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Comparative biology and population dynamics of sorghum shoot fly, *Atherigona soccata* Rond (Muscidae: Diptera)

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Abstract
Studies on the biology and population dynamics of shoot fly was carried out at the MARS, Raichur during the study period 2016-17. The biology of the muscid was studied on a susceptible hybrid of sorghum CSH-14 under controlled conditions in the laboratory. The eggs were laid singly on the under surface of leaves, parallel to midrib on third or fourth leaf blades. The egg period lasted for 2.25±0.24 and 2.92±0.32 days in *kharif* and *rabi* season, respectively. The total larval period occupied 9.85±0.99 and 12.58±1.47 days in kharif and rabi season, respectively. The pupal stage lasted for 8.92±0.94 and 10.86±1.02 days in *kharif* and *rabi* season, respectively. Total life cycle of the shoot fly occupied 21.02±2.20 and 26.36±2.48 days, respectively, during *kharif* and *rabi* season. Fish meal was used as attractant for assessing the relative abundance of *Atherigona sp*., under field condition. During the study period a total of 12,485 flies were trapped with weekly average of 240 per standard week. The peak shoot fly catch (1,025 flies per trap) was recorded during 33rd standard week (Aug 13-19).

Keywords: Sorghum, Shoot fly, *Atherigona soccata*, Biology, fish-meal trap.

1. Introduction
Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important food and fodder crop in the world because of its adaptation to a wide range of ecological conditions, suitability for low input cultivation and diverse uses [1]. It is a native of North-Eastern Africa and cultivated in warmer climates around the world being dietary staple of more than 500 million people in more than 30 countries [2]. Insect pests are one of the constraints in sorghum on a global basis. The sorghum shoot fly, (*Atherigona soccata* Rond.) an Anthomycid fly, in the family Muscidae, order Diptera is the primary pest of economic importance of sorghum [3]. The pest attacks the crop only in the early stage of the crop growth and becomes serious particularly in late sown crop. The activity of shoot fly is known to vary from region to region and season-to-season [3]. Monitoring of any pest population forms an integral component of pest management. Although the biology of shoot fly has already been studied in different parts of the country, variation in the life history in different season is totally lacking. With this background in view and growing need for the improvement in yield of sorghum, the present investigations were undertaken with the following objectives *viz.* To study the biology of sorghum shoot fly, *Atherigona soccata* during *kharif* and *rabi* season and population dynamics of sorghum shoot fly through fish meal trap. The statistical software SPSS was used for regression analysis.

2. Material and Methods
The present experiment was carried out in the Department of Entomology, College of Agriculture, Raichur. The seedlings of susceptible hybrid CSH-14 in plastic cups were exposed to field condition and seedlings were tested at every three hours for the presence of shoot fly eggs. The seedlings with eggs were brought to the laboratory and tagged with the time of egg laying. This was continued till evening and after last count, the field exposed seedlings were covered with mosquito net to avoid any oviposition during night and were exposed in the next morning for oviposition and repeated this activity till the seedlings attain 14 day. The seedlings with egg, brought from the field were placed separately according to the time of oviposition. These seedlings were observed for egg eclosion and time of eclosion was

recorded. After six days the seedlings with same aged eggs were dissected to observe maggot and continued till full grown or late instar yellow colored maggot which is about to pupate, which indicated the total larval duration. Either the fully grown maggot or pupa obtained from the dissected seedlings were collected and placed in the petri plate (measuring 90 mm diameter) with moistened sand. The pupae were observed for the emergence of adults and the duration was noted. After adult emergence male and females were sexed and released into transparent plastic container of about one liter capacity with 7 - 14 days old seedlings for further studies viz., pre-mating period, mating period, preovipositional period, ovipositional period, Longevity of female and male and fecundity. The adults provided with 10 per cent sucrose with yeast as food. Studies on biology was carried out both during *kharif* (August) and *rabi* (October) season.

To monitor the adult shoot fly populations a square pan galvanised metal (SPGM) trap was recommended by Seshu Reddy [3], but this is bulky and renders difficulty in removing and counting of flies, which is time consuming. In addition, water and fish meal have to be replaced frequently. Therefore, a simple and effective trap (Plate 4) was developed for use in routine monitoring of the shoot fly population. The trap consisted of a one litre plastic bottle (25.7 cm x 7.6 cm) with an entry hole on top for the flies and fish meal (20 g) placed inside with water (200 ml) which aids in killing. Trap was prepared by using one litre water bottle, which was cut just below the neck and the cut piece placed upside down to the same bottle (fixed firmly by using cello tape). At every time, while installing a trap a fresh fish meal was used. Such fishmeal traps were installed at six locations on the campus spread over 625 acres from January-2015 to December-2015 at a height of 30-50 cm from the ground level and operated for 24 hours during each meteorological week, traps were installed twice. The population density of shoot fly recorded twice for each meteorological week were summed up and correlated with weather data.

