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Short Communication

Predictive models of major insect-pests of okra (*Abelmoschus esculentus* L.) for their management under Terai region of West Bengal, India

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Okra, *Abelmoschus esculentus* (L.) Moench, representative of family Malvaeceae, is one of the important vegetable crops cultivated widely in the tropical and subtropical part of the world. India ranks first in terms of area and production and occupying 73.60% share in world's okra production. Okra has occupied a prominent position among the export oriented vegetables in India because of its high nutritive value, palatability and good post-harvest life. It contains good amount of vitamin A and folic acid, besides carbohydrates, phosphorus, magnesium and potassium. The crop is attacked by about 72 species of insect pests from germination to harvest (Pal *et al*., 2013). The leaf hopper, whitefly and shoot and fruit borers were reported as major insect-pests of okra (Priyanka *et al.*, 2019). The leaf hopper, *Amrasca biguttula biguttula* Ishida (Hemiptera: Cicadellidae), sucks the cell sap from lower surface of the leaves and injects toxic substance as a result of that yellowing and curling of leaf margins and stunting of plant growth occur. In okra all the important and major pests are either oligophagous or polyphagous and most of the alternate hosts are vegetables grown as preceding or succeeding crop or in vicinity to okra fields. All these favour carryover of pests and pest populations increase rapidly with development of the crop phenology.

The management strategies will become more difficult when more than one insect- pests, from different categories, occurred. In order to lessen the losses caused by pests and to produce quality crop, it is essential to manage the pest population at appropriate time with suitable measures. The multiplication of these pests has been found to be favoured by environmental factors. Therefore, knowledge on the population dynamics of insect-pests throughout the growing season of okra can become sound and economical (Das *et al.* 2011; Rajveer *et al*. 2018). Population dynamics of the insect pests provides not only the information of appearance on the pest but also the peak activity of the particular pest which can be used for designing pest management strategy.

The experiments were conducted in the Research Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India. The experimental domain comes under terai agro climatic zone of West Bengal situated between 25°57`N and 27°N latitude and 88°25`E longitude. To study the population dynamics of major insect pests of okra, the variety Arka Anamika was sown on 20^{th} SMW (3^{rd} week of May) and 33^{rd} SMW (3^{rd} week of August) during *kharif* and *post-kharif* seasons, 2019. The crop was grown in a plot size of 140 m^2 with 60 cm x 30 cm spacing following recommended agronomic practices. The pest population was recorded at weekly interval right from germination (1 week after sowing) to harvesting. For observations of pest population, twenty five (25) plants were randomly selected and tagged. The jassid population was counted before 8 AM, when they remained less active by visual count on three leaves, *i.e.* one each from top, middle and bottom canopy of tagged plants (absolute counting). In case of fruit borer, the per cent infestation of fruits on number basis was calculated by counting the infested and healthy fruits separately from selected tagged plants.Weekly data of abiotic factors such as maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, total rainfall and daily bright sunshine hours were collected from the Agro-Meteorological Centre of the University.

Five non-linear growth models named Gompartz, Logistic, Prajneshu (IASRI), Weibull and Monomolecular model (Eleroglu *et al*., 2014; Karadavut *et al.,* 2010; Khamis *et al.,* 2005; Parjenshu and Das, 2000; Prajneshu, 1998 and Seber and Wild, 1989) were used. They were compared to find out the best fit non-linear growth model for prediction of pest population build-up. For the purpose of finding out the best fitted model, two goodness of fit criteria, namely root means square error (RMSE) and coefficient of determination (R^2) were considered (Table 1).

