



RESEARCH ARTICLE

Effect of meteorological parameters on seasonal incidence of insect-pests in rice ecosystem

Yugam Sharma¹, Umesh Chandra¹, Suraj Soni^{1*}, Ankit Kumar¹, S N Singh², Aman Pratap Singh¹, Harshit Gupta¹ & Shailja Jaiswal³

¹Department of Entomology, College of Agriculture, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya 224 229, Uttar Pradesh, India

²ICAR-Indian Institute of Vegetable Research, Varanasi 221 305, Uttar Pradesh, India

³Department of Entomology, College of Agriculture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur 208 002, Uttar Pradesh, India

*Correspondence email - surajsoni5001@gmail.com

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Abstract

Understanding the relationship between meteorological parameters and insect pest incidence is essential for timely pest management and sustainable rice production. Therefore, a field experiment was conducted during kharif 2024 at the student's instructional farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India, to evaluate the influence of meteorological parameters on major insect pests of rice. Pest incidence was monitored from the 31st–46th standard meteorological weeks (SMW) and correlated with weather variables. The incidence of yellow stem borer varied from 1.08 % dead hearts during the 31st SMW to 16.48 % during the 38th SMW, while white ear incidence ranged from 5.68 % during the 42nd SMW to 10.19 % during the 44th SMW. Leaf folder infestation varied from 1.73 % during the 31st SMW to 17.00 % during the 41st SMW. The population of gundhi bug population ranged from 0.47–14.40 bugs per sweep (35th–41st SMW). Brown plant hopper (BPH) (2.33–12.27 insects per hill) and green leaf hopper (1.07–10.47 insects per sweep) populations peaked during the 41st SMW, while grasshopper population ranged from 1.00–4.07 insects per sweep. Correlation analysis revealed a significant positive relationship between yellow stem borer incidence and minimum temperature ($r = 0.455, p \leq 0.01$), whereas gundhi bug population showed a significant negative correlation with wind speed ($r = -0.338, p \leq 0.01$). Maximum temperature exhibited a significant positive correlation with BPH population ($r = 0.409, p \leq 0.01$).

Keywords: brown plant hopper; dead hearts; green leaf hopper; gundhi bug; leaf folder; rice; white ear head; yellow stemborer

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops and serves as a staple food for more than 65 % of the global population. Based on area and production, it is the second most widely cultivated crop in the world after wheat (1). Rice is grown across tropical, subtropical and temperate regions, with Asian countries such as China, India, Japan, the Republic of Korea, Sri Lanka, Pakistan and Bangladesh contributing nearly 90 % of global production and consumption (2). China is the leading producer of rice, followed by India. In addition to being a major source of dietary energy, rice provides essential nutrients, including carbohydrates, proteins, lipids and dietary fibre and utilised in various forms such as rice bran, rice bran oil, flaked rice, puffed rice and husk (3, 4).

In India, rice occupies a prominent position in the agricultural economy. During 2024–25, the crop was cultivated over 51.42 Mha, producing 150.18 Mt with an average productivity of 2882 kg ha⁻¹ (5). In Uttar Pradesh, rice was cultivated on 7.42 Mha during 2024–25, producing 20.76 Mt with a productivity of 2737 kg ha⁻¹ (5). Despite its importance, rice productivity is significantly constrained by insect pests occurring at different stages

of crop growth. More than 100 insect species infest rice, of which around 20 are considered economically important (6). Among these, plant hoppers, stem borers and leaf folders are the most destructive and pose a persistent threat to rice production (7–10).

The yellow stem borer, *Scirpophaga incertulas*, is one of the most damaging pests, causing characteristic symptoms such as “dead hearts” and “white ears,” leading to substantial yield losses (11, 12). In recent years, the rice leaf folder, *Cnaphalocrocis medinalis* (Guenee), has emerged as a major pest, although it was previously considered minor one (12, 13). Its larvae cause 5–25 % yield loss by folding leaves and scraping green tissues, resulting in drying and scorching symptoms (14). In addition, sucking pests such as the rice gundhi bug (*Leptocoris acuta* Thunberg), green leaf hopper (*Nephotettix virescens*) and brown plant hopper (BPH; *Nilaparvata lugens* Stål) adversely affect crop growth by feeding on plant sap.

