



RESEARCH ARTICLE

Population buildup of insect pests in relation to different dates of sowing in kharif maize (*Zea mays* L.)

Bidisha Borgohain*, Nirmali Borah & Prarthna Rajkumari

Department of Entomology, Biswanath College of Agriculture, Assam Agricultural University, Biswanath Chariali 787 201, Assam, India

*Correspondence email - borgohainbidisha195@gmail.com

Received: 04 December 2025; Accepted: 01 May 2026; Available online: Version 1.0: 20 June 2026

Cite this article: Bidisha B, Nirmali B, Prarthna R. Population buildup of insect pests in relation to different dates of sowing in kharif maize (*Zea mays* L.). Plant Science Today. 2026; 13(sp2): 1-19. <https://doi.org/10.14719/pst.13058>

Abstract

A field study was conducted during kharif 2024 at Biswanath College of Agriculture, Assam, to evaluate the effects of sowing dates on insect pest dynamics in maize to improve pest management. Eight insect pests were recorded, with *Spodoptera frugiperda* as the dominant species. Peak populations of *S. frugiperda* (3.25 larvae per plant), *Rhopalosiphum maidis* (72.75 aphids per leaf) and *Monolepta signata* (1.50 beetles per plant) occurred during the 19th, 21st and 19th standard meteorological week (SMW), respectively. Maximum temperature showed a significant positive correlation with *S. frugiperda* ($r = 0.659^{**}$) and aphids ($r = 0.716^{**}$), while rainfall negatively influenced aphid populations ($r = -0.542^{*}$). Predator populations were positively associated with temperature and aphid abundance. Abiotic factors explained 57.1–73.1 % of the variability in pest and predator populations. Early sowing (second fortnight of February) recorded the lowest pest incidence, whereas late sowing (second fortnight of April) showed the highest. Early sowing is therefore recommended to reduce pest infestation and improve maize productivity.

Keywords: Assam; dates of sowing; fall armyworm; invasive pest; natural enemies; population dynamics

Introduction

Maize (*Zea mays* L.), widely known as the “Queen of Cereals,” is an important food, fodder and industrial crop cultivated across diverse agro-ecological regions of India (1). Despite covering 11.24 million hectares and producing 37.66 million metric tonnes annually (2), maize productivity in India remains below the global average, largely due to substantial biotic stresses, particularly insect pests. More than 250 insect species are reported to attack maize at various growth stages, causing considerable losses (3). Major pests such as cutworms, aphids, stem borers, shoot fly and thrips continue to pose persistent threats (4).

The recent invasion of the fall armyworm, *Spodoptera frugiperda* (J.E Smith), first detected in India in 2018, has further intensified pest-related challenges (5). Its polyphagous nature, strong migratory ability and rapid reproduction have resulted in severe economic losses across major maize-growing regions of Northeast India, including Assam (6). Early-stage infestations are particularly damaging, reducing plant vigour and yield potential (7).

Climatic factors and crop phenology play a crucial role in determining pest incidence. Sowing time strongly influences pest-crop synchrony, often determining the extent of infestation. Several studies have highlighted contrasting responses of insect pest populations across sowing dates, emphasizing the importance of optimizing planting time for minimising pest risk (8, 9). Timely sowing can enable crops to escape peak pest pressure, reducing reliance on chemical control and supporting sustainable pest management practices (10, 11). Given the increasing pest

complexity in maize ecosystems, particularly with the emergence of invasive species, understanding how sowing dates and crop growth stages influence pest dynamics is essential. Therefore, the present study evaluates the impact of sowing dates on the incidence and abundance of major insect pests in maize under the agro-climatic conditions of Assam. Given the importance of maize and the damage caused by various insect pest populations, this study was undertaken to gather knowledge in this area with the following two objectives:

1. Relationship between insect pest population and weather parameters.
2. The effect of different dates of sowing on population buildup of insect pests.

Materials and Methods

A field experiment was carried out at the PG Research Farm, Biswanath College of Agriculture, Biswanath Chariali, Assam, during kharif 2024. It is located in the North Bank Plain Zone of the Brahmaputra in Biswanath district, Assam. The site lies between 92°16'–93°43' E and 26°30'–27°01' N, with an elevation ranging from 48 to 848 m above mean sea level. The site of the experimental farm falls within the subtropical climatic region and has a monsoon-type climate. The average summer temperature is around 29 °C, which is hot and humid. The fields receive natural irrigation, a beneficial hydrological attribute, whereas rivers overflowing their banks result in flooding, a significant environmental constraint. The cold and

characteristically dry winters last from October to February, with an average temperature of 16 °C. Due to snowfall in the uppermost regions of Arunachal Pradesh, it gets quite cold in late December and early January. The field experiment was conducted under natural conditions using a randomised block design (RBD), with 5 treatments and 4 replications. A total of 20 plots were laid out, each measuring 4.0 × 3.0 meters. The gross area of the experimental plots was 484 m², with a net area of 240 m². A hybrid maize variety 'Yuvraj-Gold' was planted at a spacing of 60 cm between rows and 20 cm between plants. A gap of 1.0 m was maintained between plots and replications, while a 1.5 m border was left around the experimental area. Observations were recorded fortnightly starting from 5 days after germination (DAG). The population of sucking pests, such as aphids, was recorded on 10 randomly selected plants in each plot, with three leaves sampled from each plant: upper, middle and lower. The percentage of borer infestation was calculated as the total number of infested plants among 10 randomly selected plants per plot, expressed as a percentage. The population of natural enemies and other pests, as noted above, was recorded by counting individuals on 10 randomly selected plants per plot.

Plant damage (%) =

$$\frac{\text{Number of infested plants observed}}{\text{Total number of plants observed}} \times 100 \quad (\text{Eqn. 1})$$

The population of insect pests and natural enemies recorded from the plot was correlated with weather parameters, namely maximum temperature, minimum temperature, relative humidity, sunshine hours and total rainfall. Observations were scheduled at weekly intervals throughout the crop season. During the trial period, correlation coefficients between pest populations and the abundance of their natural enemies were calculated under existing meteorological conditions.

Table 2. Insect pests associated with maize during kharif 2024

Common name	Scientific name	Order: Family	Stage of crop infestation
Fall armyworm	<i>Spodoptera frugiperda</i> (J.E. Smith)	Lepidoptera: Noctuidae	Seedling to reproductive
Corn leaf aphids	<i>Rhopalosiphum maidis</i> (Fitch)	Hemiptera: Aphididae	Seedling to maturity
White spotted leaf beetle	<i>Monolepta signata</i> (Olivier)	Coleoptera: Chrysomelidae	Vegetative to reproductive
--	<i>Mycotretus tricolor</i> (Crotch)	Coleoptera: Erotylidae	Vegetative to reproductive
Oriental armyworm or rice ear cutting caterpillar	<i>Mythimna separata</i> (Walker)	Lepidoptera: Noctuidae	Seedling to reproductive
Gundhi bug	<i>Leptocoris acuta</i> (Fabricius)	Hemiptera: Coreidae	Reproductive
Tussock moth	<i>Lymantria</i> sp. (J.E. Smith)	Lepidoptera: Lymantriidae	Seedling to reproductive
Shield bug	<i>Eurydema ornata</i> (Linnaeus)	Hemiptera: Pentatomidae	Seedling to vegetative

Table 3. Natural enemies (predators, parasitoids and entomopathogen) associated with maize during 2024

Predator			
Common name	Species	Order: Family	Prey
Rice red lady bird	<i>Micraspis discolor</i> (Fabricius)	Coleoptera: Coccinellidae	<i>Rhopalosiphum maidis</i>
Six spotted zigzag lady bird beetle	<i>Cheilomenes sexmaculata</i> (Fabricius)	Coleoptera: Coccinellidae	<i>Rhopalosiphum maidis</i>
Seven spotted lady bird beetle	<i>Coccinella septempunctata</i> (Linnaeus)	Coleoptera: Coccinellidae	<i>Rhopalosiphum maidis</i>
--	<i>Micraspis univittata</i> (Hope)	Coleoptera: Coccinellidae	<i>Rhopalosiphum maidis</i>
--	<i>Propylea dissecta</i> (Mulsant)	Coleoptera: Coccinellidae	<i>Rhopalosiphum maidis</i>
--	<i>Coccinella transversalis</i> (Fabricius)	Coleoptera: Coccinellidae	<i>Rhopalosiphum maidis</i>
--	<i>Brumoides suturalis</i> (Fabricius)	Coleoptera: Coccinellidae	<i>Rhopalosiphum maidis</i>
Red reduviid predator	<i>Rhynocoris iracundus</i> (Poda)	Hemiptera: Reduviidae	<i>Rhopalosiphum maidis</i> , <i>Spodoptera frugiperda</i>
Big assassin predator	<i>Sycanus collaris</i> (Fabricius)	Hemiptera: Reduviidae	<i>Rhopalosiphum maidis</i> , <i>Spodoptera frugiperda</i>
Leafhopper assassin predator	<i>Zelus renardii</i> (Kolenati)	Hemiptera: Reduviidae	<i>Rhopalosiphum maidis</i> , <i>Spodoptera frugiperda</i> , <i>Leptocoris acuta</i>
Parasitoids			
Ichneumonid wasps	--	Hymenoptera: Ichneumonidae	<i>Spodoptera frugiperda</i>
Tachinid flies	--	Diptera: Tachinidae	<i>Spodoptera frugiperda</i>
Entomopathogen			
NPV	<i>Nucleopolyhedrovirus</i>	Baculovirus	<i>Spodoptera frugiperda</i>

The count data were converted into mean values, which were further transformed into the square root $\sqrt{(x + 0.5)}$ and the per cent plant infestation was converted into angular values ($\arcsin \sqrt{x}$). All the transformed data were analysed for analysis of variance (ANOVA) for RBD by using OP Software. Significance of differences due to treatment effects in the field was assessed by calculating the respective F-values and comparing the treatment means with the appropriate CD values (12). The significant or non-significant difference between treatment means was ascertained by Duncan's multiple range test (DMRT) (Table 1).

Results

Insect pests of maize during kharif 2024

In the present investigation, a total of eight insect pests under sucking, borer and foliage feeding insects were observed and recorded as maize pests from the seeding stage to harvesting (Table 2). In addition to these insect pests, seven coccinellid predator species from the order Coleoptera, four predatory bug species from the order Hemiptera, two parasitoids from the orders Hymenoptera and Diptera and one nucleopolyhedrosis virus (NPV) have been recorded as natural enemies (Table 3).

Table 1. Details of the various treatments tested in the experiment

T ₁	First date of sowing on the 2 nd fortnight of February
T ₂	Second date of sowing in the 1 st fortnight of March
T ₃	Third date of sowing on the 2 nd fortnight of March
T ₄	Fourth date of sowing on the 1 st fortnight of April
T ₅	Fifth date of sowing in the 2 nd fortnight of April

Study of the seasonal occurrence of major insect pests infesting maize along with natural enemies

The occurrence of the major insect pests of maize, namely fall armyworm, corn aphid and flea beetle was recorded at weekly intervals from the 11th SMW to the 25th SMW, with effect from the 12th March 2024 to the 24th June 2024 and is provided in Table 2 and illustrated in Fig.1. The field abundance of natural enemy fauna associated with the maize pest complex, namely coccinellid predators and reduviid bug was also assessed.

Seasonal occurrence of maize fall armyworm, *Spodoptera frugiperda*

The incidence of *S. frugiperda* was first recorded on 13th SMW, with a larval population of 0.50 per plant and persisted up to 24th SMW during kharif 2024, on maize. The larval population per plant progressively increased and peaked during the 19th SMW, with a mean of 3.25 per plant (Table 2). Thereafter, pest incidence gradually decreased from the 20th SMW, with a mean larval population of 2.00 per plant and the population again began declining to its minimum of 0.25 larvae per plant on the 24th SMW.

