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Population Dynamics of Natural Enemies of Stem Borer Complex and their Correlation with Weather Parameters in Rice Ecosystem

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out at the Murjhad Research Farm, College of Agriculture Balaghat, during *Kharif* 2022 and *Kharif* 2023 to ascertain the population dynamics of natural enemies of stem borer complex, their relative abundance and correlation with abiotic factors in order to propose ecologically and financially feasible measures. Results reveal that spiders, mirid bugs, coccinellids, odonata, staphylinids, cicindelids and carabids were the most prevalent natural enemies in the rice

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ecosystem. The pooled results revealed that the population of spiders was first observed during the 31st SMW (0.10 spiders/hill) with its peak during the 40th SMW (1.21 spiders/hill). Population of mirid bugs was first observed during the 31st SMW (0.45 mirid bugs/ hill) with its peak during the 39th SMW (2.45 mirid bugs/ hill). The population of adult beetles of coccinellids was first observed during the 31st SMW (0.92 ladybird beetles/sq m) with its peak during the 40th SMW (13.51 ladybird beetles/sq m). The population of adult dragonflies and damselflies was first observed during the 30th SMW (0.40 dragonflies and damselflies/sq m) with its peak during the 38th SMW (8.28 dragonflies and damselflies/sq m). The population of adult staphylinids was first observed during the 30th SMW (1.50 adults/sq m) with its peak during the 38th SMW (18.00 adults/ sq m). The population of adult cicindelids was first observed during the 32nd SMW (0.24 adults/sq m) with its peak during the 37th SMW (0.70 adults/sq m). The population of adult beetles of carabids was first observed during the 30th SMW (0.23 adults/sq m) with its peak during the 39th SMW (3.69 adults/sq m). The pooled data on relative abundance revealed that a total of 385.55 adults of natural enemies were observed throughout the crop growth. Of them, 2.39% were spiders, 3.06% were mirid bugs, 26.78% were ladybird beetles, 18.80% were odonata, 40.98% were staphylinids, 1.14% were cicindelids, 6.85% were carabid beetles. The pooled data on correlation studies revealed that population of spiders was found significantly negative correlated with evaporation and wind velocity. (r= -0.677 and -0.568, respectively) The adult population of mirid bugs found significantly positive correlated with morning RH and evening RH (r= 0.658 and 0.594, respectively). The adult population of coccinellids, odonata and staphylinids was not found significant with any whether parameters. The adult population of cicindelids found significantly positive correlated with morning RH and evening RH (r= 0.666 and 0.644, respectively). The adult population of carabids found significantly positive correlated with morning RH and evening RH (r= 0.587 and 0.545, respectively).

Keywords: Abiotic factors; abundance; parasitoids; predators; seasonal incidence etc.

1. INTRODUCTION

Rice, *Oryza sativa* (L.) is an important cereal crop in the world belongs to the family Gramineae/Poaceae and being one of the most important cereal crops worldwide feeding more than 50 % of the human population [1]. World rice production in 2021 was 502.98 million metric tons in an area of 165.25 million hectares. China and India are considered the main producers of paddy rice worldwide. In 2021, India's paddy rice production amounted to over 195 million metric tons in an area of about 45 million hectares after China [2, 3]. In Madhya Pradesh, paddy is grown in an area of about 21.17 mha with a production of 44.14 million tons and productivity of 2085 kg/ha [4], while in the Balaghat region, it is grown on about 3.10 lakh ha area with a production of 10.25 million mt and the productivity of 3305 kg/ha [5]. Considering the area, production and productivity of Balaghat district is referred to be the "Paddy Bowl" of Madhya Pradesh.

