



# Effect of Row Spacing on Brown Planthopper Incidence in Basmati Rice under Punjab Conditions

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors SA and LKD helped in conceptualization of research work and designed the experiments. Authors SA, LKD and KSS executed the field/lab experiments and data collection. Author SA did data analysis and interpretation. Authors SA and LKD prepared the manuscript. All authors read and approved the final manuscript.*

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## **ABSTRACT**

The field experiment was conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana during *Kharif* 2018. Pusa Basmati variety was transplanted on 5<sup>th</sup> July (D<sub>1</sub>) and 15<sup>th</sup> July (D<sub>2</sub>) under three spacing (25 cm x 12 cm, 20 cm x 15 cm and 30 cm x 10 cm). The brown planthopper incidence data from 2014 to 2016 and 2018 indicated that the highest incidence at Ludhiana was observed in 2016 and the lowest in 2018. Regression analysis was carried out between different meteorological parameters and brown planthopper incidence. According to present study, the favourable temperature for brown planthopper incidence was 30.2-33.4 °C (maximum temperature) and 20.6-22.5 °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

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micrometeorological data on relative humidity was recorded at different phenological stages. The higher relative humidity was recorded in closer spacing (25 cm x 12 cm) than wider spacing (20 cm x 15 cm and 30 cm x 10 cm). The peak incidence of brown planthopper was also observed in 25 cm x 12 cm spacing (3.1 brown planthopper population/hill) as compared to 20 cm x 15 cm spacing (2.9 brown planthopper population/hill) and 30 cm x 10 cm (2.4 brown planthopper population/hill) during 2018. Hence, microclimate modification through spacing is cost effective measure for brown planthopper management in basmati rice.

**Keywords:** *Brown planthopper; microclimate; wider row spacing; closer row spacing; regression models.*

## 1. INTRODUCTION

Rice (*Oryza sativa* L.) is a short-day plant and is mostly grown in regions of high temperature, high humidity, long sunshine hours and assured rainfall. In Punjab, it covers 31.45 lakh hectares area with total paddy production of 203.71 lakh tonnes during 2021-22. The average yield of paddy recorded was 64.78 quintals per hectare during 2021-22. Like semi-dwarf rice varieties, basmati varieties require prolonged sunshine, high humidity and assured water supply. Under Punjab conditions, the crop requires a temperature range of 20 to 37.5°C for its optimum growth. The humidity range is 83 to 85 per cent and 67 to 68 per cent for the early and late sown varieties respectively [1]. Insect incidence during different seasons depend 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 these conditions, if the expected weather conditions are favourable, then serious outbreaks of insects may occur. The rice plant is attacked by more than 100 species of insects and 20 of them can cause economic damage. The brown planthopper (*Nilaparvata lugens*) is one of the important insects of rice crop. The seasonal abundance of rice brown planthopper is severely affected by weather conditions. 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°C to 28°C while mean relative humidity is 66 to 75 per cent and total weekly rainfall should be less than 25 mm [2]. Climate change affects BPH immigration patterns and breeding cycles by altering weather patterns and temperature conditions. Specifically, the northward shift of overwintering boundaries and temperature

increases impact BPH survival and breeding cycles. While warmer temperatures may expand the overwintering range of BPH, it may also limit their breeding potential due to temperature constraints. A decrease in tropical cyclones in the western North Pacific due to increased stability from global warming, while certain weather patterns favoring BPH immigration which increased with higher greenhouse gas concentrations [3].

Planting geometry of a crop affects the interception of solar radiation, crop canopy coverage, dry matter accumulation and crop growth rate [4]. Compact seedling transplanting affect rice plant growth which inturn generates microclimatic environment, conducive for brown planthopper multiplication [5]. Dense seedling plantation is favourable for brown planthopper incidence. Seedling spacing extensively modifies the microclimate for brown planthopper development [6]. Under wider spacing (20 cm x 20 cm), incidence of brown planthopper was less as compared to narrow spacing (20 cm x 15 cm). The brown planthopper population was comparatively higher in 20 cm x 15 cm spacing (2.38 individuals/hill) than 20 cm x 20 cm spacing (1.83 individuals/hill) [7]. So, plant spacing should be optimized by keeping in mind different aspects of crop and pest management techniques [8]. Keeping this in view the present study was carried out to investigate the influence of plant spacing on brown planthopper abundance in basmati rice.

## 2. MATERIALS AND METHODS

The field experiments were conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana during *kharif* 2018. Pusa Basmati variety was transplanted on 5<sup>th</sup> July (D<sub>1</sub>) and 15<sup>th</sup> July (D<sub>2</sub>) under three spacing (25 cm x 12 cm, 20 cm x 15 cm and 30 cm x 10 cm). The experiment was laid out in Factorial Randomised

Complete Block Design with four replications. Psychron (Model 566 series) was used to measure diurnal cycles of relative humidity from 1000 hours to 1600 hours at different phenological phases. Brown planthopper population data was recorded at weekly intervals. Historical field data on brown planthopper population (BPH) was obtained from the Department of Entomology, PAU, Ludhiana from 2014 to 2016. 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. From historical data, regression analysis was conducted between brown planthopper population and different meteorological parameters during different years.

### 3. RESULTS AND DISCUSSION

#### 3.1 Relative Humidity Profiles

The plant-water relations are greatly influenced by relative humidity. It affects leaf growth, photosynthesis, occurrence of diseases, incidence of insect pests and finally economic yield. Relative humidity and temperature have an inverse relation with each other. In morning hours, relative humidity is high because of low temperature whereas the rise in temperature

during noon, decreases the relative humidity percentage. The dry matter production is reduced due to saturation deficit which affects leaf water potential, stomatal control, internal water potential of plants and transpiration. Relative humidity in crop canopy is affected by row spacing. Lower relative humidity is usually recorded in wider spacing as compared to narrow spacing as air circulation is more in wider spacing as compared to narrow spacing [9].

At the maximum tillering stage, relative humidity was higher in 5<sup>th</sup> July transplanting under 25 cm x 12 cm spacing (90 per cent) than 30 cm x 10 cm spacing (88 per cent) and 20 x 15 cm spacing (89 per cent) spacing as compared to 15<sup>th</sup> July (Fig. 1). Karuna [10] also reported higher relative humidity in 20 cm x 15 cm and 25 cm x 12 cm spacings as compared to wider spacing (30 cm x 10 cm). Due to higher leaf area, the relative humidity was higher at panicle initiation stage than maximum tillering stage. The relative humidity during panicle initiation stage in 5<sup>th</sup> July transplanting under 25 cm x 12 cm (92 per cent) as compared to 15<sup>th</sup> July transplanted crop (90 per cent) (Fig. 2). Sharma et al. [11] also reported that relative humidity was higher in case of closer spacing (20 cm x 15 cm) as compared to wider spacing (30 cm x 10 cm). Biswas [9] also reported higher relative humidity under closer spacing (20 cm x 15 cm) than wider spacing (20 cm x 20 cm). Higher relative humidity was recorded in 25 cm x 12 cm spacing followed by 30 cm x 10 cm and 20 cm x 15 cm