The BPH and green leaf hopper are particularly important due to their ability to cause “hopper burn” through phloem feeding and oviposition within plant tissues. Moreover, these pests act as vectors of viral diseases such as grassy stunt virus and rice tungro virus, resulting in indirect crop damage (15). The rice gundhi bug

feeds on grains during the milky stage, causing chaffy and unfilled grains, thereby reducing yield. The incidence and population dynamics of these insect pests are governed by complex interactions among host plants, pest species and environmental conditions. Weather parameters such as temperature, rainfall, wind speed, evaporation, sunshine hours and relative humidity play a crucial role in influencing pest abundance and seasonal occurrence (16, 17).

In recent years, insect pest management in cereals has relied heavily on the use of systemic and contact insecticides applied through sprays, seed treatments and granular formulations. However, indiscriminate and injudicious use of these chemicals has led to several issues, including pesticide resistance, resurgence of sucking pests, destruction of non-target organisms and accumulation of harmful residues in food and the environment. Therefore, understanding the relationship between abiotic factors and pest populations through correlation studies is essential for developing reliable pest prediction models. Such approaches facilitate timely implementation of integrated pest management strategies, reducing dependence on chemical control, lowering production costs and minimising environmental hazards. Keeping this in view, the present investigation was undertaken to elucidate the effect of weather parameters on the population build-up of major borer and sucking pests of rice.

Materials and Methods

The present investigation was conducted at the student's instructional farm (SIF), Acharya Narendra Deva University of Agriculture and Technology (26.40° N latitude, 81.12° E longitude), Kumarganj, Ayodhya, Uttar Pradesh, India, during the kharif 2024. The experimental site falls under sandy loam soil with low organic carbon content of 0.43 % and available nitrogen content of 185 kg ha⁻¹. The site receives an average annual rainfall of about 1200 mm, most of which is concentrated between the first week of July and mid-August.

An experimental area of 36 m² was divided into 3 replications of 12 m² each and laid out in a complete randomised block design (CRBD). Seeds of rice cultivar (cv.) Sarju-52 were sown on 21st June 2024. Seedlings of sufficient age were transplanted to the main field on 11th July 2024 with a spacing of 20 × 15 cm.

Recommended doses of fertilisers (N : P : K : Zn = 100 : 60 : 60 : 25 kg ha⁻¹) were applied to the crop. Half of the nitrogen and 25 kg ha⁻¹ of zinc sulphate were applied during field puddling before transplantation in the main field. One-fourth dose of nitrogen was applied 25–30 days after transplanting and the remaining amount was administered prior to plant blossoming. Hand weeding and irrigation were provided as required and all standard crop husbandry practices were followed, except plant protection measures. Weather data were obtained simultaneously from the Department of Agrometeorology, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India.

Method of observation

Yellow stem borer

Data on the incidence of yellow stem borer were collected from five randomly selected hills by counting the total number of tillers and panicles, as well as the number of dead hearts and white ears. The percentage incidence of dead hearts and white ears was calculated using the following formula:

$$\text{Percent incidence} = \frac{\text{Number of dead hearts / white ears}}{\text{Total no. of tillers / hill}} \times 100$$

Leaf folder

Leaf folder infestation was recorded from five randomly selected hills by counting the number of affected leaves relative to the total number of leaves per hill and the data were averaged over the five hills.

$$\text{Percent incidence} = \frac{\text{Number of damaged leaves}}{\text{Total number of leaves}} \times 100$$

Gundhi bug

The population of rice gundhi bug was recorded by counting the number of nymphs and adults collected using an insect collection net, with five sweeps per observation. The average number of nymphs and adults per sweep was calculated from the total count obtained across all sweeps.

