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Agro-ecological zoning of brown planthopper [*Nilaparvata lugens* (Stal)] incidence on rice (*Oryza sativa* L.)

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Multiple linear regression models (pest-weather models) were developed between monthly mean brown planthopper (BPH), *Nilaparvata lugens* light trap catches and monthly mean values of minimum temperature (Tmin), maximum temperature (Tmax), morning relative humidity (RH_1) and evening relative humidity (RH_2) observed at Maruteru, Andhra Pradesh during 2000-2007 *kharif* seasons. Comparison between predicted and observed BPH light trap catches at Nellore (*kharif* 2004 and 2005), Ragolu (*kharif* 2003-2007) and Rajendranagar (*kharif* 2005 and 2007) evinced very high level of congruence between them, thereby validating agro-ecological zoning of BPH incidence in Andhra Pradesh. Knowledge of BPH incidence levels in different zones would facilitate strategic decisions with regard to selection of crop cultivars and management practices, and prediction of probable life of resistant cultivars.

Keywords: Brown planthopper, Pest-weather model, Pest zoning, Rice

Introduction

Insect pest complex of rice (*Oryza sativa* L.) crop has undergone a drastic change during last three decades following green revolution[1,2]. Among rice insect pests, brown planthopper [BPH, *Nilaparvata lugens* (Stal)] and white-backed planthopper [WBPH, *Sogatella furcifera* (Horvath)] are most devastating[3,4]. Planthopper population has been attaining serious proportions leading to pest outbreak and crop failure as happened in North India during 2008[5]. These infrequent but widespread outbreaks can be dealt effectively by a regional forecasting strategy[6]. Geographic information system (GIS) technology appears to be sufficiently well developed to be integrated into existing integrated pest management (IPM) programmes[7]. Pest-weather models can be used for agro-ecological zoning (AEZ) of pest population using GIS techniques[8]. Pest zoning is applicable for large area pest management, in which both tactics and strategies can be merged to achieve optimal management[9]. AEZ helps in delineating pest hot-spots and also in assessing probability of pest outbreaks in different parts of a region. This study presents AEZ of BPH incidence on rice in Andhra Pradesh (AP).

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Experimental Section

Development of Pest-Weather Regression Model (PWRM)

Weekly light trap catches (LTCs) of BPH and corresponding temperature and relative humidity (RH) data recorded at Maruteru (AP) were collected from 'Directorate of Rice Research (DRR)' Progress Reports for *kharif* season (June-October) during 2000-2007. LTC data, comprised of total planthopper population collected over a week, were further averaged over four weeks of a month to obtain mean LTC/month. Likewise, weather data were available as weekly averages, which were further averaged over four weeks of a month to calculate a monthly average. Monthly mean BPH catches and monthly mean values of TTR [minimum temperature (Tmin), maximum temperature (Tmax), morning relative humidity (RH_1) and evening relative humidity (RH_2)] in respective months were used in developing PWRMs. Software package (Microsoft Excel) was used for multiple regression analysis between meteorological parameters and LTCs of BPH. Regression equations were developed initially with TTR. However, stepwise regression was then done to eliminate non-significant weather parameters. Contribution of different weather factors towards coefficient of determination (R^2) was taken as a criterion for judging their relative importance in relation to BPH LTCs.

Table 1—Multiple linear regression between mean monthly log transformed BPH light trap catches and monthly mean values of weather factors during *kharif* seasons from 2000 to 2007 at Maruteru, Andhra Pradesh

Predictors	Coefficients	Standard error	T Stat	P-value
Constant (intercept)	27.962*	3.608	7.750	3.49E-09
T_{max} (b_1)	-0.266*	0.067	-3.974	0.000326
T_{min} (b_2)	-0.507*	0.073	-6.959	3.71E-08
RH_2 (b_3)	-0.056*	0.016	-3.601	0.000948

