Agric Res J **60** (1) : 52-58, *February* 2023
DOI No. 10.5958/2395-146X.2023.00009.1

EFFECT OF DIFFERENT METEOROLOGICAL PARAMETERS ON SEASONAL ABUNDANCE OF RICE BROWN PLANTHOPPER UNDER PUNJAB CONDITIONS

Shubham Anand[1]*, L K Dhaliwal and K S Suri[2]

[1]*Department of Climate Change and Agricultural Meteorology*
[2]*Department of Entomology, Punjab Agricultural University, Ludhiana-141004, Punjab*

ABSTRACT

The growth and survival of insects are influenced by prevailing weather conditions. The brown planthopper (BPH) population data were collected from 2014 to 2016 and 2018. Highest BPH population at Ludhiana was observed during 2016 and lowest in 2018. Correlation coefficients were calculated between BPH population and different meteorological parameters. The BPH population was found to be negatively correlated with temperature (maximum and minimum) and rainfall while it was positively correlated with morning relative humidity. Stepwise regression models were developed which indicate that minimum temperature and relative humidity (morning and evening) were found to be important parameters influencing incidence of BPH. Correlation coefficients were calculated between BPH light trap population data and different meteorological parameters. A positive role of maximum temperature in influencing BPH light trap catches was found whereas minimum temperature had no effect. Crop-weather-brown planthopper-calendar was prepared. This can be used in agro advisory to issue warnings for taking timely action to control BPH.

Keywords: Brown planthopper, Crop-weather-brown Planthopper-calendar, Meteorological parameters, Rice, Regression models

Rice (*Oryza sativa* L.) is widely cultivated under diverse ecosystems of tropical and sub-tropical regions of the world. It is a short-day plant and is mostly grown in regions of high temperature, high humidity, long sunshine hours and assured rainfall (Anonymous, 2015). Under Punjab agroclimatic conditions, the crop requires a temperature range of 20 to 37.5^{o}C for optimum growth. Relative humidity ranged from 83 to 85 per cent and 67 to 68 per cent for early and late sown varieties, respectively (Anonymous, 2019). Insect incidence during different seasons depends on weather conditions. The growth and survival of insects are influenced by the prevailing weather conditions at different phenological stages of crop. Higher relative humidity combined with moderately low range of temperature is highly conducive for insect occurrence and their multiplication. Under such cases, if the expected weather conditions are favourable, then serious outbreaks of insects may occur.

The rice crop is attacked by more than 100 species of insects and out of these 20 can cause economic damage. Brown planthopper (*Nilparvata lugens* Stal) is one of the most important insect pests of rice crop. The seasonal abundance of rice brown planthopper is severely affected by weather parameters. Among different weather parameters, air temperature and atmospheric humidity are the most important factors influencing the brown planthopper incidence. The favourable mean temperature for brown planthopper incidence is 26^{o}C to 28^{o}C while mean relative humidity is 66 to 75 per cent and total weekly rainfall should be less than 25 mm (Venilla *et al.,* 2016). On the basis of correlation and regression analysis between different meteorological parameters and brown planthopper incidence, important information regarding current or anticipated weather conditions which are likely to cause an insect incidence can be useful. Taking the week as the basic time unit, crop weather insect calendar can be prepared which assists in framing weather warnings and forecasting. Many useful aspects can be decided such as crop planning, irrigation scheduling and plant protection measures through the use of crop weather calendars.

Keeping all this in view, the present experiment was conducted to study the seasonal abundance of brown planthopper incidence.

MATERIALS AND METHODS

The field experiment was conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana with two rice varieties (PR 121 and PR 126) transplanted on different dates (20th June and 30th June) with four replications during *kharif* season 2018. The variety Pusa Basmati 1121 was transplanted on different