Brown plant hopper

The population of BPH was recorded from five randomly selected hills by counting the number of motile stages, including nymphs and adults.

Green leaf hopper

The numbers of nymphs and adults were recorded after five sweeps using a sweep net per observation. The average count per sweep was calculated from the total number of insects collected.

Grasshopper

The number of nymphs and adults was recorded using the insect collection net with five sweeps per observation. The average population per sweep was calculated based on the total number of insects calculated.

Statistical analysis

To study the correlation between different abiotic weather parameters such as maximum temperature, minimum temperature, relative humidity, sunshine hours, wind speed and rainfall with the weekly incidence of insect-pests on rice, statistical analysis was performed using SAS software (version 9.3) (14, 18).

Results and Discussion

Incidence of insect - pests in rice

Weekly observations on insect pest incidence in rice during kharif 2024 revealed the occurrence of six major insect pests, namely yellow stem borer (*Scirpophaga incertulus*), rice leaf folder (*C. medinalis*), BPH (*N. lugens*), rice gundhi bug (*L. acuta*), green leaf hopper (*N. virescens*) and grasshopper (*Hieroglyphus banian*). The incidence data are presented in Table 1 and Fig. 1. The results clearly indicated that these pests remained active during different stages of crop growth throughout the season.

Yellow stem borer (*Scirpophaga incertulus*)

The incidence of yellow stem borer (*S. incertulas*) was recorded at two crop growth stages namely the vegetative stage (dead heart) and the reproductive stage (white ear). Dead heart symptoms were first observed during the 31st standard meteorological week (SMW) of kharif 2024. At this time, the minimum incidence of yellow stem

Table 1. Incidence of insect pests affecting the rice along with the abiotic factors, during the kharif season of 2024

Insect-pests of rice										Abiotic factors			
SMW	Yellow stem borer (YSB)		Leaf folder	BPH	Gundhi bug	Green leaf hopper	Grasshopper	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Wind speed (km/hr)	Sunshine (hr)
	D.H. %	W.E. %	Damage %	Avg. no. insects / hill	Avg. no. insects / 5 sweep nets			Min.	Max.				
31	1.08	0.00	1.73	0.00	0.00	0.00	0.00	26.30	33.30	78.70	5.40	6.20	6.90
32	2.54	0.00	2.67	0.00	0.00	0.00	0.00	24.80	31.60	81.10	127.60	2.10	1.50
33	3.90	0.00	3.90	0.00	0.00	0.00	0.00	25.00	32.40	78.90	122.00	2.30	3.70
34	5.67	0.00	4.42	2.33	0.00	1.07	1.00	25.20	32.80	76.80	3.80	3.00	3.20
35	8.45	0.00	4.82	5.27	0.47	2.00	1.40	25.30	33.20	76.20	29.20	3.80	5.30
36	10.72	0.00	5.01	6.40	1.93	4.13	2.80	25.50	33.80	77.70	16.00	2.80	7.70
37	13.87	0.00	9.30	8.53	3.47	4.20	3.40	24.90	32.60	78.20	29.60	6.30	4.20
38	16.25	0.00	12.18	10.47	5.13	5.07	4.00	24.60	32.50	74.30	2.60	3.40	6.50
39	13.47	0.00	9.67	10.24	10.20	6.87	3.67	23.50	30.40	79.10	199.60	4.00	3.50
40	12.65	0.00	14.57	12.27	12.20	9.00	4.20	24.20	33.10	72.00	0.00	1.80	7.60
41	10.75	0.00	17.00	8.87	14.40	10.47	3.20	22.20	32.60	74.70	0.00	1.20	6.30
42	0.00	5.68	13.20	5.87	10.20	6.13	4.07	19.50	32.60	71.30	0.00	1.20	7.40
43	0.00	8.43	11.12	4.67	7.22	3.60	3.87	19.90	32.00	72.90	0.00	1.60	6.50
44	0.00	10.19	5.35	3.33	1.20	1.33	3.87	18.00	32.20	69.70	0.00	1.50	7.50
45	0.00	7.12	4.00	1.40	3.00	0.60	2.60	17.20	30.00	67.00	0.00	0.90	6.70
46	0.00	4.68	2.02	0.80	1.10	0.00	0.00	14.30	28.80	67.60	0.00	1.90	6.70

SMW: standard meteorological week; D.H.: dead heart; W.E.: white ear heads; BPH: brown plant hopper.

