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DEVELOPMENT OF FOREWARNING MODEL FOR SORGHUM SHOOT FLY (*Atherigonasoccata* Rondani) IN WESTERN MAHARASHTRA SCARCITY ZONE

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Abstract: *Field experiments were carried out with recommended sorghum variety Phule Vasudha to study the effect of weather parameters on incidence of shoot fly (Atherigonasoccata Rondani) at Rahuri, Maharashtra during rabi seasons. The crop was sown during October-November for fourteen consecutive years (2000-2001 to 2013-14) which is normal sowing period for rabi sorghum at Ahmednagar district, Maharashtra. The shoot fly incidence (% dead hearts) was found to be positively correlated with maximum and minimum temperature, morning and evening relative humidity and rainfall. All these parameters except morning relative humidity were significantly correlated to the shoot fly incidence (% dead hearts). Out of 14 years, twelve years data (2000-2001 to 2011-12) were used for development of the model and experimental data of (2012-13 and 2013-14) were used for validation of the data. Stepwise regression analysis was carried out to identify the important weather parameters influencing incidence of shoot fly. The model explained the incidence of shoot fly in sorghum to an extent of 97 %. Hence, this model can be used for predicting the incidence of shoot fly in sorghum.*

Key words: *Forewarning model, validation, shoot fly, sorghum.*

Sorghum (*Sorghum bicolor* (L.), Moench), one of the major coarse grains (nutritious cereals) besides wheat, rice, corn and barley, constitute two thirds of the world coarse cereals. Sorghum is widely found cultivated across the world in Africa, Asia, North and South America, Pakistan and Australia (Dhillon*et al.,* 2005 and Subbarayudu and Indira, 2007). It is the fifth major cereal crop of the world following wheat, rice, maize and barley in terms of the production and utilization. In India, sorghum is grown mainly for food and fodder in both seasons *viz., kharif* (rainy) season as a *rainfed* crop while in *rabi* (post rainy) season under residual soil moisture/limited irrigation conditions. The major sorghum growing states in the country are Maharashtra, Karnataka Rajasthan, Gujarat, Madhya Pradesh, Telangana, Tamil Nadu, Uttar Pradesh and Haryana. In India, *rabi* sorghum cultivated over an area of 3,314.5 lakh ha with 2853.2 lakh tones production and 860.8 kg ha^{-1} productivity every year (2014-15). Maharashtra has the largest area under sorghum and cultivated both in *kharif* and *rabi* seasons. It is cultivated on total area of 27.8 lakh ha in *rabi* with a production of 19.2 lakh tones and productivity of 691.0 kg ha^{-1} (2013-14). However, the average productivity under *rabi* sorghum was less in most of the states of the country. One of the reasons for low productivity is insect-pests and disease attack.

More than 100 insect species have been reported as pests on this crop throughout the world; only 10-12 % of them have studied in detail. In India, about >20 species have been recorded, out of which the major pests are shootflies, stem borers and grain midges (Gahukar and Jotwani, 1980). Sorghumshoot fly, *Atherigonasoccata* Rondani (Muscidae : Diptera) is a major pest during seedling stage (Sherwill *et al.,* 1999) and its infestation causes dead heart formation leading to killing of the plants upto 30 days from sowing. Nearly 32 % of the sorghum crop is lost due to insect pests in India (Borad and Mital, 1983), of which 5 % loss has been attributed to sorghum shoot fly (Jotwani, 1983).

However, the infestations at time may be over 90 % (Kundu *et al.,* 1977). Very few/no attempts have been made to quantify the effect of weather parameters/seasonal incidence of sorghum shoot fly. The present study has been undertaken to develop forewarning model (regression equation) for one week advance prediction of sorghum shoot fly infestation.

Materials and Methods

Field experiments were conducted at the research farm of Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri ($19^0$47' N $74^0$82' E) during *rabi* seasons for fourteen consecutive years (2000-2001 to 2013-14). The untreated seed of sorghum variety Phule Vasudha was sown under recommended sowing times (*i.e.* October and November) every year at spacing of 45×15 cm in randomized blocks of 100 m^2 with three replications. The crop was grown with all recommended practices under *rainfed*conditions.