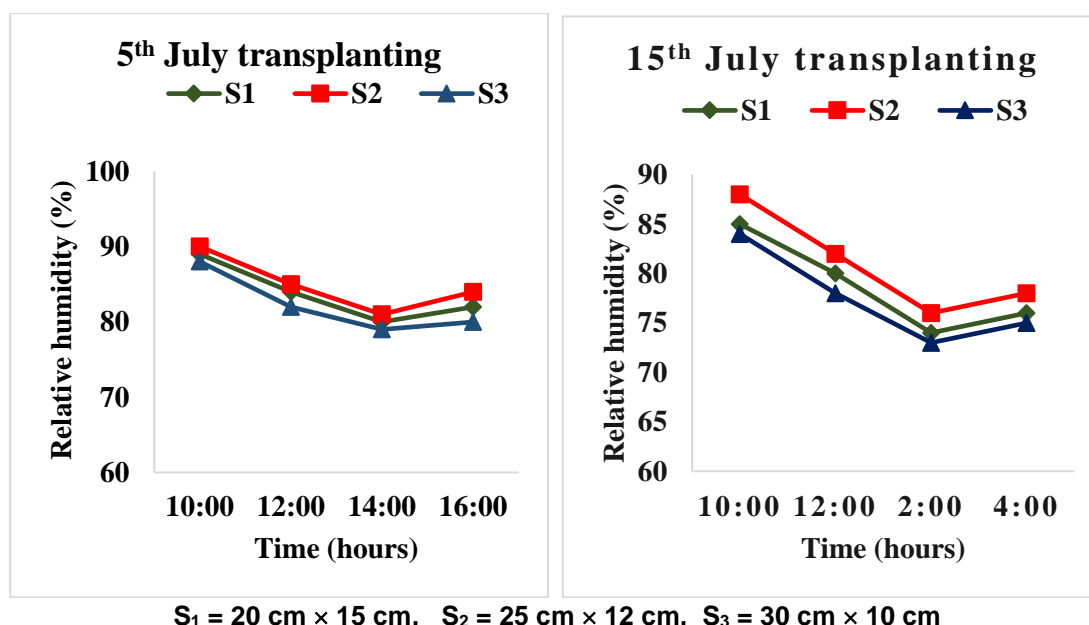
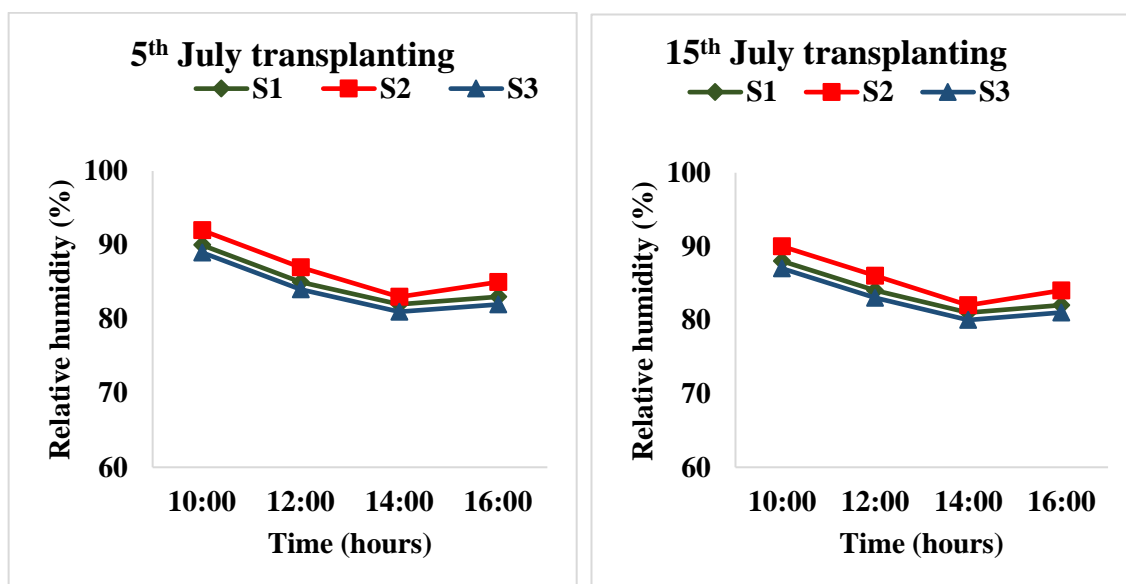
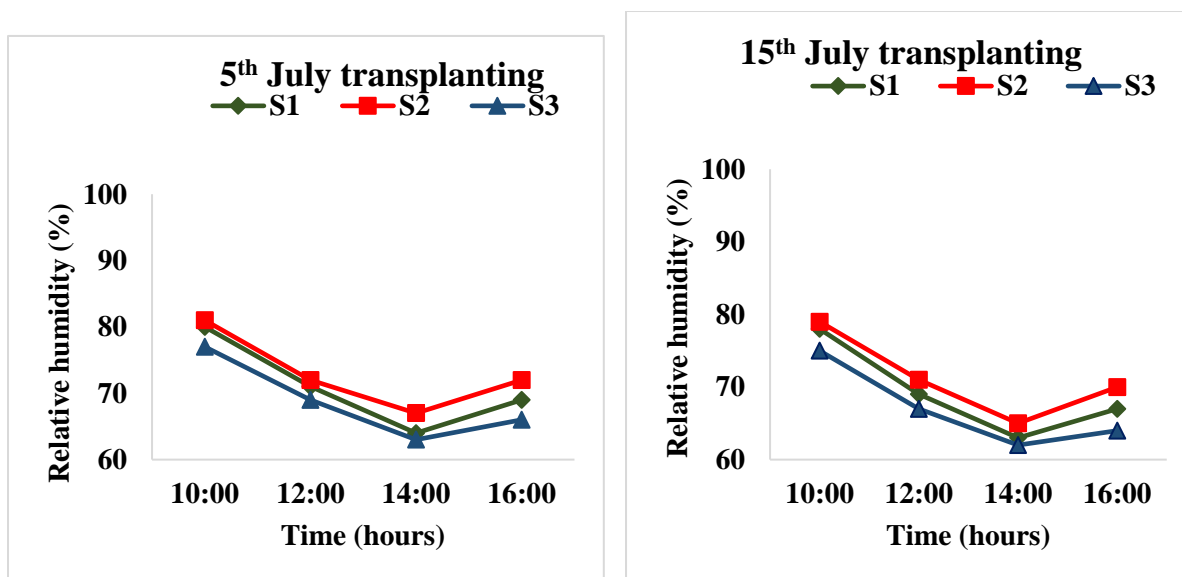


Fig. 1. Relative humidity profiles at maximum tillering stage under different spacing in variety Pusa Basmati 1121 transplanted on 5<sup>th</sup> July and 15<sup>th</sup> July



S<sub>1</sub> = 20 cm × 15 cm, S<sub>2</sub> = 25 cm × 12 cm, S<sub>3</sub> = 30 cm × 10 cm

Fig. 2. Relative humidity profiles at panicle initiation stage under different spacing in variety Pusa Basmati 1121 transplanted on 5<sup>th</sup> July and 15<sup>th</sup> July



S<sub>1</sub> = 20 cm × 15 cm, S<sub>2</sub> = 25 cm × 12 cm, S<sub>3</sub> = 30 cm × 10 cm

Fig. 3. Relative humidity profiles at grain filling stage under different spacing in variety Pusa Basmati 1121 transplanted on 5<sup>th</sup> July and 15<sup>th</sup> July

spacing due to more circulation of air within crop canopy in wider spacing. At grain filling stage relative humidity was higher for 5<sup>th</sup> July transplanting under 25 cm x 12 cm spacing (81 per cent) followed by 20 cm x 15 cm (80 per cent) and 30 cm x 10 cm (77 per cent) as compared to 15<sup>th</sup> July transplanting (Fig. 3). Thus, relative humidity decreased with an increase in row spacing [12].

### 3.2 Effect of Row Spacing on Brown Planthopper Incidence

The air flow and sunlight penetration and consequently moisture and humidity levels are affected by the space between plants. Thus, generating conducive microclimate conditions for pest development. Low pest incidence is often observed under wider spacing. In narrow

spacing, plants are closer to each other than in wider spacing. Thus, relative humidity in case of closer spacing will be more and insect development will be high under humid conditions.

