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Development of Weather Based Forewarning Model for Major Pests of High Altitude Rainfed Rice Agroecosystem

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Studies were conducted to develop weather based forewarning model for the major pests of high altitude rice *viz.,* green leaf hopper (GLH), brown plant hopper (BPH), leaf folder, yellow stem borer and ear head bug. Three field trials were conducted at Hybrid Rice Evaluation Centre, Tamil Nadu Agricultural University, Gudalur, The Nilgiris, Tamil Nadu during Kharif 2010 to 2012. Results revealed that the population of GLH and BPH started from first and second week of September, respectively and leaf folder and yellow stem borer damage started from third week of September and continued till harvest (December) of the crop. Ear head bug population was noticed during first week of October coinciding flowering of the crop with a peak during December first week and persised up to the harvest. The results of correlation and multiple regression analysis revealed that the population of GLH, BPH, ear head bug, leaf folder and stem borer damage had exerted a significant positive association with maximum temperature and significant negative association with morning relative humidity and rainfall. However, the influence of minimum temperature and evening relative humidity was not significant and 80, 81, 92, 67 and 76 per cent of variation in the population of GLH, BPH, ear head bug, leaf folder damage and stem borer damage, respectively was influenced by weather parameters. The multiple regression equation fitted with weather parameters to predict the GLH population is Y = -2.28 + 0.416 X1 - 0.043 X3 – 0.018 X5, BPH population is Y = 62.73 + 0.28 X1 – 0.67 X3 – 0.010 X5, leaf folder damage is Y = 248.23 – 1.22 X2 – 2.35 X3 + 0.04 X5, yellow stem borer damage is Y = 29.09 + 0.32 X1 -0.36 X3 – 0.002 X5, ear head bug population is Y = 26.64 – 0.253 X2 – 0.234 X3 – 0.005 X5. where, X1 - maximum temperature (oC), X2 - minimum temperature (oC), X3 - morining relative humidity (%), X4 - Evening relative humidity (%) and, X5 - rainfall (mm)

Key words: Rainfed rice, Seasonal incidence, Weather parameters, Forewarning model, Rice pests

Rice (Oryza sativa L.) is the most important and staple food crop for more than two thirds of the population of India. The slogan “Rice is the Life” is the most appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural households. Rice crop is prone to severe yield losses by both abiotic and biotic stresses to an extent of 46.4 per cent; out of which 26.7 per cent is due to insect pests (Jayaraj, 1996). There are over 70 pests infesting rice in India and 20 are of regular occurrence (Pathak, 1975). In India, losses incurred due to the different insect pests of rice is to the tune of 5,51,200 lakh rupees, which in turn comes out to 18.6 per cent of total loss. The rain fed rice area is about 24.4 million hectare with productivity of less than 0.98 tones/hectare, due to uncertainty of available water. It is a fragile ecology and divides into sub-ecologies *viz.,* croped with rainfed uplands (plain area and high altitude hill rice), deep water, semideep water and shallow rainfed (drought prone, lowland and submerged) and coastal saline rice. Upland rice is grown in unfavorable rainfed soil and weather conditions. The occurrence of climate changes is evident from increase in global average temperature, changes in the rainfall pattern and extreme climatic events. These seasonal and long term changes would affect the fauna, flora and population dynamics of insect pests. The abiotic parameters are known to have direct impact on insect population dynamics through modulation of developmental rates, survival, fecundity, voltinism and dispersal (Karuppaiah and Sujayanad, 2012). The term global change embraces a range of natural and anthropogenic environmental changes. According to Intergovernmental Panel on Climate Change, it is defined as “Change in climate over time, either due to natural variability or as a result of human activity”. Most of the warming observed over the last 50 years is attributable to human activities. The global mean surface temperature is predicted to increase by 1.4 to 5.8°C from 1990 to 2100. If temperatures rise by about 2°C over the next 100 years, negative effects of global warming would begin to extend to most regions of the world (IPCC, 2001). Such changes in climate and weather could profoundly affect the population

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dynamics and status of insect pests of crops. These may arise not only as result of direct effect on the distribution and abundance of pest population but also indirect effect on the pests, host plants, competitor and natural enemies (Porter *et al.,* 1991). Some pests which are already present but, only occur in small areas or at low densities may be able to exploit the changing conditions by spreading more widely and reaching damaging population densities (Porter *et al,* 1991; *Bale et al.,* 2002).