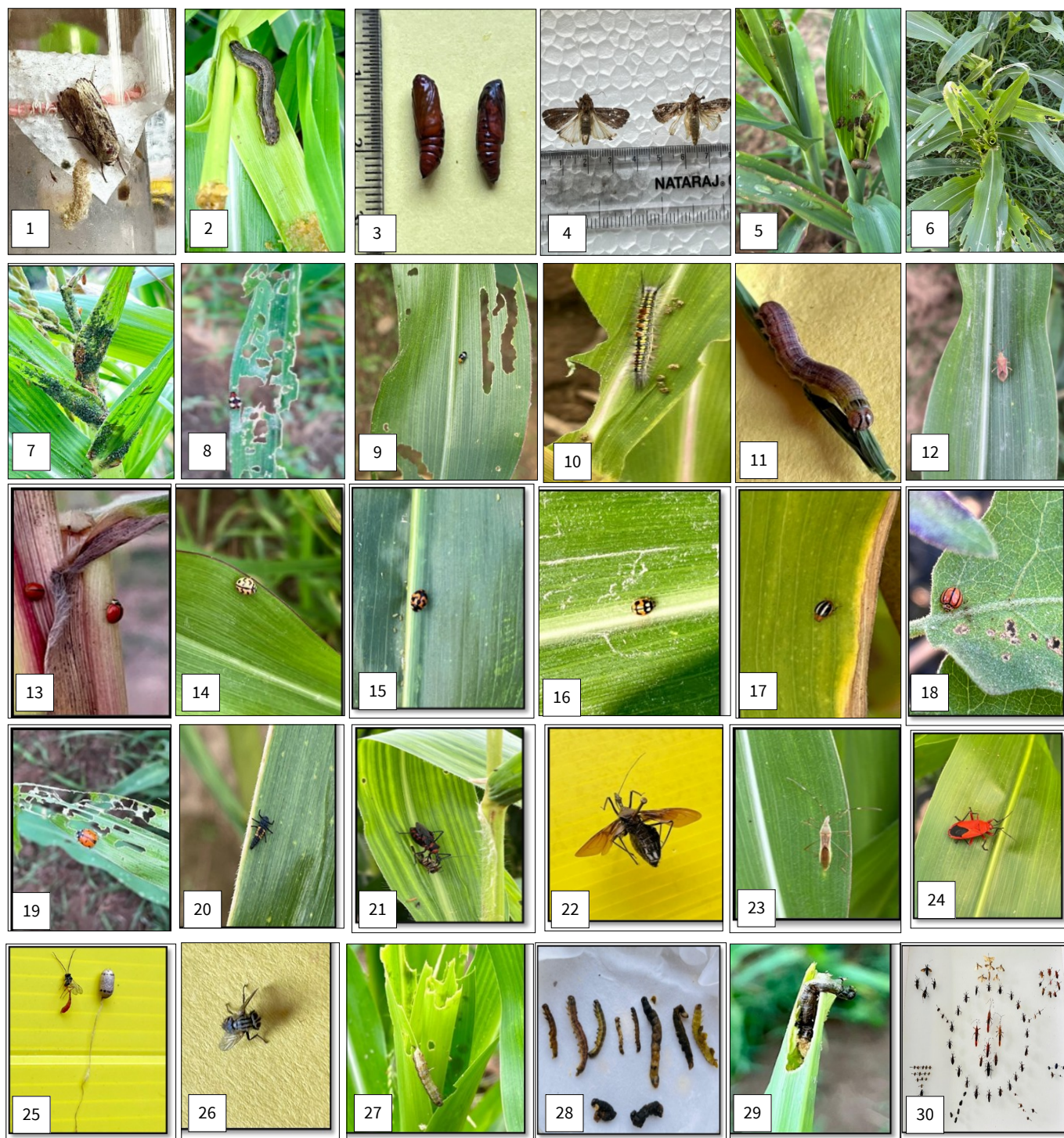


Fig. 1. Insect pests and natural enemies associated with maize during kharif 2024.

(1–4: different life stages of *Spodoptera frugiperda*; 5, 6: damage symptoms of *Spodoptera frugiperda*; 7: *Rhopalosiphum maidis*; 8: *Monolepta signata*; 9: *Mycotretus tricolor*; 10: *Lymantria* sp.; 11: *Monolepta separata*; 12: *Leptocoris oratorius*; 13: *Micraspis discolor*; 14: *Cheilomenes sexmaculata*; 15: *Coccinella transversalis*; 16: *Propylea dissecta*; 17: *Brumoides suturalis*; 18: *Micraspis univittata*; 19: *Coccinella septempunctata*; 20: larval stages of coccinellid; 21: *Rhynocoris iracundus*; 22: *Sycanus collaris*; 23: *Zelus renardii*; 24: *Antilochus coquebertii*; 25: Ichneumonid Wasp; 26: Tachinid fly; 27–29: Nucleopolyhedrosis (NPV) infected dead larvae of *Spodoptera frugiperda*; 30: Insect box).

During the peak time of incidence, the maximum and minimum temperatures, morning and evening relative humidity, sunshine hours and total rainfall were 33.08 °C, 21.08 °C, 92.71 %, 60.28 %, 4.12 hr and 0.97 mm, respectively. The percentage of plant infestation by *S. frugiperda* was recorded from 14th SMW (12.70 %) to 25th SMW, with a peak infestation of 79.29 % on 20th SMW.

Seasonal occurrence of corn aphid, *Rhopalosiphum maidis*

The incidence of *Rhopalosiphum maidis* first appeared in the 11th SMW and continued till the 25th SMW during kharif 2024, on maize. The population increased steadily and reached 1st peak during the 16th SMW with a population of 10.56 aphids per leaf (Table 2). Thereafter, the pest population reduced in 17th SMW (7.05 aphids per leaf). Again, the population gradually increased, peaking at 72.75 aphids per leaf during the 21st SMW. During the peak time of incidence, the maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, hours of sunlight and total rainfall were 35.28 °C, 25.75 °C, 86.71 %, 54.14 %, 9.32 hr and 6.85 mm, respectively.

Seasonal occurrence of corn flea beetle, *Monolepta signata*

The incidence of *M. signata* first appeared on 11th SMW at a population of 0.11 per plant and persisted on the maize crop until the 25th SMW (0.28 per plant), with a peak population of 1.50 per plant during the 19th SMW (Table 2). Thereafter, pest populations started declining. During the peak time of incidence, the highest temperature, minimum temperature, morning relative humidity, evening relative humidity, hours of sunlight and total rainfall were 29.88 °C, 21.30 °C, 88.28 %, 63.28 %, 6.42 hr and 5.44 mm, respectively.

Seasonal occurrence of natural enemies

The data obtained on natural enemy populations in maize indicated that coccinellid predators were observed in the field from the 11th SMW, with a population of 0.20 predators per plant, peaking at the 21st SMW (2.75 predators per plant). During the peak period of the predator, the maximum and minimum temperatures were 35.28 and 25.75 °C, with morning and evening relative humidity at 86.71 and 54.14 %, respectively. Total rainfall of 6.85 mm and bright sunshine hours of 9.32 were also recorded (Table 4).

The results obtained on natural enemy populations in maize revealed that the activity of the reduviid bug was observed from the 13th SMW (0.10 predators per plant) to the 25th SMW (0.35 predators per plant). The population of this predatory bug gradually increased and reached its highest at 21st SMW (1.20 predator per plant). During the peak activity period, the maximum and minimum temperatures were 35.28 and 25.75 °C, with relative humidity of 86.71 and 54.14 %, respectively. Total rainfall of 6.85 mm and bright sunshine of 9.32 hr were also recorded during the predator peak period (Table 4 and Fig. 2).

Impact of coccinellid predators on the incidence of *Rhopalosiphum maidis* on maize

During the present investigation, seven species of coccinellid predators were found to be associated with the aphid population on maize. Therefore, a correlation study of coccinellid predators was conducted with the *R. maidis* population and is presented in Table 5 and depicted in Fig. 3. From the study, it was observed that coccinellid predators had a highly significant positive impact ($r=0.819^{**}$, $p<0.001$) on the *R. maidis* population.

Table 4. Population buildup of insect pests of maize with weather parameters during kharif 2024

SMW	DAG	Weather parameters				Insect pests				Natural enemies			
		Temperature (°C)		Relative humidity (%)		Rainfall (mm)	BSSH	Spodoptera frugiperda per plant		Rhopalosiphum maidis per leaf	Monolepta signata per plant	Coccinellid predator per plant	Reduviid predator per plant
		Max T	Min T	RH (M)	RH (E)			Larvae per plant	Per cent infestation				
11	5	27.62	18.01	81.57	43.57	0.00	5.55	0.00	0.00	8.06	0.11	0.20	0.00
12	12	27.90	18.54	86.25	59.25	5.00	3.90	0.00	0.00	8.34	0.15	0.25	0.00
13	19	28.74	19.02	90.85	61.60	4.50	4.00	0.50	0.00	6.87	0.20	0.50	0.10
14	26	29.12	20.57	83.28	55.00	0.28	5.42	1.50	12.70	7.67	0.12	0.50	0.12
15	33	32.85	20.85	86.28	45.14	0.00	5.25	1.75	20.52	9.05	0.32	0.75	0.22
16	40	32.14	21.45	90.14	70.00	5.08	2.65	2.25	35.79	10.56	0.55	0.40	0.35
17	47	30.88	21.30	88.28	63.28	5.44	6.42	2.95	62.03	7.05	1.02	0.65	0.55
18	54	32.50	21.57	90.01	61.60	4.50	4.57	3.00	70.33	8.02	1.00	0.85	0.87
19	61	33.08	21.08	92.71	60.28	0.97	4.12	3.25	78.42	30.50	1.50	1.25	1.02
20	68	37.72	24.50	90.14	61.14	1.05	6.30	2.00	79.29	50.25	1.25	2.50	1.00
21	75	35.28	25.75	86.71	54.14	6.85	9.32	1.50	76.32	72.75	1.00	2.75	1.20
22	82	33.13	26.09	91.57	68.25	1.08	5.45	1.00	66.50	65.50	0.75	1.50	1.04
23	89	32.27	25.54	93.14	63.86	1.69	3.73	0.50	68.52	40.75	0.57	1.25	0.78
24	96	30.44	26.37	92.43	80.29	10.74	1.39	0.25	70.35	11.92	0.66	0.75	0.55
25	103	27.94	25.01	95.14	83.29	28.74	2.27	0.00	65.93	10.56	0.28	0.50	0.35

*SMW: Standard meteorological week; DAG: Days after germination; Max T: Maximum temperature; Min T: Minimum temperature; RH (M): Morning Relative humidity; RH (E): Evening relative humidity; BSSH: Bright sun shine hour.

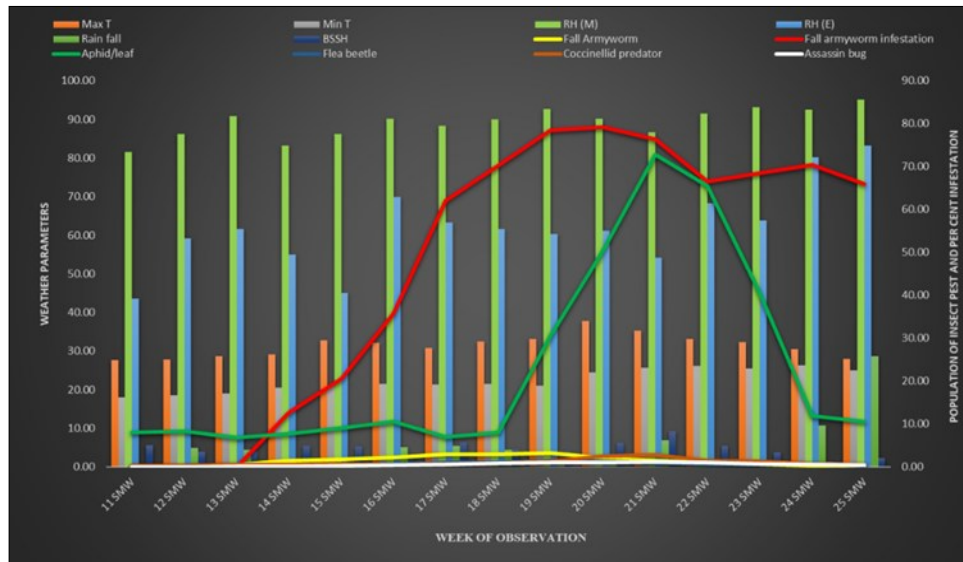


Fig. 2. Population buildup of insect pests with weather parameters during kharif 2024.

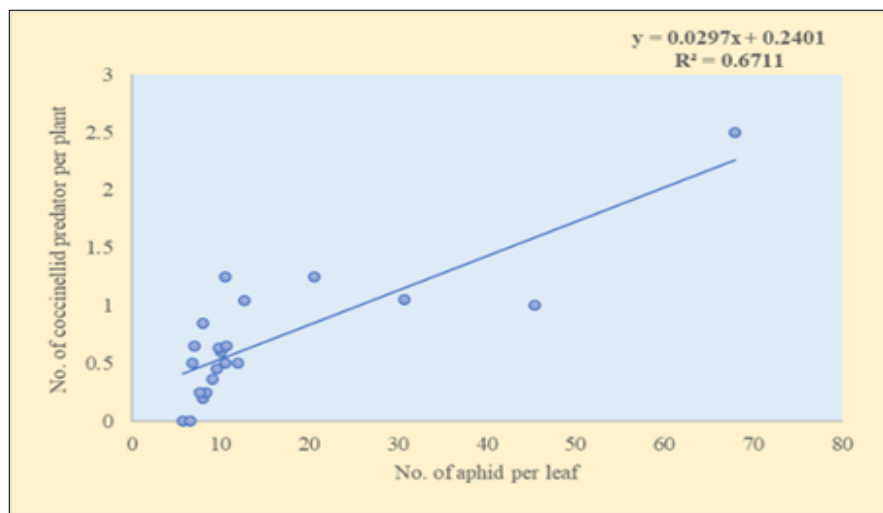


Fig. 3. Simple correlation between *Rhopalosiphum maidis* and the population of coccinellid predators.