Several investigations have revealed that rice ecosystem is very rich in natural enemies which are very useful in reducing the yield loss [6]. Predators as biocontrol agents, may be more important, because the majority of parasitoids are relatively host specific whereas, most predators are regarded as polyphagous. Amongst the predators on rice pests, spiders and coccinellids were important. Spiders alone constitute 80 percent of predatory fauna in rice ecosystem. [7] studied the population dynamics of natural enemies of stem borer complex of rice and reported that spiders, ladybird beetle, ground beetle, mirid bug, dragonfly, damselfly were observed as prevalent natural enemies during Kharif, 2016 and Kharif, 2017. Parasappa [8] surveyed the natural enemies of stem borer complex of rice under different rice ecosystems viz., manual, mechanical, aerobic and drill sown method revealed that 30 natural enemies were recorded to harbour the bund flora of selected rice fields during 2013-14. All these flowering plants were bund harboured natural enemies such as predators namely, spiders, odonata, mirids, coccinellids, carabids, cicindelids, staphylinids. However, various egg parasitoids such as Trichogramma sp., Telenomus sp. and Tetrastichus sp. have also been reported in suppression of rice stem borer in rice ecosystem by natural parasitism of yellow stem borer eggs to a maximum of 95.00 per cent [9, 10, 11] have reported the natural parasitism of YSB eggs by parasitoid species such as Telenomus dignus Gahan, Tetrastichus schoenobii Ferriere and Trichogramma japonicum Ashmead.

Studying the population dynamics of natural enemies combating the stem borer complex in rice crops is crucial for effective pest control and sustainable agriculture. These natural adversaries, like predators and parasitoids, regulate pest populations, minimizing crop damage. Understanding their fluctuations enables predictive pest management strategies and reduces reliance on chemical pesticides, promoting environmentally friendly agricultural practices. By fostering these beneficial organisms, farmers can enhance ecological balance, protect rice crops, and establish long-term, sustainable farming methods through integrated pest management approaches. In view of the above, the present study was conducted to examine the influence of abiotic factors on the occurrence and relative dominance of natural enemies of stem borer complex in rice ecosystem.

2. MATERIALS AND METHODS

A field experiment was carried out at Murjhad farm of College of Agriculture, Balaghat (M.P.) during the Kharif seasons of 2022 and 2023 in order to investigate the population dynamics of natural enemies of rice stem borer complex and their correlation with weather parameters. For this purpose, the nursery was raised with a well-established susceptible variety JRB-1 in the second fortnight of June. For transplanting, the main field was prepared by ploughing once by tractor drawn disc plough and second ploughing was done by mound board plough. In the second fortnight of July, the rice was transplanted with 15cm (plant to plant) x 15cm (row to row) spacing in 15m x 20m (300 sq. m.) plot area. Before transplanting the seedlings into main plots, the recommended doses of fertilizers (N: P: K: 100:60:40) were applied. All the recommended agronomic practices were conducted but there was no application of any pesticides during the crop season.

The observations on the population dynamics of natural enemies of stem borer complex were recorded at weekly intervals starting from their first appearance up to the harvesting of the crop. A total of 5 spots (5m x 6m each) were fixed for the recording the observations in 300 m2 plot area. The number of spiders and mirid bugs were visually counted on randomly selected 20 hills from the randomly marked $1m^2$ area at three places in each of the 5 fixed spots at weekly intervals and the population was averaged to per hill basis. The number of adult odonatans were counted by sweeping net 5 times on the top of the crop canopy from the randomly marked $1m^2$ area at three places in each of the fixed spots and the population was averaged to number of adults per square meter. For the population of carabids, cicindelid beetles, coccinellid beetles, staphylinid beetles, the number of adults were counted by visually observing the randomly marked $1m^2$ area at three places in each of the fixed spots by visually observing the plants and the population was averaged to number of adults per square meter. The relative abundance of natural enemies of stem borer complex based on number of adults during the study period was assessed by the following formula:

> Relative abundance (%) = (Total no. of individuals of each species) / (Total no. of individuals of all species) x 100

3. RESULTS AND DISCUSSION

The results revealed that spiders, mirid bugs, coccinellids, odonata, staphylinids, cicindelids and carabids, were the most prevalent natural enemies of stem borer complex recorded in the rice ecosystem. These results are supported by Kumar et al [12] who reported the most common and dominant predators of rice ecosystem as spiders, coccinellids, staphylinids, mirids, damsel flies and dragon flies.

