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Research Article

Agroclimatic Indices based Model for Rice BPH (*Nilaparvata lugens*)

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ABSTRACT

A field experiment was conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana during *kharif* 2018. Two rice varieties (PR 121 and PR 126) were transplanted on 20th June and 30th June and Pusa Basmati 1121 was transplanted on 5th July and 15th July in four replications. BPH population data were collected from 2014 to 2016 and 2018. Relationships between BPH population and agroclimatic indices *viz.* growing degree days (GDD) and humid-thermal ratio (HTR) were worked out. GDD and BPH were negatively correlated during all the years. During the highest BPH population year (2016), values of HTR were comparatively low as compared to the lowest BPH population year (2018). With an increase in HTR, BPH population has increased. Agroclimatic indices based models were developed using BPH incidence data from 2014 to 2016 and validated using BPH data of 2018. Among the growing degree day models, the per cent error between observed and predicted was minimum (6.3%) during 2015. The HTR_3 (Evening relative humidity / Maximum temperature) and HTR_4 (Evening relative humidity / Minimum temperature) based models showed less than 10 per cent error during all the years.

Key words: Rice BPH, Growing degree days, Humid thermal ratio, Agroclimatic indices based models

Introduction

Rice is principally a crop of hot and humid climate thus the areas where mean monthly temperature varies throughout the growing season from 23.3-27.7°C, within a daily minimum temperature of 15°C and a maximum temperature of 39°C give better yields. These temperatures fall well within the favourable range for rice insect pests (Mochida *et al.,* 1987). The rice plant is attacked by more than 100 species of insects and 20 of them can cause economic damage and BPH (*Nilparvata lugens*) is one of the important insect of rice crop. The favourable mean temperature for BPH incidence is 26-28°C while mean relative humidity is 66 to 75 per cent and total weekly rainfall should be less than 25 mm for Ludhiana, Punjab (Vennila *et al.,* 2016). Susceptible cultivars suffer a yield loss of 40-70 per cent under serious BPH infestation (Heong and Hardy, 2009). Yield loss of 60% is found under epidemic conditions (Kumar *et al.,* 2012).

Amid the most recent decade, the pest population scenario of rice (*Oryza sativa* L.) has seen significant changes because of fluctuations in predominant weather conditions in Punjab. Insect abundance varies with prevailing weather conditions during the crop season. Temperature and relative humidity are important meteorological parameters that affect BPH multiplication and growth. Thus, growing degree days and humid thermal ratio can be helpful in forewarning of insects. The various development stages of an

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insect can be predicted with help of growing degree days (GDDs). The knowledge about different development stages can be best known through this index. The concept of heat unit presumes a linear or logarithmic relationship between growth and temperature. The heat unit measure is departure of mean daily temperature from base temperature below which the internal biochemical activity ceases. The perceptive of humid thermal regime for the BPH can be best established using agroclimatic indices *viz.* growing degree days and humid thermal ratio. Keeping all this in view, the present investigation was carried out to study the relationship between rice BPH population and agroclimatic indices.

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) and Pusa Basmati 1121 was transplanted on different dates (5th July and 15th July) with four replications during *kharif* season 2018. The experiment was laid out in Split-Split Plot Design for rice and Factorial-RCBD Design for basmati rice. The BPH population data were recorded weekly. The BPH data from 2014 to 2016 were recorded in the Department of Entomology, PAU, Ludhiana. The data on different meteorological parameters were obtained from the Agrometerological Observatory located 150 meters away from the field. Accumulated growing degree days (AGDD) were calculated from the day of first incidence of BPH. Agroclimatic indices *viz.* growing degree days (GDD) and humid -thermal ratio (HTR) were calculated by using the following formulae:

$$GDD = \frac{T\max + T\min}{2} - T_{base}$$

$$HTR = \frac{\text{Relative humidity}}{\text{Temperature}}$$

$$HTR_1 = \frac{RHm}{T\max}$$

$$HTR_2 = \frac{RHm}{T\min}$$

$$HTR_3 = \frac{RHe}{T\max}$$

$$HTR_4 = \frac{RHe}{T\min}$$

Where,

Tmax: Maximum temperature (°C)