Table 5. Correlation coefficient (*r*) and regression equation of coccinellid predators with *Rhopalosiphum maidis* population during 2024

Insect pest	Simple regression equation
Coccinellid predator and <i>Rhopalosiphum maidis</i>	0.819** ($y = 0.029x + 0.240$)

Correlation between the development of pests and weather parameters

The effect of weather conditions on the appearance and population buildup of major insect pests of maize and their natural enemies was estimated by calculating simple correlation coefficients between pest and natural enemy populations and current weather elements. Simple correlation coefficients were calculated using this data and are shown in Table 6. Similarly, the combined effects of these seasonal parameters on the major insect pest are presented in Table 7.

Table 6. Correlation coefficient and regression equation of various insect pests on maize with weather parameters during kharif 2024

Insect-pest	Temperature (°C)		Relative humidity (M) (%)	Relative humidity (E) (%)	Rainfall (mm)	Bright sunshine hours
	Max. T	Min. T				
<i>Spodoptera frugiperda</i> (J.E. Smith)	0.659** $y = 0.277x - 7.334$	0.281	-0.087	0.128	-0.158	0.197
<i>Rhopalosiphum maidis</i> (Fitch)	0.716** $y = 5.694x - 155.84$	0.661* $y = 5.259x - 94.499$	-0.017	-0.001	-0.542* $y = -0.733x + 8.070$	0.554
<i>Monolepta signata</i> (Olivier)	-0.520* $y = -1.030x + 14.31$	-0.475	0.366	0.353	0.0430	0.079
Coccinellid predator	0.766** $y = 0.215x - 5.771$	0.625* $y = 0.165x - 2.735$	0.578* $y = 0.114x - 9.246$	0.588	-0.191	0.183
Reduviid predator	0.814** $y = 0.123x - 3.339$	0.698* $y = 0.100x - 1.700$	0.325	0.275	-0.023	0.248

*Significant at 0.05 level; **Significant at 0.01 level.

Table 7. Multiple linear regression and coefficient of multiple determination (R^2) of various insect pests in relation to weather parameters in maize during kharif 2024

Dependent variable	Regression equations	Coefficient of determination (R^2)	Coefficient of variation (%)
<i>Spodoptera frugiperda</i>	$Y_1 = -0.841 - 0.467X_1 + 2.526X_2 + 0.101X_3 - 0.039X_4 + 1.124X_5 + 0.607X_6$	0.701	70.1
<i>Rhopalosiphum maidis</i>	$Y_2 = -313.667 + 2.782X_1 + 0.485X_2 + 1.973X_3 + 0.463X_4 - 0.786X_5 + 7.384X_6$	0.685	68.5
<i>Monolepta signata</i>	$Y_3 = -4.659 - 0.119X_1 + 0.082X_2 + 0.064X_3 + 0.008X_4 - 0.025X_5 + 0.204X_6$	0.571	57.1
Coccinellid predator	$Y_4 = -10.188 - 0.010X_1 + 0.089X_2 + 0.078X_3 + 0.012X_4 - 0.019X_5 + 0.346X_6$	0.731	73.1
Reduviid predator	$Y_5 = -5.786 - 0.044X_1 + 0.067X_2 + 0.056X_3 + 0.007X_4 - 0.021X_5 + 0.169X_6$	0.729	72.9

Y: Mean number of insect pests (dependent variable); X_1 : Maximum temperature ($^{\circ}\text{C}$); X_2 : Minimum temperature ($^{\circ}\text{C}$); X_3 : RH (M) (%); X_4 : RH (E) (%), X_5 : Rainfall (mm); X_6 : Sunshine hours.

Correlation coefficients between fall armyworm and weather factors on maize during kharif 2024

The correlation studies of *S. frugiperda* larval population with various weather parameters are presented in Table 6 and Fig. 4. The data depicted that correlation between *S. frugiperda* population with abiotic parameters was found to be significantly positive with maximum temperature ($r = 0.659^{**}$) and non-significant positive with minimum temperature ($r = 0.281$), evening relative humidity ($r = 0.128$) and sunshine hour ($r = 0.197$). However, total rainfall and morning relative humidity exhibited non-significant negative correlations ($r = -0.158$ and -0.087) with the larval population of *S. frugiperda*. Multiple linear regression analysis revealed that all abiotic parameters explained 70.10 % ($R^2 = 0.701$) of the variability in the *S. frugiperda* population (Table 7).

Correlation coefficients between corn aphids and weather factors on maize during kharif 2024

Table 6, Fig. 5 and 6 describe the correlation between the seasonal incidence of *R. maidis* with various weather parameters. The maximum and minimum temperatures were the most dominant, exhibiting positive and significant correlations ($r = 0.716^{**}$ and 0.661^{*}) with the *R. maidis* population. A strong negative relationship was also observed with total rainfall ($r = -0.542^{*}$). Moreover, a non-significant positive correlation of aphid population with sunshine hours ($r = 0.554$) and a negative but non-significant association with both morning and evening relative humidity ($r = -0.017$ and 0.001)

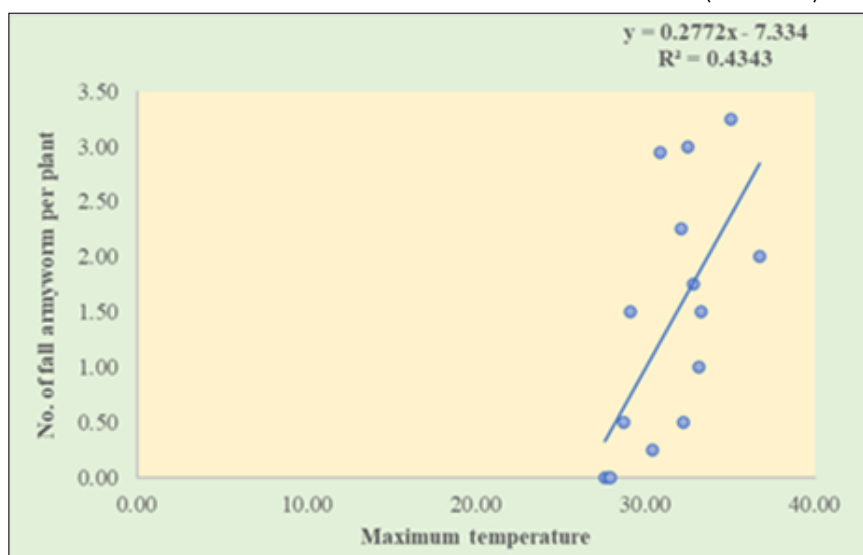
were observed. In addition to these, analysis using multiple linear regression showed that seasonal factors significantly influenced the *R. maidis* population, accounting for 68.50 % ($R^2 = 0.685$) of its variability (Table 7).

Correlation coefficients between corn flea beetle with weather factors on maize during kharif 2024

The data in Table 6 showed a considerable negative impact of maximum temperature on the *M. signata* population ($r = -0.520^{*}$). However, minimum temperature ($r = -0.475$), morning ($r = 0.366$) and evening ($r = 0.353$) relative humidity and rainfall ($r = 0.043$) did not exert a substantial influence on population buildup of flea beetle during the current study. The data in Table 6 showed a multiple linear regression analysis between the population of *M. signata* and combined abiotic parameters and it revealed that all abiotic factors explained 57.10 % ($R^2 = 0.571$) variability in the *M. signata* population.

Correlation coefficients between natural enemies and weather factors on maize during kharif 2024

The correlation studies of coccinellid predators with various meteorological parameters are presented in Table 6; Fig. 7 and 8. A pronounced positive correlation was detected between the population of coccinellid predators and maximum ($r = 0.766^{**}$) and minimum ($r = 0.625^{*}$) temperatures and morning relative humidity ($r = 0.578^{*}$). However, a non-significant negative association was observed with rainfall ($r = -0.191$). Moreover, relative humidity

**Fig. 4.** Simple correlation of *Spodoptera frugiperda* with maximum temperature.

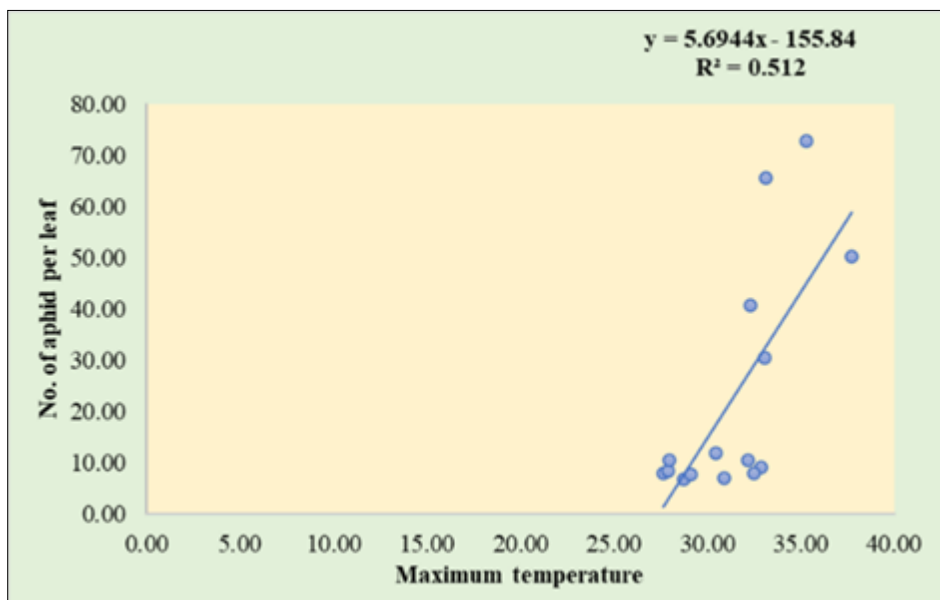


Fig. 5. Simple correlation of *Rhopalosiphum maidis* with maximum temperature.

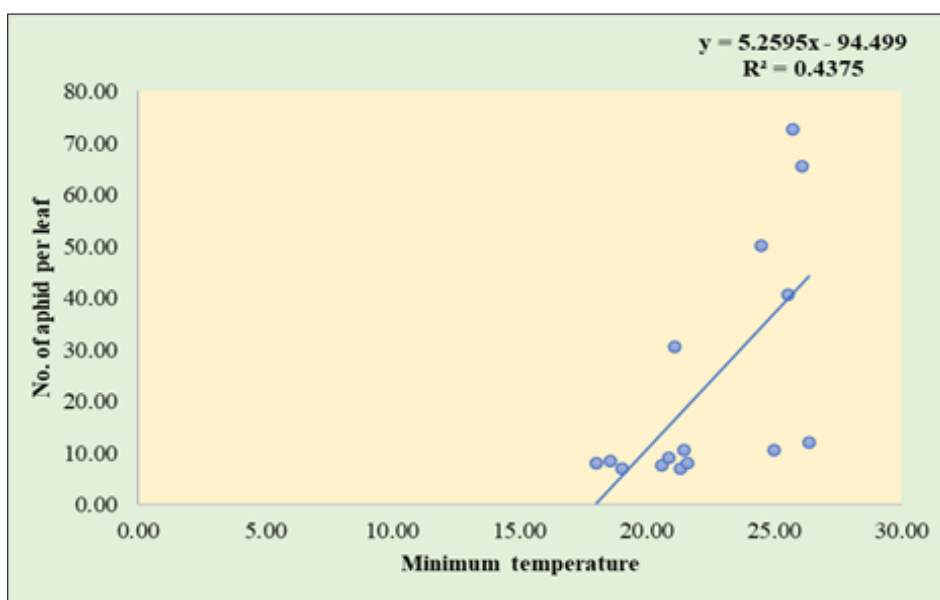


Fig. 6. Simple correlation of *Rhopalosiphum maidis* with minimum temperature.

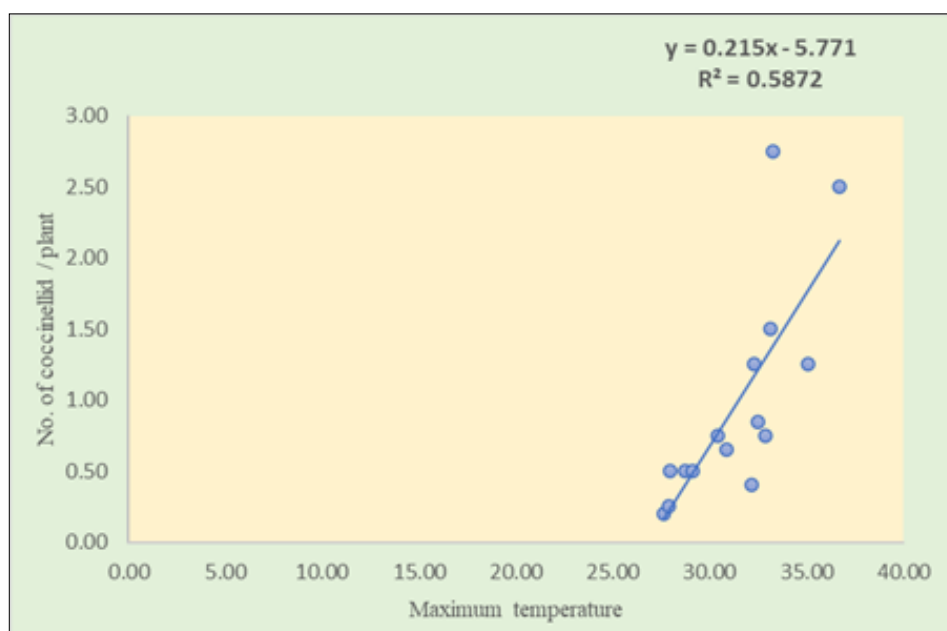


Fig. 7. Simple correlation of coccinellid predator with maximum temperature.