The pooled data of the adult population of spiders and mirid bugs per hill are presented in Table 1. The results revealed that the population of spiders was first observed during the 31st SMW (0.10 spiders/ hill). Further, it gradually increased and attained its peak during the 40th SMW (1.21 spiders/ hill) and thereafter the population started decreasing and reached 0.60 spiders/ hill during 44th SMW. Population of mirid bugs was first observed during the 31st SMW (0.45 mirid bugs/ hill). Further, it gradually increased and attained its peak during the 39th SMW (2.45 mirid bugs/ hill) and thereafter the population started decreasing and reached 0.04 mirid bugs/ hill during 44th SMW. The present results are supported by the findings of Samrit et al [13] who reported that the peak population of spiders was observed at 47th SMW (0.67 nos./hill). Joseph and Premila [14] also studied the relative abundance and species richness of spiders and found that a total of 65 species of spiders, hunters and web builders belonging to 11 families and 7 guilds was recorded. Also, [15] also reported that among the predators, spiders and mirids were the most important natural enemies. The results reported by Baruah and Dutta [16] partially supports the present findings.

Table 1. Population dynamics of natural enemies of stem borer complex (spiders and mirid bug) in rice ecosystem

SMW	No. of adults/ hill					
	Spiders			Mirid Bugs		
	2022	2023	Pooled	2022	2023	Pooled
30	0.00	0.00	0.00	0.00	0.00	0.00
31	0.14	0.06	0.10	0.62	0.28	0.45
32	0.26	0.09	0.18	0.86	0.66	0.76
33	0.38	0.13	0.26	0.87	0.76	0.82
34	0.52	0.31	0.42	0.95	0.92	0.94
35	0.62	0.49	0.56	0.96	0.98	0.97
36	0.69	0.68	0.69	0.96	0.99	0.98
37	0.81	0.82	0.82	1.22	1.92	1.57
38	0.92	0.92	0.92	1.96	2.20	2.08
39	0.95	0.98	0.97	2.10	2.80	2.45
40	1.10	1.32	1.21	0.01	0.01	0.01
41	0.85	0.88	0.87	0.36	0.34	0.35
42	0.84	0.93	0.89	0.28	0.25	0.27
43	0.73	0.79	0.76	0.14	0.09	0.12
44	0.66	0.53	0.60	0.04	0.04	0.04

The pooled data of the adult population of Coccinellids, Odonata, Staphylinids, Cicindelids and Carabids are presented in Table 2. The results revealed that the population of adult beetles of coccinellids was first observed during the 31st SMW (0.92 ladybird beetles/ sq m). Further, it gradually increased and attained its peak during the 40th SMW (13.51 ladybird beetles/ sq m) and thereafter the population started decreasing and reached 3.91 ladybird beetles/ sq m during 44th SMW. The population of adult dragonflies and damselflies was first observed during the 30th SMW (0.40 dragonflies and damselflies/ sq m). Further, it gradually increased and attained its peak during the 38th SMW (8.28 dragonflies and damselflies/ sq m) and thereafter the population started decreasing and reached 3.91 dragonflies and damselflies/ sq m during 44th SMW. The population of adult staphylinids was first observed during the 30th SMW (1.50 adults/ sq m). Further, it gradually increased and attained its peak during the 38th SMW (18.00 adults/ sq m) and thereafter the population started decreasing and reached 6.00 adults/ sq m during 44th SMW. The population of adult cicindelids was first observed during the 32nd SMW (0.24 adults/ sq m). Further, it gradually increased and attained its peak during the 37th SMW (0.70 adults/ sq m) and thereafter the population started decreasing and reached 0.08 adults/ sq m during 43rd and 44th SMW. The population of adult beetles of carabids was first observed during the 30th SMW (0.23 adults/ sq m). Further, it gradually increased and attained its peak during the 39th SMW (3.69 adults/ sq m) and thereafter the population started decreasing and reached 0.50 adults/ sq m during 44th SMW. The present results are in strong agreement with the findings of Parasappa et al [17] who reported that, predators such as spiders, dragon and damselflies, mirid bugs, coccinellids, carabids and cicindelids were found throughout the crop growing period. However, spiders, dragonfly, damselfly and coccinellids were more during the vegetative stage of the crop, whereas mirids, Staphylinids and cicindelids were more during reproductive stage of the crop. It is well known that the populations of all known predators and their prey are closely associated. Additionally, the current results are in consistent with Mondal and Chakraborty [18] who reported that at rice seedling growth stage, incidence of lady bird beetle population (14.21 individuals/ hill) was lowest. The highest LBB population (137.55 individuals/ 5 hill) was observed at the tillering growth stage.

