Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(1): 808-814

Received: 05-11-2018
Accepted: 08-12-2018

P Yogeswari
Department of Entomology, Agricultural College, Bapatla, Andhra Pradesh, India

C Sandhya Rani
Department of Entomology, Agricultural College, Bapatla, Andhra Pradesh, India

G Ramachandra Rao
Department of Entomology, Agricultural College, Bapatla, Andhra Pradesh, India

V Manoj Kumar
Department of Entomology, Agricultural College, Bapatla, Andhra Pradesh, India

Correspondence
P Yogeswari
Department of Entomology, Agricultural College, Bapatla, Andhra Pradesh, India

Influence of bio-physical factors on shoot fly infestation in different sorghum genotypes cultivated under zero tillage in rice fallows

P Yogeswari, C Sandhya Rani, G Ramachandra Rao and V Manoj Kumar

Abstract
A field experiment was carried out to screen the sorghum genotypes against shoot fly in rice fallow under zero tillage condition. As per 1-9 scale, for shoot fly infestation in terms of dead hearts among the 30 evaluated genotypes, eleven were found to be resistant, eighteen genotypes were moderately resistant with scale 5 and one genotype was found to be susceptible under sale-7. The highest number of trichomes recorded in the resistant genotypes CSV 14 R (177), followed by CSH 30 (164), CSV 29R (154), CSV 26 (153), NTJ-1 (C) (147) and CSV 22 (145) which recorded 10.13 to 14.50% dead hearts. There was a significant negative correlation between the shoot fly percent dead hearts and trichomes on the adaxial surface and trichomes on the abaxial surface while the correlation was positive with leaf glossiness and yield.

Keywords: Shoot fly, dead hearts, trichomes, leaf glossiness

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth major cereal crop after wheat, rice, maize and barley. It is the most important crop of Asia, Africa, Australia, America and is cultivated as a staple crop in the semi-arid tropics (SAT). In India it is cultivated in an area of 6.18 m ha with 5.33 million tonnes production and productivity of 863 kg/ha (Agricultural Census, 2013) [1]. In general sorghum is cultivated during *kharif*, maghi (Late *kharif*) and *rabi* seasons in Andhra Pradesh in an area of 2,87,000 ha with production of 5,46,000 tonnes and productivity of 1904 kg/ha (Agricultural Statistics at a glance, 2012-2013) as against normal area 7,60,000 ha with production of 5,52,000 tonnes and productivity of 730 kg/ha. The reasons for low productivity under the normal type of cultivation might be due to shifting of jowar area to cultivation of commercial crops, high humidity in coastal regions and ravage of pests and diseases in jowar cultivating areas.

Insect pest situations are dynamic in nature and changes with climate, farming practices, introduction of improved varieties have been known to result in pest outbreaks or changes in pest status (Duale and Nwanze, 1999) [8]. Sorghum is attacked by more than 150 insect species causing a 32% crop loss (Borad and Mittal, 1983) [4]. Losses in sorghum due to insect pests differ in magnitude on a regional basis and have been estimated at US $ 1089 million in the SAT, US $ 250 million in the USA and US $ 80 million in Australia (Anonymous, 1992). Among the insect pests, shoot fly, *Atherigona soccata* (Rondani) and stem borer, *Chilo partellus* (Swinhoe) are the major threats with 75.6% and 24.3 to 36.3% yield losses respectively (Pawar *et al*., 1984) [19].

Management of the pests is being done with the pesticides. But due to the adverse effects of pesticides it is imperative to seek for alternate integrated pest management methods like host plant resistance as it not only costless or require application skills in pest control techniques, but also enhance the effectiveness of natural enemies and reduce the need to use pesticides (Sharma, 1993) [24]. The effect of resistant genotypes on insect population is continuous and cumulative over time. Umakanth *et al*. (2004) [29] reported 'SPV 1022', 'PKV809' and 'CO28' as promising sorghum cultivars in rice-fallows.

Materials and Methods

"Influence of bio-physical factors on shoot fly infestation in different sorghum genotypes cultivated under zero tillage in rice fallows" was carried out during *rabi*, 2014 -15 in the southern block of Agricultural College Farm, Bapatla. Investigation was carried out to screen the sorghum genotypes against shoot fly in rice fallow under zero tillage condition. Twenty genotypes were procured from Directorate of Sorghum Research, Hyderabad and Regional Agricultural Research Station (R.A.R.S), Nandyal were used as source material for the screening study. The experiment was laid out in Randomized block design at the Agricultural college Farm, Bapatla and the treatments were replicated twice. The crop was sown on 7-1-2015. The length of each line was 4 m and spacing between two lines of each genotype was 45 cm and intra row spacing adopted was 15 cm.

