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Statistical relationship between date of sowing and the sorghum shootfly (*Atherigona Soccata*, Rondani L)

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Abstract: The present study was based on the available data of eleven years for shoot fly from 2000-2010 for kharif season. Different models viz., linear and non linear were tried to fit, Amongst, the linear, quadratic and cubic models produced better coefficient of determination and the models *viz.,* EGG(Shoot fly Egg) =3.760+0.196(DOS) (R^2=0.892) and EGG(Shoot fly Egg) =1.077+1.195(DOS)-0.087(DOS^2), which produced highest R^2 (0.896 at p=0.05) with less standard error (0.419) and quadratic model was also the best fit model in determining the oviposition of shoot fly, which explained 89.6 per cent variation in the oviposition of shoot fly for the 7 days after emergence of the sorghum crop. For the dead heart development (14 DAE), the model %DH (% Dead Heart) =3.535+3.104(DOS) found best fit with highest coefficient of determination of 0. 856 and exhibited significant positive relationship with the date of sowing and during 21 DAE the cubic model %DH (% Dead Heart) =10.619+10.115(DOS)-3.466(DOS^2) +0 .321(DOS ^3) had significant coefficient of determination value of 0.988 with least standard error 0.885. The quadratic model during the 28 days after emergence of the crop %DH (% Dead Heart) =-6.234+22.858(DOS) -1.399 (DOS^2) found best fit and produced significant R^2 (0.929 at 5 per cent level) and showed better relationship with the date of sowing. It was found that, both linear and non linear relationship exists between dates of sowing and shoot fly of sorghum during kharif season.

Keywords: Dead heart, Linear Regression, Nonlinear Regression, Sorghum shoot fly

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important cereal crop in the world because of its adaptation to a wide range of ecological conditions, suitability for low input cultivation and diverse uses. It is the fifth major cereal crop of world following wheat, rice, maize and barley in terms of production and utilization. It is cultivated in many parts of Asia and Africa, where its grains are used to make flat breads that form the staple food of many cultures. The grains can also be popped in a similar fashion to popcorn (Anonymous, 2012). The yield penalties to sorghum are very high starting from seedling stage to harvest, and are allotted maximally to biotic stresses. More than 150 species of insects have been recorded as pests of sorghum, of which sorghum shoot fly, Atherigona soccata (Rondani) is an important pest in Asia, Africa, and the Mediterranean Europe. Insect pests cause nearly 32 per cent of the total loss to the actual produce in India (Borad and Mittal, 1983), 20 per cent in Africa and Latin America, 9 per cent in USA (Wiseman and Morrison, 1981). Shoot flies of the genus Atherigona are known to cause 'deadhearts' in a number of tropical grass species (Deeming, 1971; Pont, 1972) and wheat (Pont and Deeming, 2001). Sorghum shoot fly causes an average loss of 50 per cent in India (Jotwani, 1982), but the infestations at times may be over 90 per cent (Rao and Gowda, 1967). The adult fly lays white, elongated, cigar shaped eggs singly on the undersurface of the leaves, parallel to the midrib. After egg hatch, the larvae crawl to the plant whorl and move downward between the folds of the young leaves till they reach the growing point. They cut the growing tip resulting in dead heart formation. Prolonged and continuous use of chemicals in pest management has been reported pest developed resistance against insecticides (Annon, 2011). Considering the above importance of the shoot fly, the date of sowing is considered in this study to prevent the attack of shoot fly, because the early sown crop escapes from shoot fly damage but the late-sown crop in most cases is affected. The shoot fly infestation is high when sorghum sowings are staggered due to erratic rainfall distribution (Ashok Kumar *et al.,* 2008). Therefore, the search for alternatives to chemical control of insect pests, especially use of validated model could gain momentum as eco-friendly approach in a sustainable

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pest management (Anonymous 2014). In this present research work an attempt was made to find out effective non chemical, statistical approach to contain the menace of the pest by changing the date of sowing based on the positive and negative value of beta (regression) coefficient for the date of sowing, which influence the sorghum shoot fly under Dharwad region of Karnataka. Many researchers studied the effect of date of sowing on shoot fly by laid out experiments (Balikai, 1999) but in this study an attempt was made to explain the same through linear and non linear models.

