Plant Archives Vol. 26, No. 1, 2026 pp. 2043-2048 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.281

SEASONAL INCIDENCE OF NATURAL ENEMIES AGAINST MAJOR INSECT PESTS OF MUNGBEAN (*VIGNA RADIATA* L.) WILCZEK

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(Date of Receiving-17-12-2025; Date of Revision-03-02-2026; Date of Acceptance-23-02-2026)

ABSTRACT

The seasonal incidence of natural enemies *Cheilomenes sexmaculata*, *Coccinella septempunctata* and *Polistes versicolor* was investigated during *Kharif* 2022 and 2023. All three species emerged from the 32nd Standard Meteorological Week (SMW). *C. sexmaculata* reached its peak of 4.8 and 3.8 adults per plant in the 35th SMW. *C. septempunctata* reached its peak of 1.6 and 1.4 adults per plant in the 35th SMW. *P. versicolor* reached its peak of 1.4 and 1.8 adults per plant in the 36th-37th SMW. The peaks were recorded at a maximum temperature of 33.1-35.1°C, minimum temperature of 22.4-25.3°C, morning relative humidity of 74.7-85%, evening relative humidity of 53-59%, rainfall of 4-37.8 mm and wind speed of 4.2-6.5 kmph. Correlation analysis revealed strong positive correlations with maximum temperature for all three species and both years ($r = 0.532$-0.695), while relative humidity, rainfall and wind speed showed negative correlations. Multiple regression analysis revealed strong meteorological effects with high R^2 values for *C. sexmaculata* (0.928-0.929), *C. septempunctata* (0.691-0.903) and *P. versicolor* (0.754-0.896). Higher temperatures were conducive to the development and peak emergence of natural enemies, while higher humidity, rainfall, and wind speed were deterrents.

Key words : *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *Polistes versicolor*, Maximum temperature, Multiple regression.

Introduction

Mungbean (*Vigna radiata*) (L.) Wilczek, commonly called golden gram, is an essential leguminous pulse crop of the Indian subcontinent. Being a member of the Leguminaceae family and the Papilionaceae subfamily, it plays a vital role in food security around the globe by occupying more than 6 million hectares of cultivation area, which is 8.5% of the global pulse footprint. Its short growth period of around 70 days, low input requirements, and tolerance to drought conditions make it a promising crop for different cropping systems in Asian, Southern European, and American countries (Hou *et al*., 2019). From a nutritional point of view, mungbean is rich in important macronutrients as well as micronutrients. Mungbean is a rich source of caloric content (347 kcal/ 100g), along with being rich in protein (23.86 g/100g) and dietary fibers (16.3 g/100g) (USDA, 2025).

Although, mungbean is a hardy crop, its productivity is significantly affected by a large number of biotic limiting factors. In fact, more than 200 species of insects from 48 families have been identified to infest mungbean at different stages of its growth. The important pest species that limit the productivity of mungbean include sucking Pests thrips species (*Caliothrips indicus*), Whitefly (*Bemisia tabaci*), Jassids (*Empoasca motti*) and Cowpea aphid (*Aphis craccivora*). Cutworm (*Agrotis ipsilon*), Semilooper (*Plusia orichalcea*) and Spotted pod borer (*Maruca vitrata*). The seasonal incidence and population dynamics of these pest species are strongly associated with their natural enemies, which play a vital role in the biological control of these pests. It has been consistently found in the studies conducted that the population dynamics of predators such as coccinellids *Coccinella transversalis* and *Cheilomenes sexmaculatus* and syrphids (*Ischiodon scutellaris*) are in high correlation with their prey populations, such as *A. craccivora* (Borah *et al*., 2012). Studies conducted on intercropping systems revealed that the diversity of natural enemies such as spiders of the family Lycosidae and predatory bugs such as *Eocanthecona furcellata* is strongly affected by microclimatic conditions, crop duration, and prey populations (Laxmi *et al*., 2015; Chakravarty *et al*., 2017). However, the population levels of these biological control agents may vary depending on the regions and seasons due to unfavorable climatic changes or agricultural practices (Indiati *et al*., 2017).