*Corresponding author : shubham-1904001@pau.edu
Date of receipt: 03.08.2021, Date of acceptance: 28.02.2023

dates (5th July and 15th July) with four replications. The experiment was laid out in Split-Split Plot Design for rice and Factorial-Randomized Complete Block Design for basmati rice. Actual field data on brown planthopper population (BPH) were collected in the Department of Entomology from 2015 to 2016 and 2018 data on BPH were collected in the Department of Climate Change and Agricultural Meteorology. Corresponding meteorological data (maximum temperature, minimum temperature, relative humidity (morning and evening), sunshine hours and total rainfall) from 2014 to 2016 and 2018 of Ludhiana were collected from the Agrometeorological Observatory, Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana. Crop-weather-brown planthopper-calendar was prepared on the basis of this data. Light trap data (2001, 2007 to 2011) were collected from CRIDA, Hyderabad website while for year 2018 it was collected in Department of Entomology, Punjab Agricultural University, Ludhiana. Corresponding meteorological data (maximum temperature and minimum temperature, relative humidity, sunshine hours, wind speed and total rainfall) of Ludhiana were collected and compiled to study the effect of different meteorological parameters on brown planthopper population. Correlation coefficients were computed between brown planthopper population and different meteorological parameters and regression analysis was conducted for the same. Similarly, for light trap BPH data, correlation coefficients were calculated with different meteorological parameters.

RESULTS AND DISCUSSION

Meteorological parameters during the highest (2016) and lowest brown planthopper (2018) incidence years

The dynamic conditions of insect's environment always cause fluctuations in its population. The abiotic factors greatly influence insect incidence in rice crop. Temperature, relative humidity, wind speed and rainfall have profound effect on insect abundance. Temperature and relative humidity are important meteorological parameters that affect brown planthopper multiplication and growth.

The outbreak of BPH was reported in many rice growing districts of Punjab in 2016 (Anonymous, 2016). The highest population of brown planthopper (BPH) was recorded in 2016 and the lowest in 2018. The comparison between different meteorological parameters (maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine hours and total rainfall) during the highest (2016) and lowest (2018) BPH incidence years was made.

Maximum temperature

Maximum temperature during the lowest BPH incidence year (2018) was mostly higher than the highest BPH incidence year (2016) from 29th SMW to 35th SMW (Fig.1). Maximum temperature during 2016 was above normal and higher than that of 2018 from 36th SMW to 45thSMW which is a period of high BPH multiplication. It indicates that maximum temperature above normal during 36th SMW to 45th SMW was favourable for BPH multiplication.

Minimum temperature

During the highest BPH incidence year (2016), minimum temperature was above normal and higher than that of the lowest BPH incidence year (2018) throughout the crop season (Fig.1). From 33rd SMW to 35th SMW, minimum temperature was higher during 2018 than that of 2016. Above normal minimum temperature during 33rd SMW to 35th SMW was conducive for BPH multiplication.

Morning relative humidity

Morning relative humidity was mostly higher during

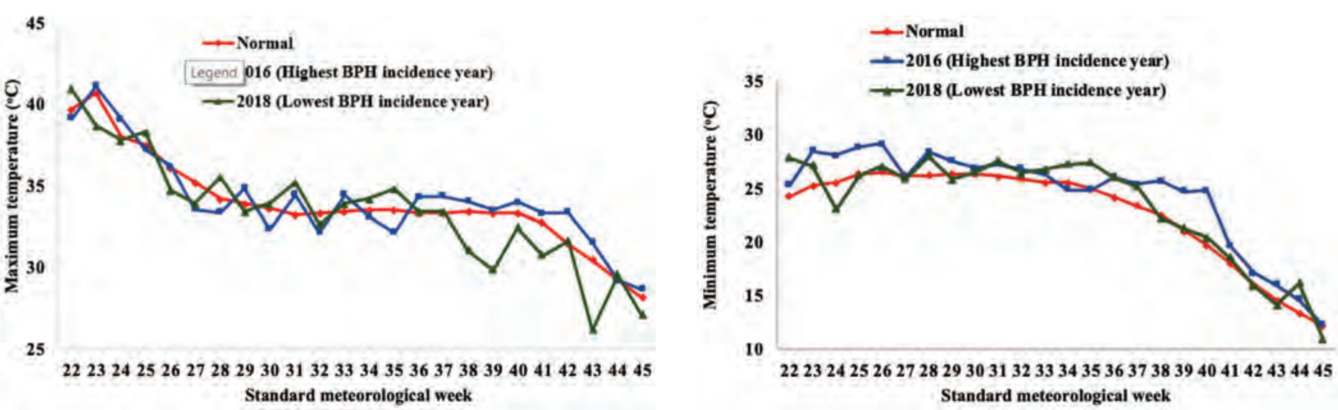

Fig. 1. Comparison of maximum (a) and minimum (b) temperatures during the highest (2016) and lowest brown planthopper (2018) incidence year

