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Forewarning models of the insects of paddy crop

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The models for forewarning about the infestation of green leafhopper *Nephotettix virescens* Dist (Cicadellidae, Hemiptera), plant hopper *Cofana spectra* Dist (Delphacidae, Hemiptera), C. *yasumatsui* Young (Kolla *mimica*, Hemiptera), rice gundhi bug *Leptocoriza acuta* Thunberg (Alydidae, Hemiptera) and yellow stem borer *Scirpophaga incertulas* Walker (Pyralidae, Lepidoptera) in rice growing season (July to November) was studied through light trap collection over fifteen years (1985-1999). Maximum population of *N. virescens* Dist (Cicadellidae, Hemiptera), C. *yasumatsui* Young (Kolla *mimica*, Hemiptera) and *L. acuta* Thunberg (Alydidae, Hemiptera) were recorded in the third week of October all the years. *C. spectra* Dist (Delphacidae, Hemiptera) had maximum population in the second and third weeks of October during the aforesaid period. Maximum population of *S. incertulas* Walker (Pyralidae, Lepidoptera) was recorded in the month of September in all the years. After making a transformation on the response variable that is, population of insects, the cubic polynomial model was fitted with week as explanatory variable and it described the dynamics of the populations of all considered insects during the weeks. The values of multiple correlations for N. *virescens* Dist (Cicadellidae, Hemiptera), *C. spectra* Dist (Delphacidae, Hemiptera), C. *yasumatsui* Young (Kolla *mimica*, Hemiptera), *L. acuta* Thunberg (Alydidae, Hemiptera) and *S. incertulas* Walker (Pyralidae, Lepidoptera) were in the order of 0.964, 0.947, 0.971, 0.881 and 0.949, respectively. We also include meteorological factors in the model and it provides the dynamics of the populations of all the above mentioned insects for forecasting.

Key words: Meteorological factors, transformation, regression analysis, rice insect pests.

INTRODUCTION

Rice is the most important and extensively grown food in the tropical and subtropical regions of the world. Several improvements have been made to boost up the average yield but insect pests still continue to be major limiting factors. Rice is attacked by more than 70 insects among which 20 have major significance (Saxena and Shrivastava, 1992). Green leafhopper *Nephotettix virescens* Dist (Cicadellidae, Hemiptera), *Cofana spectra* Dist (Delphacidae, Hemiptera), *Cofana yasumatsui* Young (Kolla *mimica*, Hemiptera) and *Leptocoriza acuta* Thunberg (Alydidae, Hemiptera) are important insect pests of rice (*Oriza sativa).* These insects are damaging pests in Asia, where they not only cause direct damage by removing plant sap, but also act as vectors of rice virus diseases, such as rice tungro virus. Yellow stemborer *Scirpophaga incertulas* Walker (Pyralidae, Lepidoptera) is an important insect pest of rice in different ecological zones, viz. rainfed lowland, irrigated and deep water areas. This pest causes damage at tillering stage as ‘dead heart’ and at panicle initiation as ‘white ear head’ resulting in reduction in yield of rice.

Rice gundhi bug *L. acuta* Thunberg (Alydidae, Hemiptera) is the most dangerous insect pest in rice growing areas of India especially in state of Uttar Pradesh (U.P.). This is a very damaging pest of rice and can reduce yield by as much as 30%. Rice bug nymphs are more destructive than the adults. They prefer grains at the milky stage. Rice bugs damage rice by sucking the contents of developing grains from pre-flowering to soft dough stage. Both nymphs and adults feed on grains at the milky stage. Such grains remain empty or only partially filled. The panicles in heavy infested fields contain many shrivelled and unfilled grains and usually remain erect. An infested field can be recognized by rice bugs severe odour. Adults are active in the late afternoon and early morning, resting in the shaded areas (Pathak, 1977). The estimated losses caused by major insects are about 31.5% in Asia and 2% in Europe. The damage

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caused by agricultural pests is indicated by the fact that a 10% increase or decrease in food grain production, on global scale, can make the difference between a glut and acute scarcity (Heinrichs, 1998).