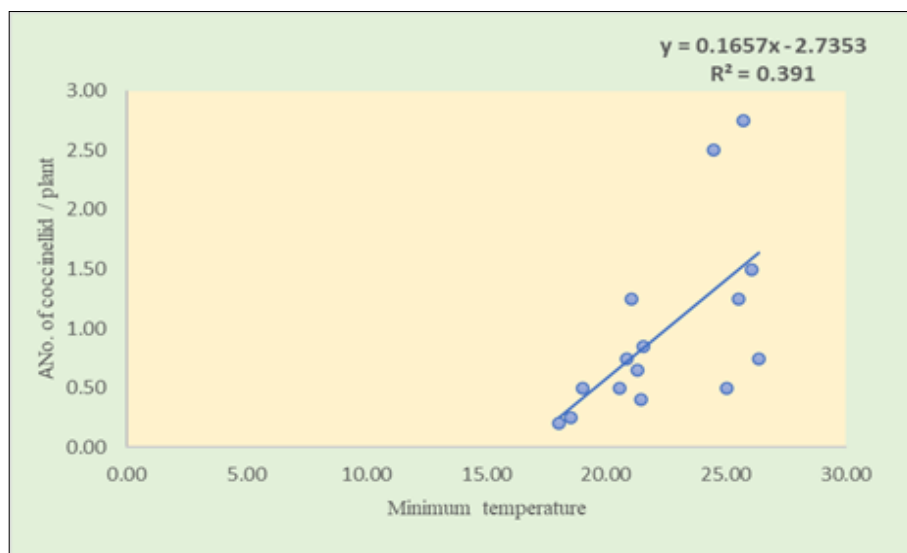


Fig. 8. Simple correlation of coccinellid predator with minimum temperature.

(evening) ($r = 0.588$) and bright sunshine hour ($r = 0.183$) showed a non-significant but positive correlation with the coccinellid predator population. The multiple linear regression analysis demonstrated that seasonal factors accounted for 73.10 % of the variation ($R^2 = 0.731$) in the coccinellid predator population (Table 7).

The correlation analysis of the reduviid bug population with various meteorological factors is presented in Table 6; Fig. 9 and 10, which show a significant positive impact of maximum ($r = 0.814^{**}$) and minimum temperature ($r = 0.697^{**}$) on the predator population. However, morning and evening relative humidity ($r = 0.325, 0.275$), total rainfall ($r = -0.023$) and bright sunshine hours ($r = 0.248$) did not exert any significant impact on the predator population. The multiple regression analysis showed that all abiotic parameters contributed 72.90 % ($R^2 = 0.729$) to the variation in the reduviid predator population, as shown in Table 7.

Incidence of insect pest across various developmental stages of maize during kharif 2024

As the population of various insect pests fluctuated throughout the crop developmental period, a correlation study of different insect pests was administered with plant age or DAG and tabulated in Table 8 and portrayed in Fig. 11. The occurrence of *S. frugiperda* larval population was relatively abundant in the vegetative period

of the crop and it started declining in later stages of the crop. Therefore, *S. frugiperda* showed a negative correlation with DAG ($r = -0.020$). In contrast, the aphid population exhibited a pronounced positive association with DAG ($r = 0.508^*$), indicating that the *R. maidis* population increased as the crop approached maturity. Likewise, a strong positive association was detected between reduviid predators and plant age ($r = 0.673^*$). However, plant age showed a positive, non-significant association with *M. signata* ($r = 0.451$) and the coccinellid predator population ($r = 0.491$) (Table 9).

Effect of different dates of sowing on population buildup of some important insect pests on maize during kharif 2024

To determine the effect of dates of sowing on population buildup of some important insect pests on maize during kharif 2024 hybrid maize Yuvraj-Gold was sown on five different dates from February to April 2024 at a fortnight interval, viz., 29 Feb 2024, 13 Mar 2024, 28 Mar 2024, 10 Apr 2024 and 20 Apr 2024. The infestation of various insect pests was documented from 5 DAG at seven-day intervals. The experimental findings pertaining to infestation of various insect pests on different dates of sowing were statistically analysed and the results are presented under the subsequent heads.

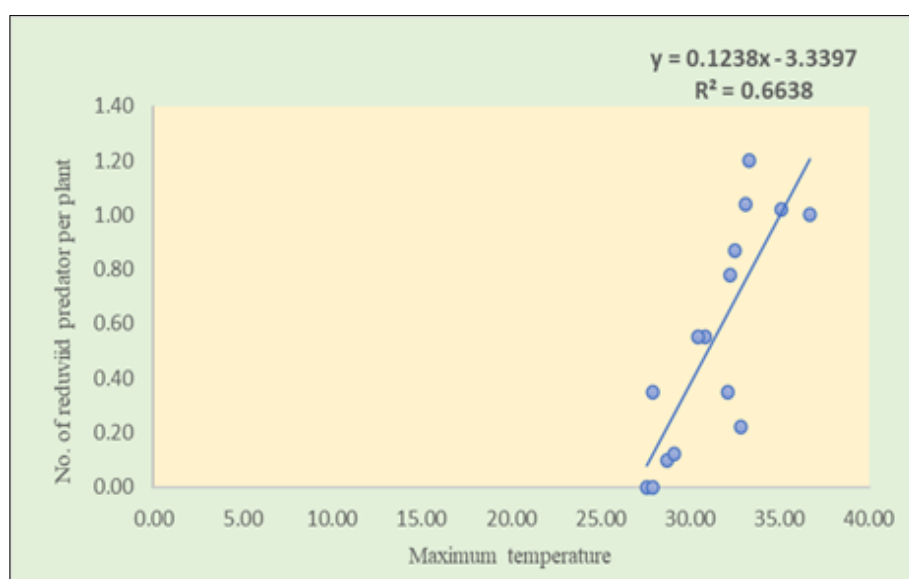


Fig. 9. Simple correlation of reduviid predator with maximum temperature.

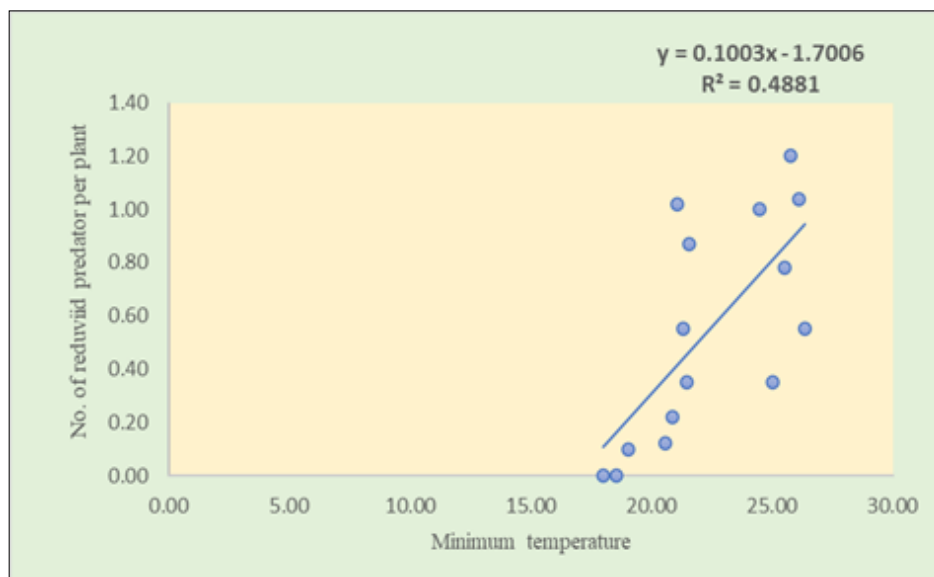


Fig. 10. Simple correlation of reduviid predator with minimum temperature.

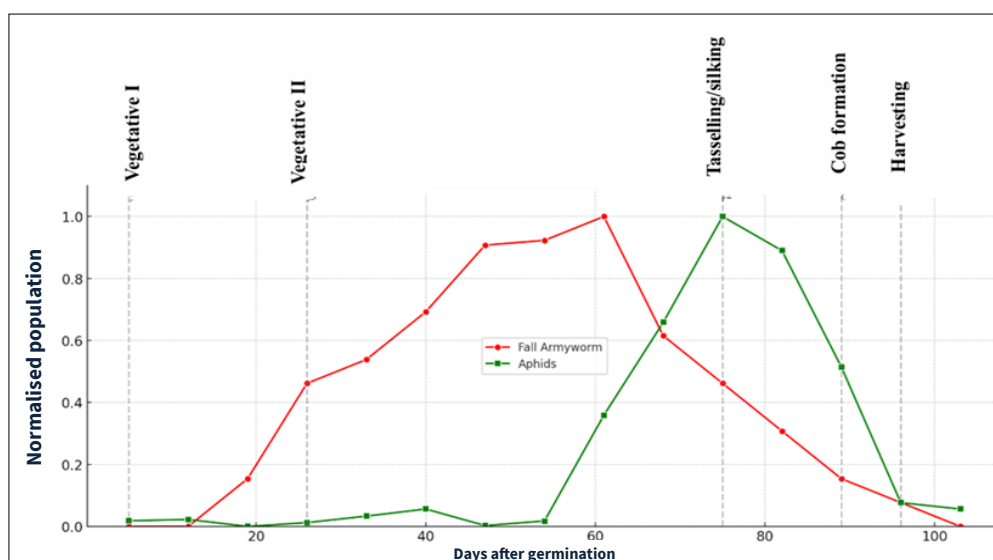


Fig. 11. Incidence of insect pests across various developmental stages of maize during kharif 2024.

Table 8. Incidence of insect pests across various developmental stages of maize during kharif 2024

Crop growth period	Plant age/ Day after germination (DAG)	No. of <i>Spodoptera frugiperda</i> larvae per plant	Normalised value	No. of <i>Rhopalosiphum maidis</i> per leaf	Normalised value
Vegetative I	5	0.00	0.00	8.06	0.01
	12	0.00	0.00	8.34	0.02
	19	0.50	0.15	6.87	0.00
	26	1.50	0.46	7.67	0.01
	33	1.75	0.53	9.05	0.03
Vegetative II	40	2.25	0.69	10.56	0.05
	47	2.95	0.88	7.05	0.01
	54	3.00	0.92	8.02	0.01
	61	3.25	1.00	30.50	0.35
	68	2.00	0.61	50.25	0.65
Tasselling/ silking	75	1.50	0.46	72.75	1.00
	82	1.00	0.30	65.50	0.89
Cob formation	89	0.50	0.15	40.75	0.51
Harvesting	96	0.25	0.07	11.92	0.07
	103	0.00	0.00	10.56	0.05

Table 9. Correlation of various insect-pests of maize with plant age (in days after germination)

Insect pest	Pearson's correlation coefficient (r)
<i>Spodoptera frugiperda</i> (J.E. Smith)	-0.020
<i>Rhopalosiphum maidis</i> (Fitch)	0.508*
<i>Monolepta signata</i> (Olivier)	0.451
Coccinellid predator	0.491
Reduviid predator	0.673*

*Significant at 0.05 level.

Effect of different dates of sowing on the number and incidence of *Spodoptera frugiperda*

Among the various dates of sowing, the lowest population and percentage of infestation of *S. frugiperda* were recorded in T₃ (0.86 larvae per plant and 37.73 %), which was found to be significantly different from T₄ (1.42 larvae per plant and 47.08 %) and T₅ (1.68 larvae per plant and 49.36 %). However, T₃ was found to be statistically comparable to T₁ (1.13 larvae per plant and 42.64 %) and T₂ (1.18 larvae per plant and 43.93 %) in reducing the population and infestation of *S. frugiperda*. These results are presented in Table 10 and illustrated in Fig. 12. The highest population and per cent infestation of *S. frugiperda* were observed in T₅ (1.68 larvae per plant and 49.36 %), which was found to be similar to T₄ (1.42 larvae per plant and 47.08 %) and found to be distinct from other treatments. It was observed that during the early sowing dates (T₁ and T₂) the population of *S. frugiperda* was relatively lower in the seedling stage (Table 11 and Fig. 13). In the case of delayed sowing dates (T₄ and T₅), a significantly higher incidence was observed during the seedling to vegetative stages of maize.

Effect of date of sowing on incidence of *Rhopalosiphum maidis*

Among the various dates of sowing the lowest population of 21.94 aphids per leaf was recorded in T₃ and which showed a significant difference from rest of the treatment presented in Table 12 and depicted in Fig. 14. In contrast, the highest mean aphid population was observed in T₅ (46.25 aphids per leaf), which was found to be statistically *at par* with T₄ (40.15 aphids per leaf). Moreover, no significant difference was also recorded among T₁ (36.71 aphids per leaf), T₂ (34.22 aphids per leaf) and T₄ (40.15 aphids per leaf). The maximum aphid population was recorded during the late vegetative and reproductive stages of the crop across various sowing dates.