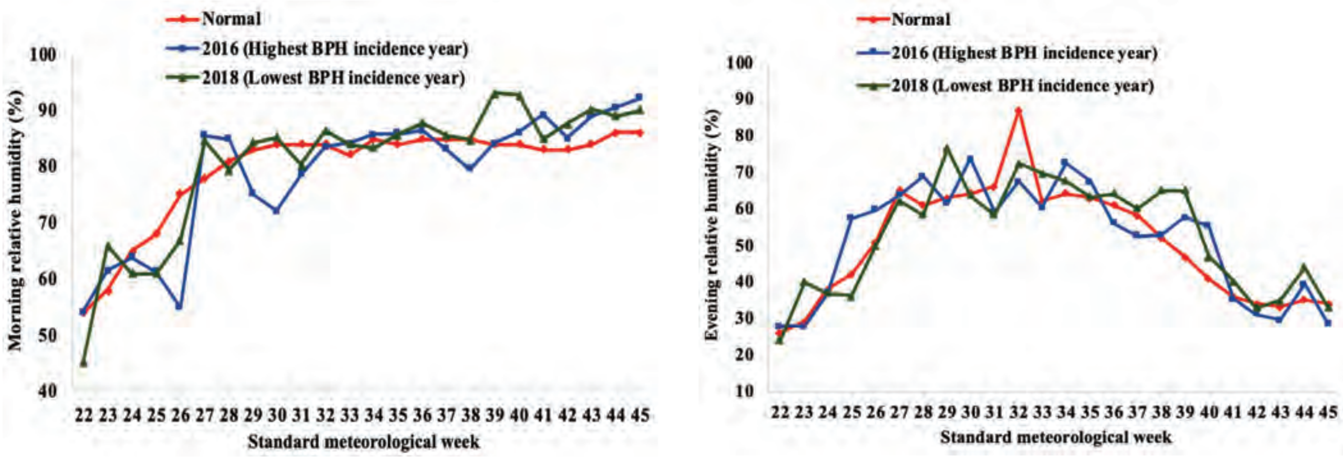

Fig. 2. **Comparison of morning (a)and evening (b)relative humidity during the highest (2016) and lowest brown planthopper (2018) incidence years**

2018 than 2016 throughout the crop growing season (Fig.2).

Evening relative humidity

From 25th to 28th SMW, the evening relative humidity during the highest BPH incidence year (2016) was higher than normal and that of the lowest BPH incidence year (2018) (Fig. 2).

Sunshine hours

Sunshine hours were mostly lower than normal during both the years of BPH incidence years. During the highest BPH incidence year (2016), the sunshine hours were mostly higher than that of the lowest BPH incidence year (2018) as shown in Fig.3.

Total rainfall

Total rainfall was mostly higher than normal during early crop stages during both the years of insect incidence (Fig. 4). During the highest BPH incidence year (2016), total rainfall (409.3 mm) was below normal (606.4 mm) while in the lowest BPH incidence year (2018), it was 845.4 mm from 22nd to 45th SMW. High amount of rainfall was received at 29th SMW (167.8 mm) and 38th SMW (146.2 mm) in the lowest BPH incidence year (2018) which may be responsible for lower BPH incidence.

Relationship between brown planthopper population (in field) and different meteorological parameters

The insect abundance is extremely influenced by the prevailing weather conditions. Different meteorological parameters viz. temperature, relative humidity, wind speed, rainfall, etc. strongly influence the life cycle of insects. Likewise, brown planthopper abundance is affected mostly by temperature, relative humidity and rainfall. The correlation analysis between different