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 without using transformation of data. Since insect data are count data and needs transformation. This was a draw back in the paper by Ramasubramaniun et al. (2006). We hope that our communication can fill this gap. The present study was undertaken to develop some suitable models to know the dynamics of insect pests in relation to weeks as well as with meteorological variables namely temperature (maximum and minimum), rainfall, relative humidity, and sunshine on light trap catches of the aforesaid insect pests so that active period may be ascertained for forewarning to avoid the loss to the rice crop caused by the infestation of the insect pests.

MATERIALS AND METHODS

Trapping and counting of insect pests

A chinsurah-type light trap (Chinsurah Rice Research Station, India) an indigenous device, was fitted with 200-watt electric bulb. It had been installed long ago at the Crop Research Station (formerly Rice Research Station), Masodha, N.D.University of Agriculture and Technology, Faizabad, Uttar Pradesh, India, to predict outbreaks of pest species and to assist farmers in making preparation to manage the pests. A wooden box containing bottle having plaster of paris and potassium cyanide is placed under the bulb. The insects that circle around the bulb drop in the wooden box and they are counted in the morning. Thus trap catches of green leafhopper *N. virescens* Dist, *C. spectra* Dist (Delphacidae, Hemiptera), C. *yasumatsui* Young (Kolla *mimica*, Hemiptera), rice gundhi bug *L. acuta* Thunberg and yellow stemborer *S. incertulas* Walker (Pyralidae, Lepidoptera) were recorded daily during the rice growing season from July to November in the years from 1985 to 1999 along with daily observations of meteorological variables, viz. temperature (maximum and minimum), rainfall, relative humidity and sunshine. These observations were compiled according to weeks and recorded after taking weekly averages. To develop the forewarning model, the following techniques were used to know about the dynamics of insect pests in relation to time and meteorological variables.

The calculated weekly averages of 15 years observations for all the five insect pests including meteorological variables are given in Tables 1 and 2. Since data of insect pests are seasonal count data, a log transformation of the data of each insect pests were made separately. $X_i = \log(Y_i+1)$ where Y_i (i=1, 2, 3, 4 and 5) are the weekly averages of the population of ith insect pest. Instead of log Y_i transformation we used log (Y_i+1) transformation because some of the values of Y_i were not available that is, zeros. Table 1 exhibits weekly averages of counts of each insect pest and their log transformations. Then the technique of curve estimation was applied to the data of each insect pest. It was found that the cubic polynomial fits well in log transformed data of each insect pest while taking time as independent variable (Figures 1 to 5). For forecasting purpose it will be useful to know the effects of meteorological variables on the transformed population of each insect pest.

Statistical analysis

The regression of meteorological variables as independent variables in the cubic model was carried out. The following statistical models were used to know the dynamics of the population of insect pests:

A. $\text{Log}(Y_i+1) = X_i = a + b\,t + c\,t^2 + d\,t^3 + e$

B. $\text{Log}(Y_i+1) = X_i = a + b\,t + c\,t^2 + d\,t^3 + b_1\,(\text{max.temp}) + b_2\,(\text{min.temp}) + b_3\,(\text{rainfall}) + b_4\,(\text{relative humidity}) + b_5\,(\text{sunshine}) + e$

Where i = 1, 2, 3, 4, 5 and t represents weeks and t = 1, 2… 20, *a* denotes intercept and b, c, d, b_1, b_2, b_3, b_4, and b_5 denote the regression coefficients of models A and B and $e \sim N(0, \sigma^2)$. A (1-α) Confidence interval for population build up for insect pests is $\hat{Y}_i \pm t_{\alpha/2,\, n-k} \times 10^{s.e}$, where $t_{\alpha/2,\, n-k}$ is a tabulated value of *t* at α/2 level and *n-k* degrees of freedom.

For each insect pest, the two models described above, were fitted using a regression technique, and the values for regression coefficients, multiple correlation (R^2), adjusted multiple correlation (R^2) and standard error were calculated. The results for each insect pest are given in Equations (1) to (9), in which the asterisks ** and* denote the significance of terms in the models at 1 and 5% levels, respectively.

RESULTS AND DISCUSSION

Green leafhopper

When the cubic model (A) was used, we got the following regression equation and values of standard error,

Table 1. Means of buildup populations of insects and their log transformation for 15 years.