Effect of date of sowing on incidence of *Monolepta signata*

Among the various sowing dates, the lowest mean population was observed in T₁ (0.52 adults per plant), which did not differ statistically from T₂ (0.63 adults per plant) or T₃ (0.54 adults per plant). The highest population of *M. signata* was recorded in T₅ (0.76 adults per plant), which was statistically comparable to T₄ (0.67 adults per plant) and considerably different from all other dates of sowing shown in Table 13 and depicted in Fig. 15.

Population buildup of natural enemies at different dates of sowing

The mean data on the population of coccinellid predators indicated that the highest population was detected in T₅ (1.72 coccinellids per plant), which had a pronounced difference from the rest of the treatments presented in Table 14 and illustrated in Fig. 16. This coincided with the highest mean aphid population of 45.62 aphids per leaf in T₅. In addition to these, the maximum number of coccinellids (2.75 coccinellids per plant) was recorded during the 24th SMW in T₅, which also corresponded to the peak aphid population (71.50 aphids per leaf). However, the lowest population of coccinellid predators was noted in T₃ (1.41 coccinellids per plant), which was statistically comparable with T₁ (1.54 coccinellids per plant), T₂ (1.53 coccinellids per plant) and T₄ (1.43 coccinellids per plant).

The mean incidence of reduviid predators was highest in T₅ (0.91 reduviid predators per plant), which differed significantly from the other sowing dates (Table 15). However, a decline in reduviid predator population was observed from 24th SMW, which was associated with a corresponding reduction in *S. frugiperda* population, suggesting a potential relationship between predator and prey activity. Moreover, T₁ recorded 0.61 reduviid predators per plant, which was statistically equivalent to T₃ (0.69 reduviid predators per plant). Additionally, no significant difference was also recorded among the T₂ (0.75 predator per plant), T₃ (0.69 reduviid predator per plant) and T₄ (0.77 reduviid predator per plant) (Fig. 17).

Discussion

Incidence of insect pests of maize and correlation studies with weather parameters during kharif 2024

Incidence of fall armyworm, *Spodoptera frugiperda* and its relationship with meteorological factors

Fall armyworm, *Spodoptera frugiperda* is a major invasive pest of maize in India, causing severe whorl and leaf damage through its

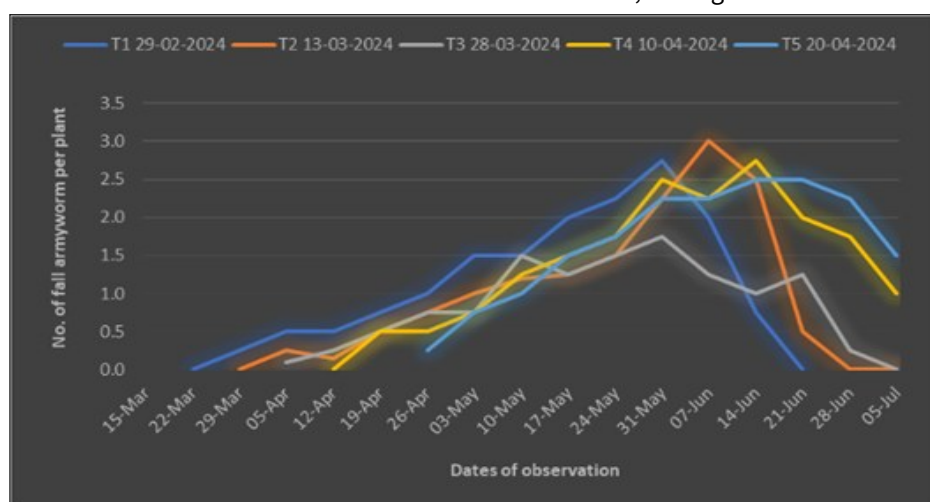
**Fig. 12.** Effect of dates of sowing on population buildup of *Spodoptera frugiperda*.

Table 10. Effect of dates of sowing on population build-up of *Spodoptera frugiperda* on maize during 2024

Per cent infested plant at different dates of sowing																
Treatment	Dates of sowing	Date of observation and SMW														
		15 th -Mar (11 SMW)	22 nd -Mar (12 SMW)	29 th -Mar (13 SMW)	05 th -Apr (14 SMW)	12 th -Apr (15 SMW)	19 th -Apr (16 SMW)	26 th -Apr (17 SMW)	03 rd -May (18 SMW)	10 th -May (19 SMW)	17 th -May (20 SMW)	24 th -May (21 SMW)	31 st -May (22 SMW)	07 th -Jun (23 SMW)	14 th -Jun (24 SMW)	21 st -Jun (25 SMW)
T ₁	29-02-24	0.00 (0.00)	0.00 (0.00)	15.50 (23.18)	18.75 (25.66)	22.25 (28.14)	27.50 (31.63)	30.50 (33.52)	41.75 (40.25)	50.25 (45.14)	53.75 (47.1)	61.75 (51.80)	63.50 (52.83)	68.75 (56.01)	70.50 (57.10)	72.25 (58.21)
T ₂	13-03-24	--	--	0.00 (0.00)	5.25 (13.25)	8.75 (17.21)	12.50 (20.70)	16.25 (23.77)	20.75 (27.10)	32.50 (34.76)	37.25 (37.6)	46.50 (42.99)	50.25 (45.14)	65.50 (54.03)	68.50 (55.86)	70.75 (57.26)
T ₃	28-03-24	--	--	--	0.00 (0.00)	7.50 (15.89)	9.25 (17.71)	13.50 (21.56)	15.25 (22.99)	27.75 (31.79)	28.25 (32.1)	45.50 (42.42)	48.50 (44.14)	60.75 (51.21)	65.50 (54.03)	67.25 (55.09)
T ₄	10-04-24	--	--	--	--	--	9.75 (18.19)	13.25 (21.56)	20.50 (26.92)	28.25 (32.11)	35.50 (36.5)	48.75 (44.28)	50.50 (45.29)	57.50 (49.31)	70.75 (61.51)	74.25 (59.51)
T ₅	20-04-24	--	--	--	--	--	--	8.50 (16.96)	11.25 (19.60)	20.50 (26.92)	38.75 (38.5)	45.50 (42.42)	56.75 (48.88)	63.25 (52.68)	73.75 (59.18)	79.50 (63.08)
S.E m. ±		--	--	--	--	--	--	--	0.12	0.15	0.13	0.19	0.22	0.25	0.27	0.30
CD at 5%		--	--	--	--	--	--	--	0.35	0.39	0.36	0.43	0.53	0.56	0.58	0.80

*Figure in parentheses are $\sqrt{(x + 0.5)}$ values; SMW: Standard meteorological week.

Table 11. Effect of dates of sowing on per cent infestation of *Spodoptera frugiperda* on maize during 2024

Per cent infested plant at different dates of sowing																
Treatment	Dates of sowing	Date of observation and SMW														
		15 th -Mar (11 SMW)	22 nd -Mar (12 SMW)	29 th -Mar (13 SMW)	05 th -Mar (14 SMW)	12 th -Apr (15 SMW)	19 th -Apr (16 SMW)	26 th -Apr (17 SMW)	03 rd -May (18 SMW)	10 th -May (19 SMW)	17 th -May (20 SMW)	24 th -May (21 SMW)	31 st -May (22 SMW)	07 th -Jun (23 SMW)	14 th -Jun (24 SMW)	21 st -Jun (25 SMW)
T ₁	29-02-24	0.00 (0.00)	0.00 (0.00)	15.50 (23.18)	18.75 (25.66)	22.25 (28.14)	27.50 (31.63)	30.50 (33.52)	41.75 (40.25)	50.25 (45.14)	53.75 (47.15)	61.75 (51.80)	63.50 (52.83)	68.75 (56.01)	70.50 (57.10)	72.25 (58.21)
T ₂	13-03-24	--	--	0.00 (0.00)	5.25 (13.25)	8.75 (17.21)	12.50 (20.70)	16.25 (23.77)	20.75 (27.10)	32.50 (34.76)	37.25 (37.61)	46.50 (42.99)	50.25 (45.14)	65.50 (54.03)	68.50 (55.86)	70.75 (57.26)
T ₃	28-03-24	--	--	--	0.00 (0.00)	7.50 (15.89)	9.25 (17.71)	13.50 (21.56)	15.25 (22.99)	27.75 (31.79)	28.25 (32.11)	45.50 (42.42)	48.50 (44.14)	60.75 (51.21)	65.50 (54.03)	67.25 (55.09)
T ₄	10-04-24	--	--	--	--	--	9.75 (18.19)	13.25 (21.56)	20.50 (26.92)	28.25 (32.11)	35.50 (36.57)	48.75 (44.28)	50.50 (45.29)	57.50 (49.31)	70.75 (57.26)	74.25 (59.51)
T ₅	20-04-24	--	--	--	--	--	--	8.50 (16.96)	11.25 (19.60)	20.50 (26.92)	38.75 (38.50)	45.50 (42.42)	56.75 (48.88)	63.25 (52.68)	73.75 (59.18)	79.50 (63.08)
S.E m. ±		--	--	--	--	--	--	--	0.12	0.15	0.13	0.19	0.22	0.25	0.27	0.30
CD at 5%		--	--	--	--	--	--	--	0.35	0.39	0.36	0.43	0.53	0.56	0.58	0.80

* Figures in parentheses are arcsine($\sqrt{x}$) values; SMW: Standard meteorological week.

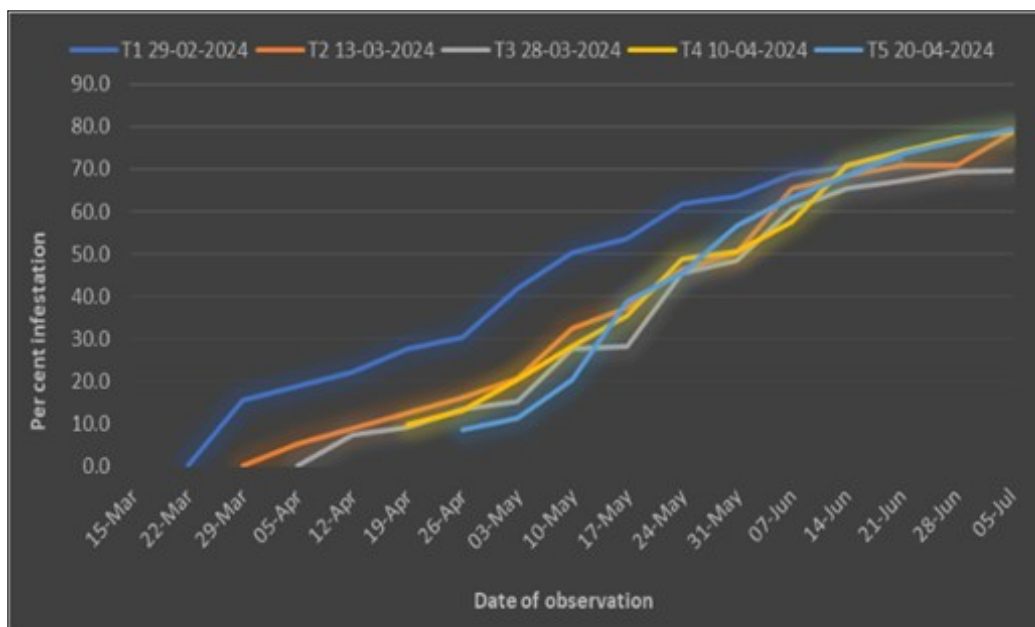


Fig. 13. Effect of dates of sowing on per cent infestation of *Spodoptera frugiperda*.

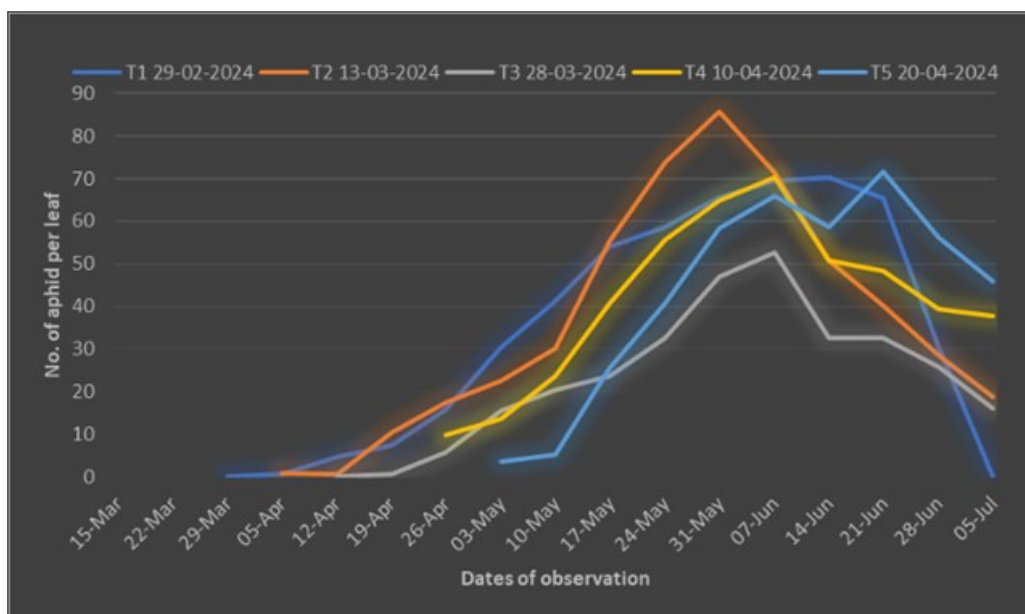


Fig. 14. Effect of dates of sowing on population buildup of *Rhopalosiphum maidis*.