Gudalur is the mid hill high rainfall region in the Nilgiri district of Tamil Nadu and it is a valley in the Western Ghats located between Doddabetta peak and Mudumalai wildlife Sanctuary at 11.50°N latitude and 76.50°E longitude at an altitude of 1350 m above MSL. It has sub tropical climate and temperature ranges from a minimum of 4 - 18°C to a maximum of 20 - 32°C with relative humidity of 35 - 65% to 70 -100 %. Annual precipitation is 2182.5 mm. Ninety percent of the precipitation takes place within four months, i.e., from June to September, July and August being the rainiest month. Rice is one of the major crops cultivated in this area during Kharif season. Leaf folder, yellow stem borer, green leaf hopper (GLH), brown plant hopper (BPH) and ear head bug are the major pests in the mid hill high rainfall rainfed rice agro-ecosystem, that can cause up to 90 per cent yield loss. Moreover, in this ecosystem we can observe high natural enemy diversity. Hence, it is necessary to find seasonal incidence and impact of weather parameters on the incidence of major pests for the effective management of the pests. With the above background, research work was carried out to assess the seasonal incidence and impact of weather parameters on the incidence of major pests of high altitude rainfed rice

Materials and Methods

Three field trials were conducted at Hybrid Rice Evaluation Centre, Tamil Nadu Agricultural University, Gudalur, Nilgiri district, Tamil Nadu to assess the seasonal incidence of the major pests of high altitude rice (Leaf folder, yellow stem borer, green leaf hopper (GLH), brown plant hopper (BPH) and ear head bug) was studied in paddy variety Bharathy sown in an area of 25 cents during Kharif 2010 to 2012. Transplanting was normally done during 34 to 35th standard week (August second fortnight). The recommended agronomic practices were followed except plant protection measures. Observation was made from transplanting and continued till harvest. The population of GLH, BPH, ear head bug and the level of damage caused by leaf folder and stem borer were recorded on ten hills at random and replicated thrice at weekly interval till harvest of the crop. The weather parameters such as maximum temperature, minimum temperature, morning relative humidity (RH(M)) , evening relative humidity (RH(E)) and rainfall were recorded daily during the crop period. For all parameters, the weekly average was worked out except for the rainfall, for which the weekly total was worked out. Three year data were polled for statistical analysis. The population of BPH, GLH, ear head bug and percent damage of leaf folder and yellow stem borer (dead heart and white ear) recorded were correlated with all the above weather parameters using the population of different insect species as dependent variable (Y) and each of the weather parameter as independent variable (X).

Results and Discussion

Data on the seasonal incidence of GLH, BPH, leaf folder, stem borer and ear head bug of high altitude rice revealed that the population of GLH had started from first week of September *i.e* 15 days after transplanting (DAT) and continued till harvest (December) of the crop (Table 1). The peak population was observed during second and third week of November (5.87 GLH per hill). Incidence of Brown plant hopper (BPH) started from second week of September with a peak during third week of November (10.41 BPH per hill). The leaf folder damage started from third week of September and continued till harvest (December) of the crop (Table 1)

The mean leaf folder damage ranged from 0.21 to 21.08 per cent on third week of September and last week of December. Yellow stem borer damage was increasing from September third week (38th standard week) (0.07 %) and attained the peak during third week of November (47th standard week) (5.86 % then decreased gradually registered 2.40 per cent damage at the time of harvest. Ear head bug population was noticed during first week of October (42nd standard week) coincide with the flowering of the crop with a peak during December first week (48th standard week) (2.47 bugs per hill) and persist up to the harvest (Table 1).

The population of GLH was correlated with corresponding mean weather parameters of previous week and a multiple regression analysis was made. GLH population exerted a significant positive association with maximum temperature (r = 0.692), negative association with morning relative humidity (RH (M)) (r = -0.653) and rainfall (r = -0.751). However, the influence of minimum temperature and RH (E) on GLH population was not significant. The result of multiple regression analysis showed a R2 value of 0.80 revealing that 80 per cent of variation in GLH population was influenced by weather parameters (Table 3). The multiple regression equation fitted with weather parameters to predict the GLH population is Y = -2.28 + 0.416 X1 - 0.043 X3 – 0.018 X5. This indicated that an increase of 1^{o}C of maximum temperature, 1 per cent of Morning RH and 1 mm of rain fall would lead to the increase of 0.416 and 0.043; and decrease of 0.018 GLH population (nos. per hill), respectively (Table 3). The population of BPH exerted a positive association with maximum temperature (r = 0.531) and negative association with RH (M) (r = -0.765) and rainfall (r = -0.750). However, the influence of minimum temperature and RH (E) were not significant. Results of the multiple regression analysis showed a R2 value of 0.81 revealing that 81 per cent of the variation in

Table 1. Seasonal incidence of insect pests of high altitude rice at Gudalur (Kharif 2010 - 2012)