It is important to study the seasonal association of major insect pest populations and their corresponding natural enemies to implement Integrated Pest Management (IPM). This study aims to investigate the seasonal occurrence of these natural enemies in the management of the mungbean pest population.

Materials and Methods

To study the seasonal incidence of natural enemies in mungbean against major insect pests of mungbean in *Kharif* 2022 and 2023. Experimental Site and Layout To study the seasonal occurrence of natural enemies and important insect pests of mungbean, (*Vigna radiata*) (L.) Wilczek, field experiments were conducted during the *Kharif* season of 2022 and 2023. The experiments were conducted in five different plots, and each plot was of the size 3 × 4 m^2. The mungbean variety used for the study is RMG-62 and the dates of sowing the crop were 14th July 2022 and 16th July 2023. The crop was harvested during the last week of September in both years. Observation of natural enemies began immediately after their first occurrence in the field and continued weekly until the harvest of the crop. Five plants were randomly selected from each of the five plots and marked using a tag and observations were recorded during the early morning hours, i.e., between 7:00 AM and 9:00 AM, when the natural enemies of the crop are relatively less active to obtain accurate results.

The following formula was used for calculating correlation coefficient (Steel and Torry, 1980).

$$r_{xy} = \frac{\Sigma XY - \frac{\Sigma X \, \Sigma Y}{n}}{\sqrt{\left[\Sigma X^2 - \frac{(\Sigma X)^2}{n}\right]\left[\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}\right]}}$$

Where;

r_{xy} = Simple correlation coefficient

X = Variable *i.e.*, abiotic component

Y = Variable *i.e.*, mean number of insects pests

n = Number of observations

The correlation coefficient (r) values was subjected to the test of significance using t-test (Gupta *et al.*, 2016)

$$t = \frac{r}{\sqrt{1-r^2}} \times \sqrt{n} - 2$$

The calculated t-value obtained was compared with the tabulated t-value at 5% level of significance. The multiple regression was also calculated for the natural enemies.

Results and Discussion

The seasonal incidence of important natural enemies, such as *Cheilomenes sexmaculata*, *Coccinella septempunctata* and *Polistes versicolor*, was studied during the *Kharif* seasons of 2022 and 2023 (Tables 1 and 2). The three natural enemies, which are generally known to be associated with aphidophagous or general predatory functions in agricultural ecosystems, showed regular patterns of occurrence and peak, which are very closely associated with the prevailing meteorological factors. In both years, the population of all three natural enemies started in the 32^{nd} Standard Meteorological Week (SMW) and reached peaks between the 35^{th} and 37^{th} SMW, corresponding to the warmer periods of the *Kharif* season. For *Cheilomenes sexmaculata*, the population started with 0.20-0.80 adults per plant in the 32^{nd} SMW and reached a peak of 4.8 per plant (2022) and 3.80 per plant (2023) in the 35^{th} SMW. These peaks occurred when the maximum temperatures were 33.2-34.7°C, minimum temperatures 22.4-25.2°C, morning relative humidity (RH) 81.1-85%, evening RH 58.5-59%, total rainfall 7-20.2 mm and wind speed 4.2-6.5 kmph.