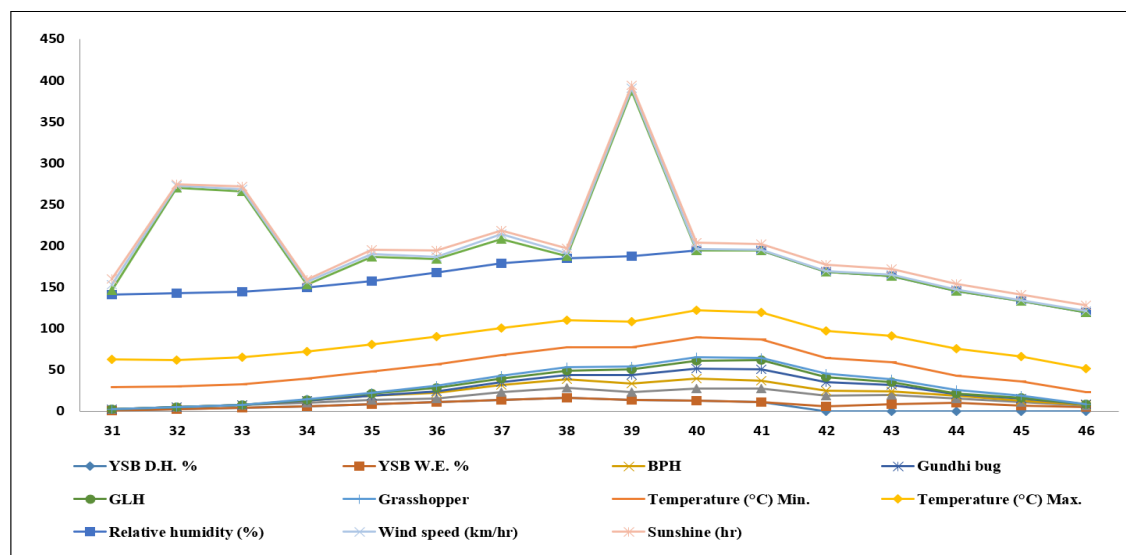


Fig. 1. Incidence of major insect pests affecting the rice along with the abiotic factors, during the kharif season of 2024.

YSB D.H.: yellow stem borer dead heart; YSB W.E.: yellow stem borer white ear; BPH: brown plant hopper; GLH: green leaf hopper.

borer was recorded as 1.08 %, occurring under a minimum temperature of 27.2 °C, maximum temperature of 34.9 °C, relative humidity of 78.3 % and rainfall of 49.8 mm. The percentage of dead hearts gradually increased to 10.72 % by the 36th SMW and reached a maximum of 16.48 % during the 38th SMW. White ear symptoms were first recorded during the 42nd SMW, with 5.68 % of panicles affected, under a minimum temperature of 19.5 °C, maximum temperature of 32.6 °C and relative humidity of 71.32 %. The incidence of white ears gradually increased, reaching a maximum of 10.19 % at the 44th SMW, under a minimum temperature of 18.0 °C, maximum temperature of 32.2 °C, relative humidity of 69.7 %, with no rainfall recorded during this period.

The incidence of yellow stem borer was first observed during the 31st SMW, with peak incidence recorded during the 38th SMW, which is in accordance with the findings of previous studies (18). Similarly, the incidence of yellow stem borer was first observed during the 32nd SMW, while white ear symptoms reached their peak during the 45th SMW (19).