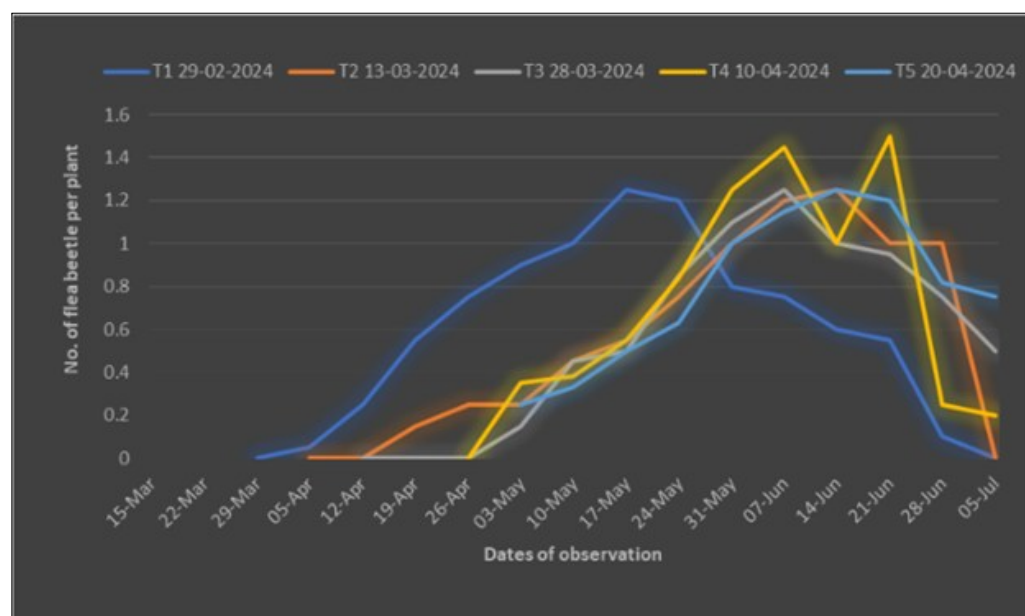


Fig. 15. Effect of dates of sowing on population buildup of *Monolepta signata* on maize.

Table 12. Effect of dates of sowing on population buildup of *Rhopalosiphum maidis* on maize during 2024

Treatment	Date of sowing	Number of aphids per leaf at different dates of sowing																	
		Date of observation and SMW																	
		15 th -Mar (11 SMW)	22 nd -Mar (12 SMW)	29 th -Mar (13 SMW)	05 th -Apr (14 SMW)	12 th -Apr (15 SMW)	19 th -Apr (16 SMW)	26 th -Apr (17 SMW)	03 rd -May (18 SMW)	10 th -May (19 SMW)	17 th -May (20 SMW)	24 th -May (21 SMW)	31 st -May (22 SMW)	07 th -Jun (23 SMW)	14 th -Jun (24 SMW)	21 st -Jun (25 SMW)	28 th -Jun (26 SMW)	05 th -Jul (27 SMW)	Mean
T ₁	29-02-24	0.00 (0.71)	0.00 (0.71)	0.50 (1.00)	4.50 (2.24)	7.40 (2.81)	15.75 (4.03)	40.50 (6.40)	45.25 (6.76)	55.90 (7.51)	58.60 (7.69)	65.75 (8.14)	69.50 (8.37)	70.30 (8.41)	65.50 (8.12)	30.50 (5.57)	-	-	36.71
T ₂	13-03-24	--	0.00 (0.71)	0.75 (1.12)	0.50 (1.00)	10.45 (3.31)	17.45 (4.24)	22.65 (4.81)	30.20 (5.54)	55.25 (7.47)	73.75 (8.62)	85.70 (9.28)	71.45 (8.48)	50.75 (7.16)	46.25 (6.84)	32.56 (5.75)	28.65 (5.40)	6.93 (2.73)	38.22
T ₃	28-03-24	--	--	--	0.00 (0.71)	0.50 (1.00)	5.75 (2.50)	15.50 (4.00)	20.45 (4.58)	23.75 (4.92)	32.50 (5.74)	47.05 (6.90)	52.50 (7.28)	30.50 (5.57)	32.57 (5.75)	25.85 (5.13)	15.93 (4.05)	5.12 (2.37)	21.94
T ₄	10-04-24	--	--	--	--	--	9.75 (3.20)	13.66 (3.76)	23.61 (4.91)	40.75 (6.42)	55.5 (7.48)	64.75 (8.08)	70.25 (8.41)	50.75 (7.16)	30.25 (5.55)	20.25 (4.56)	13.75 (3.77)	9.50 (3.16)	40.15
T ₅	20-04-24	--	--	--	--	--	--	0.00 (0.71)	5.25 (2.40)	25.50 (5.10)	40.75 (6.42)	58.25 (7.66)	65.95 (8.15)	51.50 (7.21)	71.50 (8.49)	46.25 (6.84)	40.75 (6.42)	33.50 (5.83)	46.25
S.E m. ±		--	--	--	--	--	--	--	0.10	0.24	0.28	0.35	0.42	0.51	0.69	0.96	--	--	1.55
CD at 5 %		--	--	--	--	--	--	--	0.28	0.59	0.63	0.90	1.15	1.40	1.74	2.68	--	--	4.45

* Figure in parentheses are $\sqrt{x + 0.5}$ values; SMW: Standard meteorological week.

Table 13. Effect of dates of sowing on population buildup of *Monolepta signata* on maize during 2024

Treatment	Date of sowing	Number of adults per plant on different dates of sowing																	Mean
		15 th -Mar (11 SMW)	22 nd -Mar (12 SMW)	29 th -Mar (13 SMW)	05 th -Apr (14 SMW)	12 th -Apr (15 SMW)	19 th -Apr (16 SMW)	26 th -Apr (17 SMW)	03 rd -May (18 SMW)	10 th -May (19 SMW)	17 th -May (20 SMW)	24 th -May (21 SMW)	31 st -May (22 SMW)	07 th -Jun (23 SMW)	14 th -Jun (24 SMW)	21 st -Jun (25 SMW)	28 th -Jun (26 SMW)	05 th -Jul (27 SMW)	
T ₁	29-02-24	0.00 (0.71)	0.00 (0.71)	0.05 (0.74)	0.25 (0.87)	0.55 (1.02)	0.75 (1.12)	0.90 (1.18)	1.00 (1.22)	1.25 (1.32)	1.20 (1.30)	0.80 (1.14)	0.75 (1.12)	0.60 (1.05)	0.55 (1.02)	0.10 (0.77)	--	--	0.52
T ₂	13-03-24	--	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.15 (0.81)	0.20 (0.84)	0.25 (0.87)	0.45 (0.97)	0.55 (1.02)	0.75 (1.12)	1.00 (1.22)	1.20 (1.30)	1.25 (1.32)	1.00 (1.22)	1.00 (1.22)	0.00 (0.71)	0.00 (0.71)	0.63
T ₃	28-03-24	--	--	--	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.15 (0.81)	0.45 (0.97)	0.50 (1.00)	0.85 (1.16)	1.10 (1.26)	1.25 (1.32)	1.00 (1.22)	0.95 (1.20)	0.70 (1.10)	0.20 (0.84)	0.50 (1.00)	0.54
T ₄	10-04-24	--	--	--	--	--	0.00 (0.71)	0.35 (0.92)	0.38 (0.94)	0.55 (1.02)	0.84 (1.16)	1.25 (1.32)	1.45 (1.40)	1.00 (1.22)	1.50 (1.41)	0.25 (0.87)	0.20 (0.84)	0.30 (0.89)	0.67
T ₅	20-04-24	--	--	--	--	--	--	0.25 (0.87)	0.33 (0.91)	0.50 (1.00)	0.63 (1.06)	1.00 (1.22)	1.15 (1.28)	1.25 (1.32)	1.20 (1.30)	0.82 (1.15)	0.75 (1.12)	0.50 (1.00)	0.76
S.E m. ±		--	--	--	--	--	--	--	0.12	0.14	0.09	0.07	0.11	0.11	0.15	0.17	--	--	0.04
CD at 5 %		--	--	--	--	--	--	--	0.30	0.41	0.25	0.20	0.30	0.30	0.44	0.50	--	--	0.12

* Figure in parentheses are $\sqrt{x + 0.5}$ values; SMW: Standard meteorological week.

Number of coccinellid predator per plant at different dates of sowing

*Figure in parentheses are $\sqrt{x + 0.5}$ values; SMW: Standard meteorological week.

Number of predators per plant at different sowing dates

*Figure in parentheses are $\sqrt{x + 0.5}$ values; SMW: Standard meteorological week.

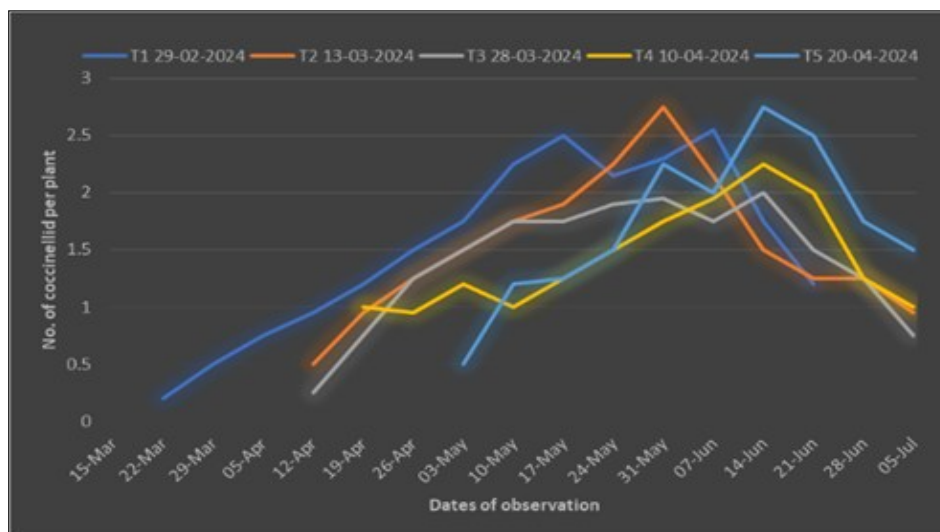


Fig. 16. Population build-up of coccinellid on maize at different dates of sowing.

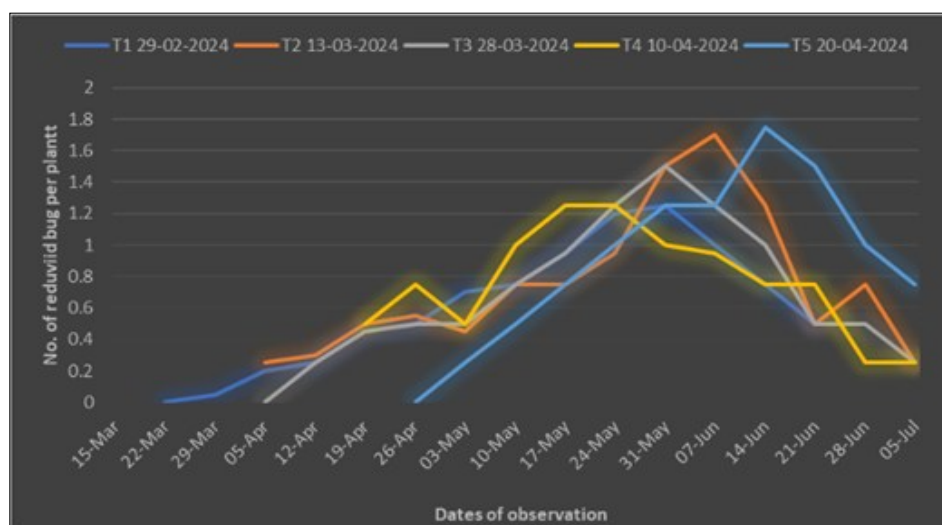


Fig. 17. Population of reduviid predators on maize at different dates of sowing.

highly voracious larvae (13, 14). In the present study, *S. frugiperda* activity was observed from the 13th to 24th SMW during kharif 2024. The population peaked at the vegetative stage during the 19th SMW, at 3.25 larvae per plant and declined thereafter. These observations are consistent with previous reports indicating peak infestation in May–June and during the vegetative-to-early-reproductive growth phases of maize (15, 16).

Correlation analysis revealed that maximum temperature had a significant positive association with larval population ($r=0.659^{**}$, $p<0.001$), consistent with earlier observations (17). Non-significant positive correlations were recorded with bright sunshine hours, evening relative humidity and minimum temperature, whereas morning relative humidity and rainfall showed non-significant negative effects. These patterns are in line with previously documented trends (18, 19).

