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FOREWARNING THE INFESTATION OF LEAF ROLLER (*DIAPHANIA PULVERULENTALIS* HAMPSON) IN MULBERRY (*MORUS SPS.*) GARDENS OF TUMKUR DISTRICT (KARNATAKA)

Hemalatha[1] and I. K. Pai[2]
[1] Department of Sericulture, Sri Siddhartha First Grade College, Tumkur – 572105, Karnataka, India.
[2]Department of Zoology, Goa University, Goa-403 206.

This paper presents a novel approach to mulberry crop protection. Linear and multiple regression models were fitted to predict and forecast the extent of infestation by leaf roller (*Diaphania pulverulentalis* H.) on mulberry under the prevailing weather conditions. A systematic survey for periodical recording of Percentage of Pest Incidence (PPI), pest population and crop loss caused by the pest was done for two consecutive years (September 2002 to August 2004), in 68 mulberry plots of Tumkur district (Karnataka). All the three parameters were maximum in winter season. The recorded data served as the basis for regression studies. Optimum regression model indicated the strong influence of maximum temperature, minimum temperature and relative humidity on PPI (R^2 = 91.1%) and pest population (R^2 = 73.6%). The linear regression implied a strong positive association (R^2 = 81%) between pest population and PPI. Both PPI and population density had significant negative correlation with maximum temperature ($r = -0.69$ and $r = -0.89$ respectively). Leaf yield loss had significant positive correlation with PPI ($r = 0.90$) and pest population ($r = 0.89$). The forecast model can be used to predict the initiation and 'red alert' season of the pest attack. This serves as a scale for the farmers to adopt effective crop protection measures at appropriate time.

It is almost a dream for the farmer to be well informed about the possible intensity of pest infestation under the agroclimatic conditions of his mulberry field. When this dream is realized it would be a boon for him, since prevention of crop loss due to pest attack can be assured, by adopting suitable crop protection measures. At times, the farmers are forced to either decrease the area under mulberry cultivation or even uproot mulberry due to the problems posed by the pest complex[1]. The leaf roller (*Diaphania pulverulentalis* H.), a lepidopteran insect, like silkworm *Bombyx mori*, feeds voraciously on mulberry foliage, decreasing the leaf yield. Though reported a decade back from Karnataka[2], the insect has rapidly spread to the adjoining states assuming the status of a major pest. Young larvae of the pest web the tender leaves by exuding white delicate silky secretion and stay within it. The larva is observed to hide within the rolled leaves and hence it is known as 'leaf roller' (Plate, 1.). The early instar larvae scrap and feed on the soft green tissue of tender leaves (Plate, 2.), making them unfit for rearing the young delicate 'chawki' silkworms. The late age larvae devour the whole leaves and thereby the attack of *D. pulverulentalis* hinders the success of silkworm rearing. The pest has assumed great significance, because of the fact that it also serves as an alternate host for the most dreaded diseases of silkworm like pebrine (*Nosema bombycis*) and white muscardine (*Beauveria bassiana*)[1,3]. This cautions the danger of infested leaves being contaminated with spores of the pathogens either through their excreta or the exuded silky filaments.

Considering above facts, prevention of this polyphagous pest gains utmost importance in protection of mulberry crop and in turn, the silk cocoon crop yield. Regression models were fitted to forecast the extent of pest infestation in farmers' fields, under a set of prevailing weather factors to combat the injuries caused by this pest.

An extensive field survey was done during September 2002 to August 2004 in mulberry (Kanva-2 variety) gardens of Tumkur district (Karnataka) to fulfill the needed database for regression studies. Seasonal variations in PPI, pest population and crop loss caused were recorded in the study period. Tumkur District lies in central southern zone of Karnataka and is a traditional sericulture belt with multivoltine seed area. It is one of the six potential districts of the state selected for strengthening bivoltine sericulture under Japan International Cooperation Agency (JICA) project.

MATERIAL AND METHODS

The survey was carried out in 17 villages of Tumkur district, representing all the ten taluks. Four farmers' fields were randomly selected in each village, thus making a total sample size of 68 plots. The PPI and pest population were recorded periodically at monthly intervals. The selected villages were 25 - 40 km apart from each other, to avoid the possibilities of pest migration / pest dominance under the identical climatic conditions. Survey was carried out by "fixed plot method"[4,5]. The minimum area of the selected gardens was not less than ½ an acre. In every selected garden, five microplots of equal size were fixed in the four corners ten meters away from the border and one in the centre of the garden. Ten mulberry plants were randomly selected in each microplot for recording observations on pest infestation (10 x 5 = 50 plants / garden). Thus, the total sample size studied was 200 plants / village (4 gardens x 50 plants). The plots selected for the study were kept free from insecticidal spray during the period of observation. The number of pest infested plants was noted at the time of observation based on the symptoms of pest attack.