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Table 1: The non-linear mechanistic growth models and their model expressions used in the experiment

Sr. No.	Non-Linear Mechanistic Growth Model	Model Expression
1.	Gompartz model	X(t)=c exp(-b exp(-at))+e
2.	Logistic model	X(t)=c/(1+b exp(-at))+e
3.	Prajneshu model (IASRI model)	$X(t)=(a\exp(bt))/(1+c\exp(bt))^2 + e$
4.	Weibull model	X(t)=a-b exp(-ctd) +e
5.	Monomolecular model	X(t)=c-(c-b) exp(-at) +e

Further the main assumptions of residuals *i.e.,* randomness and normality were examined by using run test and Shapiro-Wilk test (D'Agostino and Stephens, 1986). The optimum time for insecticidal application was calculated by the mathematical expression derived from Prajneshu (IASRI) model.

Model expression: $X(t) = (a\exp(bt))/(1+c\exp(bt))^2+e$

$$t^* = (-1/b)(\ln[(3(1+ab)+ (9a^2b^2+30ab+1)^{1/2})/2c(-2+3ab)])$$

Where X(t), the pest population at time t;

a, b, c, d are the model parameters and these were approximated by employing Layenberg-Marquardt's iterative procedure

e, the error term

t*, the optimum time for spraying insecticide.

Data computation and statistical analysis was done in SAS-9.2.

The crop was found to infested by sucking (aphid, *Aphis gossypii* Glover; jassid, *Amrasca biguttula biguttula*; and whitefly, *Bemisia tabaci*), foliage feeding (semilooper, *Anomis sabulifera* and different species of flea beetle) and internal feeding (fruit borer, *Earias vitella* Fab.) insect-pests. Among them the sucking pest jassid and internal feeder fruit borer were noticed as major insect pest of okra in terai region of West Bengal during both *kharif* and *post-kharif* seasons.

In *kharif* season the jassid infestation initiated on 24th SW *i.e.* after one month of sowing during 2nd week of June, crossed ETL level and reached peak on 37th to 38th SW (2.36-2.57/leaf) on 119-126 days old crop (2nd and 3rd week of September). The fruit borer damage started from 28th SW after two months of sowing at 56 days of crop (2nd week of July). The infestation attained ETL on 33rd SW (14.44% bored fruit) (3rd week of August) and reached peak on 37th SW (34.68% bored fruit). The higher level of both the pests were maintained from last week of August to 2nd week of October (35th to 41st SW).

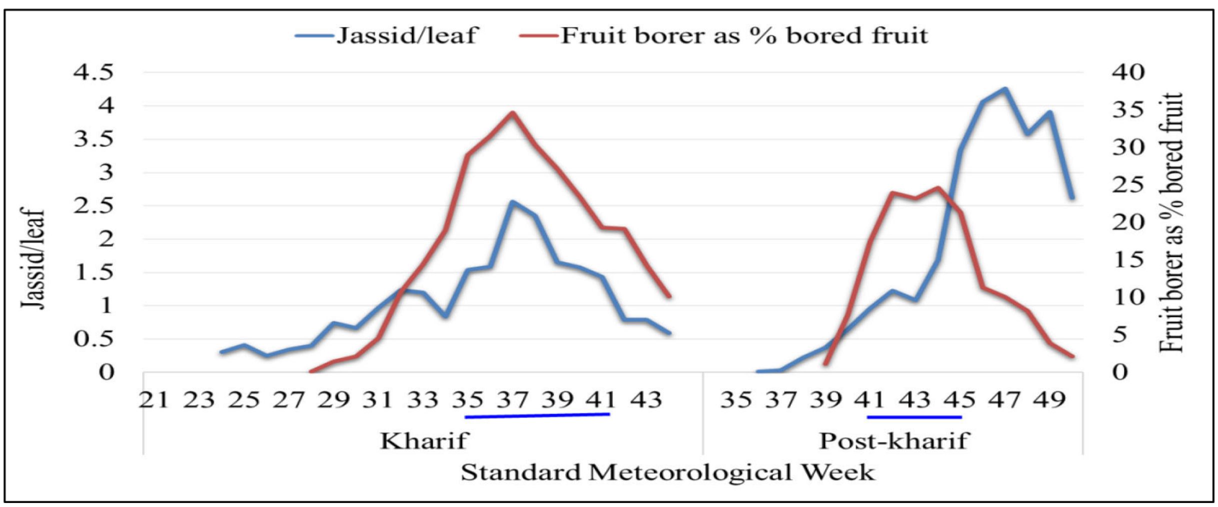

Fig. 1: Incidence pattern of jassid and fruit borer population in terai region of West Bengal

