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Study on influence of natural enemies on the insect population of sunflower (*Helianthus annus* L.)

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Abstract
Sunflower is an important oilseed crop in India. Sunflower crop was mainly attacked by more than fifty different insect pest but in this on going study only defoliator and capitulum borer insect was considered and an effort has been made to control these insect incidence by use of biological measures *i.e.*, influence of predators on defoliator and capitulum borer along with weather parameters for six consecutive cropping years. R^2, Adjusted R^2 and Root Mean squared Error value were used to determine best fitted model. In all the six years there was influence of predators and weather parameters on Defoliator and capitulum borer.

Keywords: Sunflower, defoliator, capitulum borer, multiple linear regression

Introduction
Sunflower (*Helianthus annuus* L.) one of the most essential edible oilseed crops and made a rapid elevation in the oilseed production scenario of Indian subcontinent, as it was a widely pliant crop that can be cultivated under different agro-climatic conditions and cropping system. This was a day-neutral crop. The sunflower production was majorly affected by insect pests. More than fifty species of insect have been reported on sunflowers in the Indian subcontinent. "BSH-1" was the first sunflower in the public sector was grown and published by the University of Agricultural Sciences, Bangalore. Similarly, "KBSH-1" was developed and released from UAS (B), a stable high-yielding hybrid with good oil content.
The sunflower crop was damaged by several defoliators and they were responsible for the seed yield loss about 268 kg/ha during the Kharif season. The incidence of this pest can be minimized by releasing the adults of *Zygogramma. bicolorata* as biocontrol agent. Jagadish *et al.* (2010) [2] found that the Holicoverpa damage was also reduced by use of biopesticides as it controls pest population development in larval stage only.
Helicoverpa armigera was considered as the most serious pest since it will develop resistance to the application of insecticides greatly, have broad host range and they may persist in cropping area from year to year. They appear during late budding to till late seed fill stage. Larval population nourishes on the bud forming stage and may have heavy infestation during bud stage will result in severe damage. Reddy *et al.* (2004) [4] studied that adult stage Helicoverpa was having more survival rate followed by larval stage. It was difficult to manage the larva population when they were graze on sunflower heads and under the bracts. The management of the Helicoverpa population can be done by using a wide range of parasitoids and predators. Predators are the insects which preys on other insects for their food. That is they will search for the suitable prey and later it will feed on it, hence the predator and prey relationship is biological and selective in nature. As they are also living organisms, hence they are influenced by weather conditions. Van den berg and Cock (1995) [5] studied that the population of *H. armigera* was less where there was presence of predator population.
In developing countries, insect pest causes a huge economic loss to sunflower cultivating farmers. The empirical study consisting of linear regression models were based on observed data involved in evaluating the association between the environment, predators and the insect pest.

Material and Methods
The database for this study was rooted on the experiment conducted by All India Coordinated Research Project on Sunflower (AICRP on Sunflower), ZARS, and Weather data was collected from Department of Agrometeorology GKVK, Bengaluru-65.

The experiment was conducted under field condition in an area of 4.8m X 14.4m. The incidence of pest was recorded at weekly interval throughout the cropping period. Present study was based on available secondary data for consecutive six years of Sunflower pest.

A regression model which involving more than one regressor variable is as called as multiple linear regression. The multiple linear regression model that described as follows,

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \varepsilon \quad (1)$$

Where,
Y = dependent variable (Defoliator (DF), Capitulum borer(CB)).
x_i = independent variables (Weather parameters and predators (PD)),
i= 1, 2,…p
β_0= intercept of the regression equation. β_1 .... β_p are the regression coefficients.
ε = error term, which is assumed that the expected value of the error term in equation (1) is zero and has the constant variance σ^2.

In this study, y was the population of insect pest (defoliator and capitulum borer), x_i's are the independent variables i.e., daily weather parameters and predator. The significance of the model is tested by F-test.

Coefficient of determination (R^2)
Coefficient of determination (R^2)was used to assess the adequacy of the model, which was used to know the percentage contribution of the independent variable on the dependent variable. The quantity is as follows,

$$R^2 = \frac{SS_R}{SS_T}$$

Where,
SS_R = sum of squares due to regression
SS_T = Total sum of squares.