Std Week	T max	T min	RH (M)	RH(E)	RF	GLH	BPH	LF	YSB	EHB
36	23.31	16.30	99.40	97.60	184.58	0.00	0.00	0.00	0.00	0.00
37	22.32	16.43	99.50	89.85	100.23	0.27	0.00	0.00	0.00	0.00
38	24.28	16.22	97.39	84.67	66.24	1.73	1.97	0.21	0.07	0.00
39	25.46	16.36	93.78	81.35	10.45	2.85	3.77	2.42	0.15	0.00
40	27.60	16.76	93.00	71.30	9.43	3.90	5.63	4.47	1.47	0.00
41	27.99	16.47	93.39	66.07	2.16	5.57	6.78	7.53	3.68	0.00
42	28.56	16.73	94.40	82.63	33.42	4.46	8.05	8.04	4.27	0.09
43	25.54	16.51	93.60	78.78	20.30	4.92	8.77	9.83	4.76	0.40
44	25.73	16.53	93.40	79.30	18.00	5.20	8.24	10.25	5.31	0.43
45	23.72	16.11	93.78	165.50	44.00	4.80	10.23	10.75	4.22	0.95
46	25.78	15.19	91.97	73.00	5.28	5.87	9.96	12.89	5.66	1.88
47	26.74	14.98	90.64	64.79	5.67	5.87	10.41	14.07	5.86	2.07
48	26.67	15.17	91.17	69.42	4.60	5.72	10.26	16.68	5.72	1.99
49	25.76	16.22	92.39	68.50	6.10	5.01	8.94	17.40	4.91	2.47
50	25.72	14.72	89.94	69.67	0.60	3.92	8.13	18.27	3.66	2.14
51	25.40	13.78	89.78	58.42	1.17	2.99	7.29	19.64	3.30	1.66
52	24.83	14.00	89.44	60.50	0.00	2.71	7.37	21.08	2.40	1.22

T max – Maximum temperature, T min – Minimum temperature, RH (M) – Relative humidity (Morning), RH(E) – Relative humidity (Evening), RF – Rainfall, GLH - Green Leaf Hopper, BPH – Brown Plant Hopper, 36 - August 4th week, 37 - September 1st week, 38 - September 2nd week, 39 - September 3rd week, 40 - September 4th week, 41 - October 1st week, 42 - October 2nd week, 43 - October 3rd week, 44 - October 4th week, 45 - November 1st week, 46 - November 2nd week, 47 - November 3rd week, 48 - November 4th week, 49 - December 1st week, 50 - December 2nd week, 51 - December 3rd week,52 - December 4th week

population was influenced by weather parameters (Table 3). The multiple regression equation fitted to predict the BPH population is Y = 62.73 + 0.28 X1 – 0.67 X3 – 0.010 X5. This indicated that an increase in one unit of maximum temperature, RH (M) and rainfall would lead to a change of 0.28, -0.67 and 0.01 unit of BPH population respectively (Table 3)

The weather parameters such as minimum temperature, RH (M) and rainfall, showed significant negative impact on leaf folder damage with a correlation coefficient (r) of -0.764, -0.895 and -0.667, respectively (Table 2). The results of multiple regression analysis showed a R2 value of 0.92 indicating that 92 per cent of the variation in leaf folder damage was influenced by weather parameters (Table 3). The multiple regression equation fitted with weather parameters to predict to the leaf folder damage is Y = 248.23 – 1.22 X2 – 2.35 X3 + 0.04 X5. An increase of 1 unit of minimum temperature, RH

Table 2. Correlation matrix of the relationship between weather parameters and major pests of high altitude rice

	X1	X2	X3	X4	X5	Y1	Y2	Y3	Y4	Y5
X1	1									
X2	0.076	1								
X3	-0.507*	0.687**	1							
X4	-0.464*	0.366	0.424*	1						
X5	-0.627**	0.359	0.863**	0.423*	1					
Y1	0.692**	-0.059	-0.654**	-0.132	-0.754**	1				
Y2	0.534*	-0.334	-0.797**	-0.062	-0.750**	0.917**	1			
Y3	0.267	-0.764**	-0.895**	-0.339	-0.667**	0.534*	0.768**	1		
Y4	0.503*	-0.236	-0.636**	-0.127	-0.596*	0.903**	0.934**	0.685**	1	
Y5	0.103	-0.683**	-0.707**	-0.263	-0.484*	0.484*	0.670**	0.844**	0.650**	1

**. Correlation is significant at the 0.01 level. *. Correlation is significant at the 0.05 level, X1 - Maximum temperature (oC), X2 - Minimum temperature (oC), X3 - Morining relative humidity (%), X4 - Evening relative humidity (%), X5 - Rainfall (mm), Y1 – Green leaf hopper (GLH), Y2 – Brown plant hopper (BPH), Y3 – Leaf folder, Y4 – Yellow stem borer, Y5 – Ear head bug