R^2 = 0.674; F = 24.818* ; d.f. =3, 36; Significance of F = 7E-09

*Significant at 1% level

Agro-Ecological Zoning of Brown Planthopper Incidence

PWRM developed between BPH LTCs and TTR was interpolated using GIS for AP. Monthly normal values of TTR, recorded in weather stations across AP from 1951-1990, were obtained from 'India Meteorological Department' (IMD), New Delhi. Mean *kharif*, TTR values for these stations were calculated based on monthly normal values. Environmental Systems Research Institute (ESRI) ArcGIS 9.2 package was used for GIS mapping of AEZ. Boundary of AP was digitized using ArcGIS. Weather stations along with their corresponding normal values of TTR were marked as point data in AP map using latitude and longitude coordinates. Using geostatistical analysis, point data were interpolated for AP based on 'Inverse Distance Weighted (IDW)' algorithm. Based on interpolated normal values, three different thematic layers, one each for Tmax, Tmin and RH_2, were generated for AP using ArcGIS software. These maps were clipped based on AP boundary. Model builder tool in ERDAS IMAGINE 9.2 software was used to determine BPH population for AP by using interpolated values of TTR and PWRM and a single map of BPH incidence was developed. This map was categorized into following four severity classes of BPH incidence: Severe, > 15000 BPH (log value > 4.176); High, 5000 - 15000 BPH (log value 3.699 - 4.176); Moderate, 500 - 5000 BPH (log value 2.699 - 3.699); and Low, < 500 BPH (log value < 2.699). Finally, composite map was generated using ArcGIS. AEZ map (predicted BPH LTCs) was validated with observed LTCs at Nellore during *kharif* 2004 and 2005, Ragolu during *kharif* 2003-2007 and Rajendranagar during *kharif* 2005 and 2007.

Results and Discussion

Pest-Weather Regression Model (PWRM)

PWRM between log values of LTCs of BPH and TTR was established as

$$logBPH = 31.599 - 0.304\ Tmax - 0.496\ Tmin - 0.036\ RH_1 - 0.050\ RH_2 \quad (R^2 = 0.681) \quad \ldots(1)$$

In this model, TTR could explain 68% variability in BPH LTCs. However, influence of RH_1 on BPH was not found to be significant (P-value = 0.681). Therefore, PWRM between log transformed BPH LTCs and three weather parameters (Tmax, Tmin and RH_2) was formulated as

$$logBPH = 27.961 - 0.266\ Tmax - 0.507\ Tmin - 0.056\ RH_2\ (R^2 = 0.674) \quad \ldots(2)$$

Three weather parameters could account for 67% variability in BPH LTCs, thereby demonstrating insignificant role of RH_1 on BPH LTCs. Further, Tmax was excluded and PWRM with Tmin and RH_2 was found as

$$logBPH = 16.840 - 0.524\ Tmin - 0.110\ RH_2\ (R^2 = 0.531) \quad \ldots(3)$$

Likewise, RH_2 was excluded and PWRM was established between log transformed BPH LTCs and Tmax and Tmin as

$$logBPH = 16.616 - 0.09\ Tmax - 0.43\ Tmin\ (R^2 = 0.556) \quad \ldots(4)$$

Similarly, Tmin was excluded and PWRM between log transformed BPH LTCs and Tmax and RH_2 was as

$$logBPH = 14.100 - 0.294\ Tmax - 0.027\ RH_2\ (R^2 = 0.235) \quad \ldots(5)$$

Lower coefficient of determination (R^2) values in these models suggested importance of Tmax, Tmin and RH_2 in influencing LTCs of BPH. Therefore, PWRM involving all three weather factors showed significant influence on BPH LTCs. Eventual PWRM between BPH

Table 2—Normal values of weather parameters for *kharif* season recorded at weather stations across Andhra Pradesh and in neighboring states

Station No.	Station name	Latitude	Longitude	Temperature, °C		RH, %	
				T_{max}	T_{min}	RH_1	RH_2
1	Anakapalli	17°40' N	83°00' E	33.6	24.8	86.7	62.8
2	Chelgal	18°48' N	78°52' E	32.3	23.1	79.7	61.9
3	Garikapadu	16°30' N	80°05' E	34.4	23.8	83.9	57.2
4	Ibrahipatnam	17°06' N	78°40' E	30.9	20. 9	83.7	59.9
5	Nellore	14°27' N	80°02' E	34.6	25.6	80.4	57.4
6	Pattancheru	17°32' N	79°59' E	31.1	22.2	85.9	56.9
7	Rajahmundry	17°00' N	81°46' E	33.2	24.8	87.2	63.0
8	Rajendranagar	17°19' N	78°23' E	31.5	22.3	83.8	55.2
9	Rudrur	18°30' N	77°50' E	31.9	22.3	81.5	56.5
10	Samalkota	17°03' N	82°13' E	32.7	25.3	89.9	69.4
11	Tirupati	13°37' N	79°23' E	34.7	24.2	70.5	47.2
12	Warangal	18°03' N	79°22' E	33.0	24.0	80.1	59.2
13	Yemmiganur	15°46' N	77°29' E	32.9	22.8	77.7	53.2
14	Babanpur	19°40' N	84°47' E	32.8	23.3	89.9	67.9
15	Sindewahi	20°15' N	79°40' E	32.6	23.6	84.1	60.9
16	Shakkarnagar	18°39' N	77°46' E	31.5	22.9	85.1	59.7
17	Hagari	15°10' N	77°04' E	32.6	22.9	77.9	46.9
18	Bellary	15°09' N	76°51' E	33.0	22.4	78.9	46.9
19	Hiruyur	13°52' N	76°37' E	30.3	20.9	85.6	58.1
20	Hebbal	13°00' N	77°38' E	28.5	19.1	90.1	58.4
21	Annamalainagar	11°24' N	79°44' E	34.8	24.5	83.3	51.9