S/N	GLH Y_1	LOG (GLH+1) X_1	PH Y_2	LOG (PH+1) X_2	PHY Y_3	LOG (PHY+1) X_3	RGB Y_4	LOG (RGB+1) X_4	YSB Y_5	LOG (YSB+1) X_5
1	65.5	1.66276	5.6	0.81954	20.533	1.33311	1.2	0.34242	1.333	0.36798
2	149.5	1.81291	18.533	1.29078	63.2	1.80754	2.8667	0.58734	1.667	0.42597
3	82.1	1.11394	22.4	1.36922	53.4	1.7356	1.6	0.41497	3	0.60206
4	57.9	2.04532	12.6	1.13354	73.667	1.87313	3.8667	0.68723	8.267	0.96692
5	42.9	1.95424	8.4	0.97313	39.533	1.60781	2.2667	0.5141	8.733	0.98826
6	44.1	2.22272	9.533	1.02257	37.867	1.58958	2.3333	0.52288	9.267	1.01143
7	167.6	3.23045	19.533	1.31246	63.667	1.81068	4.1333	0.7104	16.733	1.24879
8	327.5	3.49178	48.933	1.69839	95.467	1.98438	6.5333	0.87699	26.333	1.43669
9	3380.9	3.61669	54.933	1.74767	75.067	1.88119	5.8	0.83251	26.067	1.43243
10	2220.7	4.31383	72.733	1.86766	110.467	2.04715	6.6667	0.88461	59.333	1.78056
11	5321.7	4.28805	95.867	1.98617	172.133	2.23838	5.8	0.83251	54.667	1.7456
12	17704.5	4.60742	106.333	2.03073	200.6	2.30449	11.8	1.10721	190.8	2.28285
13	22522.8	4.75811	78.467	1.90018	150.467	2.18032	7.7333	0.94118	31.467	1.51144
14	34680.1	5.06944	116.333	2.06942	187.4	2.27508	10.0667	1.04402	27.733	1.45839
15	34577.7	5.13061	98.6	1.99826	178.533	2.25415	8.0667	0.95745	30.733	1.50152
16	22992.8	4.29155	95.333	1.98378	165.733	2.22202	4.6	0.74819	25.667	1.42597
17	10981	3.99839	43.467	1.64803	94.867	1.98167	3.6667	0.66901	8.4	0.97313
18	5300.5	3.11193	20.067	1.3236	35.933	1.56742	3.4667	0.64998	4.533	0.74299
19	1694.5	2.04922	6.133	0.85329	10.533	1.06195	0.4667	0.16633	1.6	0.41497
20	258.3	1.49136	1.933	0.46736	2.667	0.56427	0.2	0.07918	0	0

GLH, Green leafhopper; PH, plant hopper *Cofana spectra;* PHY, plant hopper C.yasumatsui; RGB, rice gundhi bug; YSB, yellow stem borer.

Table 2. Means of observations on explanatory variables for 15 years.

S/N	Maximum temperature	Minimum temperature	Rainfall	Relative humidity	Sun shine
1	34.4413	26.772	15.8907	83.286	4.98933
2	31.7627	26.1647	78.6127	88.6933	3.482
3	32.262	26.4747	24.2133	87.1527	4.76733
4	32.318	25.794	14.9693	86.3833	5.16267
5	32.338	26.3647	16.3647	87.24	5.18067
6	32.046	26.4127	60.276	88.31	4.56733
7	32.2147	25.7947	40.5993	89.356	5.12933
8	32.6527	26.092	12.7407	88.5047	5.698
9	32.052	25.8447	38.2413	88.356	5.066
10	31.956	25.5327	18.6367	89.518	5.44
11	31.7373	24.6813	14.3233	87.418	6.99133
12	32.1273	24.1087	3.2847	88.6507	7.13733
13	31.3027	22.6387	30.09	88.2313	7.4
14	32.0173	21.7493	2.7087	87.1213	8.22267
15	31.2693	19.18	3.114	89.286	8.94267
16	30.7867	17.0707	14.7867	89.0887	8.68733
17	30.2153	15.426	0	88.3453	8.59467
18	29.084	14.488	3.1733	89.1327	8.14267
19	28.276	13.1167	0	89.3433	7.76133
20	26.07	11.3533	0.0953	88.29	7.516