For all three species, the population began with 0.20-0.80 adults per plant in the 32^{nd} SMW and reached a peak of 4.8 per plant (2022) and 3.80 per plant (2023) in the 35^{th} SMW for *Cheilomenes sexmaculata*, with maximum temperatures of 33.2-34.7°C, minimum temperatures of 22.4-25.2°C, morning relative humidity (RH) of 81.1-85%, evening RH of 58.5-59%, total rainfall of 7-20.2 mm and wind speeds of 4.2-6.5 kmph. *Coccinella septempunctata* began with 0.50 per plant in the 32^{nd} SMW and reached a peak of 1.60 per plant (2022) and 1.4 per plant (2023) in the 35^{th} SMW, with maximum temperatures of 33.1-33.2°C, minimum temperatures of 23.4-25.2°C, morning RH of 74.7-85%, evening RH of 58.4-59%, rainfall of 4-20.2 mm, and wind speeds of 4.2-6.2 kmph. *Polistes versicolor* began with

Table 1 : Population dynamics of natural enemies on mungbean in relation to abiotic factors during *Kharif*, 2022.

Months	SMW	Date of Observation	Temperature (°C)		Relative Humidity (%)		Total Rainfall (mm)	Wind speed (Kmph)	Mean number of adult natural enemies per plant		
			Max.	Min.	Mor.	Eve.			*Cheilomenes sexmaculata*	*Coccinella septempunctata*	*Polistes versicolor*
July	31	31/07/2022	32.4	25	89	70	55.6	4.1	0.00	0.00	0.00
Aug	32	07/08/2022	31.4	23.4	93	70	90.4	6.2	0.20	0.50	0.20
	33	14/08/2022	29.6	23.2	93	76	88.2	6.7	0.60	0.20	0.60
	34	21/08/2022	33.6	24.9	75	57	14.6	7	1.20	1.00	0.80
	35	28/08/2022	33.2	25.2	85	59	20.2	4.2	4.80	1.60	1.00
Sept	36	04/09/2022	33.3	25.1	82	65	24	3.2	4.40	1.20	1.20
	37	11/09/2022	35.1	25.3	81	53	37.8	4.8	4.20	1.00	1.40
	38	18/09/2022	33	22.1	85	58	21.5	5.2	2.30	0.80	0.60
	39	25/09/2022	31	22.4	86	65	22.2	5.9	0.60	0.20	0.00

Table 2 : Population dynamics of natural enemies on mungbean in relation to abiotic factors during *Kharif*, 2023.

Months	SMW	Date of Observation	Temperature (°C)		Relative Humidity (%)		Total Rainfall (mm)	Wind speed (Kmph)	Mean number of adult natural enemies per plant		
			Max.	Min.	Mor.	Eve.			*Cheilomenes sexmaculata*	*Coccinella septempunctata*	*Polistes versicolor*
July	31	30.7.23	30.5	23.5	90.8	70.1	51.5	6.2	0.00	0.00	0.00
Aug	32	06.8.23	32.2	23.5	80	62.2	0	8	0.80	0.50	0.20
	33	13.8.23	33.6	24	78	63.2	3.5	6.6	1.60	0.20	0.40
	34	20.8.23	32.5	24.2	83	66	69	4.9	3.20	1.20	1.20
	35	27.8.23	33.1	23.4	74.7	58.4	4	6.2	3.80	1.40	1.60
Sept	36	03.9.23	34.7	22.4	81.1	58.5	7	6.5	3.60	1.20	1.80
	37	10.9.23	32.2	23	84.7	64	45	5.4	2.80	1.00	1.20
	38	17.9.23	33.9	22	88.1	63.4	21.5	6	2.00	0.60	0.40
	39	24.9.23	34.3	20.8	82.7	54.1	22.2	2.9	1.80	0.20	0.2

0.20 per plant in the 32^{nd} SMW and reached a peak of 1.40 per plant in the 37^{th} SMW (2022) and 1.8 per plant in the 36^{th} SMW (2023), with maximum temperatures of 34.7-35.1°C, minimum temperatures of 22.4-25.3°C, morning RH ~81%, evening RH of 53-58.5%, rainfall of 7-37.8 mm, and wind speeds of 4.8-6.5 kmph. The population declined to a low of 0.2 per plant in the 39^{th} SMW (2023) for *P. versicolor* (Tables 1 and 2).