On 6^{th} day of seed emergence, initial plant count was recorded after thinning. For dead hearts count, the method given by Vedamoorthy (1967) was adopted. The total numbers of plant in each plot and plants showing dead hearts in main shoots were recorded for two sowings (October and November) every year on 7, 14, 21 and 28 days of crop emergence. The average dead heart percentages upto 28 days after germination were calculated and considered for the study. The different weather parameters were recorded for the same corresponding crop period *i.e.* 41 to 48 MW from the meteorological observatory. Weekly mean weather parametersof twelve years (2000-2001 to 2011-12) were correlated with shoot fly dead hearts (%) and regression equation was developed to predict shoot fly incidence. Two year data (2012-13 and2013-14) were used to predict and validate the model.

Results and Discussion

The mean dead hearts due to shootflies summarized in Table 1 revealed that under normal sowing condition the sorghum shoot fly infestation in *rabi* season was started during 41^{st} MW for October sown crop and during 45^{th} MW for November sown crop which continued on the crop upto 44^{th} and 48^{th} MW, respectively. However, after the occurrence there was declining trend in the per cent dead heart during following meteorological weeks irrespective of weather parameters particularly the minimum temperature.

The shoot fly incidence was positively correlated with the maximum and minimum temperatures, morning and evening relative humidity and rainfall (Table 1). These weather parameters except morning relative humidity contributed significantly for the sorghum shoot fly incidence and its continuation upto a month period of time under normal sowing situation. Moreover, the minimum temperature (18.7 to 10.5 ^{0}C) exerted highly significant positive relationship with dead hearts due to shoot fly. These weather parameters were used to develop the forewarn model for sorghum shoot fly. The equation thus developed explained 97% variation in shoot fly incidence (R^2 = 0.97; Table 3).

Analysis of central tendencies of weather parameters revealed that 30.23 ± 1.17 maximum temperature, 13.89 ± 3.39 minimum temperature, 86.28 ± 3.12 relative humidity morning, 41.25 ± 4.45 relative humidity evening and 8.36 ± 6.76 rainfall are highly congenial for the multiplication of shootflies and thereby its infestation (dead hearts) from 41 to 48 MW (October-November).

Shoot fly incidence (% dead hearts) $= 118.62 + (1.34 \times T_{max}) + (2.10 \times T_{min}) - (1.77 \times \text{RH-I}) - (0.04 \times \text{RH-II}) + (0.37 \times \text{RF})$.

Where, T_{max} = Maximum temperature (^{0}C), T_{min} = Minimum temperature (^{0}C),

RH-I = Relative humidity % (morning), RH-II = Relative humidity % (evening),

RF = Rainfall (mm).

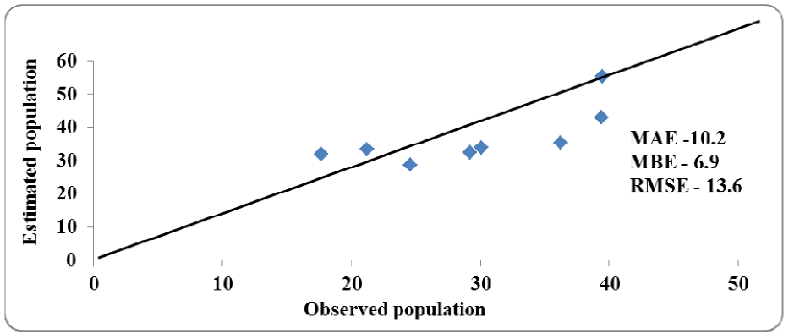

Fig. 1: Comparison of estimated and observed % dead hearts ofshoot flies (2008-09 and 2009-10)

The model was validated with two years (2012-13 and 2013-14) observed data on shoot fly incidence (% dead hearts). The standardized residual values estimated based on deviation between actual observed and predicted shoot fly incidence (% dead hearts) are in between -3.00 and + 3.00 which indicated the suitability of model for the prediction of shoot fly incidence irrespective of weather parameters. Hence the equation is best fitted for the prediction of shoot fly incidence. A graphical representation of observed and estimated shoot flies incidence (% dead hearts) is depicted in Fig. 1 for 2012-13 and 2013-14. Similarly, the performance of model evaluation using 1:1 line graph and statistical measures as given by Willmott (1982) *viz.,* mean absolute error (MAE), mean bias error (MBE) and Root mean square error (RMSE) for the same are also given for validation.