Variations reported across other regions might be attributed to climatic differences and seasonal variability (20). Multiple regression analysis further indicated that the combined influence of weather parameters accounted for 70.10 % ($R^2 = 0.701$) of the variation in *S. frugiperda* population, which is comparable to earlier estimates of weather-based explanatory models (21).

Incidence of corn aphid, *Rhopalosiphum maidis* and its relationship with meteorological factors

The incidence of *R. maidis* on maize was recorded from the 11th to 25th SMW during kharif 2024. The population fluctuated between 6.87 and

72.75 aphids per leaf, peaking during the 21st SMW. These observations correspond with earlier reports documenting continuous aphid activity, with peak infestation occurring in May (17).

Correlation analysis revealed that the maximum and minimum temperatures had significant positive associations with aphid abundance ($r=0.716^{**}$ and 0.661^{*}), whereas rainfall showed a significant negative correlation ($r=-0.542^{*}$). Morning and evening relative humidity exhibited negative, non-significant effects. These results are consistent with an earlier study (17) and are partly supported by reports indicating negative correlations between humidity and rainfall and *R. maidis* population buildup (22).

Previous reports further highlight similar trends, suggesting that temperature favors aphid multiplication, whereas rainfall and high humidity suppress population buildup (23, 24). Multiple regression analysis indicated that weather parameters collectively explained 68.50 % of the variation in *R. maidis* population ($R^2 = 0.685$), which is comparable to earlier documented estimates (25).

Incidence of flea beetle, *Monolepta signata* and its relationship with meteorological factors

The incidence of *M. signata* on maize was recorded from the 11th to the 25th SMW during kharif 2024, with the peak population (1.50 beetles per plant) occurring in the 19th SMW. Very limited published work on this pest in maize highlights a major research gap, underscoring the importance of the present study.

Correlation analysis revealed that maximum temperature had a significant negative association with flea beetle population ($r = -0.520^*$), while minimum temperature showed a negative but non-significant relationship ($r = -0.475$). These findings are consistent with earlier reports documenting strong negative correlations between both temperature parameters and flea beetle incidence in mustard (26). Other meteorological variables had a negligible influence on *M. signata* abundance, consistent with previous observations in black gram (27). In contrast, some studies have reported significant positive correlations between rainfall and relative humidity and flea beetle populations in okra, indicating possible crop- and region-specific variability in pest responses to weather factors (28). Multiple linear regression analysis showed that weather parameters collectively explained 57.10 % of the variation in *M. signata* population ($R^2 = 0.571$).

Incidence of natural enemies and their relationship with meteorological factors

Coccinellid predators were recorded from the third week of March 2024 (11th SMW) to the first week of July 2024 (25th SMW), with the population reaching a peak of 2.75 predators per plant during the second week of May 2024 (22nd SMW). These observations closely align with earlier reports indicating that peak coccinellid activity occurs in May in Meerut, Uttar Pradesh (29).

Correlation analysis revealed that the coccinellid population showed significant positive associations with both maximum and minimum temperatures ($r = 0.766^{**}$, 0.625^*) and with morning relative humidity ($r = 0.578^*$). These results are consistent with previous findings documenting positive relationships between coccinellid abundance and temperature parameters (30). Bright sunshine hours exhibited a positive but non-significant correlation ($r = 0.183$), while evening relative humidity showed a similar non-significant positive association ($r = 0.588$). Rainfall has been reported to significantly reduce coccinellid populations in other studies (31). The multiple linear regression model indicated that all abiotic factors together explained 73.10 % of the variation in coccinellid populations ($R^2 = 0.731$). These results are supported by prior researchers, who reported that abiotic factors accounted for 54 % ($R^2 = 0.54$) and 77 % ($R^2 = 0.77$) of the variation in coccinellid populations during the rabi seasons of 2021–22 and 2022–23, respectively, in mustard (32).

Reduviid bugs were present from the last week of March 2024 (13th SMW) to the first week of July 2024 (25th SMW), with the peak population (1.20 predators per plant) occurring during the fourth week of May 2024 (21st SMW). These findings are consistent with previous studies that reported maximum reduviid abundance from May to July in groundnut ecosystems (33). Additional reports also highlight the predatory effectiveness of reduviids in suppressing populations of several key insect pests, including *S. litura*, *A. craccivora*, *H. armigera*, *Chrotogonus trachyterus* and *Atractomorpha crenulata*, particularly during the early monsoon period (34).

Correlation analysis indicated that both maximum ($r = 0.814^{**}$, $p < 0.001$) and minimum ($r = 0.697^{**}$, $p < 0.001$) temperatures had a strong, significant positive influence on reduviid populations, making them the most influential climatic parameters. Morning ($r = 0.325$) and evening ($r = 0.275$) relative humidity, along with bright sunshine hours ($r = 0.248$), showed positive but non-significant correlations. Rainfall exhibited a weak negative and non-significant association ($r = -0.023$) with reduviid abundance. Multiple linear regression results indicated that the

combined effect of all-weather parameters explained 72.90 % of the variability in reduviid predator populations ($R^2 = 0.729$).

Correlation between *Rhopalosiphum maidis* and coccinellid predators

Coccinellid predators revealed a strong, highly significant positive correlation with *R. maidis* population ($r = 0.843^{**}$). The current observations were consistent with earlier reports that documented a significant positive correlation between coccinellid predators and aphid populations (35).

Incidence of insect pest across various developmental stages of maize during kharif 2024

In the present experiment, the larval population of *S. frugiperda* was relatively high during the vegetative stage of maize but declined in the later phases of the crop. As a result, the larval population of *S. frugiperda* showed a negative relationship with DAG ($r = -0.020$). The present observations were analogous to earlier reports indicating that the incidence of *S. frugiperda* is more frequent in the early stages of maize than later developmental stages (36). Previous studies have also documented that the population and damage caused by *S. frugiperda* are relatively higher during the seedling and vegetative stages than during the tasseling and silking stages (37). They also detected a decrease in the *S. frugiperda* population during the crop's later growth stages. In contrast, the aphid population exhibited a substantial positive association with DAG ($r = 0.508^*$), indicating that the aphid population increased as the crop reached maturity. Prior studies reported that the *R. maidis* population was positively and significantly correlated with DAG ($r = 0.868$) and suggested that the aphid population increased progressively as the crop reached maturity, which is consistent with the present findings (22). Similarly, a substantial positive connection was found between reduviid predators and plant age ($r = 0.673^*$). However, *M. signata* ($r = 0.451$) and coccinellid ($r = 0.491$) failed to show a significant connection with plant age.

Effect of different dates of sowing on population buildup of some important insect pests on maize during 2024

Effect of different dates of sowing on the incidence of *Spodoptera frugiperda*

The treatments evaluated in the present experiment significantly affected the mean larval population and infestation levels of *S. frugiperda*. The lowest mean larval count was recorded in T₃ (0.86 larvae per plant), which was statistically at par with T₁ (1.13 larvae per plant) and T₂ (1.18 larvae per plant) and distinctly different from T₄ (1.42 larvae per plant) and T₅ (1.68 larvae per plant). Similarly, the lowest mean infestation (37.73%) was observed in T₃ and was statistically comparable to T₁ (42.64 %) and T₂ (43.93 %). The highest infestation occurred in T₅ (49.36 %), which was statistically comparable to T₄ (47.08 %) and significantly different from all early-sowing treatments. Both larval population and infestation increased progressively with delayed sowing, underscoring the importance of optimal planting time in suppressing *S. frugiperda* incidence.

The data further revealed that T₁ experienced minimal pest incidence immediately after plant emergence and during the seedling stage. In contrast, delayed sowing, particularly in T₄ and T₅, exhibited higher larval activity during the seedling and vegetative stages. The elevated infestation in delayed sowings may be attributed to higher atmospheric temperatures and increased relative humidity, which can slow early crop development and create favorable conditions for pest establishment and multiplication.

The present findings align with earlier reports indicating reduced larval counts in maize sown at the optimum time in northeast Argentina (1.16 larvae per plant), compared with higher larval counts (1.65 larvae per plant) in late-sown crops (9). Similar studies have also documented significantly lower larval loads (0.45 larvae per plant) in early-sown maize than in later-sown maize (38). These observations further align with evidence showing that heavy rainfall can markedly reduce early-instar larval populations of *S. frugiperda*, thereby lowering subsequent adult emergence and overall infestation levels (39).

The minor variations between the present results and those of previous investigations may be attributed to differences in environmental conditions, seasonal weather patterns and the maize genotypes used across studies. Collectively, the present findings reinforce the role of sowing time as a key cultural practice in managing *S. frugiperda* and emphasise the need to integrate such strategies into location-specific IPM programs.

Effect of different dates of sowing on the incidence of *Rhopalosiphum maidis*

All sowing dates exhibited a pronounced influence on the population of *R. maidis*. The lowest mean aphid population (21.94 aphids per leaf) was recorded in T₃, which differed significantly from all other treatments. In contrast, the highest mean population was observed in T₅ (46.25 aphids per leaf), which did not differ statistically from T₄ (40.15 aphids per leaf). No significant difference was detected among T₁ (36.71 aphids per leaf), T₂ (34.22 aphids per leaf) and T₄, indicating similar levels of infestation across these sowing dates. Overall, the results clearly show that early sowing in the second fortnight of March was associated with the lowest aphid population, while both population and infestation increased progressively with delayed sowing.

The present findings align with earlier studies that reported increased aphid populations under delayed sowing, accompanied by higher infestation levels and considerable yield reduction (40, 41). Additional reports have also demonstrated that late-sown maize tends to harbour the highest *R. maidis* populations, whereas early sowing consistently results in lower infestations (42). Conversely, some studies have documented contrasting trends, with peak aphid populations occurring in early-sown maize and comparatively lower populations in later-sown crops (43, 44). Such discrepancies may be attributed to variations in climatic conditions, regional weather patterns and crop phenology, all of which strongly influence aphid development, population buildup and seasonal abundance.

Effect of different dates of sowing on the incidence of *Monolepta signata*

The incidence of *M. signata* varied significantly across sowing dates. The lowest mean adult population was recorded in T₁ (0.52 adults per plant), which was statistically comparable with T₂ (0.63 adults per plant) and T₃ (0.54 adults per plant). In contrast, the highest population occurred in T₅ (0.76 adults per plant), which was statistically comparable to T₄ (0.67 adults per plant) but significantly different from the earlier sowing treatments.

A review of the available literature reveals a notable absence of detailed studies concerning the influence of sowing dates on *M. signata* population, underscoring the novelty and relevance of the present findings. The results clearly indicate that early sowing is associated with reduced adult populations and minimal leaf damage, whereas delayed planting leads to a progressive increase in pest abundance and injury.

Effect of different dates of sowing on the incidence of natural enemies

The average coccinellid population varied significantly across sowing dates, with the lowest mean population recorded in T₃ (1.41 coccinellids per plant), which was statistically *at par* with T₁ (1.54), T₂ (1.53) and T₄ (1.43). The highest coccinellid population occurred in T₅ (1.72 coccinellids per plant), coinciding with the maximum aphid incidence (45.62 aphids per leaf). Peak predator activity (2.80 coccinellids per plant) during the 24th SMW under T₅ closely corresponded to the highest aphid population (71.50 aphids per leaf). These findings agree with earlier reports documenting increased predator abundance in delayed sowings or in later crop stages (45–47). In contrast, some studies have reported higher coccinellid populations in early-sown crops, likely reflecting agro-ecological and predator-prey dynamics specific to regional conditions (48).

A strong positive association between aphid and coccinellid populations was evident, particularly in delayed sowings, where enhanced prey availability supported higher predator abundance and better synchronisation between aphids and their natural enemies. Conversely, early sowing facilitated partial escape from *R. maidis* infestation, which aligns with recommended agronomic practices that promote early-season predator activity.

Reduviid predators followed a similar pattern, with the highest population in T₅ (0.91 predators per plant), though differences among treatments were statistically non-significant. A decline in *S. frugiperda* populations correspondingly reduced reduviid abundance, indicating prey-linked predator activity. Treatments T₁ (0.61) and T₃ (0.69) were statistically comparable, as were T₂ (0.75), T₃ (0.69) and T₄ (0.77). Earlier reports support these observations, highlighting the active role and favorable development of reduviid predators during the kharif season (49, 50). The findings highlight the key role of coccinellid and reduviid predators in suppressing aphids and fall armyworm populations, supporting their effective use in integrated pest management (IPM) programs.

Conclusion

The present study establishes fall armyworm, *Spodoptera frugiperda* as the most destructive and persistent pest of maize in Assam, occurring from seedling emergence to crop maturity and surpassing previously reported borer pests in severity. Pest incidence was lowest under early sowing and increased progressively with delayed planting. Although T₃ recorded the lowest insect infestation, T₁ (the second fortnight of February) produced the highest yield and demonstrated overall agronomic superiority, indicating that early sowing is an effective cultural strategy for reducing pest pressure while sustaining crop productivity. However, reliance on chemical control has led to resistance, resurgence, loss of natural enemies and residue concerns. These findings reinforce the need to integrate sowing time adjustment with the conservation and augmentation of natural enemies (predators and parasitoids) and other eco-friendly measures. Therefore, combining cultural, biological and need-based chemical approaches is essential for a sustainable, region-specific strategy against fall armyworm in Assam.