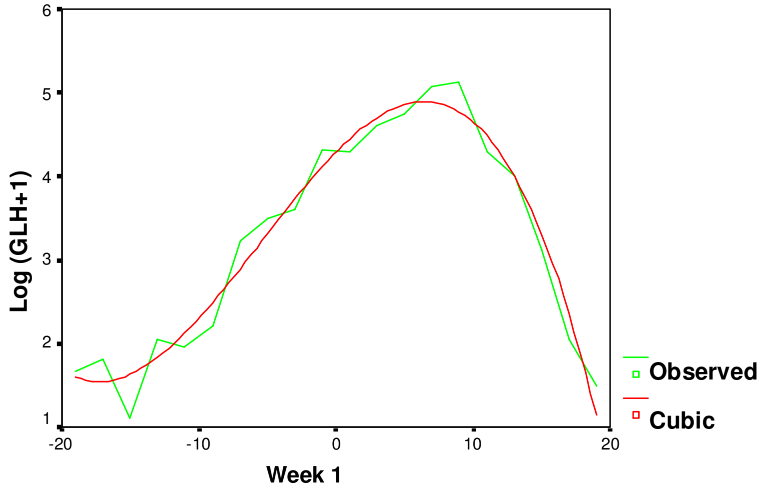

Figure 1. Curve estimation of green leaf hopper.

