/ 5 plant). Afterwards, the population build up gradually up to 35th standard week and reached to its highest (3.00/ 5 plant) when corresponding weather parameters viz. maximum temperature, minimum temperature, relative humidity at 7 hrs and 14 hrs and rainfall were 34.6 ºC, 25.7 ºC, 98.5 %, 76.8 % and 1.4 mm, respectively. Subsequently, the population decline continuously till the end of cropping season but remains disappeared. Similar trend was also observed during *Kharif*, 2019 (Table 2) with some deviation. The spider population during this season was comparatively higher than previous season. Unlike previous season the activity of spiders were first reported during 27th standard week (0.85 spiders/ 5 plant). Whereas, the maximum population was reported during 34th standard week (5.37 spiders/ 5 plant) when the corresponding weather parameters were maximum temperature (34.90ºC), minimum temperature (27.20ºC), relative humidity at 7 hrs (98.70%) relative humidity at 14 hrs (76.20%) and rainfall (0.00 mm), respectively. On the basis of pooled mean of two years data viz; 2018 and 2019, presented in Table 3, that the spider incidence commenced (0.44 spiders/ 5 plant) with the pest appearance i.e. in 27th standard week. However, the maximum population (3.94 spiders/ 5 plant) was observed in 35th standard week when prevailing abiotic factors viz. maximum temperature, minimum temperature, relative humidity at 7 hrs and 14 hrs and rainfall were 34.2 ºC, 26.5 ºC, 98.5 %, 75.3 % and 0.7 mm, respectively. The spider population thereafter showed a declining trend but remains active throughout the crop season.

From the present experimental findings, it is quite clear that the spider incidence commenced (0.44 spiders/ 5 plant) with the pest appearance i.e. in 27th standard week. However, the maximum population (3.94 spiders/ 5 plant) was observed in 35th standard week. The spider population thereafter showed a decline trend but remains active throughout the crop season. The activity of natural enemies viz. spiders and coccinellids was also studied by various workers in different parts of country on okra during *Kharif* season [11,12]. [15] reported that the important species of spider dominated in lady's fingers field were *Argiopeluzona*, *Cryptophora cicatrosa*, *Hipassa pantherina*, *Oxyopes javanes* and *Lycosa pseudoannulata*. He also reported that the peak spider activity (3.94/ plant) was recorded in May (20th standard week). However, spider population was high during April-May and August-September (standard week 12-22 and 31-39), respectively which rendered significant variation and thus, support the present findings.

During *Kharif*, 2018 spider population had positive and non-significant correlation with maximum temperature (r = 0.465) and minimum temperature (r = 0.325) Table 4. Further, the remaining abiotic factors viz. relative humidity at 7 hrs (r = - 0.007), 14 hrs (r = - 0.292) and rainfall (r = - 0.119) showed negative and non-significant correlation. However, all the prevailing abiotic factors viz. maximum temperature, minimum temperature, relative humidity at 7 hrs, 14 hrs and rainfall collectively governed 26.35 per cent towards spider build up (R^2 = 0.2635). During the subsequent crop season i.e. *Kharif*, 2019 the effect of weather parameters on spider population was found more significant it might be due to high temperature and low rainfall which favours the pests population build up and thus natural enemies (Table 5). The correlation of spider population with maximum temperature, and relative humidity (14 hrs.) had positive and significant effect (r = 0.506 and 0.509 respectively) while minimum temperature (r = 0.347) showed non-significant and positive correlation. Further, spider correlation with relative humidity at 14 hrs (r = - 0.208) and rainfall (r = - 0.336) was found negative and non-significant. However, the effect of all the weather parameters together constituted 72.00 per cent towards spider population build up (R^2 = 0.7200). It is apparent from the pooled data presented in Table 6 that more or less similar results were found comparative to both the seasons. The maximum temperature showed highly significant and positive effect (r = 0.63) on spider population. Unlike it, minimum temperature (r = 0.455) and relative humidity at 7 hrs (r = 0.330) indicated positive and non-significant effect on spider population. While, effect of relative humidity at 14 hrs (r = - 0.398) and rainfall (r = - 0.394) on spider population was found negative and non-significant. However, all the prevailing weather parameters viz. maximum temperature, minimum temperature, relative humidity at 7 hrs, 14 hrs and rainfall together contributed 48.23 per cent towards spider incidence (R^2 = 0.4823).

