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Impact of weather and crop phenology on the incidence of red banded mango caterpillar, *Deanolis sublimbalis* Snellen (Lepidoptera: Crambidae)

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ABSTRACT: Red Banded Mango Caterpillar (RBMC) is a serious pest of mango in several mango growing regions of South and South-East Asia. Efficient and timely management of RBMC can be possible through the knowledge of predicting the time of pest attack in relation to crop phenology and the prevalent weather factors as this mainly feeds on fruits. In general, the forewarning models enable the prediction of pest occurrence well in advance allowing the growers to take timely action in an efficient manner. The current study prospected the scope of host plant phenological parameters along with the abiotic factors to predict the accurate incidence of RBMC during mango fruiting period. The variables *viz*., crop phenology [flowering, fruiting (moong size, pea size, marble size, lime size, fist size, >fist size, before nut formation, after nut formation), morning relative humidity, minimum temperature were found to be reliable indicators for predicting the RBMC incidence with significant coefficient of determination (*R2*= 0.80) over other variables. The weather and crop phonological stage based forecasting model in RBMC would facilitate timely spray interventions.

Keywords: *Deanolis sublimabalis*, Mango, Population dynamics

INTRODUCTION

Mango fruit borer, *Deanolis sublimbalis* Snellen (Lepidoptera: Crambidae) commonly referred as Red Banded Mango Caterpillar (RBMC) is a serious pest in major mango growing regions of South and South-East Asia *viz.,* India, Indonesia, Papua New Guinea, Burma, Thailand, China, Brunei, Philippines, parts of Australia (Senguptha and Behura, 1955; Tipon, 1979; Kalshoven, 1981; Golez, 1991; Jha and Sarkar, 1991; Zaheruddeen and Sujatha, 1993; Waterhouse, 1998; Krull, 2004; Pinese, 2005 and Tenakanai *et al.,* 2006). In India, the research studies carried out to date in this pest mainly revolve around its biology as well as management strategies and no information is available on forecasting the incidence and severity of this monophagous insect pest well in advance to provide pest alerts to farmers to strategize the management modules. Forecasting of the pest incidence with as much accuracy as possible well in advance and describing the pest population dynamics precisely enable better management of RBMC, thus minimizing the yield loss caused by this frugivorous pest.

Weather is an important determinant in the population dynamics of the insect pests (Chen *et al.,* 1968; Heong *et al.,* 2007 and Siswanto *et al.,* 2008). The knowledge on the relationship between insect pests and abiotic factors is crucial in devising an effective integrated pest management program for any insect pest. Most of the prediction models developed for forecasting insect pest outbreaks are based on weather and/or crop phenology parameters. Earlier workers have utilized regression models (both linear and non-linear) to decipher the relationship between weather/ crop phenology and insect pest occurrence (Kamala Jayanthi and Verghese, 2011 and Prasannakumar *et al.,* 2015). A weather and crop phenology based model can be an effective scientific tool to thwart the impending attack of a pest by forewarning so that timely plant protection measures can be taken up. Hence, an attempt was made to study the feasibility of developing forecast models for RBMC using weather/ crop phenology variables.

MATERIALS AND METHODS

Field sites

The study was conducted in the orchards of *Mangifera indica* L. at Digavalli village of Krishna district (cv. Chinnarasam; 16°78'N; 77°35'E), Naguluru village of Krishna district (cv. Totapuri;15°55'N; 81°10'E), and Prakasaraopalem village of West Godavari district (cv. Totapuri;16°91'N; 81°43'E), Andhra Pradesh, India during the period of January 2016- May 2017. In all orchards, trees were of >30 years of age during the study period. The area of the experimental plot in each

Table 1: Step-wise linear models to estimate *D. sublimbalis* damage using weather variables.