Rice leaf folder (*Cnaphalocrocis medinalis*)

The incidence of rice leaf folder (*C. medinalis*) was noted during entire crop season of rice at weekly intervals. Leaf damage was first recorded during the 31st SMW with 1.73 % damaged leaves under weather conditions of 26.3 °C minimum temperature, 33.3 °C maximum temperature and 78.70 % relative humidity. Subsequently, the percentage of plant damage gradually increased and reached a peak of 17 % in the 41th SMW (second fortnight of October). During this period minimum and maximum temperature were 22.2 °C and 32.6 °C respectively, with 74.70 % relative humidity and 6.30 sunshine hours. Afterwards, the peak of leaf folder damage percentage declined gradually and reached 2.02 % damage leaves during the second week of the November (46th SMW).

These results agree with earlier studies which reported peak leaf folder infestation during the 40th SMW corresponding to October, with leaf area damage ranging from 1.14–12.2 % (20, 21). The observed trend highlights that *C. medinalis* population dynamics are closely associated with seasonal variations in temperature, humidity and sunshine hours, providing critical information for optimising the timing of pest management interventions in rice.

Brown plant hopper (*Nilaparvata lugens*)

The incidence of BPH was first recorded in the 34th SMW, with 2.33 hoppers per hill. During this initial observation, the minimum and maximum temperatures were 25.2 °C and 32.8 °C respectively, with 76.8 % relative humidity, 3.8 mm rainfall and 3.2 sunshine hours. The highest BPH population (12.27 hoppers per hill) was observed in the 40th SMW, under minimum and maximum temperatures of 24.2 °C and 33.1 °C, 72 % relative humidity, 7.6 hr of sunshine and no rainfall. Thereafter, the population began to decline, recording 8.87 hoppers per hill in the 41st SMW and continued decreasing to 0.80 hoppers per hill by the 46th SMW.

The incidence of *N. lugens* commenced during the second week of August (33rd SMW) and reached peak population during the first week of October (40th SMW), with an average population of 17.33 insects per 10 hills, which is in partial agreement with the present findings (22, 23). The population dynamics of BPH were found to be closely associated with temperature, relative humidity and sunshine hours, which influence hopper survival, reproduction and dispersal. Early-season populations were recorded under moderate temperature and high relative humidity, while peak populations coincided with slightly lower humidity and optimal temperatures, indicating that BPH thrives under warm, moderately humid conditions during the reproductive phase of rice (22–24). The subsequent decline in population may be attributed to changes in weather, natural predation and the reduced availability of tender rice plants suitable for feeding.

Gundhi bug (*Leptocorisa accuta*)

The incidence of gundhi bug (*L. accuta*) on rice was first recorded during the 35th SMW as the number of bugs per five randomly selected sweep nets. At this time, the minimum population of gundhi bugs was 0.47 per five sweep nets, with a minimum temperature of 25.3 °C, maximum temperature of 33.2 °C, relative humidity and 29.2 mm of rainfall. The peak population of gundhi bugs (14.40 per five sweep nets) was observed during the 41st SMW, when minimum and maximum temperatures ranged from 22.2–32.6 °C, relative humidity was 74.7 % and no rainfall was recorded. Subsequently, the population began to decline, recording 10.20 bugs per five sweep nets in the 42nd SMW and reaching 1.10 bugs per five sweep nets by the 46th SMW.

The population of *L. acuta* reached its peak around the 40th SMW and declined to the lowest level by the 44th SMW, which agrees with earlier findings (23, 24). This pattern suggests that gundhi bug population dynamics are closely linked to the crop growth stages and prevailing climatic conditions, highlighting the importance of timely monitoring for effective pest management in rice.