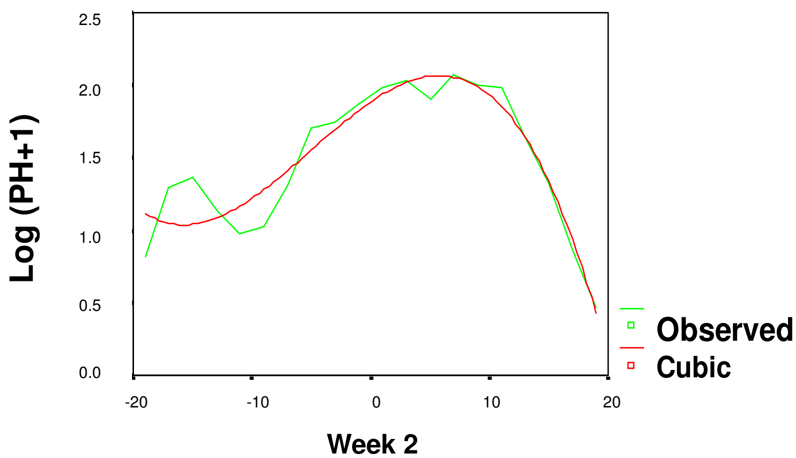

Figure 2. Curve Estimation of plant hopper *cofana spectra.*

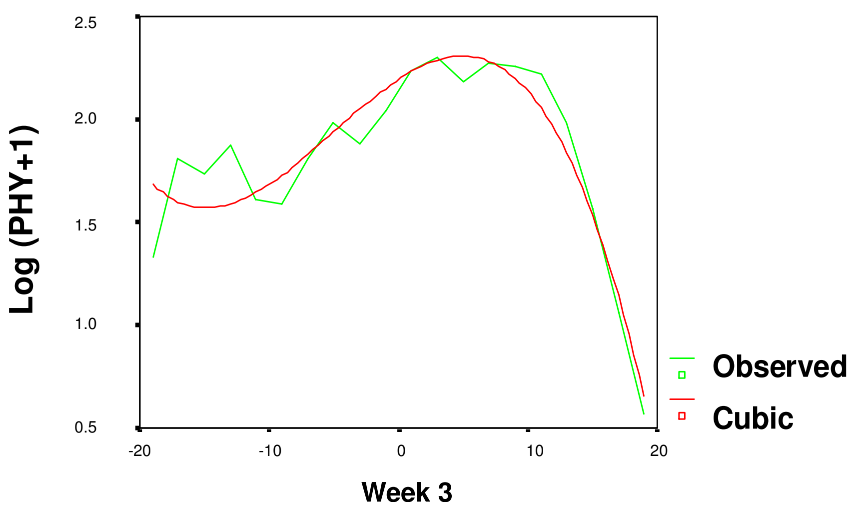

Figure 3. Curve estimation of plant hopper *C. yasumatsui.*

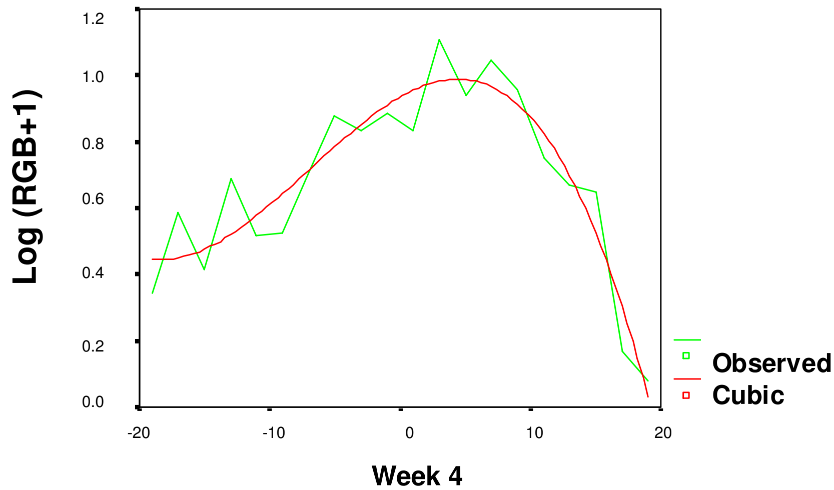

Figure 4. Curve estimation of rice gundhi bug.

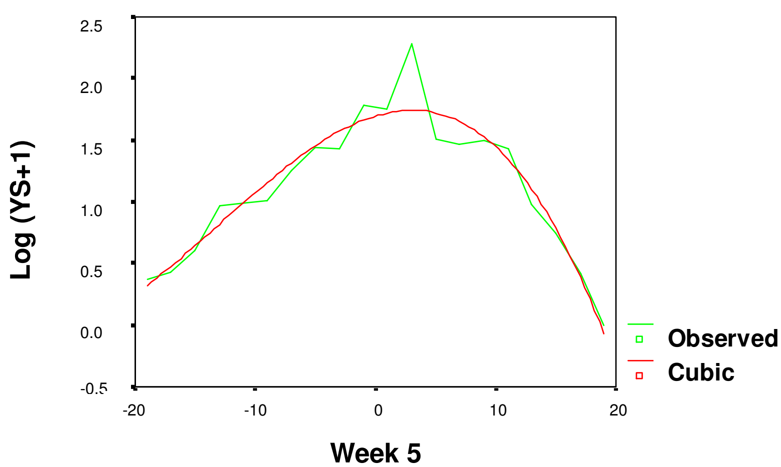

Figure 5. Curve estimation of yellow stem borer.

multiple correlations and adjusted multiple correlations.

Log (GLH+1) = 1.79 – 0.29 t + 0.09 t^{2**} – 0.003 t^{3**}
Standard error = 0.27, R^2 = 0.964, R^2 (adj) = 0.957. (1)

The value of R^2 and adjusted R^2 indicate that the cubic model fits well for the transformed population of weekly average of green leafhopper (Figure 6) and we may predict the population build up.
Model (B) was used and we obtained the following regression equation below along with standard error, multiple correlations, and adjusted multiple correlations:

Log (GLH+1) = 0.4 – 0.01 (max.temp.) +0.03 (min.temp.) – 0.0004 (rainfall) + 0.03 (relative humidity) + 0.03 (sunshine) + 0.17 t**- 0.007 t^2–0.0004 t^{3*} Standard error = 0.32, R^2 =0. 964, R^2 (adj) = 0.938. (2)

The values of R^2, adjusted R^2 and standard error obtained using model (B) are almost equal to the values obtained by model (A). The regression equation suggests that the effects of meteorological variables are insignificant on the population build up of green leafhoppers. For management purposes it will be useful to use Equation (2) to predict the dynamics of green leafhoppers population.

Plant hoppers *Cofana spectra*

The cubic model (A) was used to determine the dynamics of the population of plant hoppers *C. spectra* and the following regression equation along with values of standard error, multiple correlations and adjusted multiple correlations (Figure 7) were obtained.