Tmin: Minimum temperature (°C)

T_{mean} : Mean temperature {(Tmax + Tmin)/2}

T_{base} : Base temperature for rice (10°C) {Gao *et al* (1992)}

RHm: Relative humidity morning (%)

RHe: Relative humidity evening (%)

Agroclimatic indices based regression models for BPH were developed using these indices.

Results and Discussion

Relationship between growing degree days and BPH population

Growing degree days (GDD) were calculated for BPH using temperature (maximum and minimum) data from 2014 to 2016 and 2018. The correlation coefficients were calculated between BPH population (field data from 2014 to 2016 and 2018) and GDD (Table 1). The BPH population was negatively correlated with GDD during all the years under study. This means that more the GDD, lower will be the BPH population and vice versa. The correlation coefficients (r) between BPH population and GDD during 2014,2015, 2016 and 2018 were -0.67, -0.48, -0.73 and -0.46 respectively. Similarly, Dhaliwal *et al.* (2005) also reported that aphid population and GDD were negatively correlated *i.e.* more the GDD, less was the aphid population.

Accumulated growing degree days (AGDD) for BPH during different incidence years

Accumulated growing degree days (°C day) were computed for different years of BPH incidence. It was observed that GDD accumulated by BPH at first incidence were less (20.6 °C day) in the lowest insect incidence year (2018) as

Table 1. Correlation coefficients between BPH population and growing degree days (°C day)

SMW	No. of hoppers/Hill (Mean)				Growing degree days (°C day)			
	2014	2015	2016	2018	2014	2015	2016	2018
24	0	1	0.9	0	24.49	22.34	23.61	20.45
25	0	1.5	1.1	0	23.70	22.76	23.08	22.30
26	0.4	1.3	1.0	0	21.41	21.24	22.70	20.90
27	0.5	0.8	2.1	0	21.94	21.64	19.84	19.95
28	0.7	1.1	2.5	0	24.21	18.47	20.91	21.80
29	0.3	1.1	1.1	0	20.89	20.23	21.24	19.65
30	0.4	1.6	2.3	0	20.39	21.01	19.66	20.25
31	0.9	1.9	3.5	0	20.99	19.79	20.89	21.40
32	1.0	3.5	2.6	0	20.74	19.51	19.53	19.60
33	0.8	2	2.8	0	20.36	19.89	20.44	20.35
34	1.1	4.1	4.4	0	20.56	19.46	19.03	20.75
35	1.5	5	6.1	0	18.91	21.10	18.57	21.15
36	2.0	7.3	6.8	0	17.66	19.99	20.23	19.75
37	2.0	7.7	8.7	0	17.94	20.24	19.90	19.30
38	2.2	9.2	8-0	2.5	19.19	17.26	19.91	16.70
39	2.7	12.2	9-0	4.4	18.36	16.67	19.13	15.60
40	3.9	13.2	11.3	6.0	19.47	16.80	19.41	16.50
41	7.4	19.4	12.1	6.6	14.53	17.33	16.53	14.70
42	10.4	20.8	19.2	5.4	12.86	15.37	15.27	13.85
43	10.1	14.2	21.4	4.8	14.18	12.95	13.81	10.20
44	5.1	7	12.3	2.5	11.61	11.08	11.96	12.90
45	0	0	8	0.6	11.60	10.81	10.51	9.05
Correlation coefficient (r)					0.67**	0.48*	0.73**	0.66**
p-value					0.001	0.02	0.0001	0.001

*Significant at 5% level; **Significant at 1% level

compared to the highest insect incidence year (2016) (Table 2). It was also observed that at maximum population of insect, maximum AGDD (2675.1°C day) was cumulated in the year 2016 than 2018 (2008.5°C day). At the lowest population of insect, AGDD cumulated was higher in year 2016 (2862.3°C day) than 2018 (2018.2°C day). Thus, higher the AGDD accumulated during a year, more is the BPH attack. Dhaliwal *et al* (2005) studied relationship between peak aphid population and accumulated growing degree days.