Correlation analysis showed that maximum temperature had a positive effect on the population of all three species in both years. In the case of *C. sexmaculata*, there was a positive significant correlation with maximum temperature in 2022 (r = 0.678) and a non-significant positive correlation in 2023 (r = 0.532). *C. septempunctata* had a positive significant correlation with maximum temperature in both years (r = 0.673 in 2022 and r = 0.695 in 2023). *P. versicolor* had strong positive correlations with maximum temperature (r = 0.673 in 2022) and minimum temperature (r = 0.561 in 2022), but weak in 2023 (r = 0.336 and 0.140, respectively). Relative humidity (morning and evening), total rainfall, and wind speed had negative correlations with the population, but

Table 3 : Correlation coefficient (r) between abiotic factors and natural enemies on mungbean crop during *Kharif* 2022 and 2023.

S. no.	Abiotic factors	2022			2023		
		Cheilomenes sexmaculata	***Coccinella septempunctata***	***Polistes versicolor***	***Cheilomenes sexmaculata***	***Coccinella septempunctata***	***Polistes versicolor***
1	Maximum temperature (°C)	**0.678***	**0.673***	**0.673***	0.532 (NS)	**0.695***	-0.336(NS)
2	Minimum temperature (°C)	0.498 (NS)	0.492 (NS)	0.561(NS)	-0.029 (NS)	0.573(NS)	0.140(NS)
3	Morning Relative Humidity (%)	-0.478 (NS)	-0.595 (NS)	-0.569 (NS)	-0.510 (NS)	-0.696*	-0.464(NS)
4	Evening Relative Humidity (%)	-0.625 (NS)	**-0.684***	-0.594 (NS)	-0.042 (NS)	**-0.685***	-0.270(NS)
5	Total Rainfall (mm)	-0.539 (NS)	-0.573 (NS)	-0.364 (NS)	-0.045(NS)	-0.569(NS)	-0.028(NS)
6	Wind speed (Kmph)	-0.628 (NS)	-0.367 (NS)	-0.332 (NS)	-0.196(NS)	-0.273(NS)	0.028(NS)

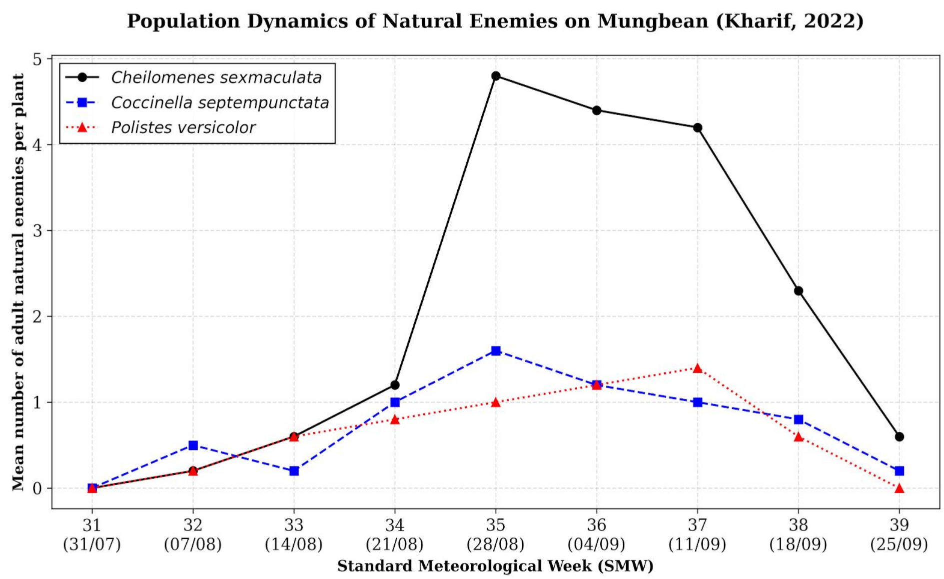

Fig. 1 : Population dynamics of natural enemies in 2022.

the strength and significance of the correlation varied between years and species. For example, *C. sexmaculata* had non-significant negative correlations with RH and rainfall in both years, while *C. septempunctata* had stronger negative correlations with RH in 2023 (Table 3).

