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Prediction model for population dynamics of brown plant hoppers (*Nilaparvata lugens*) based on generalized linear models (GLM'S)

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Abstract
The scope of any prediction model depends on its practical utility and economic importance of crop. The model developed for pest of rice, Brown Plant Hopper (BPH) has a role to evade the crop loss if we predict the pest before occurrence with significant accuracy. The mean to variance ratio of the BPH count for the study period was > 1 and it indicates that data was over dispersed and also The Kolmogorov - Smirnov test and Shapiro-Wilk's test was found to be significant and indicating the non-normality of the data. Since the insect count data were discrete and dispersed fitted with general linear models like Poisson, Quasi-Poisson and Negative binomial distribution. The poison model provided good fit with minimum performance indicators like RMSE and MAPE compared to other models. The population dynamics of BPH in the study area influenced by maximum temperature (p=0.043) and relative humidity (p=0.05). Similarly the BPH was observed more in 32nd and 44th standard meteorological weeks of crop growth period.

Keywords: Poisson, quasi poisson, negative binomial distribution, mean to variance ratio

Introduction

In modeling the count data, the Ordinary Least Square (OLS) regression model is commonly used by suitable transformation but it has not devoid of many drawbacks. Despite these, Yamamura (1999) [9] and Maindonald and Braun (2007) [6} recommend transformation of count data to normalize it. The key limitation was observed in discrete response variables (counts) data with many zero were unlikely to have a normally distributed error structure even if a value is added before transformation. Another limitation is that linear models deal with continuous response variables while count data is discrete and to make it continuous log transformation is done which may lead to the model being biased.

Recently, Generalized Linear Models (GLM'S) such as Poisson, Quasi Poisson and Negative Binomial models have been recommended for avoiding the need of transform to the count data. Hence, there is a need to compare the outcome Poisson, Quasi Poisson and NB model, where the time series count data is not transformed with the recommended transformed count data (log (y + 0.5)) under ordinary least square regression methods.

From the last two decades, rice yield has become almost stagnant or even declining over time globally (Duxbury *et al*., 2003) [1]. In pest forecasting, several intrinsic attributes of the insects and the determining environmental and host factors need to be considered. The collection and analysis of weather data from pest-affected areas is an essential input for models (Prasad and *et al*., 2012) [10]. The accurate forecasting of pest attacks before they actually take place is desired in pest control programmes, so that control measures can be planned with maximum efficiency. BPH is the one of the important rice pest throughout the country with damage severity as high as 100% occasionally. The development of a forecast model for this pest will help in management of this obnoxious pest.

Materials and Methods

This study was undertaken to construct prediction models for rice BPH in the Varanasi region which is located at 25000' to 25016' N Latitude and 82050' to 83010' E Longitude with elevation of 80.71 meters. The weekly data was collected on BPH (Numbers/hill) during 30^{th} to 48^{th} standard meteorological week (SMW) 23^{rd} July to 02^{nd} December from 2011 to 2016 along with weather parameters like Rainfall (mm), Maximum temperature (°C), Minimum temperature (°C), Maximum Relative humidity (%), Minimum Relative humidity (%) Sunshine hours (hrs.). For the given period, growing stages of the crop were also recorded.

To summarize information collected exploratory data analysis and the descriptive statistical measures were used. For studying the relationship between insect counts at different crop growth stages and weather parameters Pearson correlation coefficient was computed.

To study the pattern of distribution we employed Variance-Mean ratio ($d = \frac{\sigma 2}{\mu}$) test, Kolmogorov - Smirnov test and Shapiro-Wilk's test (Pandit *et al*. 2018) [11] were used. We were included weeks as dummy independent variable in the model by assigning 1 if that particular weeks insect counts more than the economic threshold level otherwise we assign 0. For modeling the count time series data or discrete distributions data we used generalized linear model (GLM'S) like Poisson regression model, Quasi-Poisson regression model, Negative Binomial regression model and model based on Bayesian approach. Each Models adequacy checked through the measures like Residual Deviance, Pseudo R^2, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) also with key performance indicators of the model like RMSE and MAPE.

Results and Discussion

The summarization of the insect count data was done by descriptive and exploratory data techniques mean count of BPH/hill was about 5.4 with standard deviation 4.8 maximum counts of BPH was recorded to be 28/hill and minimum counts recorded was 0. The frequency of insect counts was observed on week interval basis from the 30^{th} standard meteorological week that is from July 23^{rd} to 48^{th} week i.e. December 02^{nd} for six consecutive years and the pattern of frequency is depicted in the figure 1 clearly shows that the frequency not in a normal pattern and likely to be skewed distribution (positive skew with value 1.1).

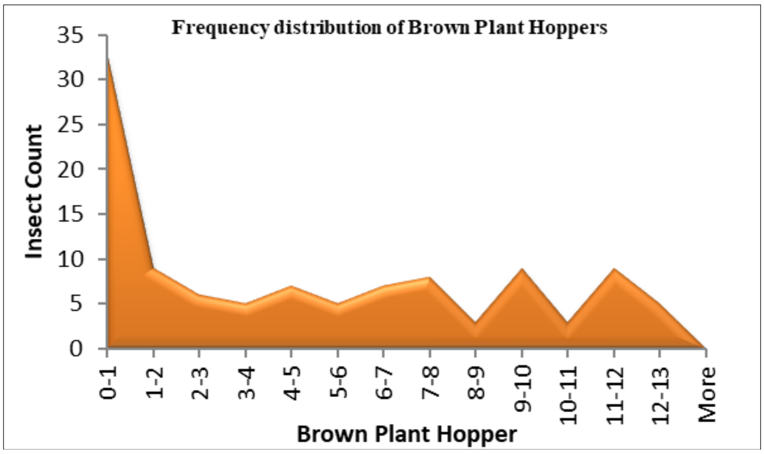

Fig 1: Frequency distribution of brown plant hoppers

The correlation between population dynamics of BPH with weather parameters were computed through Pearson product moment method and the result shows that the parameters like maximum temperature (0.42**), maximum relative humidity (0.67**) and sunshine hours (0.27*) found to be positively significant with insect occurrences similarly minimum temperature and minimum relative humidity shows positive impact but not significant and rainfall shows negative correlation with non-significant value.