The Percentage of Pest Incidence (PPI) was calculated by using the following formula [5].

$$\text{Pest Incidence (\%) (PPI)} = \frac{\text{Number of pest infested plants}}{\text{Total number of plants observed}} \times 100$$

To assess the pest population, ten infested plants were randomly selected for observation, from all the five microplots in each garden. The infested apical shoots were cut from the selected plants and brought to the laboratory in pre-labeled polythene covers. The number of larvae present in the damaged shoots was counted to assess the pest population. The late age larvae feeding on leaves, on stalks and nodes were also considered for the pest count. Meteorological data was recorded periodically and correlation analysis was carried out by standard method to study the influence of weather factors on intensity of infestation and pest population.

The impact of pest infestation was recorded by assessing the leaf yield loss[1]. In each village, two irrigated mulberry plots of almost identical size with similar type of soil and variety of mulberry were chosen. Minimum distance possible was maintained between the plots to ensure similar environmental conditions. However, sufficient buffer area was also maintained between the plots to avoid interplot interference. Among the two selected plots, one was maintained as protected plot, by spraying suitable insecticide in appropriate concentration as per the recommended schedule. The other plot was kept unprotected without taking any preventive or control measures. Similar schedule of agronomical practices and inputs was followed in both the plots. Total leaf yield per plot was recorded separately for protected and unprotected plots. The percentage of leaf yield loss caused by the insect pest was calculated based on Mckinley and Geering formula[6].

$$\text{Leaf yield loss (\%)} = \frac{Y_{PC}-Y_{NPC}}{Y_{PC}} \times 100$$

Where, Y_{PC}= Yield in plots treated for pest control and Y_{NPC} = Yield in plots not treated for pest control.

Linear and multiple regression models as indicated below were fitted in all possible combinations between the dependent variables (PPI, pest population) and the independent variables (weather factors), to assess the extent of association of different independent variables with the dependent variable, using the standard method.

$$y = a+bx+^{a}$$

and $$y = a+b_1x_1 + b_2x_2 + b_3x_3 + \dots \dots \dots \dots + b_nx_n + ^{a},$$

Where, y represents dependent variable, a = constant / intercept, b_n = regression coefficient, x_n = independent variable, ^{a} = error term.

The best suited regression equations were identified using the Montgomery and Peck method[7]. The combinations considered for the regression models were as follows:-

After fitting the regression models for both sets of combinations, based on the indications obtained from correlation coefficients, a few were selected as best fit depending on R^2 the coefficient of multiple determination,

	Independent variables	Dependent variables
Set – I	Rainfall (x_1)	PPI (Y)
	Max. temperature (x_2)	
	Min. temperature (x_3)	
	Relative Humidity (x_4)	
Set – II	Max. temperature (t_1)	Pest population (y)
	Min. temperature (t_2)	
	Rainfall (t_3)	
	Relative Humidity (t_4)	

which is a measure of adequacy of the regression model that is widely used. Models with large R^2 values are often preferred. It may be noted that, the R^2 keeps increasing progressively with addition of new variables in the regression model. However, a point may be reached when R^2 has an incremental value, but regression may not contribute significantly. Thus, a different measure called adjusted R^2 was used. The optimum model was the one with maximum adjusted R^2. This criterion was mainly applied to the multiple regression models in the present work.

RESULTS AND DISCUSSION

The observations of the present study revealed that, infestation by leaf roller – *D.pulverulentalis* was severe in winter, moderate in rainy and very low in summer season. On an average, the PPI was maximum (22.21 %) in the month of November (Fig. 1) with higher pest population (5.46 larvae/plant). During the rainy months, the PPI ranged from 9.91 % to 16.22 %. The corresponding pest population was also moderate (1.06 larvae/plant to 1.73 larvae/plant). During April - May months, both PPI and pest population were negligible (0.16 % - 0.31 % and 0.79 larvae/plant – 0.13 larvae/plant respectively). Maximum temperature had a strong negative influence on the severity of infestation (r = -0.89) (Table.1). Maximum leaf yield loss due to leaf roller infestation was recorded in the winter crop and negligible crop loss was noted in the summer leaf harvest. Leaf yield loss had significant positive correlation with PPI (r = 0.89) and pest population (r = 0.89) (Table. 2).