The results of multiple regression analyses emphasized the important role of meteorological variables in the population dynamics. In the case of *C. sexmaculata*, high R^2 values (0.929 in 2022 and 0.928 in 2023) confirmed that 92.8-92.9% of the variation could be explained by the chosen weather variables, which represented a stable and strong impact. In *C. septempunctata*, moderate correlation was observed in 2022 (R^2 = 0.691), but the relationship was much stronger in 2023 (R^2 = 0.903), indicating a higher level of dependence on weather in the latter year. In *P. versicolor*, a strong relationship was observed in 2022 (R^2 = 0.896), which was slightly lower in 2023 (R^2 = 0.754) (Table 4).

These findings are in agreement with several earlier studies on coccinellid and predatory wasp dynamics in pulse ecosystems. Borah *et al.* (2012) and Rakhshan *et*

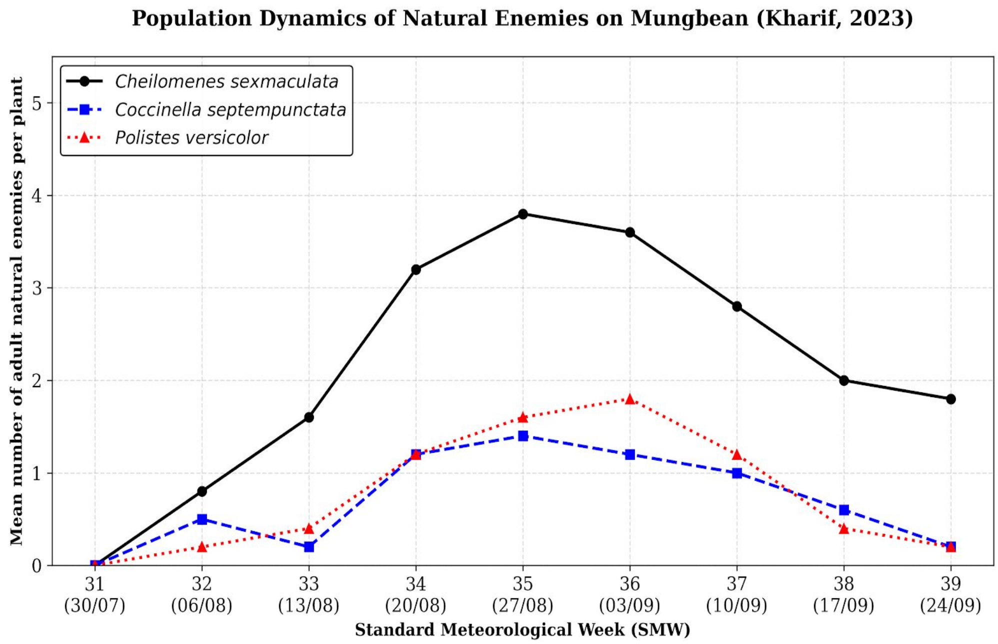

Fig. 2 : Population dynamics of natural enemies in 2023.

Table 4 : Multiple regression of weather parameters with major insect pests on mungbean crop during *Kharif* 2022 and 2023.