Table 2. Accumulated growing degree days (AGDD) for BPH during different years of BPH incidence

Brown plant hopper incidence	Accumulated growing degree days (°C day)			
	2014	2015	2016	2018
First incidence	22.5	18.1	23.2	20.6
Highest population	2327.6	2656.7	2675.1	2008.5
Lowest population	2425.6	2851.3	2862.3	2018.2

Relationship between humid thermal ratio (HTR) and BPH population

Insect abundance is generally dependent on the weather conditions prevailing during the crop season. Temperature and relative humidity are important meteorological parameters that affect BPH multiplication and growth. Thus, humid thermal ratio can be helpful in forewarning of insects. The HTR were calculated for BPH using field experiment data from 2014 to 2016 and 2018. The correlation coefficients were calculated between BPH population and HTR. The values of HTR were lower in the beginning and increased until peak BPH population and later started decreasing (Table 3 and Table 4). Higher the value of HTR, lower is the attack of BPH and vice versa. During the highest BPH population year (2016), values of HTR was comparatively low as compared to the lowest BPH incidence year (2018). This was because maximum and minimum temperatures were lower in case of the lowest BPH incidence year (2018) than the highest incidence year (2016). Thus, the values of HTR were higher during the lowest BPH incidence year (2018) than the highest BPH population year (2016). With an increase in values of HTR, BPH population also increased. After peak population was attained, the values of HTR started decreasing in most of the cases.

Correlation coefficients were computed between BPH population and HTR. A positive correlation of BPH with HTR_1 and HTR_2 was observed during 2014 and 2015. The BPH population was negatively correlated with HTR_3 and HTR_4 during 2016 while it was negatively correlated with HTR_4 during 2018. Gundappa *et al* (2016) reported that the value of HTR was higher (2.05) in 2014 as compared to 2013 (1.47) when thrips population was low. Also, a positive correlation was reported between humid thermal ratio (HTR) and thrips population during 2013 and 2014. Similarly, HTR was used to forecast karnal bunt disease in Punjab (Jhorar *et al* 1992). Dhaliwal *et al* (2005) also studied relationship between humid thermal ratio and weekly aphid population. Dutta (2006) used HTR to predict yellow rust incidence under Punjab conditions. The variation of 46 to 52 per cent in yellow rust incidence due to HTR was reported under Punjab conditions. Similarly, Kumar (2014) also developed relationship between leaf rust and meteorological parameters and found that the correlation coefficients were highest for the humid thermal ratio (HTR), maximum temperature (MXT) and special humid thermal ratio (SHTR), and these three weather variables were selected as predictor variables. Sandhu *et al* (2016) also suggested that humid thermal ratio (HTR) and special humid thermal ratio (SHTR) can be used as a yellow rust predictor.

Validation of agroclimatic indices based regression models for BPH

Different agroclimatic indices *viz.* growing degree days and humid thermal ratio based regression models were developed for BPH using data from 2014 to 2016 (Table 5). The field data of BPH collected during 2018 was used to validate these models. Among the growing degree day models, the per cent error between observed and predicted was minimum (6.3 %) during 2015. The minimum per cent error (1.7 %) was observed for HTR_1 during 2015. The regression model for HTR_2 during 2015 showed 2.6 per cent error. Similarly, minimum per cent error of 1.4 and 4.5 per cent was observed for HTR_3 and HTR_4 respectively during 2015. HTR_3 and HTR_4 based models showed less than 10 per cent error during all the years. Thus the agroclimatic indices based regression models from year 2015 gave best fits for forewarning of BPH. Pooled data regression models of HTR_1, HTR_3 and HTR_4 showed less than 10 per cent error. Among all these models, BPH can be predicted by using HTR_3 (RHe/Tmax) based model which has the lowest per cent error of +1.8%. Karuna (2019) also developed agroclimatic indices based regression models for brown leaf spot disease of rice crop and validated the same using field data of 2017.

