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Short Communication

Development of weather-based forewarning model for tomato leaf curl infestation

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Tomato (*Solanum lycopersicum* L.) is commercially important crop grown worldwide in wide range of climatic conditions in field or under protected condition and it is highly accepted as fresh salad, cooked and processed food (Peralta *et al*., 2006). Among the different biotic stresses reported on this crop, Tomato leaf curl virus (ToLCV), a gemini virus is the most important and destructive viral pathogen in many parts of India (Saikia and Muniyappa, 1989; Harrison *et al*., 1991) including West Bengal. The management of leaf curl disease in tomatoes relies mainly on the application of insecticides at frequent intervals. Excessive use of insecticides not only cause environmental hazards but also triggers the development of resistance in the insect pest and also enhances the production cost of the crop. A reduction in the number of pesticide applications could be achieved by applying pesticides only at times when weather conditions are favourable for disease development. The cause and effect relationship are generally studied using simple regression model or nonlinear regression models. But in situations where data are not in ratio scale, then regression may not be appropriate as it violates the assumption of normality and constant variance. A very well used recommendation is to apply data transformation and proceed with ordinary linear regression but there may be problem in interpretability. In such situations, beta regression model may be employed as it takes into consideration all the properties of the data (Maier, 2014; Cribari-Neto and Zeileis, 2010; Hijazi and Jernigan, 2009; Ferrari and Cribari-Neto, 2004; Kieschnick and McCullough, 2003). In Beta regression, it is assumed that the dependent variable is distributed with beta function and the mean of the beta distribution is dependent on a set of independent variables by means of linear predictor with a link function and unknown parameters. A dispersion parameter is also included in the function.

In this manuscript, attempts to relate weather variables with whitefly population and incidence of tomato leaf curl disease incidence has resulted in development of prediction models wherein Beta regression model is used to capture the variability in the pest infestation data. The developed Tomato leaf curl virus (ToLCV) forewarning model could be employed to make proper management strategy by the farming community for controlling ToLCV.

Meteorological data and study location

Field experiments were conducted at experimental plots in research station farm of Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, Nadia (Elevation: 16m, Latitude: 22° 59’ 15.2” and Longitude: 88° 27’ 26.6’’). Tomato crops were raised for eight years i.e. 2011-2012 to 2018-2019 and tomato leaf curl disease incidence was recorded periodically at 7 days interval and the number of leaf curl infected plants was noted by visual observation and accordingly percent disease incidence was calculated.

Weather parameters

The available meteorological data on weather variables viz. maximum temperature (T max) and minimum temperature (T min) and their differences (T max – T min), maximum (RH max) and minimum relative humidity (RH min) and rainfall (RF) were collected from All India Coordinated Research Project (AICRP) on Agro-Meteorology, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal.

Model description

The beta regression model is based on the assumption that the dependent variable is beta distributed. The density of beta distribution is given by:

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$$\pi(y;p,q) = \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} y^{p-1}(1-y)^{q-1}, 0 < y < 1 \quad (1)$$

Where q>0, p>0 and is the gamma function. The mean and variance of y are respectively,

$$E(y) = \frac{p}{(p+q)} \quad (2)$$

$$Var(y) = \frac{pq}{(p+q)^2(p+q+1)} \quad (3)$$

Let

$$\varphi = p + q \quad (4)$$

So

$$E(v) = u \quad (5)$$

$$Var(y) = \frac{V(u)}{1+\varphi} \quad (6)$$

where

Here μ is the overall average of the dependent variable and φ is the precision parameter. If μ is kept constant, the smaller the value of φ, the larger the variance of y and vice-versa. For the new parameterized parameters, the density of *y* can be written as:

$$f(y;u,\varphi) = \frac{\Gamma\varphi}{\Gamma(u\varphi)\Gamma((1-u)\varphi)} y^{u\varphi-1}(1-y)^{(1-u)\varphi-1}, 0 < y < 1 \quad (7)$$

Where 0<u<1 and

Let us assume to have *n* independent random variables . Here each independent random variable follows beta distribution with mean and unknown precision . Further, it is assumed that the mean of can be written as:

$$g(u_t) = \sum_{i=1}^{k} x_{ti}\beta_i = \eta_t \quad (8)$$

where are the coefficients to be estimated. are the *k* covariates which are assumed to be fixed and known.

The density plot of the Tomato leaf curl incidence data shows that the data is not normally distributed.