Log (PH) = 1.24 – 0.17 t + 0.04 t^{2**} – 0.002 t^{3**}

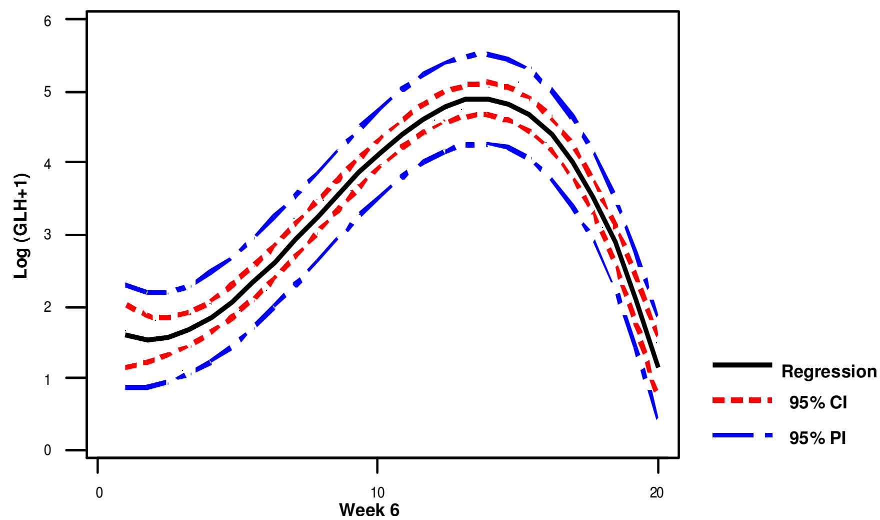

Figure 6. Regression plot of log (GLH+1).

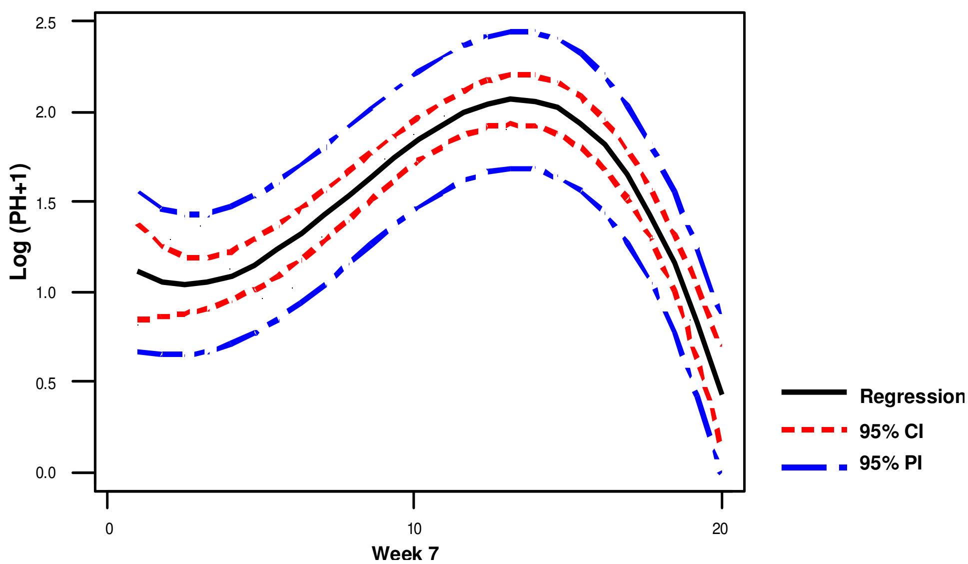

Figure 7. Regression plot of log (PH+1).

Standard Error = 0.16, R^2 = 0.899, R^2 (adj) = 0.88. (3)

Using model (B) we obtain the following regression equation along with standard error, multiple correlation, and adjusted multiple correlation**.**

Log (PH + 1) = 5.23 – 0.22 (max.temp.) – 0.048 (min.temp.) – 0.007 (rainfall) + 0.06 (relative humidity) - 0.06 (sunshine) + 0.0.4 t - 0.005 t^{2**} – 0.0003 t^{3**} Standard error = 0.14, R^2 =0. 947, R^2 (adj) =0. 908. (4)

It was observed that Equation (4) gives a better fit of the transformed data than Equation (3) of plant hoppers population. So we may use Equation (4) to predict the dynamics of plant hoppers population.

Plant hoppers C. *yasumatsui*

The use of model (A) gave rise to the regression Equation (5), and this is also presented in Figure 8.