MATERIALS AND METHODS

The present study was based on the available data of eleven years for shoot fly from 2000-2010 for kharif season. The experimental data were collected based on experiments of All India Coordinated Sorghum Crop Improvement Project conducted for the period of eleven years for insect pest (Shoot fly egg population, dead heart at different intervals of crop growth) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The data base from the experiment was treated with some of the statistical techniques *viz.*, Simple linear regression and nonlinear models.

Simple regression analysis: The data regarding insect pests will be treated with simple linear regression by taking insect pests egg and dead heart as dependent variable and weather parameters and date of sowing as independent variable.

Simple linear regression model is,

$$Y_t = \alpha + \beta X_t + \varepsilon_t$$

Where, Y_t- Dependent Variable, X_t- Independent variable at time t.

Coefficient of determination (R^2): Coefficient of determination ($\mathbf{R^2}$) is used as the measure of explanatory value of the model. It is calculated as

$$R^2 = \frac{\text{Sum of square due to regression}}{\text{Total sum of sqaures}}$$

$$= \frac{b\,\Sigma\,(X_t - \overline{X_t})(Y_t - \overline{Y_t})}{\Sigma\,(Y_t - \overline{Y_t})^2}$$

Based on the R^2, model of best fit to the data is selected.

Non-linear models: The simplest way of representing any relationship is by fitting a linear equation using the variable under study. But in all the cases it may not follow. Therefore some of the non linear models were tried. The details of the models used are given below.

Quadratic model: The form of equation is,

$$Y_t = \beta_0 + \beta_1 X_t + \beta_2 X_t^{\,2} + \varepsilon_t$$

Where, Y- dependent variable

X-selected independent variable

Are regression coefficients to be estimated.

Estimates of the parameters are obtained as in the case of multiple linear regression models where X-is taken as X_1 and X^2 as X_2.

Cubic model

Here the equation is,

$$Y_t = \beta_0 + \beta_1 X_t + \beta_2 X_t^{\,2} + \beta_3 X_t^{\,3} + \varepsilon_t$$

Inverse model

Model under consideration is,

$$Y_t = \beta_0 + \beta_1 (1/X_t) + \varepsilon_t$$

Exponential model

Model under consideration is,

$$Y_t = \alpha\, e^{\beta X_t} + \varepsilon_t$$

On transformation $Y_1 = A^1 + \beta X + \varepsilon^*$

is obtained which is of the linear form in which is the new error .

Using the usual least square estimation procedure estimates of the coefficient can be found out.

Logarithmic model

Is the linear model.

$$Y_t = \alpha + \beta \ln(X_t) + \varepsilon_t$$

The significance of regression coefficient (b) is tested by using t-test and calculated t-value is compared with table t-value for (n-2) degrees of freedom. In the same way, the significance of this model is tested by using F -statistic

$$\text{i.e., F} = \frac{\text{Regression sum of square (n-2)}}{\text{Error sum of sqaures}}$$

Calculated F-value is compared with table F for 1 and n-2 degrees of freedom.

RESULTS AND DISCUSSION

The congenial weather leads to development of shoot fly, as there exist some relationship between the development of shoot fly and the date of sowing. So the effect of date of sowing on shoot fly was studied for each interval *viz,* 7, 14, 21 and 28 DAE separately using linear and non linear models and best fit models were selected for each intervals based on highest coefficient of determination with least residuals. The F value, which was the ratio of mean sum of squares due to regression to that of residuals, gives the significance of the model fitted to the data and its significance to all the models, showed that models were significant, more over significance of regression coefficients (b's) based on t-test, indicated the significant contribution of the variables used to explain the variations in the dependent variables. Results for the shoot fly egg and dead heart in the table 1 indicated that, R^2 values were more precise in 28 days after emergence, followed by 21 and 14 days after emergence of the crop. Effect of date of sowing was highly significant at 21 DAE and 28 DAE, there was a good improvement of R^2 in quadratic model and logarithmic at 14 DAE than simple linear. For the year 2001, results of table 2

Table 1. Simple linear and non-linear models for date of sowing on shoot fly in the year 2000 kharif season (July_2nd week to September_1st week).