Also, the highest number of damselflies was recorded in tillering stage (12.55 individuals/5 hills) and lowest in seedling stage (7.63 individuals/ 5 hills). Numerically the highest number of dragonflies was found in heading stage (4.44 individuals/5 hills) and lowest in tillering stage (3.85 individuals/5 hills) and lowest in heading stage (3.00 individuals/ 5 hills). Occurrence of wasp populations is lowest in heading stage (2.10 individuals/ 5 hill). Moreover, [18] revealed that the highest population of carabid predator, Eudema tomentosus (8.4 beetles /m2) was recorded at about 56 DAT. [14]

Table 2. Population dynamics of natural enemies of stem borer complex in rice ecosystem

SMW	Coccinellids			Odonata			Staphylinids			Cicindelids			Carabids		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
30	0.00	0.00	0.00	0.22	0.58	0.40	1.00	2.00	1.50	0.00	0.00	0.00	0.25	0.20	0.23
31	0.95	0.88	0.92	2.17	1.53	1.85	5.00	5.00	5.00	0.00	0.00	0.00	0.52	0.42	0.47
32	1.31	1.05	1.18	2.85	2.04	2.45	7.00	7.00	7.00	0.30	0.18	0.24	1.11	1.11	1.11
33	3.72	2.88	3.30	4.52	3.23	3.88	11.00	8.00	9.50	0.40	0.36	0.38	1.65	1.44	1.55
34	7.22	5.52	6.37	5.18	4.88	5.03	12.00	12.00	12.00	0.50	0.38	0.44	2.23	2.22	2.23
35	7.98	7.98	7.98	6.28	5.52	5.90	13.00	13.00	13.00	0.50	0.42	0.46	2.38	2.36	2.37
36	9.42	9.42	9.42	7.82	6.41	7.12	15.00	15.00	15.00	0.60	0.40	0.50	2.72	2.52	2.62
37	11.52	10.32	10.92	7.96	7.53	7.75	16.00	16.00	16.00	0.80	0.60	0.70	3.12	2.62	2.87
38	12.85	12.85	12.85	8.53	8.02	8.28	18.00	18.00	18.00	0.60	0.50	0.55	3.30	3.32	3.31
39	13.02	13.02	13.02	7.78	6.93	7.36	14.00	14.00	14.00	0.40	0.30	0.35	3.73	3.65	3.69
40	13.59	13.42	13.51	7.21	6.32	6.77	12.00	12.00	12.00	0.35	0.20	0.10	2.15	2.05	2.10
41	9.12	8.32	8.72	5.31	4.63	4.97	11.00	11.00	11.00	0.30	0.10	0.20	1.69	1.52	1.61
42	6.44	5.33	5.89	4.92	4.25	4.59	9.00	9.00	9.00	0.20	0.10	0.15	1.19	1.05	1.12
43	5.28	5.28	5.28	3.85	3.42	3.64	9.00	9.00	9.00	0.10	0.05	0.08	0.68	0.65	0.67
44	3.91	3.91	3.91	2.98	2.12	2.55	6.00	6.00	6.00	0.10	0.05	0.08	0.51	0.48	0.50