Log (PHY + 1)) = 1.82 – 0.18 t + 0.04 t^{2**} – 0.002 t^{3**} and Standard error = 0.16, R^2 = 0.889, R^2 (adj) = 0.868. (5)

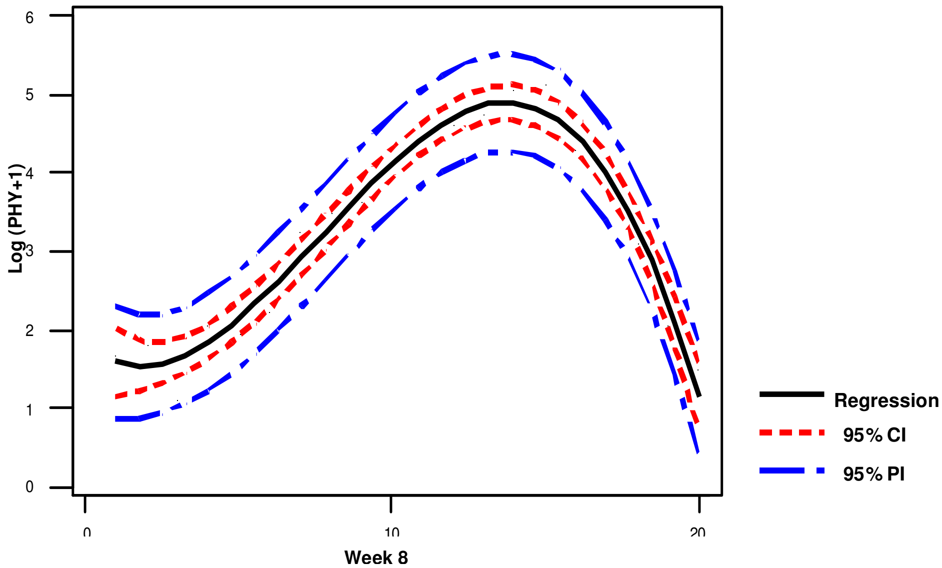

Figure 8. Regression plot of log (PHY+1).

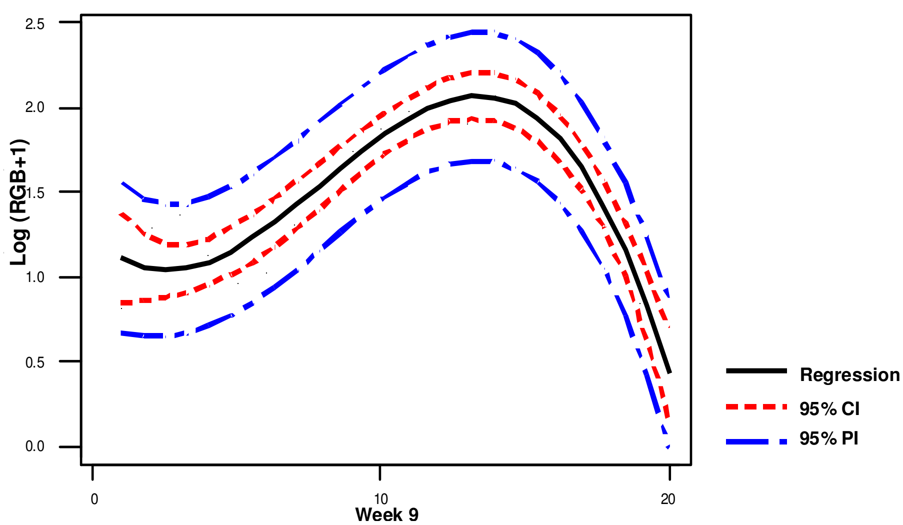

Figure 9. Regression plot of log (RGB+1).

Using model (B) we obtained the following regressionequation along with standard error, multiple correlation and adjusted multiple correlation.

Log (PHY + 1)) =1.82 – 0.20 (max.temp.)* –0.14 (min.temp)* – 0.005 (rainfall) + 0.043 (relative humidity) +0.06 (sunshine) - 0.02 t - 0.006 t^{2**} – 0.0003 t^{3**} Standard error = 0.10, R^2 = 0.971, R^2 (adj) = 0.949. (6)

We observed that Equation (6) gives a better fit of the transformed data than Equation (5) of plant hoppers population. So we may use Equation (6) to predict the dynamics of plant hoppers population.

Rice gundhi bug

Using model (A) we get the following regression equation along with standard error, multiple correlation and adjusted multiple correlation (Figure 9).