Table 1. Population dynamics of natural enemies on okra cv kashi pragati in relation to prevailing weather parameters during kharif 2018

Standard week	Mean number		Weather parameters				
	Coccinellids/ 5 plant	Spiders/ 5 plant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
			Maximum	Minimum	7 hrs	14 hrs	
27	0.00	0.00	32.50	26.00	96.00	73.00	0.00
28	0.38	0.65	33.20	25.50	99.10	76.10	27.71
29	0.63	1.13	33.30	25.80	99.00	76.50	0.00
30	0.75	1.50	34.50	26.30	98.50	81.20	9.06
31	1.25	1.75	35.20	25.20	99.10	83.10	11.14
32	1.63	2.13	33.50	26.00	98.40	78.80	0.00
33	1.88	2.25	35.80	26.00	98.50	77.20	2.63
34	2.75	2.50	36.60	27.50	96.50	62.20	0.00
35	3.38	3.00	34.60	25.70	98.50	76.80	1.43
36	3.25	2.88	32.50	27.00	93.70	67.10	13.40
37	2.63	2.38	33.30	25.60	98.80	74.50	6.63
38	2.25	2.00	33.20	25.00	98.50	76.50	10.00
39	1.50	1.38	33.70	25.30	85.10	72.70	0.00
40	1.38	1.00	33.40	26.60	99.00	74.50	1.57
41	0.50	0.88	31.50	24.40	99.10	83.70	0.00

Table 2. Population dynamics of natural enemies on okra cv kashi pragati in relation to prevailing weather parameters during kharif 2019

Standard week	Mean number		Weather parameters				
	Coccinellids/ 5 plant	Spiders/ 5 plant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
			Maximum	Minimum	7 hrs	14 hrs	
27	0.75	0.87	33.30	27.20	87.20	80.80	10.97
28	1.25	1.37	30.00	24.90	95.50	83.50	33.37
29	1.87	1.75	29.30	27.60	94.80	71.20	0.00
30	2.50	2.25	32.80	26.30	97.00	92.10	34.23
31	3.25	2.87	32.80	27.30	96.40	83.40	0.00
32	4.25	3.62	33.20	27.10	94.20	74.50	10.83
33	5.50	4.62	32.80	26.10	97.00	82.70	11.40
34	6.25	5.37	34.90	27.20	98.70	76.20	0.00
35	5.75	4.87	33.80	27.40	98.50	73.80	0.00

Standard week	Mean number		Weather parameters				
	Coccinellids/ 5 plant	Spiders/ 5 plant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
			Maximum	Minimum	7 hrs	14 hrs	
36	4.50	4.12	32.50	27.10	97.70	83.40	0.00
37	3.75	3.37	32.00	26.00	98.00	82.10	9.57
38	3.12	3.00	30.20	24.90	97.50	86.50	7.91
39	2.62	2.75	28.20	23.30	99.00	96.20	27.60
40	2.50	2.37	29.20	23.70	97.10	85.50	0.00
41	1.87	1.50	32.00	22.40	99.10	79.00	0.00

Table 3. Population dynamics of natural enemies on okra cv. kashi pragati in relation to prevailing weather parameters (based on pooled mean of two crop seasons i.e. kharif 2018 and 2019)

Standard week	Mean number		Weather parameters				
	Coccinellids/ 5 plant	Spiders/ 5 plant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
			Maximum	Minimum	7 hrs	14 hrs	
27	0.38	0.44	32.90	26.60	91.60	76.90	5.49
28	0.81	1.01	31.60	25.20	97.30	79.80	30.54
29	1.25	1.44	31.30	26.70	96.90	73.85	17.12
30	1.63	1.88	33.65	26.30	97.75	86.65	4.53
31	2.25	2.31	34.00	26.25	97.75	83.25	5.57
32	2.94	2.87	33.35	26.55	96.30	76.65	5.42
33	3.69	3.44	34.30	26.05	97.75	79.95	7.02
34	4.50	3.90	35.75	27.35	97.60	69.20	0.00
35	4.56	3.94	34.20	26.55	98.50	75.30	0.72
36	3.88	3.50	32.50	27.05	95.70	75.25	6.70
37	3.19	2.87	32.65	25.80	98.40	78.30	8.10
38	2.69	2.50	31.70	24.95	98.00	81.50	8.96
39	2.06	2.06	30.95	24.30	92.05	84.45	13.80
40	1.94	1.69	31.30	25.15	98.05	80.00	0.79
41	1.19	1.15	31.75	23.40	99.10	81.35	0.00

Table 4. Correlation coefficient and regression equation between weather parameters (X) and population of natural enemies (Y) during *kharif* 2018