(M) and rainfall would lead to a change of -1.22, -2.35 and 0.04 unit of leaf folder damage, respectively. The yellow stem borer damage exerted significant positive association with minimum temperature (r = 0.50), and negative association with RH,(M) (r = -0.636) and rainfall (r = -0.596). However, the influence of minimum temperature and RH (E) was not significant (Table 2). Results of the multiple regression analysis showed a R2 value of 0.67 revealing that 67 per cent of the variation in population was influenced by weather parameters (Table 3). The multiple regression equation fitted to predict the yellow stem borer damage is Y = 29.09 + 0.32 X1 -0.36 X3 – 0.002 X5. This indicated that an increase in one unit of maximum temperature, RH (M) and rainfall would lead to a change of 0.32, -0.36 and -0.002 unit of yellow stem borer damage, respectively. The weather parameters such as minimum temperature, RH (M) and rainfall showed significant impact on ear head bug population with a correlation coefficient (r) of -0.683, -0.707 and -0.484, respectively. However, the influence of maximum temperature and RH (E) was not significant (Table 2). The results of multiple regression analysis showed a R2 value of 0.76 indicating that 76 per cent of the variation in ear head bug population was influenced by weather parameters (Table 3). The multiple regression equation fitted with weather parameters to predict the ear head bug population is Y = 26.64 – 0.253 X2 – 0.234 X3 – 0.005 X5. This result indicated that an increase of 1°C of minimum temperature, 1 per cent of morning RH and 1mm of rainfall would lead to a decrease of 0.253, 0.234 and 0.005 ear head bug population per hill respectively.

Table 3. Multiple regression analysis of the weather parameters and pest population.

Weather Parameter	Regression co-efficient	Standard error	Constant "a"	R2
Weather parameters and GLH population				
X1 - Maximum temperature (oC)	0.416	0.240	-2.286	0.80
X3 - Morning relative humidity (%)	-0.042	0.200		
X5 - Rainfall (mm)	-0.018	0.014		
Weather parameters and BPH population				
X1 - Maximum temperature (oC)	0.281	0.433	62.73	0.81
X3 - Morning relative humidity (%)	-0.672	0.360		
X5 - Rainfall (mm)	-0.010	0.025		
Weather parameters and leaf folder damage				
X2 - Minimum temperature (oC)	-1.222	1.40	248.22	0.92
X3 - Morning relative humidity (%)	-2.355	0.81		
X5 - Rainfall (mm)	0.039	0.04		
Weather parameters and stem borer damage				
X1 - Maximum temperature (oC)	0.320	0.35	29.08	0.67
X3 - Morning relative humidity (%)	-0.365	0.9		
X5 - Rainfall (mm)	-0.002	0.02		
Weather parameters and ear head bug population				
X2 - Minimum temperature (oC)	-0.253	0.31	26.64	0.76
X3 - Morning relative humidity (%)	-0.234	0.18		
X5 - Rainfall (mm)	0.005	0.008		

Meteorological factors play an important role in seasonal abundance, distribution and population build up of insect pests. It is difficult to find a direct cause and effect relationship between any single factor and pest activity because the impact of meteorological factor on pests is usually compounded (Garg and Sethi, 1980; Krishnaih *et al.,* 1996; Harinkhree *et al.,* 1998). Bhatnager and Saxena (1999) reported that minimum temperature played an important role in the population build up of green leafhopper and rice gundhi bug, besides rainfall and evening relative humidity. According to Persson (1976), the meteorological parameters have a long term and permanent effect in insect population. The population of rice gundhi bug was found at a peak during September to October (Pathak, 1977). According to Pandey *et al.* (2001), relative humidity played an important role in population build up of yellow stem borer. Sharma *et al.* (2004) reported that no other factor except rainfall had positive correlation in the population build up of rice gundhi bug. Upadhyay and Sharma (2004) used principal component analysis to find out the factors which play important roles in the population build up of yellow stem borer and rice gundhi bug. They reported that rainfall and relative humidity played a significant role in the population build up of yellow stem borer and in case of the population of rice gundhi bug, no meteorological variables were found to be significant. Ramasubramaniun *et al.* (2006) developed statistical models for forewarning about infestation of paddy crops using step-wise regression technique and weather indices modeling technique.

Effect of climate change on insects is more in temperate region, it permits range expansion. Among the various abiotic factors, temperature and rainfall are important forces to drive the population. Temperature and rainfall cause the direct effects like survival, growth and development, voltinism and dispersal. Humidity play vital role in soil insect's abundance. Change in voltinism is more profit to multivoltine species than univoltine species. There may be the possibility of evolutionary adaption in insects for changing environment. Therefore, climate change might change population dynamics of insect pests differently in different agro-ecosystem and ecological zones, which need greater attention to understand and address these issues through more research.

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