Regression equations for per cent incidence (PPI) of the leaf roller

Predictors	Regression model	R^2%	adj. R^2%	SE
RF (x_1)	$Y = 10.1 + 0.016x_1$	1.0	0.10	8.25
Max. Temp. (x_2)	$Y = 94.5 - 2.71\ x_2$	78.4	76.20	3.85
Min. Temp. (x_3)	$Y = 26.4 - 0.92\ x_3$	10.3	1.30	7.86
RH (%) (x_4)	$Y = 37.2 + 0.649\ x_4$	15.3	6.80	7.63
Max. Temp., Min. Temp. RH(%)	$\mathbf{Y = 39.5 - 1.875x_2 - 1.67x_3 + 0.773x_4}$	**91.1**	**87.8**	**2.77**
All	$Y = 44.3 + 0.016x_1 - 1.85x_2 - 1.80x_3 + 0.72x_4$	91.5	86.6	2.89

Note: The optimum model is indicated in bold.

Where, Y = Percentage of Pest Incidence (PPI), RF = Rainfall

x_1= rainfall, x_2 = maximum temperature, x_3 = minimum temperature, x_4 = relative humidity,

R^2 = Coefficient of determination, adj. R^2= Decision factor of coefficient of determination.

SE = Standard Error of the estimate, RH = Relative Humidity

The optimum regression model indicated the strong negative influence of maximum temperature and positive influence of relative humidity on incidence of leaf roller (R^2 = 91.1 %). The best fitted multiple regression equation for population of *D.pulverulentalis* inferred that all four variables viz., maximum temperature, minimum temperature, rainfall and relative humidity had their specific influence (R^2 = 73.6 %). The linear regression indicated

Linear regression equation for population of leaf roller

Dependent variable (y)	Independent variable (x)	Linear Regression model	r	R^2%	SE
PPI	Pest Population	$Y = 4.37 + 2.42x$	0.90	81	3.62

Where, r = Coefficient of correlation, R^2 = Coefficient of determination.
SE = Standard Error of the estimate, PPI = Percentage of Pest Incidence.

Multiple regression equations for population of the leaf roller

Regression models	R^2%	adj. R^2%	SE
$\mathbf{y = 0.863 - 0.295\, t_1 - 0.976\, t_2 - 0.023\, t_3 - 0.355 t_4}$	**73.6**	**58.5**	**1.90**
$y = -5.888 - 0.31 t_1 - 0.79 t_2 + 0.434\, t_4$	67.7	55.6	1.96
$y = 31.09 - 0.618\, t_1 - 0.642\, t_3 + 0.03$	65.4	52.4	2.03
$y = -25.22 - 1.005\, t_2 + 0.606\, t_4$	63.8	55.8	1.96
$y = 31.05 - 0.771\, t_1 - 0.273\, t_2$	54.5	44.4	2.20

Note: Optimum model is indicated in bold.

Where, y = pest population, t_1 = Maximum temperature, t_2 = Minimum temperature, t_3 = Rainfall, t_4 = Relative humidity, R^2 = Coefficient of determination, adj. R^2 = Decision factor of coefficient of determination, SE = Standard Error of the estimate.

an R^2 value of 81 % showing strong positive association between pest population and PPI.

The outcome of the present observations is in co-ordination with the earlier report[8], as per which the leaf roller infestation declined when the ambient temperature increased in the months of study. Incidence of leaf roller in June which persisted upto February and disappeared from March to May[9]. Severe infestation during north-east monsoon and winter was also noticed[10]. They observed the number of caterpillars to increase from September (1.65larvae/plant with 70 % pest incidence) to October and November (22.30 larvae / plant and 16.60 larvae / plant respectively) when the incidence was 100 %. Higher number of larvae per plant (5.40 larvae / plant with 22.2% pest incidence) was noticed in the present study. This might be due to the presence of shady trees / coconut trees, areca plantations, with food crops like paddy, vegetables etc., as surrounding crops in and around the surveyed mulberry plots, which prevented direct sunlight and might have increased the relative humidity causing reduction in the atmospheric temperature, keeping mulberry leaves succulent with optimum moisture content,

Table- 1. Correlation coefficients among PPI, pest population and weather factors

Variables	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative humidity (%)	Rainfall (mm)	PPI
PPI	– 0.88**	– 0.32	0.39	0.10	
Pest Population	– 0.69*	– 0.30	0.36	0.19	0.90**