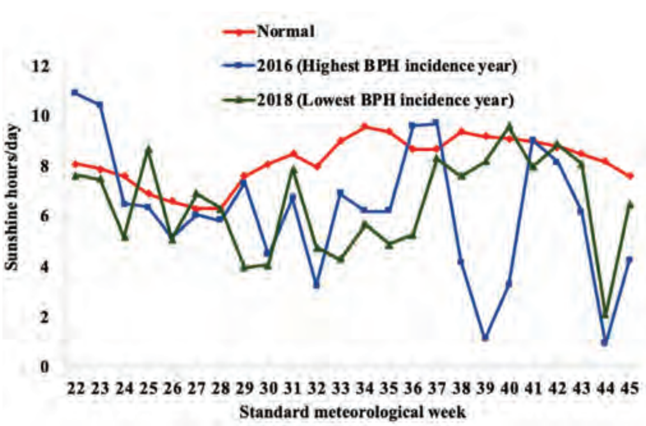

Fig. 3. **Comparison of sunshine hours during the highest (2016) and lowest brown planthopper (2018) incidence years**

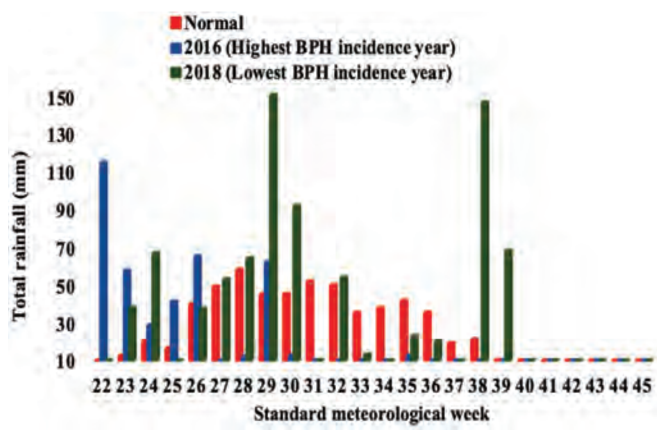

Fig. 4. **Comparison of total rainfall during the highest (2016) and lowest brown planthopper (2018) incidence years**

Table 1. **Correlation coefficient between brown planthopper population (in field) and different meteorological parameters during different years**

Year	Tmax (°C)	Tmin (°C)	RHm (%)	RHe (%)	SSH (hr/day)	WS (km/h)	RF (mm)
2014	-0.58**	-0.63**	0.52*	0.12	-0.20	-0.57*	-0.16
2015	-0.47*	-0.46	0.58*	0.15	0.03	-0.39	-0.13
2016	-0.62*	-0.71**	0.68**	-0.11	-0.27	-0.73**	-0.31
2018	-0.14	-0.28	0.22	-0.40	0.48**	-0.15	-0.09

* Significant at the 0.05 level
**Significant at the 0.01 level
Where, Tmax: Maximum temperature (°C)
Tmin: Minimum temperature (°C)
RHm: Relative humidity morning (%)
RHe: Relative humidity evening (%)
SSH: Sunshine hours (hours/day)
RF: Total rainfall (mm)

meteorological parameters and insect incidence can be helpful in developing weather-based models for forewarning of brown planthopper. For this purpose, the brown planthopper data (in field) were collected from 2014 to 2016 and 2018. Correlation coefficients between brown planthopper population and different meteorological parameters were computed and presented in Table 1.

The results indicate that maximum temperature and minimum temperature showed a negative correlation with brown planthopper population. Win *et al.* (2011) found that BPH population was negatively correlated with temperature during the rainy season. Morning relative humidity was found to be positively correlated with BPH population during all the years under study. Evening relative humidity showed a positive correlation with insect population during 2014 and 2015 while it showed a negative correlation with insect population during 2016 and 2018. Wind speed and total rainfall were found to be negatively correlated with insect population during all the years under study. Chaudhary *et al.* (2014) also reported a negative correlation between BPH population and rainfall and positively correlated with mean relative humidity. Jeyarani (2004) also reported a negative correlation between BPH population and rainfall. The sunshine hours were found to be positively correlated with BPH population during 2015 and 2018 while negative correlation was found during 2014 and 2016.