DAE	MODEL	SE	R^2
7	EGG=3.026+0.245(DOS)	0.788	0.387
	%DH=23.513+1.270*(DOS)	3.600	0.516*
14	%DH=22.372+5.266*ln(DOS)	3.224	0.612*
21	%DH=22.976+3.243**(DOS)	5.266	0.764**
	%DH=19.413+8.869**(DOS)	12.018	0.823**
28	%DH=-6.234+22.858*(DOS) -1.399*(DOS^2)	8.253	0.929*

*-significant at 5 per cent level, **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE -days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 2. Simple linear and non-linear models for date of sowing on shoot fly in the year 2001 kharif season (July_2nd week to September_1st week).

DAE	MODEL	SE	R^2
7	EGG=2.672+0.325**(DOS)	0.694	0.653**
	EGG=1.077+1.195*(DOS) -0.087*(DOS ^ 2)	0.419	0.896*
14	%DH=18.755+3.188**(DOS)	7.178	0.628**
21	%DH=18.855+4.721**(DOS)	5.345	0.870**
28	%DH=21.202+5.352**(DOS)	9.116	0.747**

*-significant at 5 per cent level, **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 3. Simple linear and non-linear models for date of sowing on shoot fly in the year 2002 kharif season (July_1st week to August_2nd week).

DAE	MODEL	SE	R^2
7	EGG=3.613-0.076(DOS)	0.485	0.121
14	%DH=32.271-0.240(DOS)	2.917	0.036
21	%DH=33.273+0.667(DOS)	1.808	0.433
	%DH=43.011-9.806*(DOS)+ 2.919*(DOS ^2) -0.234*(DOS^3)	1.081	0.878*
28	%DH=65.356-3.122(DOS)	8.769	0.415

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE -days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 4. Simple linear and non-linear models for date of sowing on shoot fly in the year 2003 kharif season(1st week of July to 3rd week of August).

DAE	MODEL	SE	R^2
7	EGG=2.276+0.184*(DOS)	0.360	0.594*
14	%DH=11.073+1.085*(DOS)	2.301	0.554*
21	%DH=9.863+2.151**(DOS)	1.597	0.910**
28	%DH=18.407-0.069(DOS)	1.636	0.0097

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE -days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

indicated that, quadratic model was more precise (based on R^2 and standard error), than simple linear in 7 DAE which explained the oviposition significantly and in the dead heart development R^2 was high during 21 DAE followed by 28 DAE and 14 DAE. The quadratic model was found good fit in explaining the variation in oviposition during 7 DAE, linear fitted well for the rest of the intervals and rest of the models were found non significant. Results from the Table 3 indicated that, in 21 DAE the cubic model was showing better improvement in R^2 (0.878) value compare to linear and other nonlinear models *viz.,* quadratic, exponential, inverse and logarithmic model in the same interval. The linear model showed good R^2 value but it was not significant in explaining the dead heart formation followed by 28 DAE and 7 DAE. In the year 2003, (Table 4) the linear model for

Table 5. Simple linear and non-linear models for date of sowing on shoot fly in the year 2004 kharif season(3rd _week of June to 2nd _week of August).

DAE	MODEL	SE	R^2
7	EGG=1.018+0.050(DOS)	0.275	0.190
14	%DH=1.783+1.264**(DOS)	1.272	0.829**
21	%DH=8.255+0.850**(DOS)	1.187	0.836**
28	%DH=24.589+2.401(DOS)	9.727	0.291

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 6. Simple linear and non-linear models for date of sowing on shoot fly in the year 2005 kharif season (last week of June to 3rd _week of August).

DAE	MODEL	SE	R^2
7	EGG=1.684+0.226**(DOS)	0.349	0.781**
14	%DH=3.535+3.104**(DOS)	3.716	0.856**
21	%DH=17.309+2.684**(DOS)	6.007	0.631**
28	%DH=25.946+2.804**(DOS)	7.236	0.562**

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 7. Simple linear and non-linear models for date of sowing on shot fly in the year 2006 kharif season(last week of June to 2nd _week of August).