In Pusa Basmati 1121, the brown planthopper incidence was observed more in 25 cm x 12 cm spacing as compared to 20 cm x 15 cm and 30 cm x 10 cm spacings (Fig. 4). Due to wider spacing, air circulation was more in case of 30 cm x 10 cm spacing. Also, delayed transplanting (15<sup>th</sup> July) recorded more brown planthopper population as compared to early transplanting (5<sup>th</sup> July). The first incidence was reported during the 38<sup>th</sup> SMW (Standard Meteorological Week) in all the spacings. The highest peak was recorded under 25 cm x 12 cm spacing (3.68 brown planthoppers/ hill) followed by 20 cm x 15 cm spacing (3.44 brown planthoppers/ hill) and 30 cm x 10 cm spacing (2.76 brown planthoppers/ hill) under 5<sup>th</sup> July transplanting in Pusa basmati 1121. However, under 15<sup>th</sup> July transplanting, the highest peak was observed in 25 cm x 12 cm spacing (8.4 brown planthoppers/ hill) as compared to 20 cm x 15 cm spacing (7.2 brown planthoppers/ hill) and 30 cm x 10 cm spacing (4.6 brown planthoppers/ hill). Satpathi et al. [7] also found that under wider spacing (20 cm x 20 cm), the incidence of brown planthopper was less as compared to narrow spacing (20 cm x 15 cm). The brown planthopper population was comparatively higher in 20 cm x 15 cm spacing (2.38 individuals/hill) than in 20 cm x 20 cm spacing (1.83 individuals/hill). Teetes [5] reported that compact seedling transplanting affects the growth of rice plant which in turn generates microclimatic environment, conducive for brown planthopper multiplication. Prasad-Ram et al. [6] also suggested that dense seedling plantation has positive influence on brown planthopper incidence. Seedling spacing extensively modifies the microclimate for brown planthopper development. Kanno et al. [13] and Katayama [14] reported similar results.

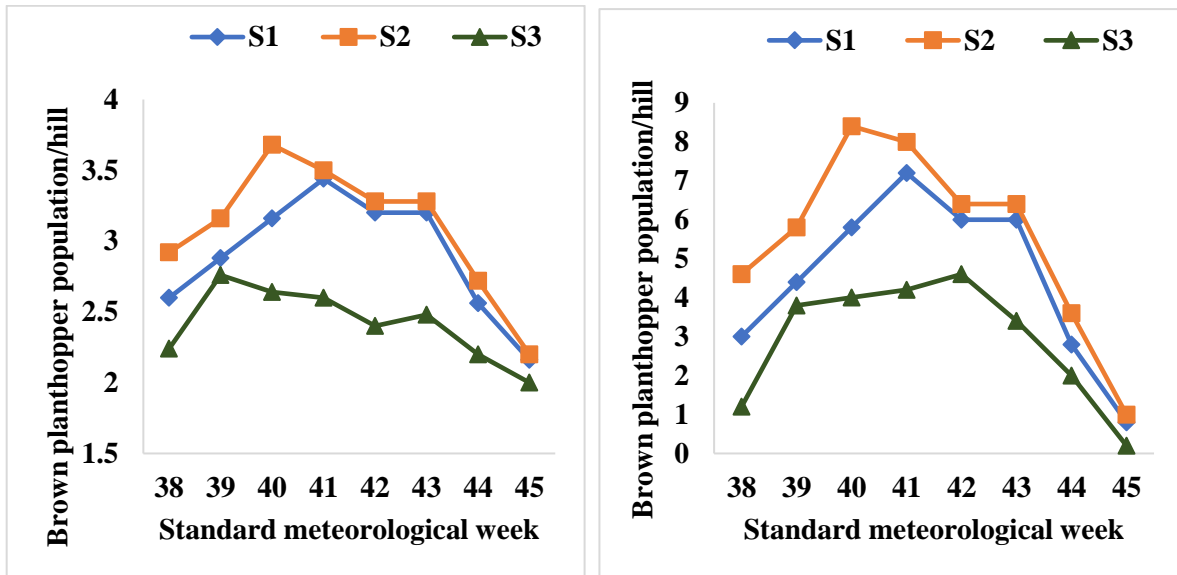
### 3.3 Meteorological Parameters and Brown Planthopper Population During different Years

Insect abundance is generally dependent on the weather conditions prevailing during the crop season. Accordingly, there are variations in insect abundance during different years. Thus, the number of insects attacking a particular crop

will be affected by the weather conditions during that season which may or may not be suitable for its growth and development. The different meteorological parameters viz. maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and total rainfall greatly influence the brown planthopper population. The effect of above stated meteorological parameters during different years (2014, 2015, 2016 and 2018) was studied.