Conclusion

Different agroclimatic indices (GDD, HTR) can be used to predict BPH incidence. Correlation of BPH population with GDD and HTR indicates

Table 3. Relationship between BPH population with humid thermal ratio

SMW		24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	Correlation coefficient (r)	P-value
HTR_1 (RHm/Tmax)																									
Year	2014	1.3	1.7	2	2	1.8	2.3	2.5	2.4	2.6	2.4	2.4	2.5	3	2.8	2.7	2.6	2.6	2.9	3	2.9	3.1	3.1	0.58**	0.01
	2015	1.5	1.7	2	2.2	2.9	2.6	2.2	2.6	2.8	2.5	2.6	2.4	2.4	2.4	2.9	2.9	2.8	2.7	3	2.9	3.4	3.3	0.47*	0.03
	2016	1.6	1.7	1.5	2.6	2.6	2.2	2.2	2.3	2.6	2.4	2.6	2.7	2.5	2.4	2.3	2.5	2.5	2.7	2.6	2.8	3.1	3.2	0.60**	0.003
	2018	1.6	1.6	1.9	2.5	2.2	2.5	2.5	2.3	2.6	2.5	2.4	2.5	2.6	2.6	2.8	3.1	2.9	2.8	2.8	3.4	3	3.3	0.56**	0.01
HTR_2 (RHm/Tmin)																									
Year	2014	2	2.3	2.7	2.7	2.4	2.8	3	3	3.2	3	3	3.3	3.7	3.9	3.7	3.7	3.6	5.1	5.7	4.8	6.4	6.2	0.69**	0.0004
	2015	2.2	2.3	2.7	2.8	3.4	3.1	2.7	3.1	3.4	3.3	3.4	3.1	3.2	3.4	3.8	4.2	4.5	4	4.9	5.2	6.5	6	0.52*	0.013
	2016	2.3	2.1	1.9	3.3	3	2.7	2.7	2.9	3.1	3.2	3.4	3.4	3.3	3.3	3.1	3.4	3.5	4.5	5	5.5	6.2	7.5	0.7**	0.0003
	2018	2.6	2.3	2.5	3.3	2.8	3.3	3.2	2.9	3.3	3.1	3.1	3.1	3.4	3.4	3.9	4.4	4.5	4.6	5.5	6.3	5.5	8.2	0.54**	0.01