Relationship between brown planthopper light trap data and different meteorological parameters

Light traps are commonly used for monitoring insect pests of various crops. The light trap catches of insects are greatly influenced by the prevailing

Table 2. **Correlation coefficient between brown planthopper light trap data and different meteorological parameters during different years**

Year	Tmax (°C)	Tmin (°C)	RHm (%)	RHe (%)	SSH (hr/day	WS (km/h)	RF (mm)
2001	0.41	-0.06	-0.29	-0.49	-0.35	-0.18	-0.43
2007	-0.04	-0.56*	-0.24	-0.72**	0.44	-0.30	-0.63*
2008	0.02	-0.31	0.55*	0.28	0.55*	-0.49	-0.13
2009	-0.06	-0.50	-0.06	-0.60*	0.28	-0.41	-0.34
2010	0.21	0.16	-0.39	0.13	-0.35	0.07	0.01
2011	0.11	-0.24	0.05	-0.54*	0.67**	-0.44	-0.24
2018	0.58**	-0.71**	0.33	-0.61**	0.03	-0.48*	-0.41

* Significant at the 0.05 level
**Significant at the 0.01 level
Where, Tmax: Maximum temperature(°C)
Tmin: Minimum temperature(°C)
RHm: Relative humidity morning (%)
RHe: Relative humidity evening (%)
SSH: Sunshine hours (hr/day)
WF: Wind speed (km/h)
RF: Total rainfall (mm)

Table 3. **Step-wise regression analysis between brown planthopper population (in field) and different meteorological parameters during different years**

Year	Stepwise regression models	R^2 value
2014	Y= 12.19 – 0.43 Tmin	0.40
	Y= 5.17 – 0.35 Tmin +0.1 RHm	0.50
2015	Y= 12.13 + 0.22 RHm	0.34
	Y= -15.26 + 0.41 RHm – 0.23 RHe	0.52
2016	Y= 28.21 – 0.94 Tmin	0.50
	Y= 8.01 – 0.68 Tmin + 0.18 RHm	0.67
2018	Y= 8.1 -0.29 Tmin	0.49
Pooled data	Y= 19.87 – 0.66 Tmin	0.53
	Y= 13.39 – 0.71 Tmin + 1.2 SSH	0.67

Where, Tmin: Minimum temperature (°C)
RHm: Relative humidity morning (%)
RHe: Relative humidity evening (%)
SSH: Sunshine hours (hours/day)

weather conditions. Many workers have reported the effect of different meteorological parameters on brown planthopper light trap catches. Temperature, humidity and rainfall are important meteorological parameters which effects brown planthopper light trap catches.

Correlation coefficients between light trap catches and different meteorological parameters were worked out (Table 2). It was observed that maximum temperature was positively correlated with brown planthopper light trap catches except in years 2007 and 2009. A negative correlation was found between brown planthopper light trap catches and minimum temperature except in the year 2010. Prasannakumar and Chander (2014) found that the brown planthopper light trap catches were positively correlated with maximum temperature while these had a negative relationship with minimum temperature. Fast development of BPH takes place when temperature is higher (within favorable range of the species).

It is clear from the results that there is a positive role of maximum temperature in influencing brown planthopper light trap catches whereas minimum temperature had no effect on brown planthopper abundance. The maximum temperature acts as a source of heat energy during night for brown planthopper to take flight. The minimum temperature (during early morning) does not influence the brown planthopper activity during night. Morning relative humidity was negatively correlated with brown planthopper light trap catches except in 2008, 2011 and 2018. The brown planthopper light trap catches were negatively correlated with evening relative humidity except in the year 2008 and 2010. Yadav *et al*. (2010) also reported that the brown planthopper light trap catches were influenced by temperature and evening relative humidity. Rainfall was negatively correlated with brown planthopper light trap catches except in 2010. Similarly, Chander and Palta (2010) also found that rainfall affected the brown planthopper light trap catches directly as well indirectly through relative humidity. Higher relative humidity conditions due to early commencement of rainfall in summer with more number of rainy days contribute to brown planthopper outbreak. Sunshine hours were positively correlated with brown planthopper light trap catches unlike in the years 2001 and 2010.

Step-wise regression analysis between brown planthopper population (in field) and different meteorological parameters during different years

Step-wise regression analysis is a method of fitting regression models in which the choice of predictive variables is carried out by an automatic procedure. In each step, a variable is considered for addition or subtraction from the set of explanatory variables. This method gives information about the factor individually and with addition of other variables.