Green leaf hopper (*Nephotettix virescens*)

The incidence of green leaf hopper (*N. virescens*) was first recorded during the 34th SMW, with 1.07 insects per five sweep nets, under minimum and maximum temperatures of 25.2 °C and 32.8 °C, relative humidity of 76.8 % and 3.8 mm of rainfall. The maximum population (10.47 insects per five sweep nets) was observed during the 41st SMW, when temperatures ranged from 22.2–32.6 °C, relative humidity was 74.7 % and no rainfall occurred. Thereafter, the population declined, recording 6.13 insects per five sweep nets in the 42nd SMW and decreasing further to 0.60 insects per five sweep nets by the 45th SMW at crop maturity.

The population of green leaf hopper reached its peak during the 41st SMW and declined gradually towards crop maturity, which agrees with earlier reports (24, 25). This pattern indicates that population build up is closely associated with favourable temperature and relative humidity during the reproductive stage of rice, emphasising the importance of timely pest monitoring and management to minimise crop damage.

Grasshopper (*Hieroglyphus banian*)

The incidence of grasshopper (*H. banian*) was first recorded during the 34th SMW, with an average of 1.0 insect per five sweep nets. The pest activity continued throughout the crop season, showing fluctuations in population. The number of grasshoppers gradually increased, reaching a peak of 4.07 insects per five sweep nets during the 42nd SMW, under minimum and maximum temperatures of 19.5 °C and 32.6 °C and relative humidity of 71.3 %. Thereafter, the population declined to 3.87 insects per five sweep nets in the 43rd SMW and further decreased to 2.60 insects per five sweep nets by the 45th SMW, coinciding with crop maturity.

The population dynamics of *H. banian* showed a gradual increase, peaking during the 42nd SMW, followed by a decline towards crop maturity. This trend suggests that grasshopper activity is influenced by favourable temperature and relative humidity conditions during the mid to late crop growth stages. These findings are consistent with previous reports, indicating that monitoring grasshopper populations during critical crop growth stages is important for timely pest management to prevent significant crop damage (25).

Effect of abiotic factors on the incidence of insect pests in rice during kharif season, 2024

The correlation between insect pest incidence and abiotic factors was analysed and is presented in Table 2 and Fig. 1.

Yellow stem borer (*Scirpophaga incertulus*)

The correlation analysis between the incidence of yellow stem borer and abiotic factors revealed that the dead heart percentage exhibited a significant positive correlation with minimum temperature ($r = 0.455$, $p \leq 0.01$) and relative humidity ($r = 0.328$, $p \leq 0.01$). In contrast, wind speed ($r = 0.283$), rainfall ($r = 0.171$) and maximum temperature ($r = 0.166$) showed positive but non-significant correlations, while sunshine hours ($r = -0.164$) displayed a negative, non-significant association with dead heart incidence. Regarding the percentage of white ears, a significant negative correlation was observed with minimum temperature ($r = -0.820$, $p \leq 0.05$), relative humidity ($r = -0.754$, $p \leq 0.05$) and wind speed ($r = -0.551$, $p \leq 0.01$). Additionally, rainfall ($r = -0.371$, $p \leq 0.01$) and maximum temperature ($r = -0.410$, $p \leq 0.01$) were negatively correlated with white ear percentage.

The present findings are broadly consistent with previous reports (25–27). These studies indicated that temperature exerted a significantly negative effect on the incidence of white ear caused by *S. incertulus*, whereas its effect on dead heart incidence was positively correlated with minimum temperature but non-significant with maximum temperature (25, 26). Relative humidity was found to have a significant positive correlation with dead heart incidence, but a non-significant negative correlation with white ear formation (24). Rainfall showed a non-significant positive influence on dead heart incidence, while significantly reducing the occurrence of white ear symptoms (26, 27). The higher incidence of white ear under lower temperature and humidity likely reflects the synchronisation of pest activity with the crop's reproductive stage, which occurs during relatively cooler and drier conditions. Such environmental conditions may also reduce the activity of natural enemies, thereby enhancing larval survival.