3. Results and Discussion

Results of the various biological parameters studied are presented in Table 1. The eggs were laid singly on the under surface of leaves, parallel to midrib (Plate 1) on third or fourth leaf blades. Generally single egg was laid and rarely two to three eggs were observed per leaf. The eggs were cylindrical or cigar shaped slightly broadened at the middle and sculptured. Freshly laid eggs were creamy or milky white in color. The egg period lasted for 2.25±0.24 and 2.92±0.32 days in *kharif* and *rabi* season, respectively. The results are in conformity with observations made by earlier workers Kundu and Prem Kishore [4], Barry [5], Somasekhar [6], Karibasavaraja [7], Kalaisekar [8] and Hari [9].The maggot hatched from the anterior region of the egg, which is dirty white in color (Plate 1). After hatching it rested for a short time on the leaf and made U-turn before entering inside the leaf blade. It took on an average of 32.5 minutes to enter the plant. After maggots entry the plant took 36 to 40 hours to show first visible symptom of dead heart. *Atherigona* maggots are apodus endophytic. The total larval period occupied 9.85±0.99 and 12.58±1.47 days in *kharif* and *rabi* season, respectively. The results of the present study are in line with the findings of Kalaisekar [8], Barry [5] and Taskdal and Balliwada [10] who reported a larval duration of 8.04 to 10.45, 11.5 to 14.5 and 8 to 10 days, respectively. A prolonged larval period of extra three days during *rabi* season may be due to lower temperature during the study period (October–2015). No such correlation studies for different seasons are available in literature. The pupa was of coarctate type and light brown in color at the initial stage, which later turned to dark brown (Plate 1) and usually found at the base of the plant near to bored hole on the shoot. However, pupation was also observed in soil. The pupal stage lasted for 8.92±0.94 and 10.86±1.02 days in *kharif* and *rabi* season, respectively. Similar, observations were made on pupa by Kundu and Prem Kishore [4], Somasekhar [6] and Karibasavaraja [7]. After completion of pupal duration, the fly pushed the anterior lid of pupa to for emergence and after that the whole body moved out the pupal case. Females had prominent six spots on the dorsal part of the abdomen, while male had four spots on abdomen. Reproductive characteristics of the shoot fly was studied and presented in the Table 2. Mating took place normally during morning (6.30 to 8.00 am) and evening (5.00 to 6.30) hours. After mating, the female fly lands at random on plant. Once the female landed, it rapidly moves up and down the plant, exhibiting characteristic tapping with its front tarsi after that oviposition noticed. Eggs were laid on the lower surface of the leaf parallel to midrib. During the study period from January 2015 to December 2015 the total number of adult flies trapped at weekly intervals in at six locations on the campus and are pooled and presented in Figure 1. During the study period a total of 12,485 flies were trapped with weekly average of 240 per standard week. Even the flies trapped during same weeks at different location within the campus there was a variation in number of adults found in traps. Data in the figure showed that the shoot fly population ranged from 0 (Zero) during 21st, 22nd, 23rd and 25th standard weeks to 2,106 flies in 33rd standard week (Aug 13-19). The moderate trap catch (105 to 238 flies / SW) of adult flies were noticed between 2nd SW to 6th SW and also between 39th SW to 52nd SW of 2016. The present finding are in conformity with Karibasavaraja [11] also reported maximum shoot fly activity between 27th to 44th standard weeks. Balikai [12] also reported that shoot fly population began to increase in July, reached its highest peak in August and declined thereafter with a slight peak in October, which again declined confirming the present findings. Raigar [13] reported that shoot fly dead hearts increased rapidly during first week of August (47.63 %) and thereafter the infestation continues to increase and became constant after third week of August. Similarly, Murti [14] also observed that incidence of shoot fly increasing in early August. It was at its peak during second fortnight of August till early September which confirms the present results.

The relationship between fish meal trap catches with weather parameters (Table 3) during the year 2015 indicated that the morning relative humidity had significant correlation during 3rd and 4th week before trap catches. The afternoon relative humidity had highly significant positive relationship with trap catches on all correlated weeks. The average rainfall had highly significant positive correlation with trap catches during one week after trap catches (0.384) and four week before trap catches (0.384). The rainy days had significant positive association (0.332) with trap catches during same week of trap catch. These findings are in agreement with Taneja [15] and Singh and Verma [16] who also explained that relative humidity exerts a significant positive relationship with the trap catches. In the present study rainfall and rainy days exerted very poor correlations with trap catches during the same week of observation which is contradicted to the findings of Taneja and Leuschner [17] who reported rainfall

was found to influence trap catches. The disagreement may be due to variation in adult activity as influenced by weather parameters.

4. Conclusion

The total life cycle of sorghum shoot fly, *Atherigona soccata* Rond. occupied 21.02±2.20 and 26.36±2.48 days, respectively during *kharif* and *rabi* season. A prolonged period of five days during *rabi* season may be due to lower temperature during the study period (October – 2015). The adult population of sorghum shoot fly was at its peak during 33rd standard week (August, 13-19) followed by 34th (August 20-26) and 35th standard week (August-25 to September-02), whereas, no or negligible population caught during 21st to 25th standard week of 2015.

Table 1: Comparative laboratory biology of sorghum shoot fly, A. soccata Rond. During Kharif and Rabi season (2015).