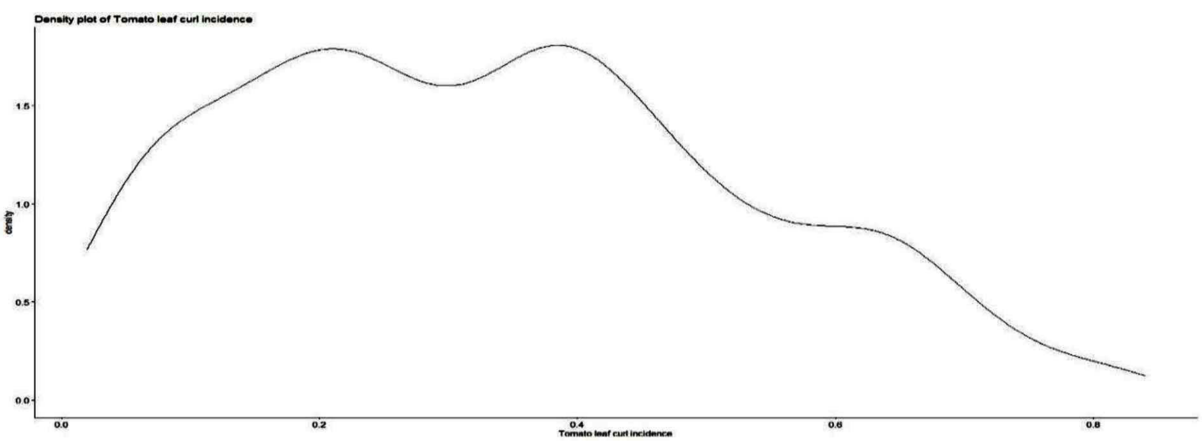

Fig.1: Density plot of the tomato leaf curl incidence data

Further, a quantile-quantile plot (Q-Q plot) was also drawn, wherein it was seen that the data deviated from the usual normal plot.

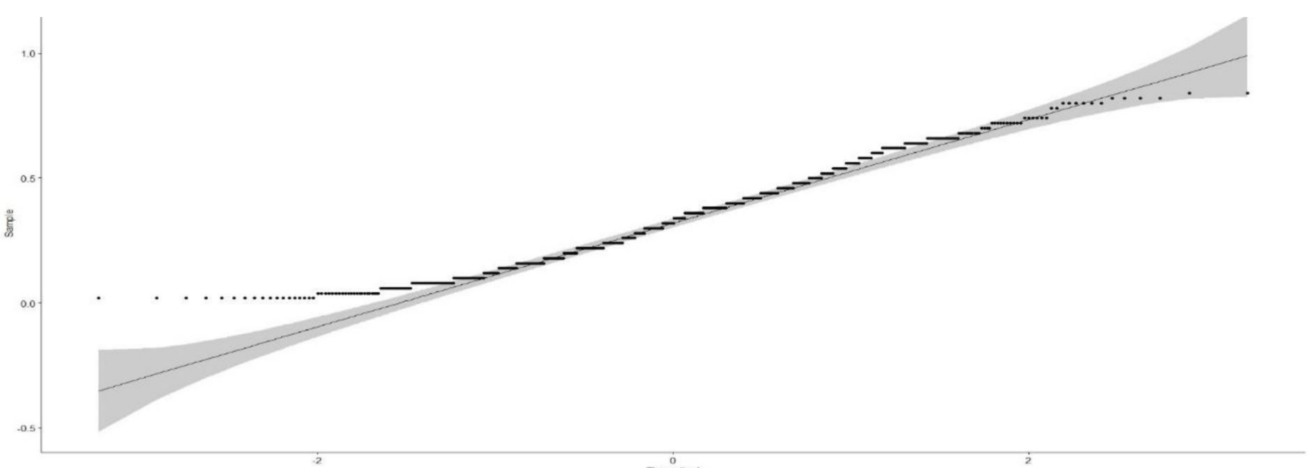

Fig.2: Q-Q plot of the tomato leaf curl incidence data

Shapiro-Wilk normality test was also carried out to test statistically the normality assumption of the data. The Shapiro-Wilk test statistics was computed as 0.970 which had a p-value <0.001. So we have enough evidence to reject the null hypothesis of data being normal. Hence, regression analysis is not a valid option for the data under consideration. Thus a better option in the form of Beta regression is employed. The Beta regression model is fitted to the data using betareg and the obtained result is presented in the table below.

Table 1: Fitted Beta regression model

Coefficients (mean model with logit link):					
Estimate	Estimate	Std. Error	Z value	Pr(>|z|)	
(Intercept)	-0.168	1.196	-0.141	0.887	
Max.temp (°C)	0.025	0.026	0.987	0.323	
Min.temp (°C)	-0.134	0.020	-6.600	<0.001	***
Mean RH. (%)	-0.008	0.006	-1.267	0.205	
Rainfall(mm)	0.018	0.013	1.314	0.188	
Sunshine (h/day)	0.014	0.003	3.724	<0.001	***
Wind (km/h)	-0.033	0.021	-1.569	0.116	
Phi coefficients (precision model with identity link):					
(phi)	6.508	0.306	21.210	<0.001	***

The residuals obtained from the estimated values were also tested using Box-Pierce test statistic to check if they were independent or not. The test statistic was computed as 0.201 with p value 0.653. So we do not have enough evidence to reject the null hypothesis of independence. We can infer that the fitted Beta regression model is appropriate for the data under consideration.

In the present study forewarning model for Tomato leaf curl virus (ToLCV), a gemini virus which is an important and destructive viral pathogen in many parts of India, was developed by means of Beta regression technique. R software package "betareg" was employed for developing the model after due exploratory analysis of the data was carried out. . Such forewarning models have been developed for other crops too (Sandhu *et al*., 2021; Ghongade *et al*., 2021; Kaur *et al*., 2021). Thus, the forewarning model developed in the present study, can be used by operational plant protection agencies and growers for development of management strategies against tomato leaf curl disease in Gangetic alluvial region of West Bengal, India

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