LTCs and three weather parameters was found to be the best fit model (Table 1) as

$$logBPH = 27.961 - 0.266\ Tmax - 0.507\ Tmin - 0.056\ RH_2\ (R^2 = 0.674) \quad \ldots(6)$$

A positive correlation between LTCs and field incidence of BPH was reported and therefore LTCs were considered as a representation of field incidence of BPH[10]. Tmax and Tmin during *kharif* were found to be very important parameters contributing more towards population build up of BPH[11]. Analysis of LTCs at Maruteru from 1990 to 2000 showed highly similar trend between estimated and observed BPH catches[11].

Weather-based forewarning models for major pests of rice have been investigated and validated using meteorological data[12]. Relationship between population dynamics of *N. lugens* and temperature was analyzed and it was found to be one of the key factors affecting population development[13]. However, in present study, besides temperature, RH_2 was also found to be an important factor influencing BPH catches.

Agro-Ecological Zoning of Brown Planthopper Incidence

AEZ of rice BPH incidence, done for AP by interpolating PWRM using GIS, included latitude, longitude and normal values of TTR during *kharif* season (June-October) recorded at various stations across AP and adjoining weather stations in neighboring states (Table 2). GIS map for AP (Fig.1) depicted severe level of BPH LTCs at Ibrahipatnam and in two patches in southern AP. High level of BPH was witnessed in central to western parts of AP including Hyderabad, Rajendranagar, Kurnool, Mahboobanagar, Maruteru and Anantpur. Moderate level of BPH LTC was depicted for northern AP and in a strip in central AP running north to south including Guntur and parts of Ongole, Cuddapah and Chittoor. Low incidence of BPH was found in Nellore and north-eastern parts of AP.

According to AEZ map, validated with monthly mean BPH LTCs at Nellore, Ragolu and Rajendernagar stations, Nellore showed low incidence of BPH (<500) similar to observed LTCs during *kharif* 2004 and 2005 except one catch during October 2004 (Table 3, Fig. 2). AEZ map depicted low incidence of BPH at Ragolu, which was in total agreement with observed BPH catches during *kharif* 2003-2007. AEZ map was also in consensus with observed BPH catches at Rajendranagar during October 2005 and 2007. Although, model slightly overestimated BPH counts, AEZ of BPH incidence in AP was assumed to be practically validated because some differences between model predictions and real time data are always bound to be there.

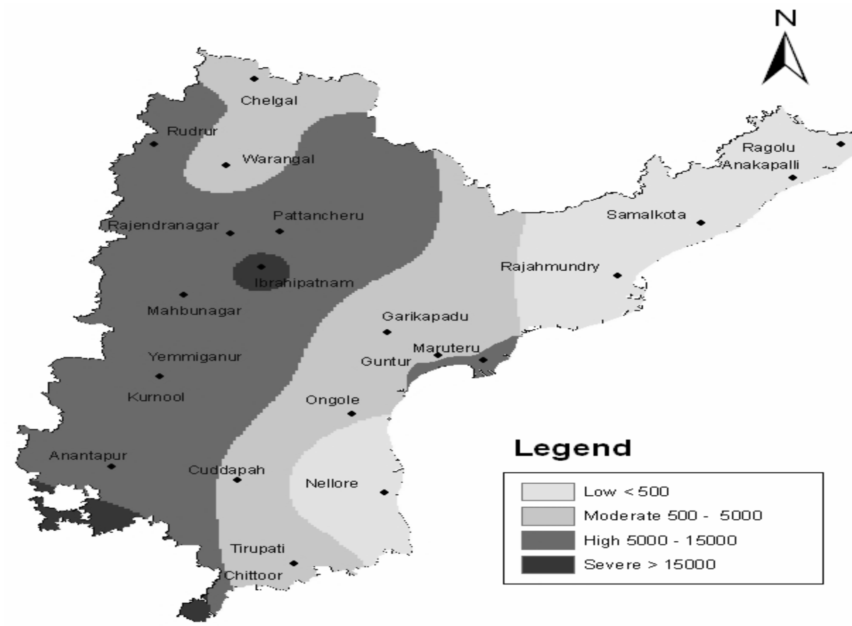

Fig. 1—Agro-ecological zoning of brown plant hopper (BPH) incidence in Andhra Pradesh