Log (RGB + 1) = 0.47 – 0.04 t + 0.02 t^{2**} – 0.0007 t^{3**} Standard error = 0.10, R^2 = 0.881, R^2 (adj) = 0.859. (7)

Using model (B) we obtain following regression equation along with standard error, multiple correlation and adjusted multiple correlation.

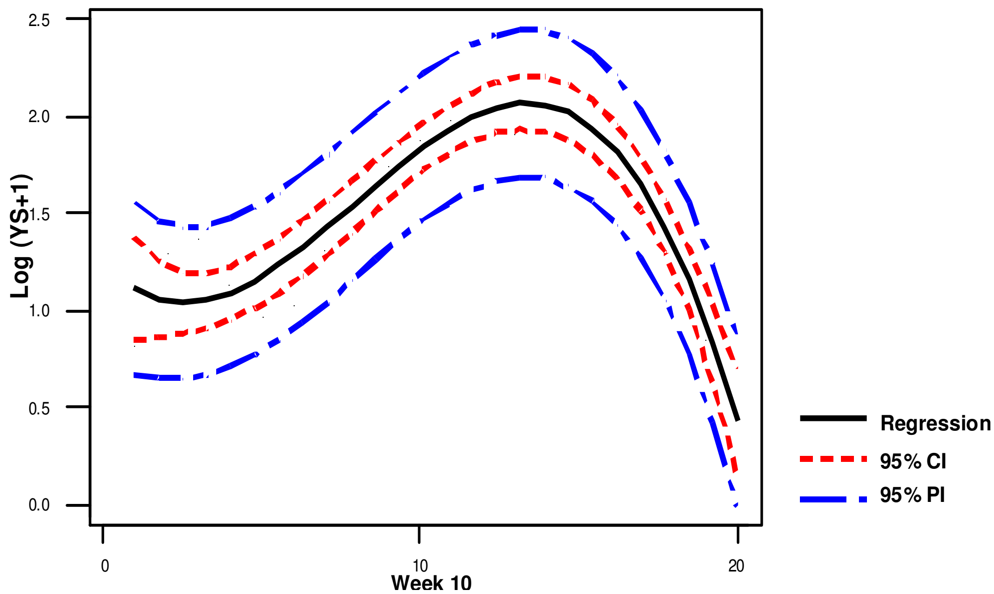

Figure 10. Regression plot of log (YS+1).

Log (RGB) = 1.29 – 0.07 (max.temp.) – 0.01 (min.temp.) – 0.003 (rainfall) + 0.03 (relative humidity) -0.02 (sunshine) + 0.02 t - 0.002 t^2 – 0.0001 t^{3*} Standard error = 0.12, R^2 = 0.90, R^2 (adj) = 0. 829 (8)

We found that Equation (7) gives a better fit for the transformed data than Equation (8) of rice gundhi bug population because the adjusted R^2 is greater in cubic equation. But for management purposes it will be useful to use Equation (8) to predict the dynamics of rice gundhi bug population.

Yellow stem borer

When model (A) was used, the following regression equation along with standard error, multiple correlations and adjusted multiple correlations (Figure 10) were got.

Log (YS + 1) = 0.17 – 0.13 t + 0.01 t^{2**} – 0.0009 t^{3**}
Standard error = 0.17, R^2 = 92.0, R^2 (adj) = 90.5. (9)

Using model (B) we obtain following regression equation along with standard error, multiple correlation and adjusted multiple correlation.

Log (YS + 1) = -3.81 – 0.06 (max.temp.) +0.05 (min.temp.) – 0.008 (rainfall) + 0.07 (relative humidity) - 0.03 (sunshine) + 0.05 t - 0.004 t^2– 0.0001 t^3 Standard error = 0.17, R^2 = 0.949, R^2 (adj) = 0.913. (10)

On the basis the values of standard error, R^2 and R^2 (adjusted) in both the regression Equations (9) and (10), it was found that Equation (10) gives a better fit of the transformed data than Equation (9) of yellow stem borer population. So we may use the second model to predict the dynamics of plant hoppers population.

Conclusion

The forewarning models described in the present communication may be used to predict the dynamics of the populations of insect pests considered in this paper. These considerations may help to reduce certain degree of loss caused by these rice crop insect pests.

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