Observations were recorded starting from 7 days after emergence (DAE) of seedlings and continued up to 35 days. In both the rows total number of dead hearts were counted and per cent dead hearts was calculated as per the given formula given below

$$\text{Dead hearts (\%)} = \frac{\text{No. of plants with dead hearts}}{\text{Total no. of plants observed}} \text{ X } 100$$

Table 1: Based on 1-9 scale the 30 genotypes were categorized as follows (Gomashe *et al*., 2010) [10]

Scale	% infestation	Reaction
1	≤ 10% infestation	Highly resistant
3	10 to 20%	Resistant
5	20 to 35%	Moderately resistant
7	35 to 50% infestation	Susceptible
9	≥50% infestation	Highly susceptible

Trichomes density

The presence and density of trichomes was measured on the central portion of the 5th leaf (from the base) taken from three seedlings at random. For this purpose, leaf pieces (2 cm^2) taken from the central portion of the leaf were placed in acetic acid and alcohol (2:1) in stoppered glass vials (10 ml capacity) for 24 h to clear the chlorophyll, and subsequently transferred into lactic acid (90%) as a preservative (Maiti and Bidinger, 1979) [17]. The leaf sections were mounted on a glass slide in a drop of lactic acid, and magnified at 10X under a stereo-microscope. The trichomes on leaf surfaces, both abaxial and adaxial surfaces, were expressed as number of trichomes/10X microscopic field. The images were taken with the help of tablet microscope digital camera at Department of Genetics and Plant Breeding, Agricultural College, Bapatla.

Leaf glossiness

The leaf glossiness was evaluated on a 1 to 5 rating scale at 10 DAE in the morning hours when there was a maximum reflection of light from the leaf surfaces (1= highly glossy-light green, shiny, narrow, and erect leaves; 5= non-glossy-dark green, dull, broad, and drooping leaves) (Dhillon *et al*., 2005) [7].

Results and Discussion

The data on the number of dead hearts, per cent dead hearts, trichomes on both adaxial and abaxial leaf surface and leaf glossiness was recorded from thirty genotypes evaluated under zero tillage in rice fallows during 2014-15. The results on shoot fly infestation revealed that, there was a significant difference among the genotypes.

Dead Hearts Caused by Shoot fly

The data on the number of dead hearts and percent dead hearts recorded at 21 days after emergence (DAE) was ranged from 0.00 to 0.08 and 0.00 to 7.83 respectively. The highest number of dead hearts and percent dead hearts was noticed in the genotype NTJ-4 (C) (0.08 and 7.83) followed by CSV 29R (0.06 and 5.99), NTJ-2 (C) (0.05 and 5.19), NLCW-6 (0.05 and 4.76) compared to the checks NTJ-1 (0.01 and 1.22), CSH 16 (0.02 and 1.92) and NTJ-3 (0.02 and 2.00). Dead hearts were not noticed in the genotypes Mahalaxmi 296 (C), CSH 24 MF, CSV 216R, CSV 15, CSV 15, CSH 14, CSV 26 and N-13. These findings are in conformity with the findings of Shekharappa (2007) [25] who reported the least dead hearts 9.28% in SPV 1360 genotype. Khandare *et al.*, (2013) [13] reported 7.98%-72.41% dead hearts due to shoot fly in sorghum at 21DAE. The reason for the lesser shoot fly infestation might be the off season and unfavoured weather and physico-chemical factors in the genotypes responsible for shoot fly development.

Subbarayudu *et al.* (2011) [27] recorded shoot fly dead hearts at 21 DAE ranged from 35% to 78.7% with a mean of 52.0% and genotypes, ICSV 705, ICSV 745, SR 770-2, SR 833, SR 970-2, SR 115-1, SR 1247-1, GFS 261 were statistically on par with the resistant check (IS 2312) which recorded 36.8% dead hearts and also reported 55.1% dead hearts in CSV 15 in *kharif* season. Chikkarugi and Balikai (2011) [5] recorded 18.0 % dead hearts at 21DAE in the sorghum genotype CSV 216R. Vyas *et al.* (2014) [31] recorded 53.39% and 44.09% dead hearts in the genotypes CSH 20 MF and CSV 21MF respectively.

The results revealed that there is an increasing trend in shoot fly infestation from 21 DAE. The number of dead hearts and percent dead hearts at 28 DAE ranged from 0.06 to 0.24 and 5.67 to 23.91%. The highest number of dead hearts and percent dead hearts were noticed in the genotype CSV 216R (0.24 and 23.91) followed by NTJ-4 (C) (0.22 and 22.35), CSH 20 MF (0.22 and 21.54), and BRJ-358 (0.21 and 21.21) whereas the lowest number noticed in CSH 14 (0.06 and 5.67), NTJ-1(C) (0.06 and 6.10) followed by CSV 29R (0.07 and 7.01), N-13 (0.07 and 7.14) compared to the Mahalaxmi 296 (C) (0.08 and 8.05) and CSH 16 (0.13 and 13.18). The change in the weather parameters like relative humidity (RH) in the environment during the crop growth period from 67.9 to 83.3% might be the reason for the shoot fly infestation after 21 DAE. Sable *et al.* (2009) [21] reported that high RH was favorable for shoot fly population and dead hearts were positively correlated with RH and negatively correlated with temperature.