Acknowledgements

The authors are deeply indebted to the Department of Entomology, Biswanath College of Agriculture, Assam Agricultural University, Assam for providing all the facilities for conducting the study.

Authors' contributions

NB conceived the research idea and designed the experimental framework. BB carried out the field experiments, performed data analysis and prepared the manuscript. PR contributed to manuscript writing and supervised the overall research work. NB also assisted in writing and review editing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflict of interest to declare

Ethical issues: None

References

1. Suman S, Bhadauria NS, Tomar SPS, Singh P, Naveen. Seasonal incidence of sucking insect pests of maize and their natural enemies. *Pharma Innov J*. 2023;12(8S):740–3.
2. Statista [Internet]. 2023. Available from: <https://www.statista.com/statistics/1140254/india-production-volume-of-maize/>
3. Mathur LML. Genetics of insect resistance in maize. In: Sarkar KR, Singh HN, Sachan JKS, editors. *Maize Genetic Perspectives*. New Delhi: Indian Society of Genetics and Plant Breeding; 1991. p. 238–50.
4. Reddy YVR, Trivedi S. *Maize Production Technology*. 1st ed. New Delhi: Academic Press; 2008. p. 1–192.
5. Sharanabasappa, Kalleshwaraswamy CM, Asokan R, Swamy HM, Maruthi MS, Pavithra HB, et al. First report of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. *Pest Manag Hortic Ecosyst*. 2018;24(1):23–9.
6. Sarma AK, Goswami H, Kalita J, Sarma PK, Barthakur L. Occurrence of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in Assam. *Indian J Entomol*. 2020;85(4):1039–42.
7. Pilcher CD, Rice ME. Effect of planting dates and *Bacillus thuringiensis* corn on the population dynamics of European corn borer (Lepidoptera: Crambidae). *J Econ Entomol*. 2001;94(3):730–42. <https://doi.org/10.1603/0022-0493-94.3.730>
8. Reddy KJ, Kumari K, Saha T, Singh SN. First record, seasonal incidence and life cycle of fall armyworm *Spodoptera frugiperda* (J.E. Smith) in maize at Sabour, Bhagalpur, Bihar. *J Entomol Zool Stud*. 2008;8(5):1631–5.
9. Ayala OR, Navarro F, Virla EG. Evaluación de las tasas de ataque y el nivel de daños por el gusano cogollero del maíz, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), en el noreste de Argentina. *Rev FCA UNCuyo*. 2013;45(2):1–12.
10. Togola A, Boukar O, Tamò M, Chamarthi S. Stem borers of cereal crops in Africa and their management. In: Haouas D, Hufnagel L, editors. *Pests control and acarology*. London: IntechOpen; 2021. <https://doi.org/10.5772/intechopen.83719>
11. Kamweru I, Anani BY, Beyene Y, Makumbi D, Adetimirin VO, Prasanna BM, et al. Genomic analysis of resistance to fall armyworm (*Spodoptera frugiperda*) in CIMMYT maize lines. *Genes*. 2022;13(2):251. <https://doi.org/10.3390/genes13020251>
12. Gomez KA, Gomez AA. *Statistical procedures for agricultural research*. 2nd ed. New York: John Wiley & Sons; 1984. p. 680.
13. Gowda MAP, Sekhar JC, Soujanya PL, Yathish KR, Rahman SJ, Mallaiah B, et al. Correlation studies between maize planting dates, weather parameters and the incidence of fall armyworm (*Spodoptera frugiperda*). *Plant Arch*. 2024;24(1):101–7. <https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.1.015>
14. Nivetha TK, Srinivasan G, Shanthi M, Gurusamy A, Vellaikumar S. Seasonal incidence and influence of weather factors on the incidence of *Spodoptera frugiperda* (J.E. Smith) on maize. *Pharma Innov J*. 2022;11(6S):407–10.
15. Nagoshi RN, Meagher RL. Seasonal distribution of fall armyworm (Lepidoptera: Noctuidae) host strains in agricultural and turf grass habitats. *Environ Entomol*. 2004;33(4):881–9. <https://doi.org/10.1603/0046-225X-33.4.881>
16. Patel AK, Purjeet, Kumar K, Dhanger K, Netam PK, Deole S. Seasonal incidence of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on maize (*Zea mays* L.) in Kanker District of Chhattisgarh, India. *Pharma Innov J*. 2023;12(10S):412–4.
17. Saha R, Mondal Ghosh S, Gope A, Lala RK, Chakraborty G. Seasonal incidence and effect of weather parameters on key insect pests in maize. *Pharma Innov J*. 2023;12(11S):86–92.
18. Sangle SV, Jayewar NE, Gaikwad BB. Seasonal incidence of maize aphids and its correlation with weather parameters. *Pharma Innov J*. 2023;12(12):2229–32. <https://doi.org/10.22271/tpi.2023.v12.i12ab.24880>
19. Deshmukh S, Prasanna BM, Kalleshwaraswamy C, Jaba J, Choudhary B. Fall army worm (*Spodoptera frugiperda*) (J.E. Smith). Singapore: Springer; 2021. https://doi.org/10.1007/978-981-15-8075-8_8
20. Sunitha SV, Swathi M, Madhumathi T, Kumar PA, Chiranjeevi CH. Population dynamics of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on maize. *Forage Res*. 2023;49(1):130–3.
21. Sunitha SV, Swathi M, Madhumathi T, Kumar PA, Chiranjeevi CH. Population dynamics of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on sorghum. *Int J Environ Clim Change*. 2021;11(11):222–9. <https://doi.org/10.9734/ijec/2021/v11i1130537>
22. Singh G, Kumar V, Kumar A. Seasonal incidence of insect pests and their natural enemies on kharif maize. *Int J Theor Appl Sci*. 2023;15(2):39–43.
23. Singh G, Jaglan MS. Seasonal incidence of different insect pests in kharif maize. *J Pharmacogn Phytochem*. 2018;7(3):3666–9.
24. Choudhary PK, Kumawat KC, Jakhar S. Seasonal abundance of aphid, *Rhopalosiphum maidis* (Fitch) and its natural enemies on barley (*Hordeum vulgare* Linn.) and predatory potential of major coccinellid predators on aphid (*Rhopalosiphum maidis*). *Pharma Innov J*. 2022;11(2):2760–4.
25. Patil VP, Rode NS, Sureja BV. Study on population dynamics of aphid, *Rhopalosiphum maidis* on maize. *Bioinfolet*. 2015;12(1B):143–6.
26. Mounika A, Sreenivasa Rao C, Sudharani D, Nirmali S, Lahari K. Seasonal incidence of *Rhopalosiphum maidis* (Fitch) on maize crop in Guntur and Krishna districts of Andhra Pradesh. *J Res ANGRAU*. 2024;51(4):57–62. <https://doi.org/10.58537/joragrau.2023.51.4.07>
27. Patel S, Singh CP, Yadav S. Seasonal incidence of mustard flea beetle, *Phyllotreta cruciferae* on *Brassica* species in relation to weather parameters at different dates of sowing. *J Entomol Zool Stud*. 2017;5:673–7.
28. Dubey R, Jat HK, Lal B, Bhadauria NS. Insect population associated with black gram and the influence of abiotic factors on the occurrence of insect pests affecting black gram. *Int J Adv Biochem Res*. 2025;9(1S):920–2. <https://doi.org/10.33545/26174693.2025.v9.i1S1.3629>
29. Nair N, Giri U, Bhattacharjee T, Thangjam B, Paul N, Debnath MR. Biodiversity of insect pest complex infesting okra (*Abelmoschus esculentus*) in Tripura, N.E. India. *J Entomol Zool Stud*. 2017;5(5):1968–72.
30. Kumar R, Alam T, Mukherjee U. Studies on seasonal incidence of *Chilo partellus* (Swinhoe) on maize with relation to abiotic factors. *J Exp Zool India*. 2017;20(2):1075–8.

31. Borkakoti RN, Saikia DK. Effect of weather parameters on population buildup of predatory coccinellids and spiders present in brinjal crop ecosystem of Assam. *Int J Curr Microbiol Appl Sci*. 2020;9(9):114–7. <https://doi.org/10.20546/ijcmas.2020.909.014>
32. Borah N, Saikia DK. Seasonal incidence of major insect pests of brinjal and their natural enemies. *Indian J Entomol*. 2017;79(4):449–55. <https://doi.org/10.5958/0974-8172.2017.00081.5>
33. Geethanjali L, Singh H, Singh B, Kant C, Patel A, Anvesh K, et al. Studies on diversity of major insect pests and coccinellid predators on mustard crop ecosystem in relation to abiotic factors. *Environ Ecol*. 2023;41(4B):2666–74. <https://doi.org/10.60151/envec/AQPF3952>
34. Sahayaraj K, Martin P. Assessment of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) as augmented control in groundnut pests. *J Cent Eur Agric*. 2003;4(2):103–10.
35. Sahayaraj K, Ravi C. Evaluation of reduviid predators and plant products against chosen groundnut pests. *Arch Phytopathol Plant Prot*. 2007;40(4):281–90. <https://doi.org/10.1080/03235400600586716>
36. Harshita AP, Saikia DK, Devesh A, Bora LC, Phukan SN. Seasonal incidence of aphid, *Aphis gossypii* and coccinellid beetles in tomato ecosystem, *Solanum lycopersicum* L. *J Entomol Zool Stud*. 2019;7(3):879–82.
37. Ullah F, Anwar S, Badshah H, Mashwani M, Khan M, Anwar H, et al. Effect of different planting dates of maize on infestation of maize stem borer *Chilo partellus* (Swinhoe) (Pyralidae: Lepidoptera). *Sarhad J Agric*. 2010;26:621–4.
38. Kumar NV, Yasodha P, Justin CGL. Seasonal incidence of maize fall armyworm *Spodoptera frugiperda* (J.E. Smith) (Noctuidae: Lepidoptera) in Perambalur district of Tamil Nadu, India. *J Entomol Zool Stud*. 2020;8(3):1–4.
39. Darshan R, Prasanna PM, Guruprasad GS, Jayalaxmi Narayan Hegde. Population dynamics of fall armyworm, *Spodoptera frugiperda* and its natural enemies in maize. *J Adv Biol Biotechnol*. 2024;27(4):83–8. <https://doi.org/10.9734/jabb/2024/v27i4741>
40. Waddill VH, Mitchell ER, Denton WH, Poe SL, Schuster DJ. Seasonal abundance of the fall armyworm and velvetbean caterpillar (Lepidoptera: Noctuidae) at four locations in Florida. *Fla Entomol*. 1982;65(3):350–4. <https://doi.org/10.2307/3494308>
41. Hake LG, Deshwal HL, Yadav VS. Effect of different sowing dates on the incidence of aphid, *Hyadaphis coriandari* (Das) on fennel *Foeniculum vulgare* (Mill.). *Int J Curr Microbiol Appl Sci*. 2018;S6:2158–62.
42. Biradar SR, Kotikal YK, Balikai RA. Seasonal incidence of insect pests and natural enemies on maize. *Int J Plant Prot*. 2011;4(2):402–5.
43. El-Heneidy AH, Abbas MST. Population dynamics of certain predators associated with aphids in maize fields in Giza Region. *Beitr Trop Landwirtsch Veterinarmed*. 1984;22:407–13.
44. El-Gepaly HMKH. Studies on some natural enemies of certain pests infesting sorghum and corn plants in Sohag Governorate [MSc thesis]. Minia: Minia University; 2007.
45. Mahmoud HH, Abd El-Rahman SF, Naroz MH, Ahmed SS. Effect of sowing dates on the populations of three major insect pests and associated natural enemies throughout the growth stages of maize plants. *Pol J Entomol*. 2021;90(3):130–44. <https://doi.org/10.5604/01.3001.0015.2381>
46. Suman S, Bhadauria NS, Tomar SPS, Singh P, Naveen. Seasonal incidence of sucking insect pests of maize and their natural enemies. *Pharma Innov J*. 2023;12(8S):740–3.
47. Anandhi S, Saminathan VR, Yasodha P, Sheeba Joyce Roseleen S, Sharavanan PT, Rajanbabu V. Correlation of fall armyworm *Spodoptera frugiperda* (J.E. Smith) with weather parameters in maize ecosystem. *Int J Curr Microbiol Appl Sci*. 2020;9(8):1213–8. <https://doi.org/10.20546/ijcmas.2020.908.135>
48. Gameel SM. Effect of planting date on seasonal abundance of *Aphis craccivora* Koch and the associated predators in the New Valley, Egypt. *Egypt Acad J Biol Sci*. 2014;7(2):97–103. <https://doi.org/10.21608/eajbsa.2014.13141>
49. Behera P, Mishra BK. Occurrence of natural enemies of maize stem borer *Chilo partellus* (Swinhoe) in kharif maize ecosystem. *Int J Curr Microbiol App Sci*. 2020;9(3):2409–17. <https://doi.org/10.20546/ijcmas.2020.903.275>
50. Bhojar ES, Wadaskar RM, Dadhe CG, Sormare SG. Influence of season on biology of predatory reduviid bug, *Rhynocoris marginatus*. *J Entomol Zool Stud*. 2021;9(6):259–62.

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonpublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.