DAE	MODEL	SE	R^2
7	EGG=2.155-0.064(DOS)	0.445	0.1488
14	%DH=19.270-0.966**(DOS)	1.654	0.744**
21	%DH=17.167+1.230(DOS)	7.508	0.187
28	%DH=43.729+0.890(DOS)	9.653	0.067

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 8. Simple linear and non-linear models for date of sowing on shoot fly in the year 2007 kharif season (3rd_week of June to 1st_week of August).

DAE	MODEL	SE	R^2
7	EGG=2.146+0.008(DOS)	0.252	0.007
14	%DH=15.950-0.417*(DOS)	0.858	0.622*
21	%DH=13.554+1.364(DOS)	5.612	0.292
	%DH=10.619+10.115*(DOS) -3.466*(DOS^2)+0 .321*(DOS ^3)	0.885	0.988*
28	%DH=18.899+0.729(DOS)	3.580	0.224

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

the effect of date of sowing in 21 DAE was good fit and produced highly significant coefficient of determination value (R^2=0.910 at p=0.01) and R^2 found significant in 7 and 14 DAE towards egg and dead heart development respectively but in 28 DAE coefficient of determination was low and showed no linear relationship.

In table 5, the models for 14 DAE and 21 DAE were precise and highly significant (at 1 per cent level) in explaining the linear relationship between dates of sowing and shoot fly development, but in 7 and 28 DAE the contributions were negligible and non significant. Crop sown during june last week to second week of august (Table 6), the linear models in 7, 14, 21 and 28 DAE were showed highly significant coefficient of determination and the coefficient values (b's). R^2 in 14 DAE was high (0.856) followed by 7 DAE (0.781), 21 DAE (0.6311) and 28DAE (0.5627). The results in table 7 revealed that, the linear model for 14 DAE showed good and highly significant R^2 (0.744) value compared to rest of the intervals and all the nonlinear models resulted in low R^2 and found non-significant. Vijay Lakshmi *et al.* (2010) reported that, the coefficient

Table 9. Simple linear and non-linear models for date of sowing on shoot fly in the year 2008 kharif season (last week of July to last week of July).

DAE	MODEL	SE	R^2
7	EGG=3.760+0.196**(DOS)	0.121	0.892**
14	%DH=32.908+0.046(DOS)	1.224	0.005
21	%DH=36.833+0.297(DOS)	1.593	0.103
28	%DH=38.077+0.853*(DOS)	0.879	0.758*

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 10. Simple linear and non-linear models for date of sowing on shoot fly in the year 2009 kharif season (2^{nd}_week of June to last week of July).

DAE	MODEL	SE	R^2
7	EGG=3.343-0.019(DOS)	0.182	0.050
14	%DH=28.347+0.149(DOS)	2.518	0.019
21	%DH=35.210+0.051(DOS)	1.692	0.005
28	%DH=37.684+1.122(DOS)	3.251	0.399

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

Table 11. Simple linear and non-linear models for date of sowing on shoot fly in the year 2010 kharif season(last week of July to 1^{st} week of September).

DAE	MODEL	SE	R^2
7	EGG=2.306+0.059(DOS)	0.544	0.126
14	%DH=15.846+1.467*(DOS)	3.056	0.597*
21	%DH=25.312+1.633**(DOS)	2.354	0.611**
28	%DH=23.230+5.722**(DOS)	8.492	0.829**