Life Stages	Kharif Season			Rabi Season		
	Duration in days	Measurement in mm		Duration in days	Measurement in mm	
		Length	Width		Length	Width
Egg	2.25±0.24 (n=25)	1.32±0.65	0.45±0.11	2.92±0.32 (n=25)	1.28±0.53	0.46±0.15
Larva	9.85±0.99 (n=20)	0.73±0.26*	0.40±0.15*	12.58±1.47 (n=20)	0.90±0.12*	0.34±0.13*
		7.05±0.72**	1.05±0.15**		7.24±0.45**	0.95±0.13**
Pupa	8.92±0.94 (n=20)	3.52±0.03	1.15±0.13	10.86±1.02 (n=20)	3.58±0.29	1.17±0.15
TLC	21.02±2.20			26.36±2.48		

TLC= Total life cycle **(*)** =I instar **(**)** =IV instar n= number of observations

Table 2: Oviposition, fecundity and adult longevity of *A. soccata* Rond. During *Kharif* and *Rabi* season

Life stages	Duration	
	Kharif (5 replication)	Rabi (5 replication)
Premating period(days)	1.38±0.18	1.52±0.21
Mating period (minutes)	1.25±0.36	1.63±0.18
Preovipositional period (days)	4.76±0.52	5.12±0.55
Ovipositional period(days)	8.40±0.92	10.2±1.08
Longevity of female (days) with food	13.5±1.25	15.6±1.54
Longevity of male (days) with food	7.5±0.82	9.6±1.03
Fecundity (no.)	25.8±2.70	21.2±2.34

Table 3: Correlation between sorghum shoot fly trap catches and weather parameters.

Correlated weeks	Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)	Rainy days	R^2 value
	Maximum	Minimum	Morning	Afternoon			
4 week before trap catch	-0.235	0.046	0.318*	0.495**	0.384**	0.190	27.5
3 week before trap catch	-0.082	0.100	0.286*	0.357**	0.064	0.212	25.6
2 week before trap catch	-0.113	0.091	0.264	0.373**	0.074	0.134	22.9
1 week before trap catch	-0.129	0.086	0.233	0.370**	0.095	0.209	20.2
Same week of trap catch	-0.185	0.072	0.262	0.398**	0.211	0.332*	20.6
One week after trap catch	-0.121	0.046	0.227	0.385**	0.384**	0.051	25.4

N = 17, "r" value 0.575 at 0.01 level "r" value 0.456 at 0.05 level
** Significant at 0.01 level.
Significant at 0.05 level.

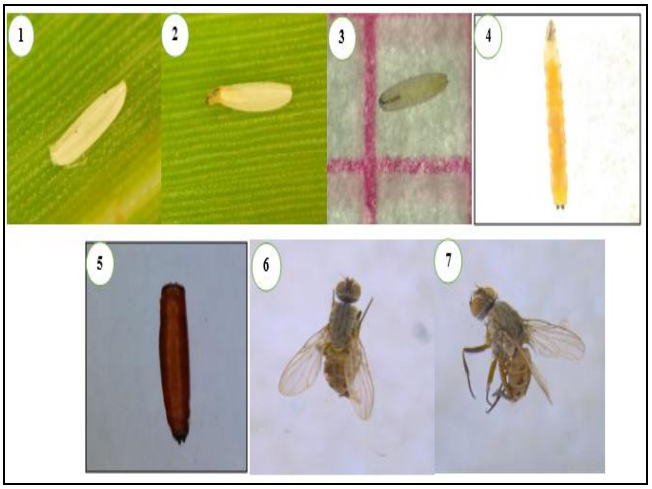

Plate 1: 1. Egg on lower surface of leaf. 2. Larva hatches out from egg. 3. First instar larva (0.73 x 0.40mm). 4. Final instar larva (7.05 x 1.05 mm) 5. Puparium (3.52 x 1.15 mm). Fully developed 6. Male and 7. Female flies.

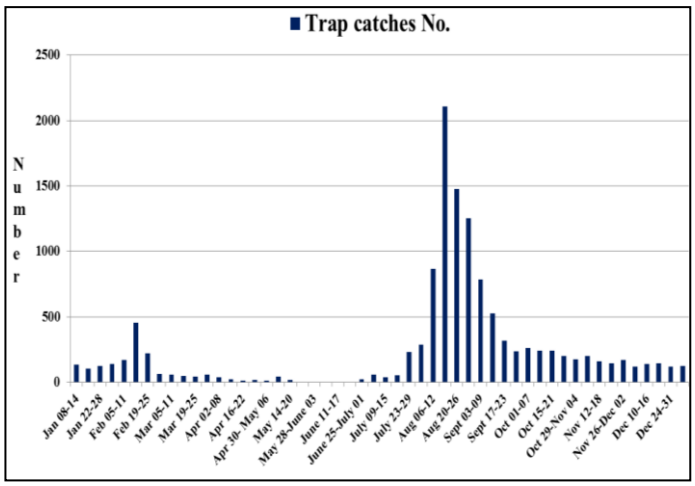

Fig 1: Fish meal trap catches of *Atherigona soccata* adults during 2015 at UAS, Raichur campus.

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