Table 3. Species abundance of natural enemies of stem borer complex of rice ecosystem

S. No.	Family	Total Adult Population			Relative Abundance (%)		
		2022	2023	Pooled	2022	2023	Pooled
1.	Spiders	09.47	8.93	9.20	2.39	2.38	2.39
2.	Mirid Bugs	11.33	12.24	11.79	2.86	3.26	3.06
3.	Coccinellids	106.33	100.18	103.26	26.84	26.71	26.78
4.	Odonata	77.58	67.41	72.50	19.59	17.98	18.80
5.	Staphylinids	159.00	157.00	158.00	40.14	41.87	40.98
6.	Cicindelids	05.15	3.64	3.32	1.30	0.97	1.14
7.	Carabids	27.23	25.61	26.42	6.87	6.83	6.85
	Total	396.09	375.01	385.55	100.00	100.00	100.00

Table 4. Corelation coefficients (r) of natural enemies of stem borer complex with weather parameters in rice ecosystem

Stem borer complex		Correlation coefficients (r)							
		Maximum Temperature (ºC)	Minimum Temperature (ºC)	Morning RH (%)	Evening RH (%)	Rainfall (mm)	Evaporation (mm)	Wind Velocity (kmph)	Sunshine Hours (hr)
Spiders	2022	0.238^{NS}	-0.253^{NS}	0.654**	-0.299^{NS}	-0.297^{NS}	-0.243^{NS}	-0.287^{NS}	0.363^{NS}
	2023	0.385^{NS}	-0.409^{NS}	-0.228^{NS}	-0.183^{NS}	-0.280^{NS}	-0.640*	-0.501^{NS}	0.290^{NS}
	Pooled	0.408^{NS}	-0.333^{NS}	-0.190^{NS}	-0.255^{NS}	-0.369^{NS}	-0.703**	-0.568*	0.342^{NS}
Mirid Bugs	2022	-0.117^{NS}	0.418^{NS}	0.418^{NS}	0.505^{NS}	0.368^{NS}	-0.494^{NS}	0.229^{NS}	-0.554*
	2023	-0.177^{NS}	0.446^{NS}	0.622*	0.638*	0.378^{NS}	0.346^{NS}	-0.699**	-0.492^{NS}
	Pooled	-0.205^{NS}	0.437^{NS}	0.658**	0.594*	0.405^{NS}	0.231^{NS}	-0.304^{NS}	-0.549*
Coccinellids	2022	0.182^{NS}	0.107^{NS}	0.580*	0.071^{NS}	-0.158^{NS}	-0.456^{NS}	-0.064^{NS}	0.020^{NS}
	2023	0.210^{NS}	-0.014^{NS}	0.221^{NS}	0.270^{NS}	0.000^{NS}	-0.246^{NS}	-0.702**	-0.025^{NS}
	Pooled	0.256^{NS}	0.046^{NS}	0.241^{NS}	0.171^{NS}	-0.101^{NS}	-0.388^{NS}	-0.494^{NS}	-0.005^{NS}
Odonata	2022	0.118^{NS}	0.207^{NS}	0.698**	0.188^{NS}	0.016^{NS}	-0.392^{NS}	0.044^{NS}	-0.035^{NS}
	2023	0.054^{NS}	0.140^{NS}	0.395^{NS}	0.456^{NS}	0.202^{NS}	-0.067^{NS}	-0.684**	-0.176^{NS}
	Pooled	0.108^{NS}	0.175^{NS}	0.406^{NS}	0.335^{NS}	0.088^{NS}	-0.196^{NS}	-0.395^{NS}	-0.131^{NS}
Staphylinids	2022	-0.021^{NS}	0.223^{NS}	0.730**	0.265^{NS}	0.173^{NS}	-0.310^{NS}	0.171^{NS}	-0.084^{NS}
	2023	-0.011^{NS}	0.156^{NS}	0.435^{NS}	0.486^{NS}	0.247^{NS}	-0.010^{NS}	-0.674**	-0.204^{NS}
	Pooled	-0.001^{NS}	0.194^{NS}	0.461^{NS}	0.383^{NS}	0.200^{NS}	-0.100^{NS}	-0.321^{NS}	-0.163^{NS}
Cicindelids	2022	-0.220^{NS}	0.408^{NS}	0.599*	0.506^{NS}	0.296^{NS}	-0.435^{NS}	0.413^{NS}	-0.276^{NS}
	2023	-0.264^{NS}	0.463^{NS}	0.679**	0.733**	0.492^{NS}	0.464^{NS}	-0.462^{NS}	-0.405^{NS}
	Pooled	-0.278^{NS}	0.433^{NS}	0.666**	0.644**	0.452^{NS}	0.273^{NS}	0.024^{NS}	-0.370^{NS}
Carabids	2022	0.007^{NS}	0.397^{NS}	0.572*	0.419^{NS}	0.124^{NS}	-0.578*	0.181^{NS}	-0.319^{NS}
	2023	0.022^{NS}	0.378^{NS}	0.561*	0.626*	0.226^{NS}	0.205^{NS}	-0.808**	-0.330^{NS}
	Pooled	0.021^{NS}	0.393^{NS}	0.587*	0.545*	0.200^{NS}	0.045^{NS}	-0.363^{NS}	-0.355^{NS}