*- Significant at 5 per cent level. **-Significant at 1 per cent level, SE- standard error, R^2-coefficient of determination, DAE-days after emergence, DOS- dates of sowing, %DH- percentage dead heart. Egg- Shoot fly Egg count

of determination (R^2) was improved by 6 to 20% when non-linear regression equations were fitted, but in the present study best model for 21 and 28 DAE were cubic and quadratic respectively produced better coefficient of determination than linear models and for 7 and 14 DAE linear produced better coefficient of determination than non linear models, therefore both linear as well as non linear relationship were exhibited by the date of sowing and shoot fly egg and dead heart. During the year 2007, the cubic model for 21 DAE found good fit with significant coefficient of determination (0.988) for the shoot fly dead heart formation and the linear model for 14 DAE also showed significant R^2 value but in 7 and 28 DAE all model results were non-significant and their contribution was negligible (Table 8). In the table 9, the coefficient of determination value of linear model for 7 DAE found to be good fit and highly significant (R^2=0.892 at p=0.01) in determining the number of eggs and was followed by 28 DAE (R^2=0.758) for the dead heart formation. But in 14 and 21 DAE all models found non-significant and their contributions were less towards the dead heart formation. The results of table 10 for the year 2009 indicated that, all linear and nonlinear models found not good fit and their contribution was less towards egg and dead heart formation in all four intervals and during the year 2010 it was found that during 28 DAE linear model showed highly significant R^2 (0.829) and coefficient (b's) values in determining the dead heart followed by 21 DAE (0.611) and 14 DAE (0.597) value of R^2 is found to be significant at 5 percent level but in 7 DAE the effect was negligible (Table 11).

The above discussion can be concluded that, the shoot fly remained active throughout the kharif season (Kulkarni *et al.* 1978) due to positive coefficient values for the date of sowing in most of the years but Crop sown in the month of June and early July were less prone to attack due to negative coefficient values for the date of sowing. The results in the year 2002 during 7, 14 and 28 DAE were confirmed the negative effect of date of sowing due to negative coefficient values for the date of sowing (the crop sown during first week of july to second week of august) and during 2006 which was sown during last week of june to second week of august was found negative for 7 and 14 DAE (Table 7) but crop sown on last week of August were more prone to attack in Kharif (during 2000, 2001, 2005 and 2010) due to positive coefficient values. Results were in accordance with Kulkarni *et al.* (1978), Balikai, (1999). Number of eggs laid and dead heart formation were significantly low on the crop sown at end of June (Ghandhale *et al*. 1983) because lesser the number of eggs laid during 7 days after emergence of the crop lesser the per cent dead heart in the next successive intervals.

Since linear models with date of sowing alone were not sufficient to explain the variation in shoot fly egg and dead heart development in some intervals. So there was a possibility of relationship other than linear existing between date of sowing and shoot fly. The models were showed negative coefficient value during 2002, 2006 and 2009 for the oviposition of shoot fly and the crop was sown during the June months and rest of them showed positive. Amongst, the linear and quadratic model produced better fit values and the models *viz.*, EGG = 3.760 + 0.196 (DOS) (R^2 = 0.892) and EGG= 1.077+1.195 (DOS) -0.087 (DOS^2) which produced highest R^2 (0.896 at 5% level) with less standard error (0.419) and quadratic was found best in determining the oviposition of shoot fly. For the dead heart development (14 DAE) the model %DH=3.535+3.104(DOS) choose to be the best with highest coefficient of determination value 0.856(p=0.01) and exhibited significant positive relationship with the date of sowing and during 21 DAE the cubic model % DH=10.619 +10.115 (DOS) - 3.466 (DOS^2) + 0.321(DOS^3) had significant coefficient of determination value 0.988(p=0.05) with least standard error (0.885). The quadratic model during the 28 days after emergence of the crop %DH=-6.234+22.858(DOS) -1.399(DOS^2) with significant R^2 (0.929 at p=0.05) exhibited better relationship with the date of sowing.

Conclusion

It was concluded from this study that shoot fly was active throughout the Kharif season, therefore timely sowing will reduce the incidence of shoot fly. But the crop was less prone to attack of the shoot fly when the crop was sown during the early June and the models showed negative significant value for the regression coefficients. The linear and quadratic models were significant in determining the oviposition (Egg development) and linear alone during 14 DAE was significant to determine dead heart development but during 21 and 28 DAE the cubic and quadratic found best fit models. Therefore, the study confirmed that both linear and non linear relationship exists between dates of sowing and shoot fly incidence. The date of sowing found very important cultural practice and was suggested to follow apart from the use of chemical pesticides to avoid the crop loss and environmental pollution.

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