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Forecasting podfly (*Melanogromyza obtusa*) in late pigeonpea (*Cajanus cajan*)

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ABSTRACT

Qualitative and quantitative models were developed for damage due to podfly (*Melanogromyza obtusa*) on late maturing pigeonpea [*Cajanus cajan* (L.) Millsp] in Kanpur. Historical data from 1987-88 to 2009-10 on per cent pod damage and weekly weather variables were considered for model fitting. Weather based indices were generated which were used as explanatory variables. Models were validated on subsequent periods (2010-11 and 2011-12) data and found to be satisfactory for both qualitative (epidemic/non-epidemic year) and quantitative (extent of damage) forewarning of damage due to podfly in late pigeonpea at Kanpur.

Key words : Forecasting, Logistic Model, Podfly, Weather based regression model

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of the major grain legumes grown in India, which covers about 90% area in global scenario. The crop is attacked by more than 250 insect pests but three insect pests, viz. *Helicoverpa armigera, Melanagromyza obtusa* and *Maruca vitrata* are the major biotic constraints in the production of pigeonpea, particularly in the central and northern part of our country. *Melanagromyza obtusa* (podfly) causes heavy toll of losses to pigeonpea at crop reproductive phase much in the late maturing varieties. Monitoring infestation of podfly is difficult as infested pods hardly have any external symptoms (except for holes of oviposition by female adult on matured pods). So it is necessary to destructively sample pods by opening each one to ascertain the presence or absence of eggs, larvae or pupae. The only life stage that occurs outside the pod is the adult stage; so any monitoring not involving destructive pod sampling would involve counting only adult podflies. Forecast of pest pressure is central to the effective management of any pest. Despite the seriousness of podfly as dreaded pest in pigeonpea, no concerted efforts have so far been made to develop a forecasting module for this pest. Timely forecast would certainly be useful for determining insecticide budget, or making strategic decision. Therefore, there is a need to develop forewarning systems, which can provide advance information for outbreak of the pest. Any pest can only progress if the conditions provided by the host plants as well as weather conditions are favorable. Weather is one of the major factors responsible for infestation of diseases in the crop. A weather-based model can be an effective scientific tool for forewarning pest in advance so that protection measures can be implemented before the actual onset of the damage. Most of the earlier workers have utilised regression models (both linear and non-linear) for pests/diseases forewarning (Agrawal and Mehta 2007, Chattopadhyay *et al*. 2005a, 2005b, Desai *et al*. 2004 and Dhar *et al*. 2007).

MATERIALS AND METHODS

The pest data comprised of % pod damage due to pod fly from 1987-88 to 2011-12 for Kanpur. The data pertaining to the weather variables - maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and Rainfall (X_1 to X_5) for the period 1987-88 to 2011-12 were considered as explanatory variables in the study.

A weather-based model can be an effective scientific tool to thwart the impending attack of pest by forewarning so that timely plant protection measures can be taken up. For taking timely control measures, merely the idea about the expected population count below or above a threshold level may be enough which can be obtained from models based on qualitative data. On the other hand, expected number of population counts/extent of damage may be required for some purposes (for instance, working out losses etc.) which can be computed from the models based on quantitative data. Hence, development of models based on both qualitative as well as quantitative data has been attempted. The details of

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the models developed under the study are described below:

The pest population/damage below the threshold value can be taken as non-epidemic status whereas above the threshold value as epidemic status of a pest. Accordingly, the quantitative data on % pod damage due to pod fly (Y) has been converted into two categories, i e dichotomous form : Y' = 0 for non-epidemic and 1 for epidemic status. To forecast epidemic status of crop**,** logistic regression model was developed. The pest epidemic-status (Y') was considered as dependent variable and weather indices as explanatory variables. For each weather variable two indices were developed, one as simple total of values of weather variables in different weeks and the other one as weighted total, weights being correlation coefficients between % pod damage and weather variable in respective weeks. The first index represents the total amount of weather variable received by the crop during the period under consideration while the other one takes care of distribution of weather variable with special reference to its importance in different weeks in relation to the the extent of damage. On similar lines, indices were computed with products of weather variables (taken two at a time) for joint effects (Agrawal *et al.* 1986 and Agrawal and Mehta 2007). The model used was