Pawar *et al.* (2015) studied the influence of weather parameters on the incidence of sorghum shoot fly and reported that peak incidence (dead hearts) of shoot fly in *rabi* season was in the month of October-November. They also, reported that minimum temperature, relative humidity morning and evening showed significant and positive effect while maximum temperature had significant and negative effect on the incidence of shoot fly. Karibasavaraja and Balikai (2006) noticed that the sorghum shoot fly was active from July first week (27^{th} MW) to October last week (44^{th} MW). They also reported that the combined weather parameters of maximum temperature with afternoon and morning relative humidity were highly significant and negatively correlated with dead heart formation, whereas the morning and afternoon relative humidity and minimum temperature together exerted highly significant positive relationship with dead heart due to shoot fly. Similarly, the influence of weather variables on the incidence of sorghum shoot fly in *rabi* season was studied by Venkatesh and Balikai (2002) who reported that the rainfall received at one week after emergence (four weeks lead time) and higher day temperature at two weeks after emergence (three weeks lead time) reduced shootfly infestation, whereas lower afternoon relative humidity at four weeks after emergence (one weeks lead time) increased it. This justifies the results of the present investigations. However, the weather based predictive models for sorghum shoot fly during *kharif* season were tried by Matti*et al.* (2013). Earlier workers (Campbell *et al.,* 1998) stated that the model is a concise way of representing any system of their reality in a symbolic and simplified form.

Conclusion

The correlation studies conducted between the shoot fly incidence in sorghum and 14 years average weather parameters indicated that there was a significant positive correlation between the shoot fly incidence and the weather parameters *viz.,* maximum and minimum temperature, relative humidity (afternoon and the rainfall). The stepdown regression analysis was also carried out using 12 years data which came out with a model by use of which the shoot fly incidence in sorghum can be predicted with 97 % accuracy. The crop in early seeding stage is most vulnerable to shoot fly attack during 41^{st} to 48^{th} MW and hence it is advisable to go for early sowing during September to enable the crop to escape from shoot fly infestation.

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Table 1: Effect of weather on shoot fly population of sorghum during 2000-2001 to 2011-12 (Average of twelve years)

MW	T_{max}(^{0}C)	T_{min} (^{0}C)	RH-I (%)	RH-II (%)	RF (mm)	Shoot fly incidence (% dead hearts)	
						Observed	Estimated through equation
41	31.2	18.7	89.4	53.5	36.4	51.8	52.8
42	31.3	17.1	87.3	45.4	11.2	45.2	44.3
43	31.4	14.9	86.9	39.3	2.1	34.8	37.4
44	30.5	14.5	87.2	42.4	9.6	39.7	37.4
45	30.3	12.7	83.1	37.3	1.6	37.3	37.9
46	30.3	11.5	84.1	36.8	1.9	36.8	33.7
47	29.6	11.2	84.3	37.8	1.6	28.0	31.7
48	27.2	10.5	87.9	37.5	2.5	20.9	20.9
r value	0.82*	0.90**	0.32	0.81*	0.76*	-	-

Table 2: ANOVA.

Source	d.f.	SS	MS	F	Prob
Regression	5	603.879	120.776	7.110	0.128
Residual	2	33.973	16.986	-	-
Total	7	637.851	-	-	-

Table 3: Correlation (r) and regression coefficient and R^2 for shoot fly populationon sorghum during 2000-2001 to 2011-12

Parameter	Regression coefficient (with significant parameters)
	Linear Model
Constant (Y)	118.62
T_{max}	1.342
Tmin	2.097
RH-I	-1.773
RH-II	-0.040
RF	0.375
R^2	0.97

SSF = $118.62 + 1.34 \times T_{max} + 2.10 \times T_{min} - 1.77 \times \text{RH-I} - 0.04 \times \text{RH-II} + 0.37 \times \text{RF}$

Where,

SSF = Sorghum shoot fly incidence (% dead hearts)

T_{max} = Max. Temp. (^{0}C),

T_{min} = Min. Temp. (^{0}C),

RH-I = Relative Humidity % (morning).

RH-II = Relative Humidity % (evening).

RF = Rainfall (mm).