In *post-kharif* crop the jassid population was first noticed after three weeks of sowing (36thSW), attained ETL level on 45th SW (3.34/leaf) and reached peak on 47th SW (4.27/leaf). The fruit borer infestation was initiated with the appearance of flowering, just after 6 weeks of sowing (39thSW). The pest rapidly increased its number and crossedETL level when the crop was 56 days old on 41stSW (2nd week of October) (17.48% bored fruit) and two peaks were recorded one on 42nd SW (24.01% bored fruit) and other on 44th SW (24.61% bored fruit) (3rd week of October and 1st week of November).

During *kharif* season the minimum temperature only showed positive significant impact on jassid population build-up. In *post-kharif* season the temperature, relative humidity had significant and negative relation with jassid population build-up. The fruit borer infestation was significantly and negatively influenced by maximum temperature (Table 2). Therefore, it can be said that temperature played the significant role in jassid and fruit borer population build-up in okra crop in different seasons.

Table 2: Correlation between weather parameters of 1-lag week and insect-pest population (Pearson Correlation Coefficients, N = 24 Prob > |r| under H0: Rho=0

Pests	Seasons	Weather parameters					
		X1	X2	X3	X4	X5	X6
Jassid/leaf	Kharif	0.2078	0.4682	0.2632	0.1970	0.0869	0.1216
		0.3298	0.0210	0.2140	0.3561	0.6864	0.5713
	Post-kharif	-0.6701	-0.9157	-0.5154	-0.6721	-0.3041	0.0848
		0.0032	<.0001	0.0342	0.0031	0.2354	0.7462
Fruit borer as % bored fruit	Kharif	0.2122	0.2757	0.1675	0.0410	-0.0486	0.0718
		0.3196	0.1922	0.4341	0.8491	0.8216	0.7387
	Post-kharif	-0.4798	-0.4089	-0.1306	-0.1511	0.0624	-0.2368
		0.0500	0.1031	0.6174	0.5628	0.8119	0.3602

X1= Maximum temperature, X2= Minimum temperature, X3= Morning relative humidity, X4= Evening relative humidity, X5= Total rainfall, X6= Bright sunshine hour,

Table 3: Estimated model equations, diagnostic checks and different precision criteria on Jassid and fruit borer of Okra for five nonlinear growth models during *kharif* season

Sr. No.	Non-Linear Mechanistic Growth Model	Jassid/leaf/plant						Fruit borer as % bored fruit					
		Kharif			Post- Kharif			Kharif			Post- Kharif		
		Goodness of Fit MSE (R^2)	Shapiro-Wilk test (W)	Run-test |Z|	Goodness of Fit MSE (R^2)	Shapiro-Wilk test(W)	Run-test |Z|	Goodness of Fit MSE (R^2)	Shapiro-Wilk test(W)	Run-test |Z|	Goodness of Fit MSE (R^2)	Shapiro-Wilk test(W)	Run-test |Z|
1	Gompartz	0.501 (0.571)	0.941 (0.154)	2.584	0.324 (0.891)	0.905 (0.083)	1.985	28.388 (0.827)	0.910 (0.031)	1.925	47.134 (0.549)	0.930 (0.215)	2.226
2	Logistic	0.514 (0.712)	0.930 (0.088)	1.880	Failed to converge and estimate the parameter			27.595 (0.832)	0.892 (0.013)	1.860	29.535 (0.832)	0.912 (0.085)	1.952
3	Prajneshu (IASRI)	0.072 (0.872)	0.963 (0.479)	1.825	0.095 (0.968)	0.891 (0.289)	1.812	4.765 (0.971)	0.919 (0.066)	1.765	6.108 (0.942)	0.969 (0.803)	1.882
4	Weibull	0.202 (0.666)	0.875 (0.005)	1.924	0.230 (0.928)	0.925 (0.181)	1.915	84.856 (0.482)	0.916 (0.042)	2.965	84.080 (0.254)	0.915 (0.119)	3.436
5	Monomolecular	0.514 (0.423)	0.930 (0.088)	3.272	0.555 (0.813)	0.956 (0.555)	2.431	90.387 (0.385)	0.930 (0.088)	3.662	83.604 (0.144)	0.881 (0.034)	4.182