Variables considered	Correlation Coefficient (*r*)	Model	R^2	VIF	Adjusted R^2
x_1	0.63**	$-66.86+2.47x_1$	0.40	1.67	0.37
x_2	0.66**	$-53.00+3.36x_2$	0.43	1.75	0.40
x_3	-0.85**	$165.69-1.74x_3$	0.73	3.70	0.71
x_4	-0.64**	$63.64-1.32x_4$	0.41	1.70	0.38
x_5	NS	$15.00+0.05x_5$	-	-	-
x_1+x_2	-	$-62.37+0.95x_1+2.27x_2$	0.44	1.79	0.38
x_1+x_3	-	$188.61-0.34x_1-1.87x_3$	0.73	3.70	0.70
x_1+x_4	-	$9.18+1.07x_1-0.81x_4$	0.42	1.72	0.36
x_1+x_5	-	$-70.85+2.58x_1+3.50x_5$	0.42	1.72	0.35
x_2+x_3	-	$159.25+0.14x_2-1.70x_3$	0.73	3.70	0.70
x_2+x_4	-	$0.50+2.11x_2-0.77x_4$	0.51	2.04	0.46
x_2+x_5	-	$-53.88+3.39x_2+1.70x_5$	0.43	1.75	0.37
x_3+x_4	-	$169.36-1.83x_3+0.12x_4$	0.73	3.70	0.70
x_3+x_5	-	$168.02-1.77x_3+3.03x_5$	0.74	3.85	0.71
x_4+x_5	-	$68.37-1.47x_4+5.93x_5$	0.46	1.85	0.40
$x_1+x_2+x_3$	-	$181.88-0.82x_1+0.86x_2-1.8x_3$	0.74	3.85	0.69
$x_1+x_2+x_4$	-	$225.72-7.20x_1+6.78x_2-2.97x_4$	0.63	2.70	0.57
$x_1+x_2+x_5$	-	$-65.70+1.15x_1+2.09x_2+2.60x_5$	0.45	1.82	0.40
$x_2+x_3+x_4$	-	$160.87+0.19x_2-1.78x_3+0.14x_4$	0.73	3.70	0.68
$x_2+x_3+x_5$	-	$161.82+0.13x_2-1.73x_3+3.03x_5$	0.74	3.85	0.70
$x_2+x_4+x_5$	-	$9.74+1.92x_2-0.93x_4+4.72x_5$	0.54	2.17	0.46
$x_3+x_4+x_5$	-	$167.73-1.76x_3-0.01x_4+3.06x_5$	0.74	3.85	0.70
$x_1+x_2+x_3+x_4$	-	$240.53-3.42x_1+2.73x_2-1.48x_3-1.06x_4$	0.75	4.00	0.69
$x_1+x_2+x_3+x_5$	-	$178.54-0.62x_1+0.68x_2-1.81x_3+2.60x_5$	0.75	4.00	0.68
$x_1+x_2+x_4+x_5$	-	$263.56-8.00x_1+7.05x_2-3.45x_4+6.53x_5$	0.69	3.23	0.61
$x_2+x_3+x_4+x_5$	-	$161.82+0.13x_2-1.73x_3+0.00x_4+3.03x_5$	0.74	3.85	0.68
$x_1+x_2+x_3+x_4+x_5$	-	$264.50-4.38x_1+3.37x_2-1.32x_3-1.60x_4+4.42x_5$	0.77	4.35	0.70

Max. temp. (x_1), Min. temp. (x_2), Relative humidity morning hours (x_3), Relative humidity evening hours (x_4), Rainfall(x_5); ** Significant at $P = 0.01$, NS= Non-significant.

study village was 1.5 ha, 2 ha and 6 ha with a total plant population of 150, 200, 600 mango plants planted with a spacing of 10×10 m spacing in Digavalli, Naguluru, Prakasaraopalem, respectively.

Data collection

A total number of five unsprayed trees from each location were selected randomly to observe the incidence of *D. sublimbalis*. In each tree, data collection on the number of RBMC damaged fruits and number of total fruits was carried out in all four directions (east, west, north and south). In each direction, three branches were selected randomly for calculation of extent of fruits damaged at weekly intervals. Mean percentage of fruits damaged per tree was worked out.

Field observations on the host-plant phenology parameters *viz.,* flowering, fruiting [moong size, pea size, marble size, lime size, fist size, >fist size, before nut formation, after nut formation] were recorded by thoroughly inspecting each tree (n = 5) canopy randomly for availability of the above phenological stages. All variables were visually scored on percent basis (0-100) on as mentioned above. The contemporaneous data on daily weather parameters were collected from the meteorological section of Mango Research Station, Nuzvid (16°78'N; 80°84'E) and College of Horticulture, Venkataramannagudem, Andhra Pradesh (17°40'N; 78°48'E) that were proximal to the respective study areas and the weekly means of the weather variables [maximum (x_1) and minimum temperatures (x_2) (^{o}C); morning (x_3) and evening (x_4) relative humidity (%); rainfall (mm), x_5] were also calculated.