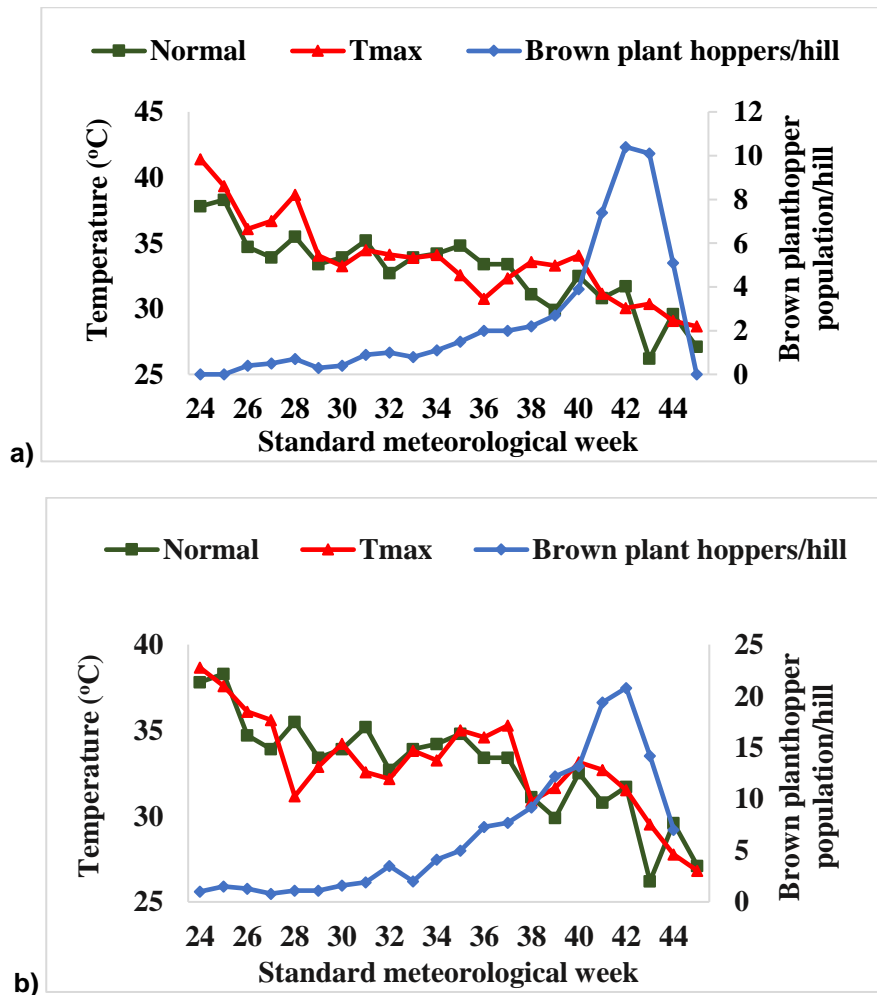
### 3.4 Maximum Temperature

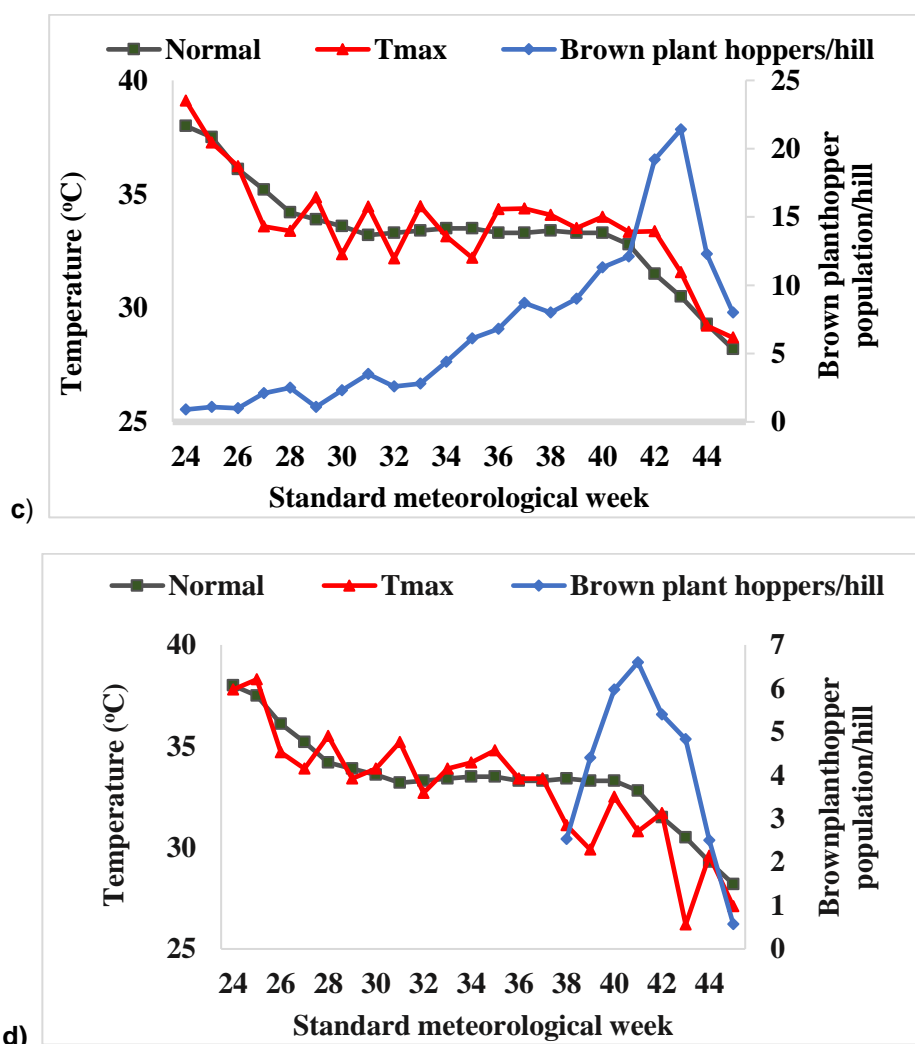
During 2014, the maximum temperature ranged from 28.7°C to 41.7°C from 24<sup>th</sup> to 45<sup>th</sup> SMW. Initially the brown planthopper population was less due to high temperature (36.1°C to 41.4°C) later, it started increasing when temperature range was in range of 30.4°C to 34.1°C (34<sup>th</sup> SMW onwards) (Fig. 5a). Win et al. [15] reported that brown planthopper population was negatively correlated with temperature. The peak brown planthopper population (10.4 brown planthoppers/hill) was observed during 42<sup>nd</sup> SMW and thereafter it started declining. The maximum temperature ranged from 26.8°C to 38.7°C during 2015 (Fig. 5b). The brown planthopper population was initially low due to high temperature (35.6°C to 38.6°C) but it showed an increasing trend when temperature range was from 30.9°C to 34.6 °C i.e. 34<sup>th</sup> SMW onwards. During 42<sup>nd</sup> SMW, the peak brown planthopper population (20.8 brown planthoppers/hill) was observed and later it started declining. During 2016, the maximum temperature ranged from 28.7°C to 39.1°C. Initially the brown planthopper population was low due to high temperature (36.2°C to 39.1°C) and later, it started increasing when temperature range was from 31.5°C to 34.5°C i.e. 34<sup>th</sup> SMW onwards (Fig. 5c). The peak brown planthopper population (21.4 brown planthoppers/hill) was observed during 43<sup>rd</sup> SMW and later it started declining. The maximum temperature ranged from 28.2°C to 38.3°C during 2018. The brown planthopper was observed during 38<sup>th</sup> SMW and then it started increasing when the temperature range was from 29.9°C to 32.5°C. During 41<sup>st</sup> SMW, the peak brown planthopper population (6.6 brown planthoppers/hill) was observed and later it started declining as shown in Fig.5d. The maximum temperature mostly remained above normal from 38<sup>th</sup> SMW onwards which was peak brown planthopper multiplication period during 2014,2015 and 2016 unlike 2018



S<sub>1</sub> = 20 cm × 15 cm, S<sub>2</sub> = 25 cm × 12 cm, S<sub>3</sub> = 30 cm × 10 cm

Fig. 4. Brown planthopper incidence under different spacing in variety Pusa Basmati 1121 transplanted on 5<sup>th</sup> July and 15<sup>th</sup> July



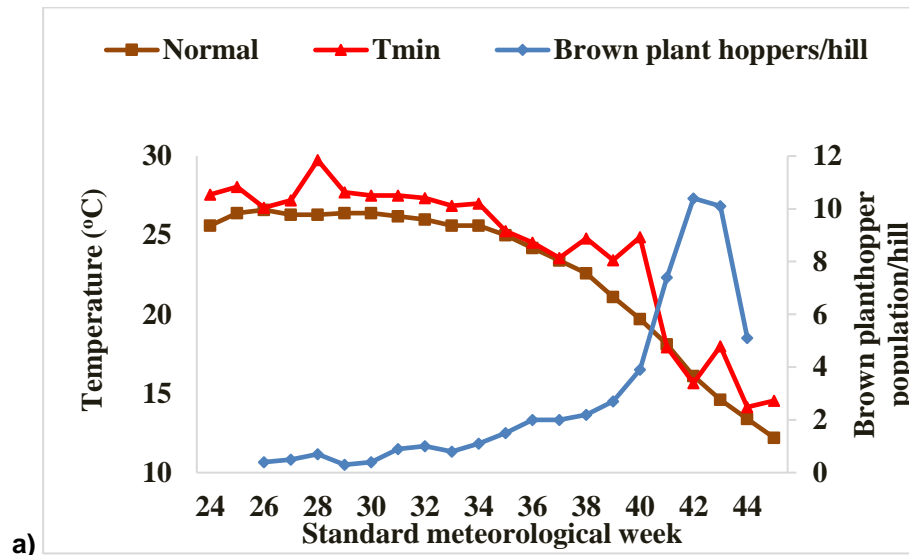


**Fig. 5. Comparison of maximum temperature and brown planthopper population during 2014 (a), 2015 (b), 2016 (c) and 2018 (d)**

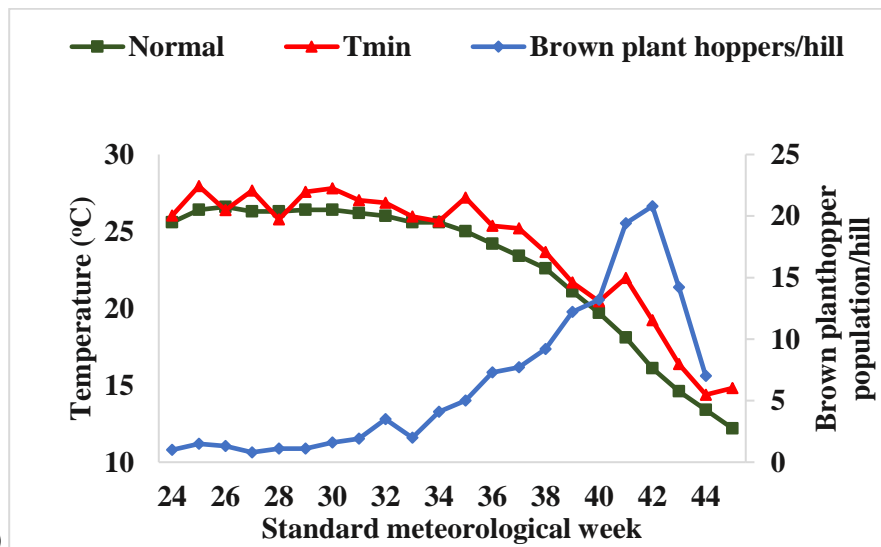
### 3.5 Minimum Temperature

The minimum temperature ranged from 14.5°C to 29.4°C from 24<sup>th</sup> to 45<sup>th</sup> SMW during 2014. The brown planthopper population was less due to high minimum temperature (26.7°C to 29.4°C) initially but it started increasing when minimum temperature range was 15.7 °C to 23.4 °C i.e. 34<sup>th</sup> SMW onwards (Fig. 6a). During 42<sup>nd</sup> SMW, the peak brown planthopper population (10.4 brown planthoppers/hill) was observed and later it started declining. During 2015, the minimum temperature ranged from 14.3°C to 27.9°C. Initially the brown planthopper population was low due to high minimum temperature (25.7°C to 27.9°C) but later, it started increasing when minimum temperature range was 19.2°C to 25.3°C i.e. 34<sup>th</sup> SMW onwards. The peak brown planthopper population (20.8 brown