Test of significance of the R^2 was done by employing the F test and test statistic was defined as follows,

$$F = \frac{R^2/p}{(1-R^2)/(n-p-1)}$$

Where,
p= number of independent variables.
n = size of the sample.

The computed test statistic value of F was compared with the F table value at (p, n-p-1) degrees of freedom for the given level of significance.

Adjusted R^2 ($\bar{R}^2$)
It is a R^2 modification of that adjust for the number of explanatory terms in the model (p) relative to total number of data point (n). It is given as follows,

$$\bar{R}^2 = 1 - (1 - R^2)\frac{n-1}{n-p-1}$$

Where,
n -1 = degrees of freedom for population
n-p-1 = degrees of freedom for error

Root mean squared error
RMSE is the positive square root of the arithmetic mean of the squared error that is the difference between the observed value and fitted value.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}}$$

Where,
y_i = observed value
$\hat{y}_i$ = fitted value and
n = total no. of observations

Stepwise regression was one of the most regularly used algorithm used for variable selection. This method was an improvement over the forward selection and backward elimination. In this method, all the regressor variables entered into the model previously were reverified at each stage by using their partial F-statistics. The elimination of the variable from the model was done when the partial F- statistics value was less than the F_{OUT}.

Result and Discussion
From table 1 we can interpret that in all the six years except for the 6th year predators were having the significant effect on defoliators at 1 percent and 5 percent level of significance and along with the predators weather parameters were also having impact on the pest population. Patil *et al.* (2011) [3] had also found that incidence of mealybug was reduced by presence of predator and parasitoid, along with them weather parameters were also had positive impact. For first year the fitted model is $\hat{y} = 120.466 - 1.037(RH-1) - 0.861(T_{MAX}) + 0.438(PD)$. The multiple regression coefficients were significant for the given level of significance, and also the fitted model was also significant with R^2, $\bar{R}^2$ and RMSE value for the model were 0.668, 0.526 and 0.557 respectively. Similarly, for second year the fitted model for DF was $\hat{y} = 6.687 - 0.305(T_{MIN}) - 0.023(PD)$, among which T_{MIN} coefficient was significant at 1 per cent level of significance and significance of PD variable was noticed at 5 per cent significance level. 0.621, 0.526 and 0.328 were respective R^2, $\bar{R}^2$ and RMSE value. Significance of R^2 was found at 5 per cent significance level which explains 62.1. For third year the fitted model is $\hat{y} = -0.850 + 4.421(PD)$, the coefficient was significant at 1 per cent level of significance and respective R^2, $\bar{R}^2$ and RMSE value for that model was 0.572, 0.524 and 0.299. The R^2 value was found to be significant at 5 per cent level of significance and explains variability of 57.2 per cent in this model. For fourth, fifth and sixth year the fitted regression model for DF was $\hat{y} = 2.621 - 0.157(T_{MIN}) + 2.348(PD)$, $\hat{y} = -3.963 + 0.015(RH-2) + 0.146(RF) + 0.241(PD)$ and $\hat{y} = 0.564 - 0.053(WS) + 0.032(PD)$ respectively. All the multiple regression coefficients in models for fourth and fifth year were significant for the given level of significance whereas the coefficients in sixth year model was not significant for the given level of significance.

Table 1: Multiple linear regression models for Defoliator (DF) in sunflower with weather parameters and Predators (PD) for six years.