Forewarning model

To develop a forewarning model for *D. sublimbalis*, the data were subjected to correlation as well as regression analyses, with RBMC fruit damage (%) as the dependent variable and weather as well as crop phenology variables as independent factors. Significant ($P = 0.05$) correlation coefficient (r) values were taken as a criterion to select suitable factor(s) for developing series of step-wise regression models to achieve a maximum coefficient of determination (R^2) for predicting the RBMC damage (%). The model accuracy was confirmed by the value of the coefficient of determination (R^2).

The Variance Inflation Factor (VIF) that estimates the extent of multicollinearity was calculated to measure the correlated increase in the variance of the estimated regressio\n coefficient because of collinearity among the variables.

RESULTS AND DISCUSSION

Among the weather variables studied, the *D. sublimbalis* damage showed a positive relationship with the both minimum ($r = 0.66$**, $P = 0.01$) and maximum temperatures ($r = 0.63$**, $P = 0.01$).

However, morning relative humidity ($r = -0.85$**, $P = 0.01$) and evening relative humidity ($r = -0.64$**, $P = 0.01$) showed a negative relationship with the damage. Further, correlation between rainfall and RBMC damage was not significant (Table 1).

Crop phenology ($r = 0.86$**, $P = 0.01$) showed a highly significant and positive relationship with damage of RBMC (Table 2). These results indicated that temperature (both maximum and minimum), relative humidity (both morning and evening hours) along with crop phenology were found to be significant factors that influence the incidence of RBMC.

Weather variables

The linear models developed considering each weather variable independently explained the variability in the RBMC damage up to 40, 43, 73 and 41 percent with the maximum temperature, minimum temperature, morning relative humidity and evening relative humidity respectively. The VIF values computed for these variables were in agreement with the acceptable limit (< 10.0) (Table 1).

The step-wise regression models involving weather parameters could improve the R^2 value from 0.40 to 0.75. However, the regression model considering all weather variables (maximum temperature (^{o}C), x_1; minimum temperature (^{o}C), x_2; morning relative humidity (%), x_3; evening relative humidity (%), x_4; rainfall (mm); x_5) explained 77 percent variability in the RBMC damage (Table 1).

Crop phenology

The linear regression models using crop phenology (x_6) alone could explain the variability in the fruit borer damage to the tune of 75 per cent. The VIF value computed for this model was in agreement with the acceptable limit (< 10.0) (Table 2).

Combining weather parameters and crop phenology

The step-wise regression models involving all weather parameters and crop phenology explained the RBMC fruit damage variability in the range of 40 per cent to 82 per cent with the acceptable VIF value (Table 2).

The regression model combining all weather parameters and crop phenology could explain the

Table 2: Step-wise linear models to estimate *D. sublimbalis* damage using crop phenology and weather variables.