Rice leaf folder (*Cnaphalocrocis medinalis*)

The results revealed that the rice leaf folder (*C. medinalis*) infestation on rice crop showed a significant negative correlation with rainfall ($r = -0.399$, $p \leq 0.01$). However, the correlations between leaf folder incidence and other abiotic factors were generally non-significant, showing weak positive associations with minimum temperature ($r = 0.081$), relative humidity ($r = 0.008$) and sunshine hours ($r = 0.057$). In contrast, maximum temperature ($r = -0.006$) and wind speed ($r = -0.065$) exhibited non-significant negative correlations with leaf damage percentage caused by the

Table 2. The correlation between prominent insect pests of the rice and weather parameters during the kharif 2024

	D.H. %	W.E. %	Leaf folder	BPH	Gundhi bug	Green leaf hopper	Grasshopper
Sunshine (hr)	-0.164	0.403*	0.057	0.085	0.218	0.143	0.456*
Windspeed (km/hr)	0.283	-0.551*	-0.065	0.005	-0.338*	-0.162	-0.284
Rainfall (mm)	0.171	-0.371	-0.399*	-0.425*	-0.015	0.067	-0.233
Relative humidity (%)	0.328*	-0.754**	0.008	0.009	-0.211	-0.088	-0.363*
Max.	0.166	-0.410*	-0.006	0.409*	-0.092	0.488*	-0.013
Min.	0.455*	-0.820**	0.081	0.102	-0.163	-0.104	-0.231

D.H.: dead heart; W.E.: white ear; BPH: brown plant hopper; Max.: maximum; Min.: minimum; *significant at 0.01 level; **significant at 0.05 level.

leaf folder.

These findings are consistent with the results of previous studies which reported that rainfall and evening relative humidity adversely affected *C. medinalis* populations (22). In contrast, minimum and maximum temperatures, as well as morning relative humidity, exhibited mixed effects, showing both positive and negative influences on pest abundance. Similarly, a non-significant positive correlation of leaf folder incidence with rainfall and relative humidity, whereas both maximum and minimum temperatures were negatively correlated, albeit non-significantly, with pest populations (18). The observed negative correlation with rainfall in the present study may reflect reduced larval survival under wetter conditions, while non-significant association with other climatic factors suggests that leaf folder population dynamics are influenced by a combination of environmental and crop phenological factors.

Brown plant hopper (*Nilaparvata lugens*)

Study on the effect of various weather parameters on the fluctuation of BPH (*N. lugens*) population on rice during kharif 2024 indicated that maximum temperature ($r = 0.409, p \leq 0.01$) showed a positive correlation. The incidence of BPH exhibited a significant negative correlation with rainfall ($r = -0.425, p \leq 0.01$), indicating reduced pest activity under higher precipitation. In contrast, correlations with other abiotic factors were positive but non-significant, including minimum temperature ($r = 0.102$), sunshine hours ($r = 0.085$), relative humidity ($r = 0.090$) and wind speed ($r = 0.005$). These results suggest that while rainfall plays a key inhibitory role in BPH populations, other climatic parameters exert weaker, non-significant influences.

These findings are consistent with previous reports (6, 23), which observed a significant negative correlation between BPH (*N. lugens*) occurrence and both rainfall ($r = -0.488$) and relative morning humidity ($r = -0.614$). In contrast, maximum temperature showed a positive correlation with pest incidence, highlighting the role of warmer conditions in favouring BPH activity. Brown plant hopper populations were most strongly suppressed by rainfall, highlighting the role of precipitation in controlling pest abundance. Integrating these climatic insights with pest management strategies could enhance predictive models and improve timing for interventions in rice cultivation.

Gundhi bug (*Leptocoris accuta*)

These results indicated that gundhi bug (*L. accuta*) infestation on rice crop showed a significant negative correlation with wind speed ($r = -0.338, p \leq 0.01$), suggesting reduced pest activity under higher wind conditions. The incidence of *L. accuta* showed a non-significant positive correlation with sunshine hours ($r = 0.218$) and non-significant negative correlations with minimum temperature ($r = -0.163$), average relative humidity ($r = -0.211$), total rainfall ($r = -0.015$) and maximum temperature ($r = -0.092$). These results suggest that wind speed plays a notable role in influencing gundhi bug activity, while other abiotic factors have weaker, non-significant effects on pest population dynamics.