$$P(Y' = 1) = \frac{1}{1 + e^{-L}} + \varepsilon$$

L being a linear function of weather-indices defined below:

$$L = a_0 + \sum_{i=1}^{p} \sum_{j=0}^{1} a_{ij} Z_{ij} + \sum_{i,l}^{p} \sum_{j=0}^{1} b_{ii'j} Z_{ii'j} + e$$

where

$$Z_{ij} = \sum_{w=n_1}^{n_2} r_{iw}^{j} X_{iw}$$

$$Z_{ii'j} = \sum_{w=n_1}^{n_2} r_{ii'w}^{j} X_{iw} X_{i'w}$$

X_{iw}, value of i^{th} weather variable in w^{th} week; r_{iw}, correlation coefficient between Y and X_{iw}; $r_{ii'w}$, correlation coefficient between Y and product of X_{iw} and $X_{i'w}$; p, number of weather variables considered; n_1, initial week for which weather data were included in the model; n_2 final week for which weather data were included in the model; e, error term.

Forecast/prediction was obtained using following rule:

P > 0.5 possibility of pest epidemic

$P \leq 0.5$ possibility of non-occurrence of pest-epidemic

Quantitative model has been developed taking % pod damage as dependant variable and weather indices as explanatory variables. The form of the model was

$$L = a_0 + \sum_{i=1}^{p} \sum_{j=0}^{1} a_{ij} Z_{ij} + \sum_{i,l}^{p} \sum_{j=0}^{1} b_{ii'j} Z_{ii'j} + e$$

The symbols are already defined earlier.

The performance evaluation measure considered is Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{1}{m} \sum_{i=1}^{m} \left| \frac{Y_i - F_i}{Y_i} \right| \quad 100$$

where Y_i and F_i are the observed and forecast values respectively and m is the number of observations for which forecasts were worked out.

RESULTS AND DISCUSSION

Qualitative model

The data in the quantitative form was classified into two categories by taking epidemic status as 1 for the pod damage (%) more than 15 and 0 otherwise. For development of model for forewarning epidemic status, logistic regression model was used. With a view to forecast epidemic status well in advance, models based on different groups of weeks starting from 45^{th} standard meteorological week (smw) onwards, by taking the weather data for the period 1987-88 to 2009-10, were attempted. Weather indices were considered as independent variables while qualitative data (two classes, viz. 1 (epidemic status) and 0 (non- epidemic status)) for pod fly in pigeonpea was used as dependent variable. Forecasts along with the probabilities have been obtained for subsequent years not included in model development. The linear functions (to be used in logistic models) alongwith forewarning at different weeks of forecast are presented in Table 1.

Perusal of the Table 1 indicates that the models forewarned the status correctly for both the years, i.e. 2010-11 and 2011-12 at all weeks of forecasts (1^{st} smw to 4^{th} smw). Therefore reliable forewarning of epidemic status can be provided using data from 45 to 1^{st} smw. Weighted index of interaction of max. temperature and evening relative humidity was found to be important. Using this model, predictions (for

Table 1 Models for forewarning epidemic status

Data used (smw)	Linear function	Epidemic status for 2010-11			Epidemic status for 2011-12		
		Forewarning		Observed status	Forewarning		Observed status
		Prob.	Status		Prob.	Status	
45 to 1	$L = -2.475 - 0.016\ Z_{141}$	0.905	1	1	0.931	1	1
45 to 2	$L = -1.802 - 0.014\ Z_{141}$	0.803	1	1	0.998	1	1
45 to 3	$L = 1.368 - 0.008\ Z_{141}$	0.819	1	1	0.912	1	1
45 to 4	$L = 3.128 + 0.007\ Z_{141}$	0.883	1	1	0.972	1	1