The regression models were developed using BPH data (in field) during different years. During 2014 and 2016, minimum temperature and morning relative humidity were considered to have significant effect on BPH population (Table 3). Minimum temperature was negatively correlated with brown planthopper population. Morning relative humidity was positively correlated with brown planthopper population. During 2015, morning relative humidity and evening relative humidity had significant effect on brown planthopper population. Morning relative humidity was positively correlated while evening relative humidity was negatively correlated with brown planthopper population. The minimum temperature was negatively correlated with brown planthopper population and alone had significant effect on brown planthopper population during 2018. The R^2 value indicated that it contributed 49 per cent

CROP WEATHER INSECT CALENDER FOR BROWN PLANT HOPPER

CROP NAME: BASMATI RICE — STATE: PUNJAB — DISTRICT: LUDHIANA

MONTH	JUNE				JULY					AUGUST				SEPTEMBER				OCTOBER					NOVEMBER	
Std. week / Parameter	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Tmax(°C)	39.5	38.0	37.5	36.1	35.2	34.2	33.9	33.6	33.2	33.3	33.4	33.5	33.5	33.3	33.3	33.4	33.3	33.3	32.8	31.5	30.5	29.3	28.2	26.9
Tmin(°C)	25.3	25.6	26.4	26.6	26.3	26.3	26.4	26.4	26.2	26.0	25.6	25.6	25.0	24.2	23.4	22.6	21.1	19.7	18.1	16.1	14.6	13.4	12.2	10.8
Tmean(°C)	25.3	25.6	26.4	26.6	26.3	26.3	26.4	26.4	26.2	26.0	25.6	25.6	25.0	24.2	23.4	22.6	21.1	19.7	18.1	16.1	22.6	22.9	19	19
RHm(%)	58.3	65.4	68.2	75.0	77.9	80.9	82.6	83.6	83.8	84.4	81.6	84.5	84.3	84.9	84.7	85.1	83.9	83.7	82.9	82.7	83.7	86	86	87
RHe(%)	29.2	37.6	42.3	51.1	55.3	61.2	62.9	64.1	66.4	67.1	62.2	63.8	62.7	60.8	57.7	52.3	47.2	40.8	36.2	36.6	32.5	35	34	34
RHmean(%)	43.8	51.5	55.2	63.1	66.6	71.1	72.7	73.9	75.1	75.8	71.9	74.1	73.5	72.9	71.2	68.7	65.6	62.2	59.6	58.1	58.1	60	60	60
Rainfall (mm)	12.4	20.2	16.4	39.7	49.1	57.9	45.0	45.2	51.9	49.9	35.2	37.7	41.6	35.3	19.1	21.3	10.2	3.4	2.0	5.0	0.6	2.6	0.6	0.6
Ssh(hrs)	10.1	9.7	9.0	8.1	7.9	7.6	6.9	6.6	6.3	6.3	7.6	8.1	8.5	8.0	9.0	9.6	9.4	8.7	8.7	9.3	9.5	8.2	7.6	7

PHENOPHASES | NURSING SOWING | TRANSPLANTING | TILLERING | PANICLE INITIATION | FLOWERING | PHYSIOLOGICAL MATURITY

CLIMATIC NORMALS FOR INSECT INCIDENCE (BROWN PLANT HOPPER)

Hot, cloudy and humid conditions are conducive for BPH multiplication

MAXIMUM TEMPERATURE (°C)	30.2-33.4	MORNING RELATIVE HUMIDITY (%)	86-90
M INIMUM TEMPERATURE (°C)	20.6-22.5	EVENING RELATIVE HUMIDITY (%)	48-60

SYMPTOMS

- ✓ Both nymphs and adults of these pests suck the cell sap particularly from the leaf-sheath from July to October.
- ✓ The crop dries up in patches. As the plants dry up, the hoppers migrate to the adjoining plants and kill them.
- ✓ In a few days, the areas of the dry patches enlarge.