S. no.	Major insect pests	Multiple regression equation 2022	R-square value 2022	Multiple regression equation 2023	R-square value 2023
1.	*Cheilomenes sexmaculata*	Y= 273.27+ (-4.581) x B1 +(0.386) x B2 + (-0.700) x B3+ (0.950) x B4 +(0.155) x B5 + (3.358) x B6	0.929	Y = 1.032 + (0.753) × B1 + (5.78) × B2 +(12.06) × B3 + (0.96) × B4 + (-3.44) × B5 + (4.61) × B6	0.928
2.	*Coccinella septempunctata*	Y=44.75 + (-0.814) x B1+ (0.189) x B2 + (-0.104) x B3 +(-0.182) x B4 + (0.02) x B5 + (0.478) x B6	0.691	Y = 61.20 + (0.198) × B1 + (-2.549) × B2 + (0.519) × B3 + (0.370) × B4 + (0.107) × B5 + (0.859) × B6	0.903
3.	*Polistes versicolor*	Y= 85.83 + (-1.314) x B1+ (0.042) x B2 + (-0.284) x B3 + (-0.261) x B4 + (0.059) x B5 + (-0.937)	0.896	Y = 50.92 + (-0.306) × B1 + (-2.072) × B2 + (-0.471) × B3 + (0.294)× B4 + (0.073) × B5 + (0.877) × B6	0.754

al. (2018) reported that *C. sexmaculata* populations closely followed aphid density and were positively influenced by temperature, with peaks occurring under favourable thermal conditions. Laxmi *et al.* (2015) and Jat and Rana (2018) also observed *C. sexmaculata* as the dominant coccinellid predator in groundnut and black gram, with peak abundance during warm periods and decline associated with increased humidity or prey scarcity. Kale *et al*. (2020) similarly recorded *C. sexmaculata* as the most abundant predator (9.76%) in cowpea, showing moderate diversity and temperature-linked activity. The positive correlation of *C. septempunctata* with maximum temperature and its negative association with humidity and rainfall align with Akkabathula and Rana (2019), Jat and Rana (2018), who noted higher activity of this species during warmer, drier phases of the *kharif* season in pigeonpea and black gram ecosystems. Chakravarty *et al.* (2017) further reported positive correlations of predatory bugs with maximum temperature and rainfall in pigeonpea, suggesting that predatory activity in pulses is generally enhanced under warm conditions with moderate moisture. For *Polistes versicolor*, the positive relationship with temperature and negative association with humidity and rainfall are consistent with general observations on vespid wasps in tropical agroecosystems, where higher temperatures promote foraging and nesting activity, while excessive rain and high humidity restrict flight and reduce prey capture efficiency (Indiati *et al.*, 2017; Akkabathula and Rana, 2019).

The stronger meteorological influence in 2023 for *C. septempunctata* (R^2 = 0.903) compared to 2022 (R^2 = 0.691) and the relatively weaker association for *P. versicolor* in 2023 may reflect year-to-year differences in prey availability (lepidopteran larval density) and microclimatic variations, which are known to modulate predator–prey synchrony (Borah *et al.*, 2012 and Rakhshan *et al.*, 2018).

Conclusion

The seasonal incidence of natural enemies during *Kharif* 2022 and 2023 commenced consistently in the 32nd SMW. The predatory coccinellids, *C. sexmaculata* and *C. septempunctata*, reached their peak populations during the 35th SMW (ranging from 1.40 to 4.80 individuals per plant), while the predatory wasp, *P. versicolor*, attained its peak slightly later between the 36th and 37th SMW (1.40 to 1.80 adults per plant). These peak activities were closely associated with maximum temperatures ranging from 33.1°C to 35.1°C Across all three species, maximum temperature consistently showed a significant positive correlation (r = 0.695), while morning and evening relative humidity acted as significant negative regulators, particularly for the coccinellids. The multiple linear regression models demonstrated high predictive accuracy for the natural enemy complex. The multiple linear regression models demonstrated high predictive accuracy, explaining for *C. sexmaculata* consistently exceeding 92.8%, while *C. septempunctata* and *P. versicolor* showed varying explanatory power ranging from 69.1% to 90.3%. Stepwise regression analysis further substantiated that the proliferation of these beneficial insects is essentially heat-driven and moisture-suppressed. High maximum temperatures and night-time warmth (minimum temperature) were identified as the primary drivers of activity, whereas increased humidity and rainfall served as consistent natural limiting factors.

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