Table 2 Predictions and forecasts – Qualitative model

Year	% pod damage	Observed status	Prediction/ Forecast	
			Probability	Status
1987	22.1	1	0.95	1
1988	21.2	1	0.97	1
1989	20.0	1	0.94	1
1990	20.2	1	0.85	1
1991	24.6	1	0.94	1
1992	21.6	1	0.98	1
1993	10.0	0	0.93	1
1994	42.5	1	0.95	1
1995	32.6	1	0.89	1
1996	35.0	1	0.48	0
1997	26.9	1	0.99	1
1998	22.3	1	0.81	1
1999	10.3	0	0.32	0
2001	14.0	0	0.11	0
2002	20.0	1	0.38	0
2003	18.0	1	0.50	1
2007	24.7	1	0.97	1
2008	34.7	1	0.98	1
2009	34.3	1	0.99	1
2010	31.7	1	0.99	1
2011	32.5	1	0.96	1

the years 1987-88 to 2009-10) and forecasts (for the years 2010-11 and 2011-12) are presented in Table 2. The results indicate that for most of the years (86%) the approach has provided correct epidemic status.

Quantitative model

Weather variables for the period from 1987-88 to 2009-10 were considered for model development for forecasting % pod damage due to pod fly. Weather indices based regression models were developed using weather indices as independent variables while % pod damage was used as dependent variable. Forecasts have been obtained for subsequent years not included in model development. Models for forecasting of % pod damage due to pod fly at different weeks of forecast are presented in Table 3.

Table 3 Models for forecasting % pod damage at different weeks of forecast

Data used (smw)	Model	R^2
45 to 1	$Y = 20.40 + 0.078\ Z_{121} + 0.0197\ Z_{141}$	0.52
45 to 2	$Y = 21.27023 - 0.70425\ _{Z20} + 0.23411\ Z_{121}$	0.56
45 to 3	$Y = 5.278 + 0.0013\ Z_{140} + 0.0708\ Z_{121} + 0.0316\ Z_{141}$	0.70
45 to 4	$Y = -2.755 + 0.00097\ Z_{140} + 0.0829\ Z_{121} + 0.028\ Z_{141}$	0.76

Table 4 Prediction and forecasts – Quantitative model

Year	% pod damage (obs)	Prediction	Forecast	% Deviation from observed
1987	22.1	24.64	25.01	13.2
1988	21.2	21.50	23.68	11.7
1989	20.0	19.01	19.11	4.5
1990	20.2	21.91	21.66	7.2
1991	24.6	20.77	21.31	13.4
1992	21.6	26.48	26.53	22.8
1993	10.0	20.72	19.90	99.0
1994	42.5	38.22	40.22	5.4
1995	32.6	27.38	30.34	6.9
1996	35.0	27.86	26.96	23.0
1997	26.9	25.05	24.20	10.0
1998	22.3	24.71	23.31	4.5
1999	10.3	11.75	8.70	15.5
2001	14.0	14.41	12.39	11.5
2002	20.0	26.32	27.66	38.3
2003	18.0	17.79	17.61	2.2
2007	24.7	24.03	21.68	12.2
2008	34.7	22.79	22.51	35.1
2009	34.3	29.55	32.96	3.9
2010	31.7	37.74	37.82	19.3
2011	32.5	36.47	34.27	5.4

MAPE = 17.4

Coefficient of determination (R^2) was 0.52 at 1st smw which increased to 0.76 at 4th smw. Therefore, model at 4th smw was used for forecasting per cent pod damage. In this model, both unweighted and weighted indices of interaction of max. temperature and evening relative humidity and weighted index of interaction of max. and min. temperature were found important. Forecast for subsequent years (not included for model development) using data upto 4th smw were 38.18 and 35.1 against observed values 31.7 and 32.5 for the years 2010-11 and 2011-12 respectively.

For studying the stability of the model, models were fitted by deleting each observation one by one and forecasts for deleted observation was obtained. Predictions (using model based on complete data) and forecasts (based on model using data excluding year of forecast) are given in Table 4.

The results indicate that for most of the years, per cent deviation of forecasts from observed was low (below 20%). MAPE of forecast was obtained as 17.4 which is quite reasonable for quantitative forewarning of the pest. Predictions and forecasts are in close agreement indicating the stability of the model.

CONCLUSION

Reliable quantitative forecasts for per cent damage due to pod fly in late pigeon pea at Kanpur can be obtained at 4th smw using data on maximum temperature, minimum temperature and evening relative humidity. Over all epidemic status (qualitative forewarning) can be provided at first smw using data on max. temperature and evening relative humidity.

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