The test like The Kolmogorov - Smirnov test (0.14** for 114 df) and Shapiro-Wilk's test (0.91** for 114 d f) and the variance mean ratio (4) results shows the non-normality of insect counts and degree of dispersion or variations of the data respectively.

The generalized linear models fitted to the given data and the result of goodness of fit for different GLM models and for the best model fitted Bayesian approach is depicted in the table 1.

Table 1: Goodness of fit for different model fitted for BPH

	Chi-square Goodness of fit		
Model	**Test statistics**	**DF**	**P**
Poisson	62.95	71	0.74
Quassi Poisson	62.95	71	0.74
Negative Binomial	43.28	71	0.32
Bayesian model	1615	1564	0.29

Result shows that based on Chi-square Goodness of fit model with Poisson and Quasi Poisson approach gives more chi square value with high probability 0.74 for 71 d f accept the null hypothesis that both observed and expected frequency are same. The model coefficient for Poisson regression is given by $\ln(y_t) = 0.023 - 0.009$ (Rain fall) + 0.06 (Max Temp) + 0.072 (Min Temp) + 0.144 (S S Hrs) + 0.065 (Y_{t-1})

Table 2: Selection of best model for prediction of number of BPH/plot

Models	AIC	BIC	Pseudo R^2	RMSE	MAPE
Poisson	376.325	437.618	0.84	0.893	0.670
Quasi-Poisson	-	-	0.84	0.893	0.670
Negative Binomial	378.33	442.177	0.74	0.924	0.801
Bayesian Poisson	-	-	-	1.736	0.732

The model selection criteria for the best prediction and forecasting of the BHP pest incidences is referred to the table 2 it explains that generalized linear models like Poisson model, Quasi-poisson model, Negative binomial model and Bayesian approach out of this we were obtained good predictive ability measures for Poisson regression model like AIC and BIC is about 376.325 and 437.618 respectively with Pseudo R^2 of 0.84 and 0.893, 0.670 of RMSE and MAPE respectively. So we proceeded to for forecasting of pest incidences of BPH using Poisson regression coefficients and the result of actual observation and predicted observation for the year of 2016 for Brown plant hoppers was depicted in the figure 2.

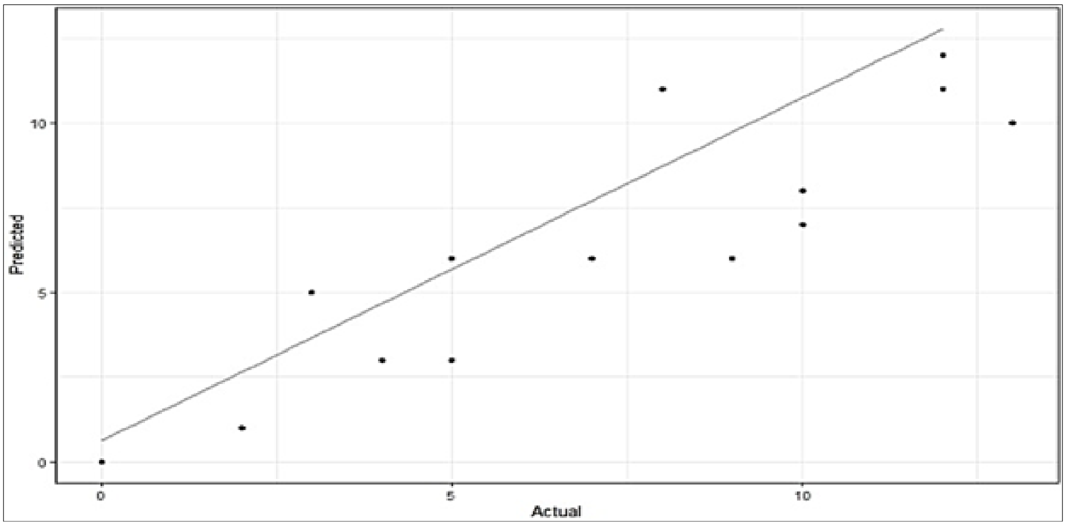

Fig 2: Graph showing the actual and predicted pest counts of brown plant hopper

So for the given study area the Brown plant hoppers population dynamics is explained by Poisson model compared with other models by giving lesser value of key performance indicator and good Pseudo R^2 value. The weather parameters like maximum temperature, maximum relative humidity, Sunshine hours plays an important role in population dynamics of BPH and also the lagged value also contributing to the insect counts.

Conclusion

The study's comprehensive analysis of Brown Plant Hopper (BPH) population dynamics over a period spanning from late July to early December for six consecutive years revealed a complex relationship with various weather parameters, underlining a positively significant correlation with maximum temperature, relative humidity, and sunshine hours. The data exhibited a skewed distribution with a notable variation in BPH counts, confirmed by statistical tests indicating non-normality. Among the evaluated generalized linear models, the Poisson regression model emerged as the most effective for forecasting BPH occurrences, evidenced by its superior goodness of fit metrics and predictive performance indicators such as AIC, BIC, and pseudo R^2 values. This model, highlighting the critical influence of weather conditions on BPH populations, proves indispensable for predicting pest incidences, thereby facilitating more informed pest management decisions in the studied area.

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