Table 3—Comparison between observed and predicted light trap catches of brown planthopper in Andhra Pradesh

Station name	Year	Month	Observed No. of BPH in light trap catches	Observed pest zone	Predicted pest zone
Nellore	2004	June	422	Low	Low
		July	307	Low	Low
		August	261	Low	Low
		September	368	Low	Low
		October	521	Moderate	Low
	2005	June	275	Low	Low
		July	164	Low	Low
		August	355	Low	Low
		September	317	Low	Low
		October	329	Low	Low
Ragolu	2003	July	7	Low	Low
		August	41	Low	Low
		September	66	Low	Low
		October	204	Low	Low
	2004	July	10	Low	Low
		August	55	Low	Low
		September	165	Low	Low
		October	104	Low	Low
	2005	July	3	Low	Low
		August	24	Low	Low
		September	54	Low	Low
		October	43	Low	Low
	2006	July	4	Low	Low
		August	14	Low	Low
		September	39	Low	Low
		October	61	Low	Low
	2007	July	3	Low	Low
		August	27	Low	Low
		September	39	Low	Low
		October	202	Low	Low
Rajendranagar	2005	October	8125	High	High
	2007	October	7844	High	High

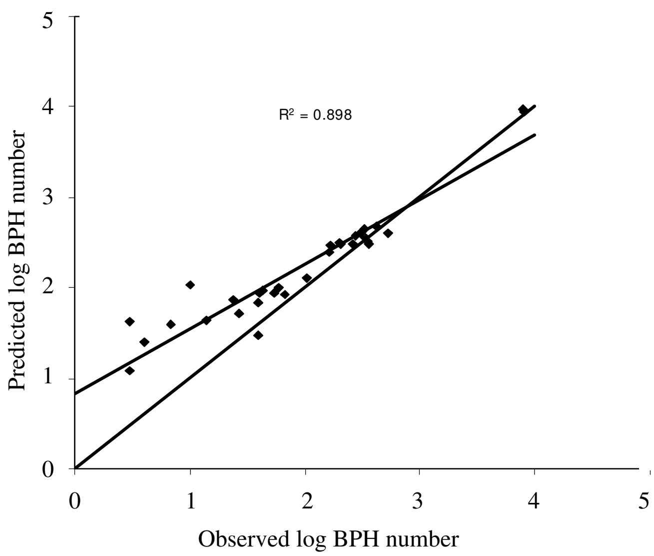

Fig. 2—Relationship between observed and predicted BPH number at different locations in Andhra Pradesh

AEZ of rice stem borer, *Scirpophaga incertulas* incidence for Tamil Nadu, Kerala and AP has been done using PWRM and GIS[9]. Earlier in absence of GIS, PWRMs were being developed for each and every location individually. However, GIS and other geospatial techniques have facilitated extrapolation of location-specific PWRMs to entire state or region, thereby dispensing with the need of PWRM development for each location separately. Population dynamics model based on long-term population and weather trends at a site has been found to be useful in predicting likelihood of pest outbreaks[8]. Site predictions could then be extrapolated through GIS to delineate zones of equal epidemic potential for a pest. Knowledge of pest incidence levels in different zones would facilitate strategic decisions with regard to selection of crop cultivars and management practices, and prediction of probable life of resistant cultivars[14].

Conclusions

Multiple linear regression analysis between monthly mean BPH LTCs and monthly mean values of Tmin, Tmax, RH_1 and RH_2 at Maruteru, AP revealed that RH_1 did not influence LTCs. Using PWRM, monthly normal values of Tmin, Tmax and RH_2 for different weather stations across AP and adjoining stations in neighbouring states, and GIS, the state could be divided into four zones corresponding to severe, high, moderate and low BPH outbreak potential. Comparison between predicted and observed BPH LTCs at Nellore, Ragolu and Rajendranagar evinced validation of agro-ecological zoning of BPH incidence in AP.

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