Variables considered	Correlation coefficient (*r*)	Model	R^2	VIF	Adjusted R^2
x_6	0.86**	$-6.49+4.42x_6$	0.75	4.00	0.73
x_6+x_1	-	$20.89+5.45x_6-0.98x_1$	0.40	1.67	0.74
x_6+x_2	-	$25.47+6.15x_6-1.99x_2$	0.77	4.35	0.76
x_6+x_3	-	$70.64+2.61x_6-0.79x_3$	0.78	4.55	0.75
x_6+x_4	-	$-6.79+4.43x_6+0.01x_4$	0.75	4.00	0.72
x_6+x_5	-	$-6.82+4.44x_6+1.68x_5$	0.75	4.00	0.72
$x_6+x_1+x_2$	-	$29.97+6.25x_6-0.32x_1-1.72x_2$	0.78	4.55	0.75
$x_6+x_1+x_3$	-	$111.46+3.60x_6-1.13x_1-0.88x_3$	0.80	5.00	0.76
$x_6+x_1+x_4$	-	$100.17+5.49x_6-2.44x_1-0.84x_4$	0.79	4.76	0.76
$x_6+x_1+x_5$	-	$19.25+5.43x_6-0.93x_1+0.80x_5$	0.77	4.35	0.73
$x_6+x_2+x_3$	-	$83.01+4.49x_6-1.74x_2-0.63x_3$	0.80	5.00	0.76
$x_6+x_2+x_4$	-	$25.92+6.13x_6-1.99x_2-0.01x_4$	0.78	4.55	0.75
$x_6+x_2+x_5$	-	$24.63+6.13x_6-1.96x_2+1.35x_5$	0.78	4.55	0.75
$x_6+x_3+x_4$	-	$73.25+2.72x_6-0.92x_3+1.35x_4$	0.77	4.35	0.74
$x_6+x_3+x_5$	-	$77.50+2.48x_6-0.86x_3+2.41x_5$	0.78	4.55	0.74
$x_6+x_4+x_5$	-	$-2.96+4.29x_6-0.09x_4+1.96x_5$	0.75	4.00	0.71
$x_6+x_1+x_2+x_3$	-	$102.95+4.41x_6-0.67x_1-1.12x_2-0.74x_3$	0.80	5.00	0.76
$x_6+x_1+x_2+x_4$	-	$105.13+5.40x_6-2.63x_1-0.20x_2-0.90x_4$	0.79	4.76	0.75
$x_6+x_1+x_2+x_5$	-	$27.85+6.21x_6-0.22x_1-1.76x_2+1.17x_5$	0.79	4.76	0.73
$x_6+x_2+x_3+x_4$	-	$84.55+4.51x_6-1.69x_2-0.73x_3+0.16x_4$	0.80	5.00	0.75
$x_6+x_2+x_3+x_5$	-	$88.09+4.29x_6-1.66x_2-0.69x_3+1.99x_5$	0.80	5.00	0.76
$x_6+x_2+x_4+x_5$	-	$28.50+5.98x_6-1.96x_2-0.08x_4+1.63x_5$	0.79	4.76	0.73
$x_6+x_3+x_4+x_5$	-	$77.96+2.55x_6-0.92x_3+0.11x_4+2.06x_5$	0.78	4.55	0.73
$x_6+x_1+x_2+x_3+x_4$	-	$139.12+4.16x_6-2.08x_1+0.01x_2-0.63x_3-0.57x_4$	0.81	5.26	0.75
$x_6+x_1+x_2+x_3+x_5$	-	$103.52+4.26x_6-0.55x_1-1.16x_2-0.78x_3+1.62x_5$	0.81	5.26	0.75
$x_6+x_1+x_2+x_4+x_5$	-	$133.11+4.91x_6-3.41x_1+0.92x_2-1.31x_4+2.95x_5$	0.80	5.00	0.74
$x_6+x_2+x_3+x_4+x_5$	-	$88.29+4.33x_6-1.65x_2-0.74x_3+0.08x_4+1.76x_5$	0.80	5.00	0.74
$x_6+x_1+x_2+x_3+x_4+x_5$	-	$165.09+3.73x_6-2.84x_1+0.70x_2-0.61x_3-0.97x_4+2.84x_5$	0.82	5.56	0.75

Max. temp. (x_1), Min. temp. (x_2), Relative humidity morning hours (x_3), Relative humidity evening hours (x_4), Rainfall (x_5), Crop phenology (x_6); ** Significant at $P = 0.01$.