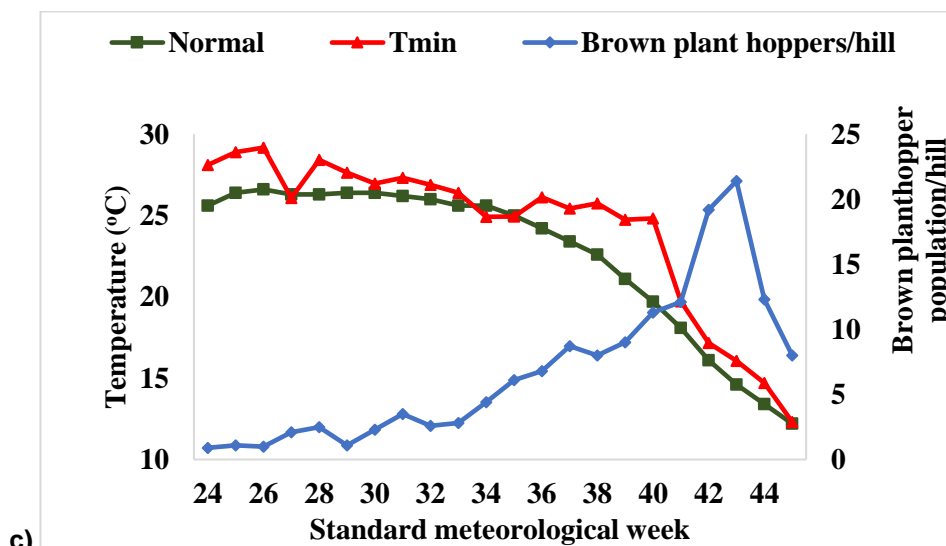
planthoppers/hill) was observed during 42<sup>nd</sup> SMW and later it started declining (Fig. 6b). The minimum temperature ranged from 12.3°C to 29.2°C during 2016. Initially the brown planthopper population was low due to high minimum temperature (26.1°C to 29.2°C) but later, it started increasing when temperature range was 17.2°C to 24.9°C i.e. 34<sup>th</sup> SMW onwards (Fig. 6c). The peak brown planthopper population (21.4 brown planthoppers/hill) was observed during 43<sup>rd</sup> SMW and later it started declining. During 2018, the minimum temperature ranged from 11°C to 28.1°C. The brown planthopper was observed during 38<sup>th</sup> SMW and then it started increasing when minimum temperature range was 18°C to 20.5°C. During 41<sup>st</sup> SMW, the peak brown planthopper population (6.6 Brown planthoppers/hill) was observed and later it started declining (Fig. 6d).



a)

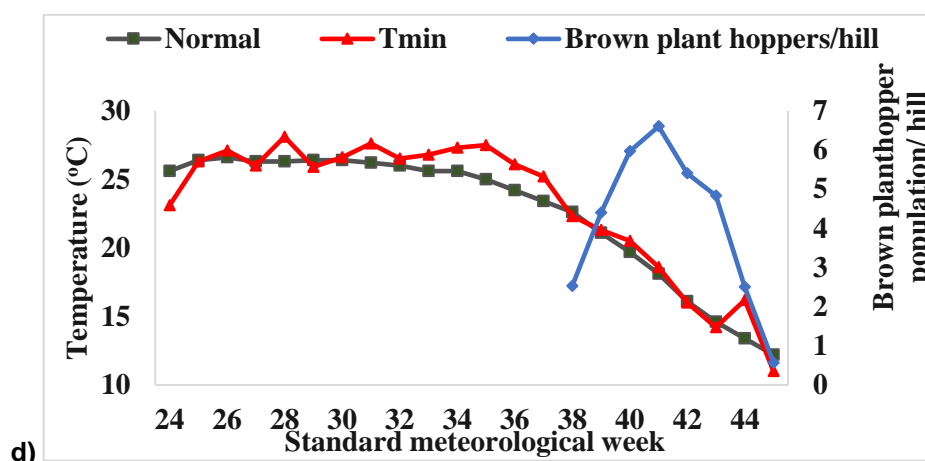


b)



c)





**Fig. 6. Comparison of minimum temperature and brown planthopper population during 2014 (a), 2015 (b), 2016 (c) and 2018 (d)**

### 3.6 Morning Relative Humidity

During 2014, morning relative humidity ranged from 55.6 per cent to 91.3 per cent during the entire crop season. Morning relative humidity was low (55.6-80 per cent) and mostly below normal during initial crop stages (Fig. 7a). It increased 34<sup>th</sup> SMW onwards and simultaneously, an increase in brown planthopper population was also observed. During peak brown planthopper population (42<sup>nd</sup> SMW), it ranged from 86.9-91.3 per cent. Chander and Palta [16] reported that higher relative humidity conditions due to early commencement of rainfall in summer with more number of rainy days contribute to brown planthopper outbreaks. During 2015, relative humidity (morning) ranged from 56.1 per cent to 94 per cent (Fig. 7b). High brown planthopper population was observed when relative humidity (morning) ranged from 92.1 per cent to 94 per cent. Relative humidity (morning) during 2016 was between 55 per cent and 92.3 per cent. Low brown planthopper population was observed when morning relative humidity was 55-78.6 per cent while peak brown planthopper population was observed under high relative humidity conditions (89.2-92.3 per cent) (Fig.7c). During 2018, morning relative humidity was 60 per cent to 93 per cent and comparatively lower brown planthopper population was observed during this year. The peak brown planthopper population was observed when morning relative humidity was 87-92.3 per cent (Fig.7d).

### 3.7 Evening Relative Humidity

During 2014, evening relative humidity ranged from 29.6 per cent to 78.9 per cent. Evening