1st year	**Intercept**	**RH-1**	**MAX**	**RF**	**PD**	**R^2**	**$\bar{R}^2$**	**RMSE**
	120.466**	-1.037**	-0.861**	-	0.438*	0.668*	0.526	0.557
2nd year	Intercept	MIN	WS	RH-2	PD	R^2	$\bar{R}^2$	RMSE
	6.687**	-0.305**	-	-	-0.023*	0.621*	0.526	0.328
3rd year	Intercept	MIN	MAX	RH-2	PD	R^2	$\bar{R}^2$	RMSE
	-0.850*	-	-	-	4.421**	0.572*	0.524	0.299
4th year	Intercept	MIN	SSH	RH-1	PD	R^2	$\bar{R}^2$	RMSE
	2.621**	-0.157*	-	-	2.348**	0.893*	0.869	0.186
5th year	Intercept	RH-2	RF	MAX	PD	R^2	$\bar{R}^2$	RMSE
	-3.963*	0.015*	0.146*	-	0.241*	0.644*	0.466	0.052
6th year	Intercept	WS	MAX	MIN	PD	R^2	$\bar{R}^2$	RMSE
	0.564**	-0.053^{NS}	-	-	0.032^{NS}	0.360^{NS}	0.177	0.105

* 5 per cent level of significance, ** 1 per cent level of significance, NS Non-significant.

The fitted multiple regression models for Capitulum borer insect for all the six year was tabulated in table 2, $\hat{y} = 0.167 + 0.959(PD)$ was final fitted regression model for CB insect for first year and model was significant with 0.465 R^2 value, 0.406 $\bar{R}^2$ value and RMSE value was found to be 0.437. For second and third year the fitted model was $\hat{y} = 2.829 - 0.259(T_{MIN}) + 0.049(RH-2) - 0.014(PD)$ and $\hat{y} = -0.489 + 3.029(PD)$ respectively and also these two models were significant with the significant multiple regression coefficients for the given level of significance. This result is on par with Choudhary (2016) [1] as he studied that sucking pest population was affected by temperatire, rainfall and relative humidity. Similarly for third and fourth year the fitted models were $\hat{y} = 8.493 - 0.251(SSH) + 1.322(PD)$ and $\hat{y} = -1.999 + 0.307(T_{MAX}) - 0.222(PD)$ these fitted models were significant at the given level of significance and also the coefficients of multiple regression were significant. The R^2, $\bar{R}^2$ and RMSE value for respective models were tabulated in the table 2 with their significance. Finally for the sixth year the fitted model was $\hat{y} = 4.815 - 0.209(T_{MAX}) - 0.036(PD)$ this model was not significant as the coefficients were not significant and also the value of R^2, $\bar{R}^2$and RMSE was not significant. The above discussed result was on par with Vennila (1998) [6] reported that there was a significant predator - aphid association was negative.

Table 2: Multiple linear regression models for Capitulum borer (CB) in sunflower with weather parameters and Predators (PD) for six years.

1st year	**Intercept**	**RH-1**	**MAX**	**RF**	**PD**	**R^2**	**$\bar{R}^2$**	**RMSE**
	0.167^{NS}	-	-	-	0.959*	0.465*	0.406	0.437
2nd year	Intercept	MIN	WS	RH-2	PD	R^2	$\bar{R}^2$	RMSE
	2.829^{NS}	-0.259*	-	0.049**	-0.014*	0.768*	0.668	0.241
3rd year	Intercept	MIN	MAX	RH-2	PD	R^2	$\bar{R}^2$	RMSE
	-0.489*	-	-	-	3.029**	0.517*	0.463	0.229
4th year	Intercept	MIN	SSH	RH-1	PD	R^2	$\bar{R}^2$	RMSE
	8.493**	-	-0.251**	-0.030**	1.322**	0.936**	0.912	0.107
5th year	Intercept	RH-2	RF	MAX	PD	R^2	$\bar{R}^2$	RMSE
	-1.999^{NS}	-	-	0.307**	-0.222**	0.866*	0.821	0.181
6th year	Intercept	WS	MAX	MIN	PD	R^2	$\bar{R}^2$	RMSE
	4.815**	-	-0.209**	-	-0.036^{NS}	0.689*	0.600	0.139

* 5 per cent level of significance, ** 1 per cent level of significance, NS Non-significant.

Conclusion

From the above study we can conclude that the predators were having significant effect on the sunflower insect population and also the weather parameters such as maximum and minimum temperature, morning and after noon relative humidity, sunshine hours were affecting the growth and development of the defoliator and capitulum borer infestation. $R^{2,}$ Adjusted R^2 and RMSE values were calculated to check the goodness of fit for built models.

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