These results are partially consistent with previous reports which observed negative correlations between gundhi bug populations with both maximum and minimum temperatures and a positive correlation with average relative humidity (23, 28). Similarly, it was reported that there exist significant negative correlations between gundhi bugs and several weather parameters, including

minimum temperature ($r = -0.668$), average temperature ($r = -0.547$), morning relative humidity ($r = -0.671$), evening relative humidity ($r = -0.853$), average relative humidity ($r = -0.859$) and rainfall ($r = -0.616$) (6). Conversely, sunshine hours exhibited a significant positive correlation with pest populations ($r = 0.767$), whereas maximum temperature showed a non-significant relationship. These findings indicate that gundhi bug activity is strongly influenced by multiple climatic factors, with cooler and drier conditions along with increased sunlight favouring higher infestation levels.

Green leaf hopper (*Nephotettix virescens*)

Analysis of the data indicated that the incidence of green leaf hopper (*N. virescens*) exhibited a significant positive correlation with maximum temperature ($r = 0.488, p \leq 0.01$). Non-significant positive correlations were observed with sunshine hours ($r = 0.143$) and rainfall ($r = 0.067$). In contrast, minimum temperature ($r = -0.104$), relative humidity ($r = -0.088$) and wind speed ($r = -0.162$) showed non-significant negative correlations with green leaf hopper incidence.

These results suggest that higher maximum temperatures favour pest activity, while other climatic factors have weaker, non-significant influences, which agrees with the findings reported by previous studies (23, 26).

Grasshopper (*Hieroglyphus banian*)

Analysis of the data indicated that the incidence of grasshopper (*H. banian*) generally exhibited non-significant associations with studied abiotic factors. However, a significant positive correlation was observed with sunshine hours ($r = 0.456, p \leq 0.01$), while relative humidity showed a significant negative correlation ($r = -0.363, p \leq 0.01$). Non-significant negative correlations were recorded with minimum temperature ($r = -0.231$), maximum temperature ($r = -0.013$), wind speed ($r = -0.284$) and rainfall ($r = -0.233$).

These findings suggest that grasshopper activity is favoured by increased sunlight, whereas humidity and other climatic factors exert weaker influences on population dynamics, which agrees with earlier observations (25).

Conclusion

The study revealed that rice yellow stem borer incidence in the form of dead heart symptoms commenced during the vegetative stage in the 31st standard meteorological week (SMW) and reached its peak at 38th SMW, while white ear incidence at the reproductive stage occurred from the 42nd–44th SMW. Leaf folder populations peaked at 1.73 % and 17 % in the 31st and 41st SMWs respectively. Gundhi bug, brown plant hopper, green leaf hopper and grasshopper populations exhibited distinct temporal patterns, with peaks largely between the 34th and 42nd SMWs. Correlation analysis showed mostly non-significant relationships between pest populations and abiotic factors such as temperature, relative humidity, rainfall, sunshine hours, wind speed and daylight, indicating that pest dynamics are influenced by multiple interacting factors beyond weather conditions alone. These findings provide valuable insights for anticipating pest outbreaks and highlight the potential for developing weather-based integrated pest management strategies. Early detection and timely interventions can reduce overreliance on insecticides, minimise pest damage and lower overall rice cultivation costs,

supporting more sustainable crop protection practices. Further research is needed on seasonal and regional pest trends, biotic and abiotic influences, resistant rice varieties and climate-informed integrated pest management strategies.

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Authors' contributions

YS contributed to the conceptualisation of the study, conducted the experiments and performed data analysis and data curation. UC was responsible for supervision, methodology development, review and editing of the manuscript. SS, HG, SNS, APS, AK and SJ contributed to the preparation of the final draft, data analysis and review and editing of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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