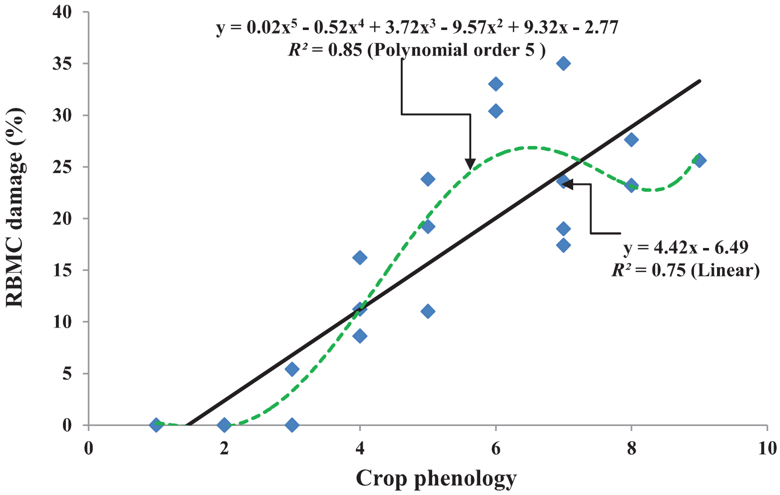

Fig. 1: Relationship between the crop phenology and *D. sublimbalis* damage

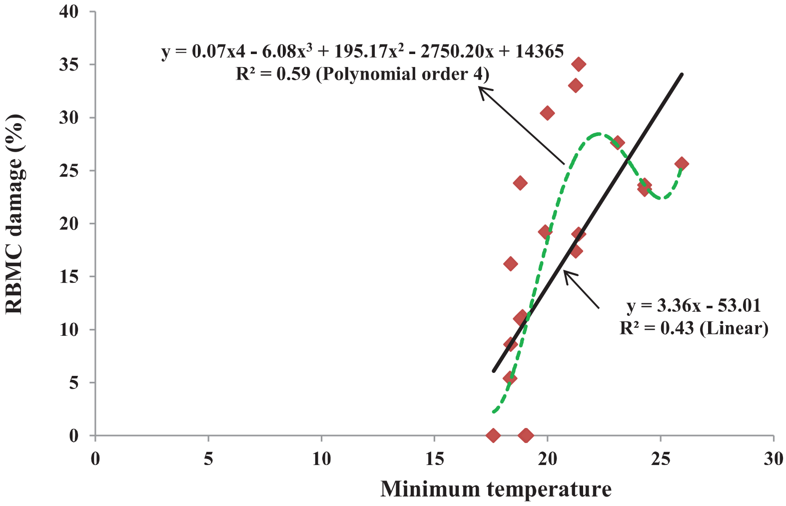

Fig. 2: Relationship between the minimum temperature and *D. sublimbalis* damage

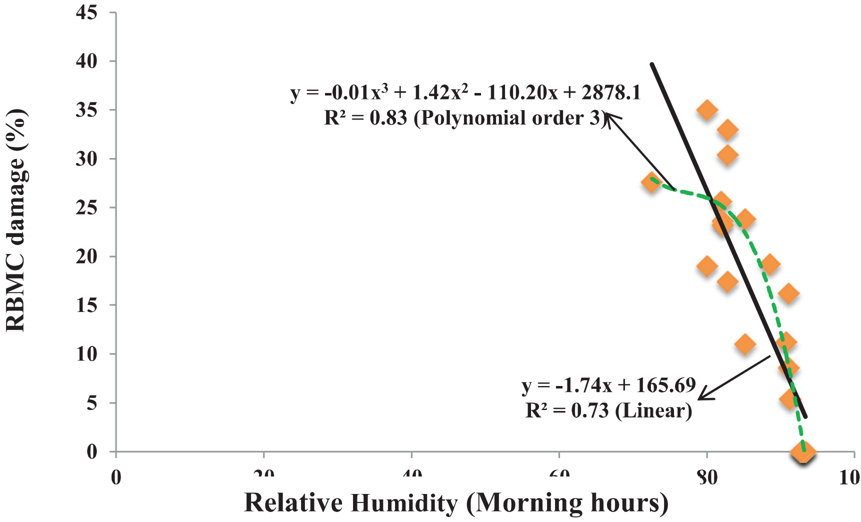

Fig. 3: Relationship between the morning RH and *D. sublimbalis* damage

variability in the RBMC damage to the tune of 82 percent. Though, incorporation of both weather parameters and crop phenology in to the linear regression model explained the 82 percent variability in the damage of RBMC, the linear regression model based on all-weather variables alone could explain the variability to the tune of 77 percent. However, it was clear that the coefficient of determination (R^2) in all model combinations was influenced by only two individual parameters *viz.,* morning relative humidity (73%), crop phenology (75%) (Table 1 and 2).

Polynomial models with crop phenology increased the coefficient of determination from 75 percent (Linear model) to 85 percent with a 3rd order. However, the coefficient of determination could not be improved beyond 85 percent (R^2 =0.8241, 0.8378, 0.8382, 0.8516 with an order (2), (4), (5), (6) respectively) with different polynomial orders (Fig. 1).

In the case of minimum temperature, the polynomial models increased the coefficient of determination to 59 percent (43% with linear model) with 4thorder. However, the coefficient of determination could not be effectively improved beyond 62% [R^2=0.5632, 0.5632, 0.5977 and 0.6152 for polynomial model orders (2), (3), (5), (6) respectively] (Fig. 2).

In the case of morning relative humidity, the polynomial model order (5) increased the R^2 to the tune of 85 percent when compared to 73 percent with a linear model. However, the other polynomial orders could improve the R^2 to the tune of 0.7987, 0.8216, 0.8415 and 0.8531with an order (2), (3), (4) and (6) respectively (Fig. 3).

Plotting the residuals of RBMC damage (%) using the minimum temperature, morning relative humidity and crop phenology as the independent variables showed a random dispersal of points across x-axis explaining the good-fit of the linear model (Fig. 4, 5 and 6). Since, the aim of the optimized model was to predict the *D. sublimbalis* damage using a minimum number of variables and with a reasonable R^2 value, the following model was optimized [$y = 83.01+4.49x_6-1.74x_2-0.63x_3$ (R^2=0.80)] with three variables *viz.,* minimum temperature, morning relative humidity, crop phenology over six variables *viz.,* maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall and crop phenology that were used in actual model [$y = 165.09+3.73x_6-2.84x_1+0.70x_2-0.61x_3-0.97x_4+2.84x_5$ (R^2=0.82)]. The VIF value (5.00) computed for the optimized model was <10.0 indicating the lack of multicollinearity as per Kutner *et al.* (2004).