Control measures

- ✓ 120 g Chess 50 WG (pymetrozine)
- ✓ 40 ml Confidor 200 SL/Crocodile 17.8 SL (imidacloprid)
- ✓ 800 ml Ekalux/Quinguard/Quinalmass 25 EC (quinalphos) in 100 litres of water per acre

Fig. 5. Crop-weather-calendar for brown planthopper

to brown planthopper abundance. The pooled data in step-wise regression analysis indicated that minimum temperature and sunshine hours had significant effect on brown planthopper population. Minimum temperature was negatively correlated with brown planthopper population while SSH were positively correlated with BPH population and together contributed 67 per cent to brown planthopper abundance. Prasannakumar and Chander (2014) developed stepwise regression models for brown planthopper light trap catches and studied its relationship with different meteorological parameters. Such regression models can be used for forewarning of insect pests.

Crop-weather-brown planthopper-calendar

Crop weather calendar is the pictorial representation of detailed information for a crop with respect to sowing period and duration of important phenological stages in its life cycle, the optimum of climatic requirement during different stages of the crop and actual and normal weather for that station/location. It comprises of life history of the crop (from sowing to period of maturity). It includes information on crop growth stages/ phonological stages, normal weather conditions during crop season, warnings to be issued based on prevailing weather conditions, and meteorological conditions favourable for development of crop pests and diseases. Crop-weather-insect-calendar consists of three parts. Climatic normals for crop throughout cropping season are mentioned in the first part. The second part consists of picture description of different phenophases (nursery sowing, transplanting, tillering, panicle initiation, booting, flowering and grain filling) of crop. Climatic normals for insect incidence are included in the same part. Symptoms caused by insect and the necessary control measures are stated in last part.

Crop-weather-brown planthopper-calendar was prepared on the basis of four years insect data (from 2014 to 2016 and 2018) and presented in Figure 5. It consists of three parts. In the first part, climatic normals for rice throughout cropping season were mentioned. The second part consists of picture description of different phenophases (nursery sowing, transplanting, tillering, panicle initiation, booting, flowering and grain filling) of rice crop. Climatic normal for brown planthopper incidence were calculated by using field experiment data from 2014 to 2016 and 2018. According to present study, the favourable temperature for brown planthopper incidence was 30.2-33.4^{o}C (maximum temperature) and 20.6-22.5^{o}C (minimum temperature) while relative humidity was 86-90 per cent in the morning and 48-60 per cent in the evening. Hot, cloudy and humid conditions are conducive for brown planthopper multiplication.

Symptoms caused by BPH and the necessary control measures were given in third part. Both nymphs and adults of brown planthopper suck cell sap particularly from the leaf-sheath from July to October. The crop dries up in patches. As the plant dries up hoppers migrate to the adjoining plants and kill them. In few days, the area of patches enlarges.

Taking the week as the basic time unit, forecasters use the compiled information that assist in framing weather warnings and forecasts. Through this, information on crop can be gathered such as growth stages, normal weather for crop growth, warnings to be issued based on prevailing weather condition, water requirement of crops during various phenophases and weather conditions favorable for development of crop pests and diseases. Many useful aspects can be decided such as crop planning, irrigation scheduling and plant protection measures through the use of crop weather calendars. Thus, crop-weather-brown planthopper-calendar can be used to issue warnings based on prevailing weather conditions and can be used in agro advisory.

In conclusion, the favourable temperature for brown planthopper incidence under Punjab conditions was 30.2-33.4^{o}C (maximum temperature) and 20.6-22.5^{o}C (minimum temperature) while relative humidity was 86-90 per cent in the morning and 48-60 per cent in the evening. Hot, cloudy and humid conditions are conducive for brown planthopper multiplication. The brown planthopper population was found to be negatively correlated with temperature (maximum and minimum) and rainfall while it had a positive correlation with morning relative humidity. A positive role of maximum temperature in influencing brown planthopper light trap catches was found whereas minimum temperature had no effect on brown planthopper light trap catches. Stepwise regression models infer that minimum temperature and relative humidity (morning and evening) were found to be important parameters in incidence of brown planthopper. Crop-weather-brown planthopper-calendar can be used to issue warnings based on prevailing weather conditions and can be used in agro advisory.

Authors' contribution

Conceptualization of research work and designing of experiments (SA, LKD); Execution of field/lab experiments and data collection (SA, LKD, KSS); Analysis of data and interpretation (SA); Preparation of manuscript (SA, LKD)

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