Sl. No.	Natural enemies	Correlation coefficient (r)					Multiple regression equation	R^2 (%)
		(X_1)	(X_2)	(X_3)	(X_4)	(X_5)		
1.	Coccinellids	0.350	0.370	–0.122	–0.485	–0.088	Y = + 6.961 + 0.228 (X_1) – 0.290 (X_2) – 0.036 (X_3) – 0.120 (X_4) – 0.007 (X_5)	31.57
2.	Spiders	0.465	0.325	–0.007	–0.292	–0.119	Y = – 4.779 + 0.263 (X_1) – 0.058 (X_2) + 0.024 (X_3) – 0.043 (X_4) – 0.008 (X_5)	26.35

Weather parameters: X_1 - maximum temperature (ºC), X_2 - minimum temperature (ºC), X_3 - relative humidity at 7 hrs (%), X_4 – relative humidity at 14 hrs (%) and X_5 - rainfall (mm)
Coefficient of determination (R^2)

Table 5. Correlation coefficient and regression equation between weather parameters (x) and population of natural enemies (y) during kharif 2019

Sl. No.	Natural enemies	Correlation coefficient (r)					Multiple regression equation	R^2 (%)
		(X_1)	(X_2)	(X_3)	(X_4)	(X_5)		
1.	Coccinellids	0.565*	0.389	0.495*	–0.275	–0.369	Y = – 55.584 + 0.327 (X_1) + 0.416 (X_2) + 0.384 (X_3) + 0.011 (X_4) – 0.017 (X_5)	75.52
2.	Spiders	0.506*	0.347	0.509*	–0.208	–0.336	Y = – 46.733 + 0.219 (X_1) + 0.393 (X_2) + 0.318 (X_3) + 0.025 (X_4) – 0.016 (X_5)	72.00

Weather parameters: X_1 - maximum temperature (ºC), X_2 - minimum temperature (ºC), X_3 - relative humidity at 7 hrs (%), X_4 – relative humidity at 14 hrs (%) and X_5 - rainfall (mm), Coefficient of determination (R^2)
**Significant at P = 0.01*

Table 6. Correlation coefficient and regression equation between weather parameters (x) and population of natural enemies (y) (based on pooled mean of two crop seasons i.e. kharif 2018 and 2019)

Sl. No.	Pests	Correlation coefficient (r)					Multiple regression equation	R^2 (%)
		(X_1)	(X_2)	(X_3)	(X_4)	(X_5)		
1.	Coccinellids	0.615**	0.435	0.325	–0.444	–0.433	Y = – 14.694 + 0.354 (X_1) + 0.023 (X_2) + 0.119 (X_3) – 0.080 (X_4) – 0.029 (X_5)	49.90
2.	Spiders	0.630**	0.455	0.330	–0.398	–0.394	Y = – 16.819 + 0.314 (X_1) + 0.089 (X_2) + 0.106 (X_3) – 0.044 (X_4) – 0.016 (X_5)	48.23

Weather parameters: X_1 - maximum temperature (ºC), X_2 - minimum temperature (ºC), X_3 - relative humidity at 7 hrs (%), X_4 – relative humidity at 14 hrs (%) and X_5 - rainfall (mm), Coefficient of determination (R^2)
**Significant at P = 0.01

Very few information is available on population dynamics of spiders with abiotic factors in literature. Although, [15] showed non-significant positive correlation of different spiders with average temperature and relative humidity but non-significant negative correlation with weekly total rainfall which in partial agreement with the present investigation. In actual the spider or any natural enemies are not too much affected by abiotic factors but it is mainly affected by pests' densities. [14] revealed that minimum temperature and relative humidity had highly significant effect on spiders population which varied from the present results.

4. CONCLUSION

From the above discussion it may be concluded that the coccinellids population in okra agro-ecosystem was high during 35th standard week while its appearance was observed from 28th to 41st standard week. The incidence of spider was commenced during 27th standard week with its peak during 35th standard week. The correlation study evinced that the affect of temperature on coccinellids and arachnids was positive and highly significant whereas relative humidity at 14 hrs and rainfall shows negative association. Moreover, the relative humidity at 7 hrs and minimum temperature had poor positive correlation with coccinellids and spiders. All the weather parameters together governed 49.90 % and 48.23 % towards coccinellids and spider population build up, respectively. Thus it seems to appear that abiotic factors not only controlled the population fluctuation of coccinellids and arachnids but presence of food i.e. pests population also play a crucial role.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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