In order to establish sustainable pest management strategies, it is essential to know the percentage of damage in different standard weeks of cropping season and its relationship with various climatic factors. The fruit damage (%) by *D. sublimbalis* followed a similar trend in both the years. The mango fruit damage (%) by *D. sublimbalis* in different standard meteorological weeks during the study period indicated that highest RBMC damage was noticed during March-April with an extent of 35 percent (Table 3 and 4). Similarly, Sujatha and Zaheruddeen (2005) reported that the pest was found to be active from February to May. Sahoo and Das (2004) also revealed that the congenial period for the mango fruit borer, *D. albizonalis* occurrence is between April-May and reported an infestation of 4 to 42 percent during these months.

Among the weather variables studied, maximum temperature (x_1) and minimum temperature (x_2) showed a significant positive relationship with RBMC damage whereas morning relative humidity and evening relative humidity exhibited a significant negative relationship. However, rainfall did not show any influence on the borer infestation. As insects are poikilotherms, their development depends on the temperature to which they are exposed in the environment and this has been used as a foundational concept for insect population prediction models (Herms, 2004).

Gundappa *et al.* (2016) revealed that *Orthaga euadrusalis* (Walker) showed significant negative correlation with minimum temperature and a positive correlation with the relative humidity. Vijayaraghavendra and Basavanagoud (2016) reported that sapota fruit borer; *Phycita erythrolophia* Hampson exhibited significant and positive correlation with maximum temperature. Basavaraj *et al.* (2013) divulged that castor capsule shoot and fruit borer, *C. punctiferalis* was negatively correlated with maximum temperature and significantly positively correlated with morning relative humidity and evening relative humidity. Justin and Preetha (2013) revealed that *Scirpophaga incertulas* Walker showed a significant positive correlation with relative humidity and negative correlation with minimum temperature and rainfall.

The linear models developed considering each weather variable independently explained the variability in the RBMC incidence up to 73 percent. Interestingly morning relative humidity alone explained the variability in the fruit borer damage to the tune of 73 percent, and no other weather variable depicted variability beyond 43 percent. However, step-wise regression models of all combinations of weather parameters improved the R^2 up to 77 percent. It is clearly established that morning relative humidity is the only parameter that influenced all other weather variables. Further, a perusal of adjusted

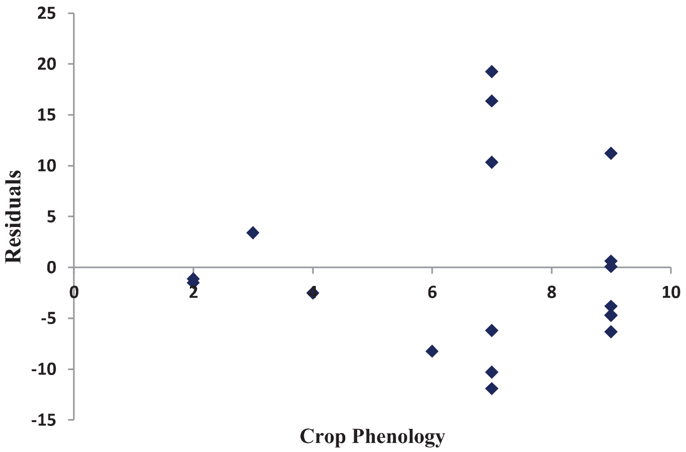

Fig. 4: Plot of the residuals against the crop phenology used as the independent variable

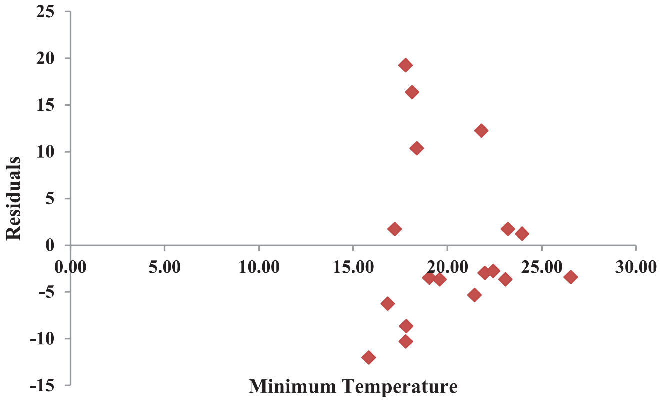

Fig. 5: Plot of the residuals against the minimum temperature used as the independent variable