Note : ** Highly significant. ($P<0.01$), * Significant ($P<0.05$)

Table- 2. Seasonal variation in the leaf yield loss (LYL %) due

Season	Leaf yield loss (%)	PPI	Pest popln.
Rainy (Jul – Oct)	3.84	15.01	3.85
Winter(Nov–Feb)	7.39	15.74	4.00
Summer (Mar - Jun)	0.01	1.90	0.24
Correlation coefficients			
	Leaf yield loss (%)	**PPI**	**Pest popln.**
Leaf yield loss (%)	1.00		
Pest incidence (%)	0.89 **	1.00	
Pest population	0.89 **	0.99	1.00

Note : ** = Highly significant ($P<0.01$), PPI = Percentage of Pest Incidence, popln. = population.

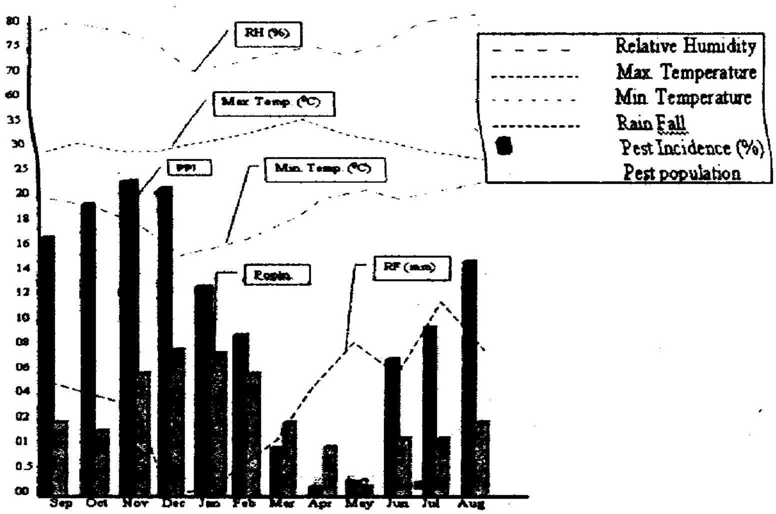

Fig. 1. **Incidence (%) and population of leaf roller in relation to weather factors during September 2002 to August 2004.**

along with providing congenial environment for pest multiplication and spread. The same conditions might have influenced the continuous pest prevalence throughout the period of survey. Similar observations were also made on location specific variation in leaf roller incidence[11]. They noticed higher incidence of *D. pulverulentalis* in mulberry gardens with coconut trees and surrounding paddy fields, which increased relative humidity and decreased the intensity of direct sunlight in mulberry ecosystem. Peak pest incidence (12.12%) in November with 13.00 larvae / 10 plants and least (0.04 larvae / 10 plants) was observed during March[12]. It was also observed that the pest infestation to start soon after the commencement of south west monsoon during June – July which reached maximum in winter followed by gradual decrease in summer[13]. The leaf yield loss caused by leaf roller was 12.8% with average pest incidence of 27.85% in Karnataka[14]. The pest caused 66% reduction of leaf yield in M_5 variety of mulberry[15]. The leaf yield loss due to roller caused was reported to the extent of 12.18% mainly in southern states of India[16]. Highest level of leaf roller infestation, with corresponding leaf yield loss of 12.7% in December[13]. The present findings are in conformity with the earlier observations[13,14,16-19].

The best suited regression equations had the support of R^2 – the coefficient of determination, which indicated that, the variables considered in the model could explain the variability in percentage incidence of pests / pest population to an extent of the R^2 value obtained. It was further meant that, about 70 -90% of the variability in the models was explained by the variables considered, as indicated in the set of models for each parameter. Indirectly it also implied that, the models were reliable to the extent of the value of R^2 represented. It was also observed that, there was a very close similarity between the equations and R^2 obtained for PPI as dependent variable and population as the dependent variable in association with the weather factors. Further, the association of PPI and pest population as represented by the linear regression models revealed that, there was a very strong positive relationship between the two variables. Based on the above explanation it could be stated that, the best fit regression models with highest R^2 value, serve as the forecast model for the estimation of PPI and pest population using the data of the independent variables (weather factors). The prediction models framed in the present study; work out efficiently under similar conditions of the database considered for their construction. The same can be used for forewarning the farmers about the appearance and peak period (red alert period) of pest attack, so that effective plant protection measures can be adopted at right time to enhance the quality and yield of mulberry leaves.

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