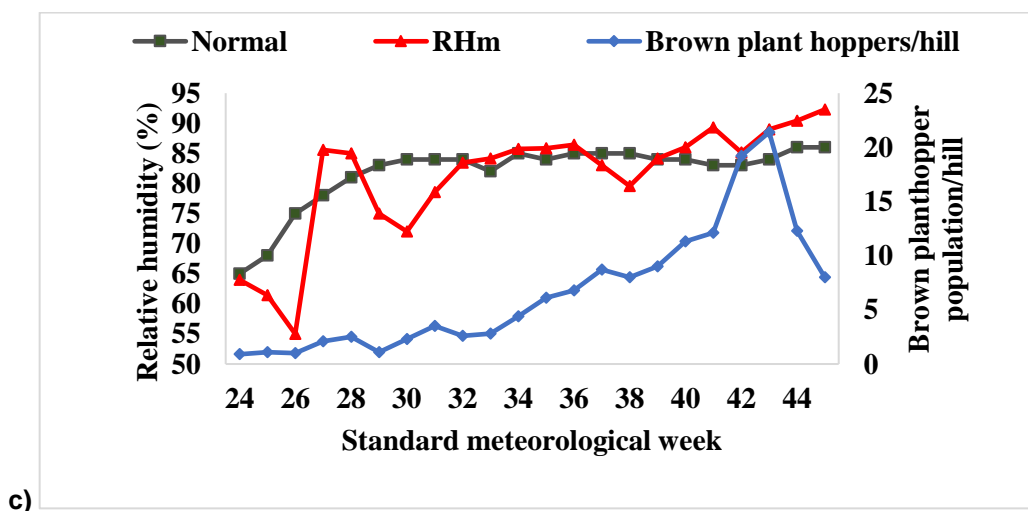
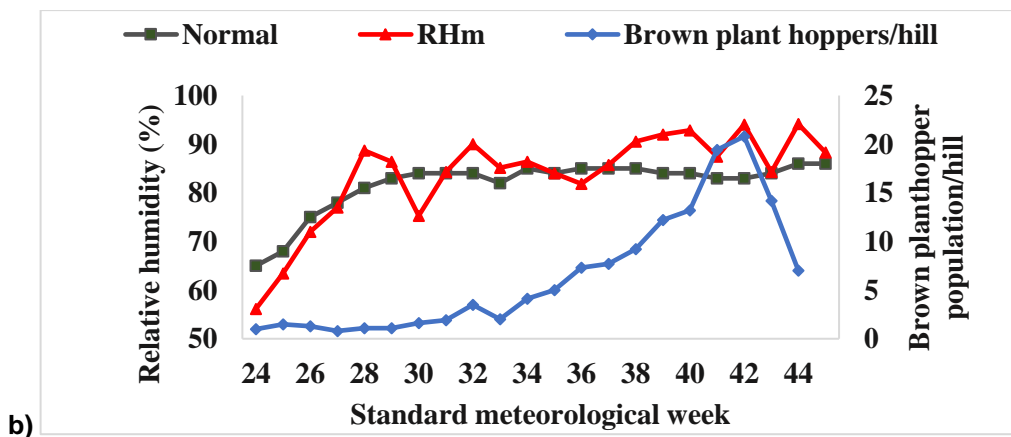
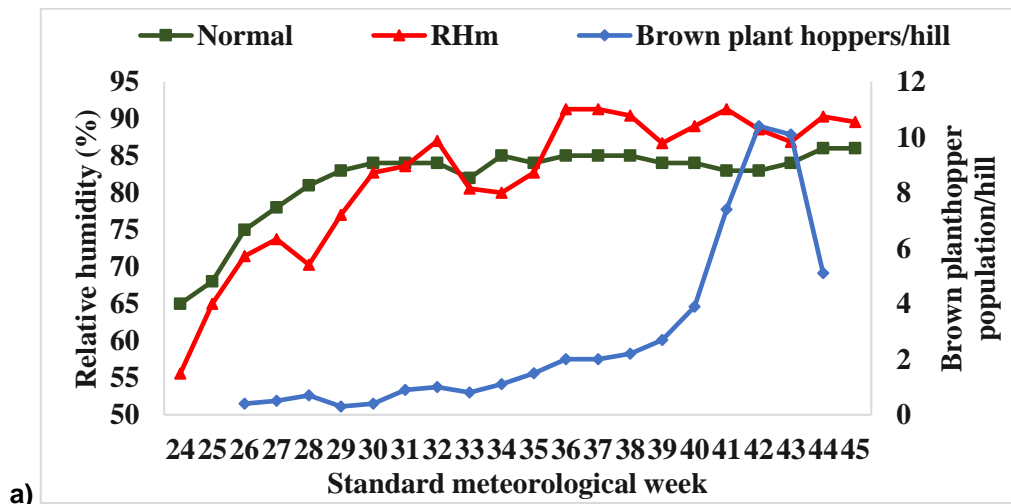
relative humidity was low (29.6-64.4 per cent) during initial stages. It increased 34<sup>th</sup> SMW onwards and started decreasing after 36<sup>th</sup> SMW (Fig.8a). During peak brown planthopper population, it ranged between 40.4 to 55.6 per cent. During 2015, evening relative humidity ranged from 31.7 to 81.7 per cent. High brown planthopper population was observed when evening relative humidity ranged from 45.9-60.4 per cent (Fig. 8b). Evening relative humidity during 2016 was ranged between 28.7-73.6 per cent. The peak brown planthopper population was observed when it was 29.6-55.1 per cent (Fig. 8c). During 2018, it ranged from 33 per cent to 76 per cent and comparatively lower brown planthopper population was observed during this year (Fig. 8d). The peak brown planthopper population was observed when evening relative humidity was 47-65 per cent.

### 3.8 Total Rainfall

The total rainfall (as recorded 24<sup>th</sup> SMW onwards) was higher (807.6 mm) in year 2018 followed by 2015 (535.4 mm), 2014 (420.7 mm) and 2016 (237.3 mm). Low brown planthopper was recorded during high rainfall year 2018. During 2014, brown planthopper population was found to increase with decrease in rainfall from 30<sup>th</sup> SMW onwards. Later during dry conditions, its population increased up to 36<sup>th</sup> SMW and again became constant during rainfall period. In the succeeding weeks, brown planthopper population increased during dry period (Fig.9a). During 2015, brown planthopper population remained low during rainfall period and started increasing later (34<sup>th</sup> SMW onwards) as shown in Fig.9b. The brown planthopper population showed an increasing trend with decrease in

rainfall 30<sup>th</sup> SMW onwards in year 2016 (Fig.9c). The first incidence of brown planthopper was recorded during 38<sup>th</sup> SMW during 2018. The dry period after 39<sup>th</sup> SMW showed increase in brown planthopper population (Fig.9d). During 2016, total rainfall (409.3 mm) was below normal (606.4 mm) while in (2018, it was 845.4 mm from 22<sup>nd</sup> to 45<sup>th</sup> SMW. High amount of rainfall was

received at 29<sup>th</sup> SMW (167.8 mm) and 38<sup>th</sup> SMW (146.2 mm) in year 2018 which may be responsible for lower BPH incidence [17]. Chaudhary et al. [18] reported a negative correlation between brown planthopper population and rainfall. Jeyarani [19] also reported a negative correlation between brown planthopper population and rainfall.



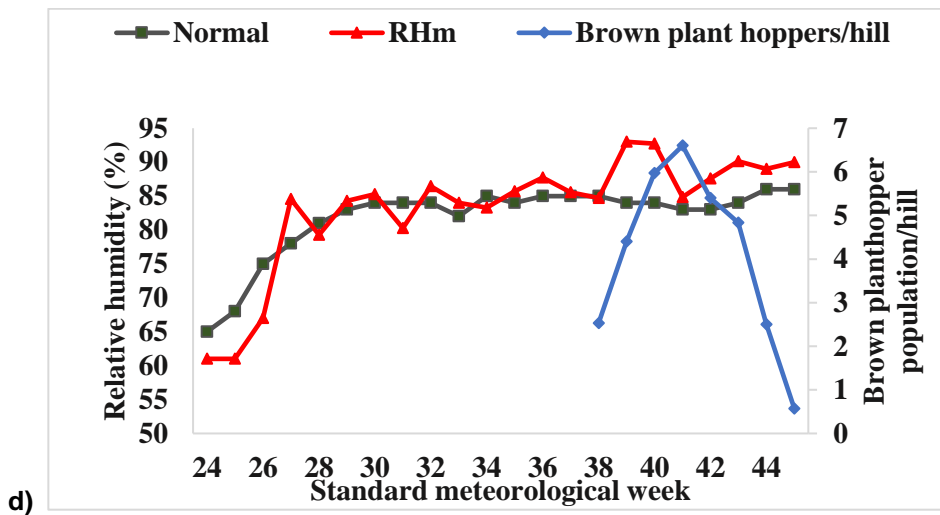
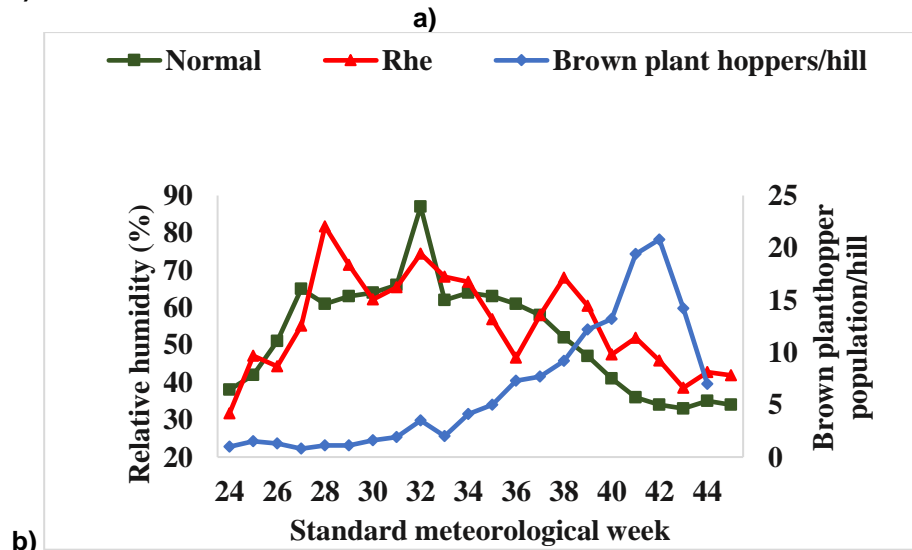
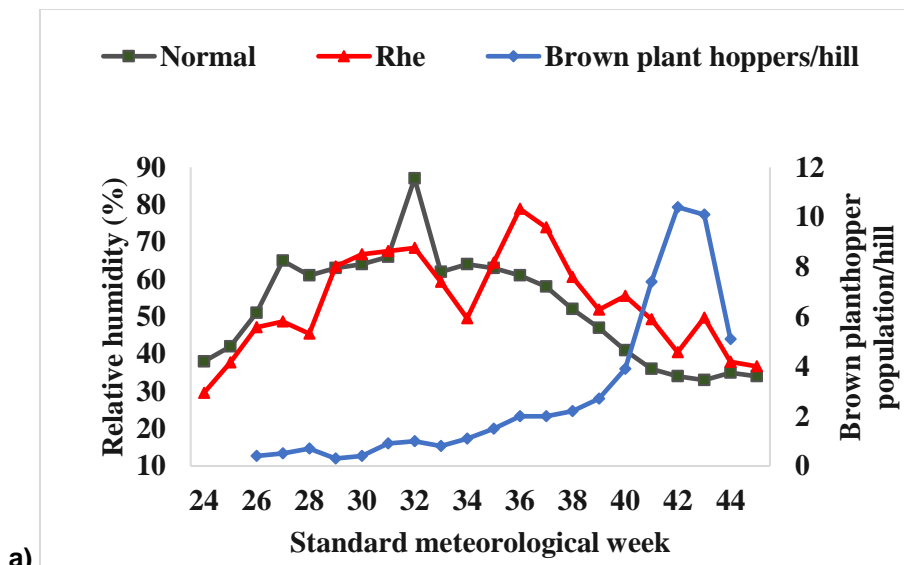