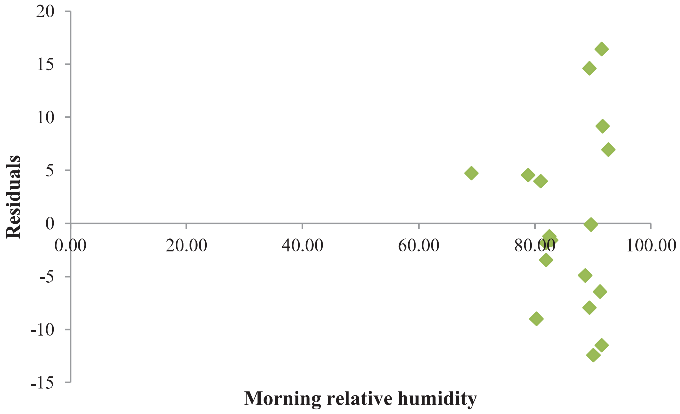

Fig. 6: Plot of the residuals against the morning relative humidity used as the independent variable.

R^2 value revealed that morning relative humidity has a greater impact on the RBMC incidence whereas minimum temperature has limited impact.

The linear regression model developed based on crop phenology exhibited higher accuracy ($R^2 = 0.75$) in predicting the RBMC infestation when compared to weather variables. Incorporation of crop phenology variable along with weather variables tremendously increased the predicted accuracy of RBMC infestation. As reported earlier, synchronous occurrence of specific life stages with host-plant phenology is a basic ecological requisite for many insect species survival (Powell and Logan, 2005). The RBMC being a specific feeder of mango fruits, it has to synchronize its occurrence to suit the seasonal abundance of mango fruits. Previous studies also clearly stated that the plant phenological sequences could be used as reliable indicators for predicting insect activity from year-to-year with greater consistency compared to weather which exhibits a tremendous variation (Herms, 1990 and Mussey and Potter, 1997). However, combining all weather parameters and crop phenology in step-wise regression did not improve the R^2 value over and above the 0.82.

Further, morning relative humidity and crop phenology alone could explain the variability in the RBMC incidence to the tune of 73 and 75 percent respectively. However, combining morning relative humidity, minimum temperature and crop phenology resulted in the coefficient of determination of 0.80. Thus, the parameters *viz*., morning relative humidity, minimum temperature, crop phenology could explain the variability in the occurrence of *D. sublimbalis* more accurately than other parameters.

However, the present study proposes the crop phenology, morning relative humidity and minimum temperature as accurate indicators for predicting the RBMC infestation with more reliability over other parameters.

REFERENCES

Basavaraj, K., Naik, M. I. and Ganesha. 2013. Effect of weather parameters on incidence of castor capsule shoot and fruit borer, *Conogethes punctiferalis* Guenee (Pyralidae: Lepidoptera). *Environment and Ecology*. **31**(3A): 1511-14.

Chen, C. M., Liu, C. L. and Zeno, X.Z. 1968. Study on the regularity of outbreaks of the paddy borer in Hunan Province. I. Ecological geographical distribution. *Acta Entomologica Sinica.* **1**: 115-24.

Golez, H. G. 1991. Bionomics and control of mango seed borer *Noorda albizonalis* Hampson (Pyralidae: Lepidoptera). *Acta Horticulture*. **291**: 418-24.

Gundappa., Adak, T. and Shukla, P. K. 2016. Seasonal incidence and weather based forecasting model for mango leaf webber, *Orthaga eudrusalis walker* (Lepidoptera: Pyralidae) under subtropical conditions. *Current Advances in Agricultural Sciences*. **8**(1): 96-99.

Heong, K. L., Manza, A., Catindig, J., Villareal, S. and Jacobsen, T. 2007. Changes in pesticide use and arthropod biodiversity in the IRRI research farm. *Outlooks on Pest Management.* **18**: 229-33.

Herms, D. A. 1990. Biological clocks: using plant phenology to predict insect activity. Am. Nurseryman. 162: 56-63.

Herms, D. A. 2004. Using degree-days and plant phenology to predict pest activity. In: Krischik, V, Davidson, J. (Eds.), IPM of Midwest Landscapes. University of Illinois, USA, 49-59.