Figure in the parenthesis indicates exact level of significance

Table 4: Optimum time for management of the pests

Season	Pests	Pest population	Optimum time (observing week) for taking control measure	Standard Week	Month
Kharif	Jassid/leaf/plant	1.59	15.95	35	4th week of August
	Fruit borer as % bored fruit	14.44	13.21	33	3rd week of August
Post-kharif	Jassid/leaf/plant	3.34	12.05	45	2nd week of November
	Fruit borer as % bored fruit	17.48	8.12	41	2nd week of October

Five non-linear growth models were compared on the basis of the weekly average population data for identifying the best fit model for prediction of the pest population build up and determining optimum spraying time (Table 3). To assume residuals, run test statistic and Shapiro-Wilk test statistic were calculated. At the 5% significance level, a Z-score with an absolute value less than 1.96 indicates randomness.

In *kharif* crop the highest R^2 and lowest RMSE were found from Prajneshu (IASRI) model for jassid (R^2= 0.872, RMSE =0.072) and fruit borer (R^2=0.971, RMSE = 4.765) followed by Logistic model (R^2= 0.712, RMSE = 0.514 for jassid and R^2=0.832, RMSE = 27.595 for fruit borer) and Gompartz model (R^2=0.571, RMSE = 0.501 for jassid and R^2=0.827, RMSE = 28.388for fruit borer). For jassid population the calculated value of run test statistic $|Z|$ was found less than the tabulated value at 5% level for Prajneshu (IASRI) model (1.825) followed by Logistic (1.880) and Weibull (1.924) models but in case of fruit borer it was Prajneshu (IASRI) model (1.765) followed by Logistic (1.860) and Gompartz (1.925) models

In *post-kharif* season the Logistic model failed to converge and estimate the parameter of Jassid population build-up. The highest value of R^2 and lowest value of RMSE for jassid population were found from Prajneshu (IASRI) model for jassid (R^2= 0.968, RMSE =0.095) followed by Weibull model with R^2= 0.928, RMSE =0.230. In case of fruit borer population Prajneshu (IASRI) model found to be best (R^2=0.942, RMSE = 6.108) followed by Logistic model (R^2= 0.832, RMSE =29.535). The │Z│ value was found less than the tabulated value at 5% level in Prajneshu (IASRI) model (1.812) followed by Weibull (1.915) model for jassid population. In case of fruit it was Prajneshu (IASRI) model (1.882) followed by Logistic model (1.952).

The calculated value for Shapiro-Wilk statistics lie in acceptance region at 5% level in Prajneshu (IASRI) model for both the pests and seasons. So, considering the above all criteria it may be concluded that Prajneshu (IASRI) model was the best model for prediction of population buildup of jassid and fruit borer in both the seasons. Goodness of fit statistics for other model was found to be much poor.

The determination of optimum time for taking control measures was explored (Table 4) from best fitted Prajneshu (IASRI) model and it was found that during *kharif* season the prophylactic measure to check the pest population in attaining the peak level should be started from 3rd week of August for fruit borer and 4th Week of August for jassid. In *post-kharif* season management schedule to be initiated from 2nd week of October targeting the fruit borer infestation but for jassid it should be one month later *i.e.* 2nd week of November.

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