*Significant at 5% level; **Significant at 1% level

Table 4. Relationship between BPH population with humid thermal ratio

SMW		24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	Correlation coefficient (r)	P-value
HTR_3 (RHe/Tmax)																									
Year	2014	0.7	1	1.3	1.3	1.2	1.9	2	2	2	1.8	1.5	2	2.6	2.3	1.8	1.6	1.6	1.6	1.4	1.6	1.3	1.3	0.20	0.37
	2015	0.8	1.3	1.2	1.6	2.6	2.2	1.8	2	2.3	2	2	1.6	1.4	1.6	2.2	1.9	1.4	1.6	1.5	1.3	1.5	1.6	0.01	0.96
	2016	0.9	1.5	1.7	1.9	2.1	1.8	2.3	1.7	2.1	1.8	2.2	2.1	1.6	1.5	1.6	1.7	1.6	1.1	0.9	0.9	1.3	1	-0.43*	0.05
	2018	1	1	1.4	1.8	1.6	2.3	1.9	1.7	2.2	2.1	2	1.8	1.9	1.8	2	2.2	1.5	1.3	1	1.3	1.5	1.2	-0.31	0.17
HTR_4 (RHe/Tmin)																									
Year	2014	1.1	1.3	1.8	1.8	1.5	2.3	2.4	2.5	2.5	2.2	1.8	2.6	3.2	3.1	2.4	2.2	2.2	2.8	2.6	2.8	2.7	2.5	0.51*	0.15
	2015	1.2	1.7	1.7	2	3.2	2.6	2.2	2.4	2.8	2.6	2.6	2.1	1.8	2.3	2.9	2.8	2.3	2.4	2.4	2.4	3	2.8	0.26	0.24
	2016	1.3	2	2.1	2.4	2.4	2.2	2.7	2.2	2.5	2.3	2.9	2.7	2.2	2.1	2.1	2.3	2.2	1.8	1.8	1.8	2.7	2.3	-0.04	0.86
	2018	1.6	1.4	1.9	2.4	2.1	3	2.4	2.1	2.7	2.6	2.5	2.3	2.5	2.4	2.7	3.1	2.3	2.2	2.1	2.5	2.7	3	0.10	0.66

*Significant at 5% level; **Significant at 1% level

Table 5. Validation of agroclimatic indices based regression models for BPH

Year	Regression models	R^2	Brown plant hopper population		
			Observed	Predicted	% Error
Growing degree days based regression models					
2014	Y= 12.95 - 0.56 GDD	0.46	2.43	2.80	-15.2
2015	Y= 21.19 - 0.81 GDD	0.20	6.18	6.57	-6.3
2016	Y= 29.86 – 1.22 GDD	0.51	6.69	7.84	-17.2
Pooled data	Y= 22.78- 0.94 GDD	0.44	5.10	5.87	-15.1
Humid thermal based regression models					
HTR_1 =RHm/Tmax					
2014	Y = 6.54 + 3.62 HTR_1	0.30	2.43	2.76	-13.6
2015	Y = -7.47 + 5.31 HTR_1	0.16	6.18	6.29	-1.7
2016	Y = -12.30 + 7.81 HTR_1	0.31	6.69	7.77	-16.1
Pooled data	Y = -11.41+ 6.62 HTR_1	0.33	5.10	5.60	-9.8
HTR_2= RHm/Tmin					
2014	Y = -3.64 + 1.67 HTR_2	0.44	2.43	2.82	-16.0
2015	Y = -3.8 + 2.59 HTR_2	0.22	6.18	6.34	-2.6
2016	Y = 3.81 + 2.92 HTR_2	0.47	6.69	7.49	-11.9
Pooled data	Y = -4.21+ 2.56 HTR_2	0.40	5.10	5.70	-11.8
HTR_3= RHe/Tmax					
2014	Y = 2.38 + 0.03 HTR_3	0.30	2.43	2.59	-6.6
2015	Y = 10.57 – 2.59 HTR_3	0.31	6.18	6.27	-1.4
2016	Y = 20.05 – 8.33 HTR_3	0.37	6.69	6.22	+7.6
Pooled data	Y = 12.16- 4.31 HTR_3	0.08	5.10	5.01	+1.8
HTR_4=RHe/Tmin					
2014	Y = -3.52 + 2.60 HTR_4	0.21	2.43	2.64	-8.6
2015	Y = 2.20 + 1.68 HTR_4	0.02	6.18	6.46	-4.5
2016	Y = 14.79 – 3.64 HTR_4	0.05	6.69	6.16	+7.9
Pooled data	Y = -3.22+ 3.63 HTR_4	0.06	5.10	5.38	-5.5

Where, Y = BPH population

negative relationships. Growing degree day based model gave 15% error and it is underestimating BPH population. The HTR_3 (Evening RH/Tmax) model has the lowest percent error of +1.8% which can be used for prediction of BPH population under Punjab conditions. But still there is a need to validate these models with multiyear field data for better results.

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