Jha, S. and Sarkar, A. 1991. Mango in Malda, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia ., W.B :13

Justin, C. G. and Preetha, G. 2013. Seasonal incidence of rice yellow stem borer, *Scirpophaga incertulas* (walker) in Tamil Nadu. *Indian Journal of Entomology.* **75**(2): 109-12.

Kalshoven, L. G. E. 1981. The pests of crops in Indonesia. PT Ichtiar Baru – Van Hoeve. *Jakarta.* 701.

Kamala jayanthi, P. D. and Verghese, A. 2011. Host plant phenology and weather based forecasting models for population prediction of the oriental fruit fly, *Bactrocera dorsais* Hende. *Crop protection.* **30**: 1557-62.

Krull, S. M. E. 2004. Studies on the mango-ecosystem in Papua New Guinea with special reference to the ecology of *Deanolis sublimbalis* Snellen. (Lepidoptera, Pyralidae) and to the biological control of Ceroplastes rubens (Homoptera, Coccidae). *Ph. D. Thesis.* Justus-Liebig-Universitat Gieben. 190.

Kutner, M. H., Nachtsheim, C. J. and Neter, J. 2004. Applied Linear Regression Models, fourth ed. McGraw-Hill Irwin, 701.

Mussey, G. J. and Potter, D.A. 1997. Phenological correlations between flowering plants and activity of urban landscape pests in Kentucky. *Journal of Economic Entomology.* **90**: 1615-27.

Pinese, B. 2005. Biology, damage levels and control of red-banded mango caterpillar in Papua New Guinea and Australia – project update (Internet). Australian Centre for International Agricultural Research available from: http://www.aciar.gov.au/web.nsf/doc/ACIA-68K3JQ (accessed 11 Jan 2006).

Powell, J. A. and Logan, J. A. 2005. Insect seasonality: circle map analysis of temperature driven life cycles. *Theoretical Population Biology*. **67**: 161-79.

Prasannakumar, N. R., Chander, S. and Kumar, L.V. 2015. Development of weather based rice yellow stem borer prediction model for the cauvery command rice areas, Karnataka, India. *Cognet food and agriculture*. **1**: 9952-81.

Sahoo, A. K. and Das, B. K. 2004. Incidence and biological observations of mango fruit borer, *Deanolis albizonalis* Hampson. (Pyralidae: Lepidoptera) in West Bengal. *Environmental and Ecology*. **22**(2): 180-83.

Sengupta, G. C. and Behura, B. K. 1955. Some new records of crop pests from India. *Indian Journal of Entomology.* **17**: 283–85.

Siswanto, R. M., Dzolkhifli, O. and Elna, K. 2008. Population fluctuation of *Helopeltis antonii* Signoret on cashew *Anacarcium occidentalle* L. in Java Indonesia,.*Pertanika*. *Journal of Tropical Agriculture Science.* **31**: 191–96.

Sujatha, A. and Zaheruddeen, S.M. 2005. Seasonal incidence of Mango Fruit Borer *Deanolis albizonalis* (Hampson) in Andhra Pradesh. *Indian Journal of Applied Entomology*. **19**(2): 95-97.

Tenakanai, D., Dori, F. and Kurika, K. 2006. Red-banded mango caterpillar, *Deanolis sublimbalis* Snellen. (Lepidoptera: Pyralidae: Odontinae), in Papua New Guinea. In 'Pest and disease incursions: risks, threats and management in Papua New Guinea'. ACIAR Technical Reports No. 62 (Ed TV Price) pp. 161–165. (Australian Centre for International Agricultural Research: Canberra). *The National Academy of Sciences.* **107**(33): 14909-14.

Tipon, H.T. 1979. Seed borer in mango. Paper present at the 2nd national fruit crop symposium. December 12-14. Cebu city.

Vijayaraghavendra, R. and Basavanagoud, K. 2016. Seasonal incidence and effect of abiotic factors of sapota fruit borer, *phycita erythrolophia* hampson on sapota dhs-2 hybrid. *International Journal of Current Advanced Research*. **5**(1): 564-65.

Waterhouse, D.F. 1998. Biological Control of Insect Pest: Southeast Asian Prospects, ACIAR monograph No. 5: pp-548.

Zaheruddeen, S.M., and Sujatha, A. 1993. Record of *Deanolis albizonalis* (Hampson.) (Pyralidae: Odontinae) as mango fruit borer in Andhra Pradesh. *Journal of Bombay Natural Historical* Society. **90**(3):528.

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