Fig. 7. Comparison of relative humidity and brown planthopper population during 2014 (a), 2015 (b), 2016 (c) and 2018 (d)



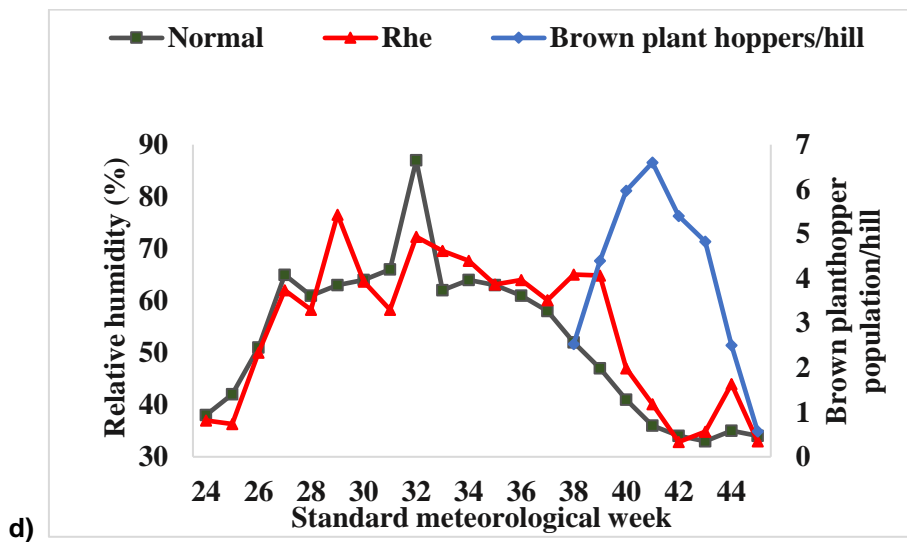
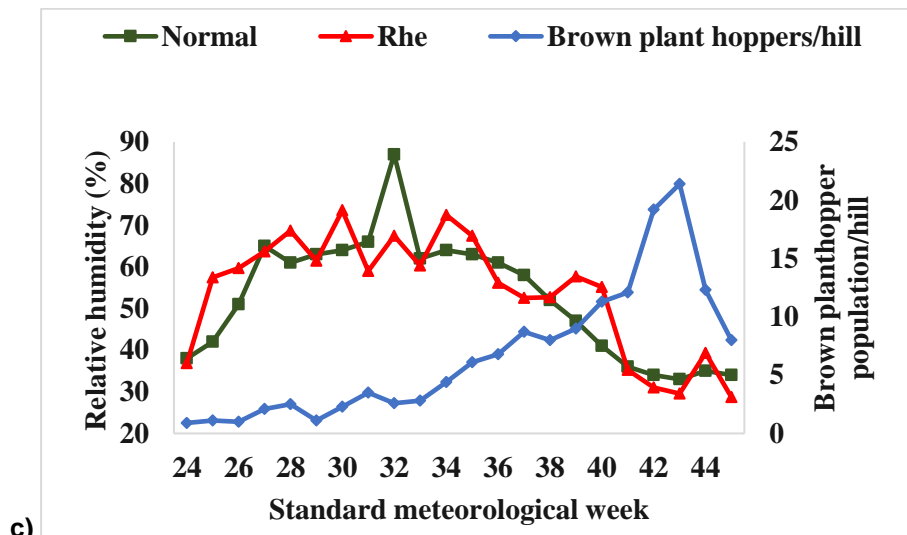
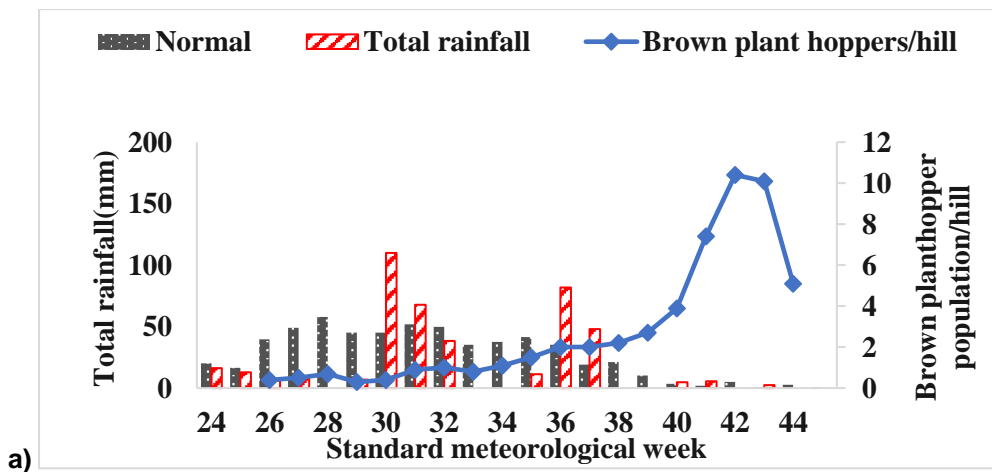


Fig. 8. Comparison of evening relative humidity and brown planthopper population during 2014 (a), 2015 (b), 2016 (c) and 2018 (d)