**Significant at 5% level of significance; **Significant at 1% level of significance; NS= Non-Significant*

reported that Coccinellids and Cicindelids were also found on the bunds of flowering plants. The collected specimens were identified as predatory. Other significant natural enemies on the insect pests of rice recorded as hymenopteran parasitoid.

The data on the relative abundance of population of natural enemies is presented in Table 3. The pooled data revealed that a total of 385.55 adults of natural enemies were observed throughout the crop growth. Of them, 9.20 spiders were observed sharing 2.39 per cent, 11.79 mirid bugs were observed sharing 3.06 per cent, 103.26 ladybird beetles were observed sharing 26.78 per cent, 72.50 dragonflies and damselflies were observed sharing 18.80 per cent, 158.00 staphylinids were observed sharing 40.98 per cent, 4.40 cicindelids were observed sharing 1.14 per cent, 26.42 and carabid beetles were observed sharing 6.85 per cent The present results are in line with the findings of [17] who studied the relative abundance of natural enemies in kharif rice field and reported the rank order of natural enemies as: Lady bird beetles > Carabid beetle > Damsel fly > Dragon fly > Wasps. They also revealed that Carabid beetles were found to roam in the rice fields showing relative abundance of 7.47%. Damsel flies were also found active all of the rice growth stages with the relative abundance of 6.54%. Dragon flies were comparatively less helpful as they could not invade rice crop canopy with the gross relative abundance was 2.96%. Jadhao and Bondage [19] also reported the similar results. Yadav et al [15] partially supported the present findings and revealed that out of 38 types organisms. Out of them, 23 types are natural enemies enumerated, hymenopterans, coleopterans, dipterans, odonata, Arachnida, Hemiptera.