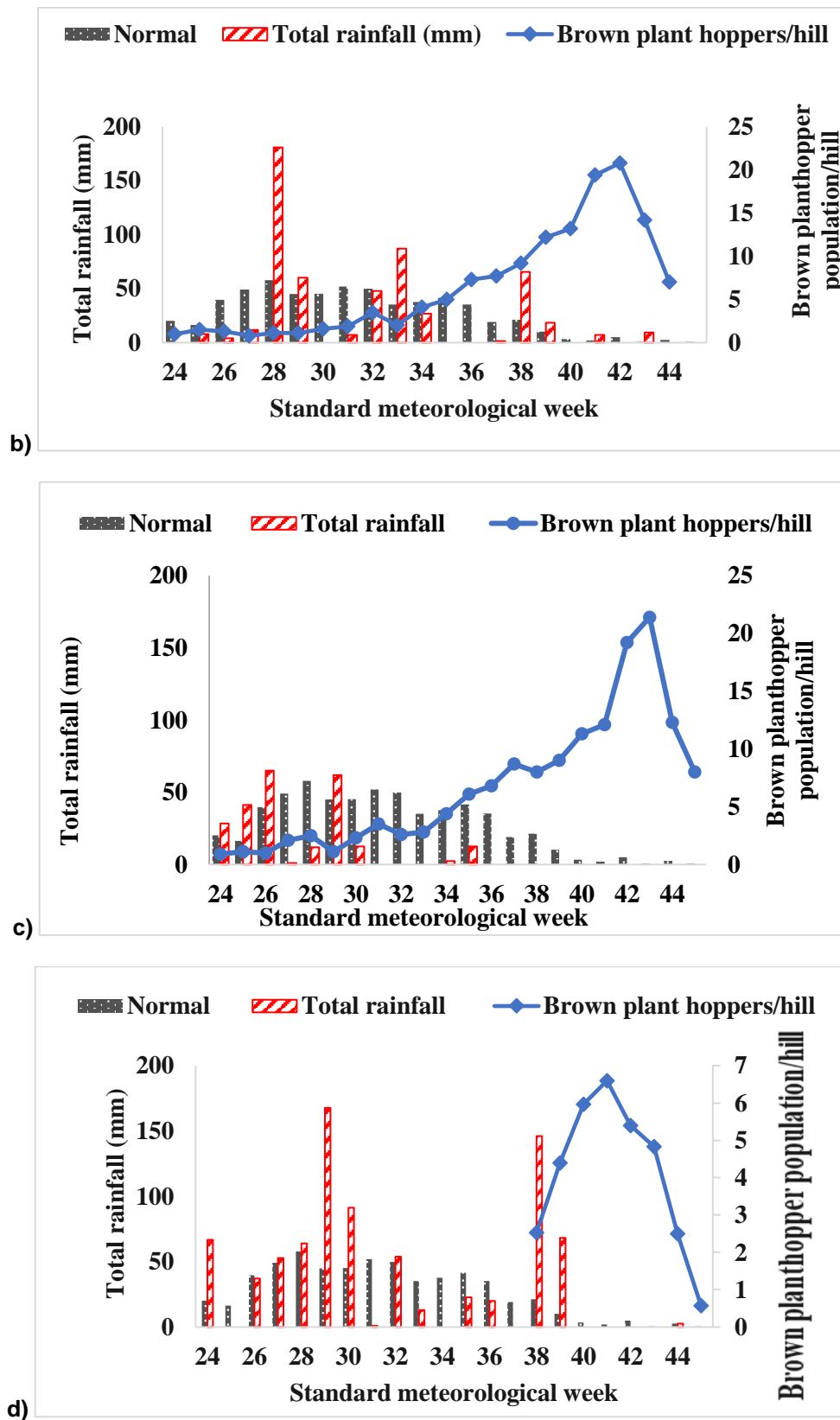


Fig. 9. Comparison of total rainfall and brown planthopper population during 2014, 2015, 2016 and 2018

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

Year	Regression equations	R <sup>2</sup> value
<b>2014</b>	Y= 17.04 - 0.22 Tmax- 0.30 Tmin	0.46
	Y= 17.38-0.44 Tmax- 0.1 RHm	0.33
	Y = 10.89 – 0.47 Tmin +0.05 RHe	0.47
	Y = 24.81 – 0.58 Tmax- 0.05 RHe	0.40
	Y= -16.24 + 0.57 Tmax – 0.60 Tmin + 0.14 RHm + 0.04 RHe	0.53
	Y= -17.28 + 0.70 Tmax – 0.71 Tmin + 0.12 RHm+ 0.09 RHe – 0.14 SSH – 0.16 RF	0.56
	<b>2015</b>	Y = 32.85 - 0.5 Tmax- 0.45 Tmin
Y = -28.23+0.32 Tmax+0.29 RHm		0.34
Y = 20.36 – 0.89 Tmin+0.12 RHe		0.31
Y= 39.38-0.92 Tmax -0.06 RHe		0.23
Y = -73.84 + 1.74 Tmax– 0.89 Tmin + 0.56 RHm-0.06 RHe		0.59
Y = -68.31 + 1.83 Tmax – 1.27 Tmin + 0.45 RHm + 0.10 RHe+ 0.20 SSH– 0.17 RF		0.61
<b>2016</b>		Y= 42.57 – 0.57 Tmax - 0.71 Tmin
	Y= -5.63-0.19 Tmax+0.23 RHm	0.46
	Y= 27.98 – 1.13 Tmin +0.1 RHe	0.57
	Y= 64.61 – 1.46 Tmax– 0.17 RHe	0.59
	Y = 3.04 – 0.1 Tmax – 0.36 Tmin + 0.25 RHm – 0.09 RHe	0.68
	Y = -4.39 + 0.05 Tmax – 0.33 Tmin + 0.30 RHm – 0.12 RHe – 0.13 SSH+0.09 RF	0.69
	<b>2018</b>	Y = 6.51 + 0.10 Tmax - 0.33 Tmin
Y= 14.75 – 0.41 Tmax+0.1 RHm		0.31
Y= 8.43 – 0.24 Tmin – 0.03 RHe		0.50
Y= 15.14 -0.30 Tmax – 0.08 RHe		0.51
Y = -12.38 +0.14 Tmax + 0.03 Tmin + 0.19 RHm -0.14 RHe		0.65
Y = - 14.04 +0.1 Tmax + 0.13 Tmin + 0.22 RHm -0.18 RHe + 0.01 SSH + 0.1 RF		0.66
<b>Pooled regression analysis</b>		Y= 17.88 + 0.1 Tmax-0.70Tmin
	Y= 8.81 – 0.50 Tmax + 0.15RHm	0.36
	Y= 19.63-0.69 Tmin+0.02 RHe	0.53
	Y= 38.44 – 0.80 Tmax- 0.14 RHe	0.48
	Y= -50.56+0.71 Tmax+0.11 Tmin+0.54 RHm-0.29 RHe	0.70
	Y= -26.82- 0.1 Tmax+ 0.22 Tmin+ 0.43 RHm- 0.29 RHe+ 0.91 SSH+ 0.04 RF	0.75

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)

### 3.9 Regression Analysis

Regression models are widely used to study the relationship of different meteorological parameters with insect abundance or disease incidence. The variability between observed and predicted values of insect or disease can be studied through regression models. Shekhar et al. [20] developed regression models for per cent damage of leaf folder and meteorological

parameters that gave significant R<sup>2</sup> value (0.75). Dhaliwal et al. [21] also developed models for brown leaf spot disease of rice and relationship between observed and predicted values gave significant R<sup>2</sup> value (0.89). Anand et al. [22] developed agroclimatic indices-based regression models for forewarning of rice brown planthopper. Regression models were developed to study the relationship of different meteorological parameters with the brown

planthopper population in field for years 2014,2015,2016 and 2018 as shown in Table 1. The pooled data regression equation is as follows:

$$Y = -26.82 - 0.1 T_{max} + 0.22 T_{min} + 0.43 RH_{m} - 0.29 RH_{e} + 0.91 SSH + 0.04 RF \quad (R^2 = 0.75)$$

The maximum temperature was negatively correlated with brown planthopper population while minimum temperature showed a positive correlation with brown planthopper population. Morning relative humidity, sunshine hours were positively correlated with brown planthopper population. Total rainfall was found to have weak positive correlation with brown planthopper population. Evening relative humidity showed a negative correlation with brown planthopper population. All the factors together showed 75 per cent variation in brown planthopper population.

#### 4. CONCLUSIONS

The favourable temperature for brown planthopper incidence was 30.2-33.4 °C (maximum temperature) and 20.6-22.5 °C (minimum temperature) while morning relative humidity was 86-90 per cent and evening relative humidity was 48-60 per cent. Hot, cloudy and humid conditions are conducive for brown planthopper multiplication. Closer spacing (25 cm x 12 cm) had a higher BPH population than wider spacing (20 cm x 15 cm and 30 cm x 10 cm) due to changes in micrometeorological parameters. Hence, microclimate modification through spacing is cost-effective measure for brown planthopper management in basmati rice.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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