Correlation studies of natural enemies with weather parameters are presented in Table 4. The pooled data on correlation studies revealed that population of spiders was found significantly negative correlated with evaporation and wind velocity. (r= -0.677 and -0.568, respectively) The adult population of mirid bugs found significantly positive correlated with morning RH and evening RH (r= 0.658 and 0.594, respectively). The adult population of coccinellids, odonata and staphylinids was not found significant with any whether parameters. The adult population of cicindelids found significantly positive correlated with morning RH and evening RH (r= 0.666 and 0.644, respectively). The adult population of carabids found significantly positive correlated with morning RH and evening RH (r= 0.587 and 0.545, respectively). The present results are supported by the findings of Kalita et al [21] who reported that the correlation study revealed that the population build-up of different natural enemies of insect pests of rice crop was influenced by the weather parameters during the study period. Moreover, Morya and Kumar [20] also revealed that the influence of weather parameters on population of bioagents were inferenced by correlation coefficient. Of the total observed bioagents groups population in all rice growth stages maximum temperature, minimum temperature, relative humidity, and rainfall, the correlation coefficients were - 0.602, - 0.581, - 0.490, and 0.768 for predators; - 0.459, - 0.436, - 0.337, and 0.649 for parasitoids respectively.

4. CONCLUSION

The pooled data revealed that spiders, mirid bugs, coccinellids, odonata, staphylinids, cicindelids and carabids were the most prevalent natural enemies of stem borer complex recorded in the rice ecosystem. The results revealed that the population of spiders was first observed during the 31st SMW (0.10 spiders/ hill) with its peak during the 40th SMW (1.21 spiders/ hill) and reached 0.60 spiders/ hill during 44th SMW. Population of mirid bugs was first observed during the 31st SMW (0.45 mirid bugs/ hill) with its peak during the 39th SMW (2.45 mirid bugs/ hill) and reached 0.04 mirid bugs/ hill during 44th SMW. The population of adult beetles of coccinellids was first observed during the 31st SMW (0.92 ladybird beetles/ sq m) with its peak during the 40th SMW (13.51 ladybird beetles/ sq m) and reached 3.91 ladybird beetles/ sq m during 44th SMW. The population of adult dragonflies and damselflies was first observed during the 30th SMW (0.40 dragonflies and damselflies/ sq m) with its peak during the 38th SMW (8.28 dragonflies and damselflies/ sq m) and reached 2.55 dragonflies and damselflies/ sq m during 44th SMW. The population of adult staphylinids was first observed during the 30th SMW (1.50 adults/ sq m) with its peak during the 38th SMW (18.00 adults/ sq m) and reached 6.00 adults/ sq m during 44th SMW. The population of adult cicindelids was first observed during the 32nd SMW (0.24 adults/ sq m) with its peak during the 37th SMW (0.70 adults/ sq m) and reached 0.08 adults/ sq m during 43rd and 44th SMW. The population of adult beetles of carabids was first observed during the 30th SMW (0.23 adults/ sq m) with its peak during the 39th SMW

(3.69 adults/ sq m) and reached 0.50 adults/ sq m during 44th SMW. The pooled data on relative abundance revealed that a total of 385.55 adults of natural enemies were observed throughout the crop growth. Of them, 9.20 spiders were observed sharing 2.39 per cent, 11.79 mirid bugs were observed sharing 3.06 per cent, 103.26 ladybird beetles were observed sharing 26.78 per cent, 72.50 dragonflies and damselflies were observed sharing 18.80 per cent, 158.00 staphylinids were observed sharing 40.98 per cent, 4.40 cicindelids were observed sharing 1.14 per cent, 26.42 and carabid beetles were observed sharing 6.85 per cent. The pooled data on correlation studies revealed that population of spiders was found significantly negative correlated with evaporation and wind velocity. (r= -0.677 and -0.568, respectively) The adult population of mirid bugs found significantly positive correlated with morning RH and evening RH (r= 0.658 and 0.594, respectively). The adult population of coccinellids, odonata and staphylinids was not found significant with any whether parameters. The adult population of cicindelids found significantly positive correlated with morning RH and evening RH (r= 0.666 and 0.644, respectively). The adult population of carabids found significantly positive correlated with morning RH and evening RH (r= 0.587 and 0.545, respectively).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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