At 35 DAE the number of dead hearts and percent dead hearts ranged from 0.10 to 0.36 and 10.13 to 35.58 respectively (Table: 2). The highest number of dead hearts and percent dead hearts were noticed in the genotype CSH 20MF (0.36

and 35.58), CSH 23 (0.33 and 32.91), NTJ-4 (C) (0.30 and 30.30), CSH 22SS (0.29 and 28.58) while the lowest were noticed in CSV14R (0.10 and 10.13) followed by CSV 29R (0.11 and 10.66), CSV 26 (0.11 and 11.06) and CSH 30 (0.11 and 11.42) which were on par with the resistant check NTJ-1 (0.12 and 12.09) and percent dead hearts in resistant check CSH 16 (0.21 and 20.0%) significantly differed from popular check Mahalaxmi 296 (0.26 and 26.00). Mahalaxmi 296 (C), CSV 24SS, CSH 22SS, CSV 23, CSH 20MF, SSV 84, CSV 216R, CSV 15, CSH 23, CSH 25, NTJ-2 (C), NTJ-3 (C), N-13, N-14, BRJ-358 were on par with resistant check CSH 16 interms of dead hearts percentage values, eventhough they are classified based on reaction scale. The present investigation results are in close conformity with the findings of Kishore *et al.* (2002) [14], Khandare *et al.* (2013) [13] but contrary to the findings of Hussian *et al.* (2014) [11] who reported that the lowest dead hearts were produced in the resistant check CSV 15.

Table 2: Reaction of Sorghum genotypes against Shoot fly, *A. soccata* during 2014-15

S. No.	Genotype	No of Dead Hearts caused by Shoot fly ¥		
		21 DAE	28 DAE	35 DAE
1	CSV 24SS	0.02 (1.01)	0.10 (1.05)	0.28 (1.13)
2	CSH 22SS	0.01 (1.00)	0.19 (1.09)	0.29 (1.13)
3	CSV 23	0.03 (1.01)	0.15 (1.07)	0.26 (1.12)
4	CSH 20MF	0.02 (1.01)	0.22 (1.10)	0.36 (1.16)
5	CSH 24MF	0.00 (1.00)	0.13 (1.07)	0.18 (1.09)
6	CSV 17	0.02 (1.01)	0.12 (1.06)	0.16 (1.08)
7	SSV 84	0.01 (1.00)	0.13 (1.07)	0.27 (1.13)
8	CSV 216R	0.00 (1.00)	0.24 (1.11)	0.28 (1.13)
9	CSV 15	0.00 (1.00)	0.11 (1.05)	0.29 (1.13)
10	CSH 14	0.00 (1.00)	0.06 (1.03)	0.21 (1.10)
11	CSV 22	0.01 (1.01)	0.13 (1.06)	0.15 (1.07)
12	CSV 26	0.00 (1.00)	0.09 (1.04)	0.11 (1.05)
13	CSH 23	0.02 (1.01)	0.10 (1.05)	0.33 (1.15)
14	CSV 29R	0.06 (1.03)	0.07 (1.03)	0.11 (1.05)
15	CSH 30	0.02 (1.01)	0.09 (1.04)	0.11 (1.05)
16	CSV 14R	0.02 (1.01)	0.10 (1.05)	0.10 (1.05)
17	CSH 13	0.03 (1.02)	0.13 (1.06)	0.15 (1.07)
18	N-13	0.00 (1.00)	0.07 (1.03)	0.27 (1.13)
19	N-14	0.04 (1.02)	0.15 (1.07)	0.26 (1.12)
20	BRJ-358	0.03 (1.02)	0.21 (1.10)	0.26 (1.12)
21	NLCW-6	0.05 (1.02)	0.19 (1.09)	0.21 (1.10)
22	NLCW-8	0.03 (1.02)	0.17 (1.08)	0.23 (1.11)
23	NLCW-12	0.04 (1.02)	0.08 (1.04)	0.20 (1.09)
24	Mahalaxmi 296 (C)	0.00 (1.00)	0.08 (1.04)	0.26 (1.12)
25	CSH 16 (C)	0.02 (1.01)	0.13 (1.06)	0.21 (1.10)
26	CSH 25	0.01 (1.01)	0.10 (1.05)	0.21 (1.10)
27	NTJ-1 (C)	0.01 (1.01)	0.06 (1.03)	0.12 (1.06)
28	NTJ-2 (C)	0.05 (1.03)	0.21 (1.10)	0.29 (1.14)
29	NTJ-3 (C)	0.02 (1.01)	0.15 (1.07)	0.22 (1.10)
30	NTJ-4 (C)	0.08 (1.04)	0.22 (1.10)	0.30 (1.14)
	G. Mean	1.01	1.06	1.10
	SEm±	0.01	0.02	0.02
	CD (0.05%)	0.03*	0.05*	0.06*
	CV%	1.26	2.48	2.86

Note: **¥ =** Values in the parenthesis are square root transformed values.
* = Significant

The evaluated 30 genotypes were categorized based on 1-9 scale *viz*., highly resistant (1 = ≤ 10% infestation), resistant (3 = 10 to 20%), moderately resistant (5 = 20 to 35%), susceptible (7 = 35 to 50% infestation) and highly susceptible (9 = ≥50% infestation). Among the 30 evaluated genotypes, eleven namely CSH 16 (C), CSH 24MF, CSV 17, CSV 22, CSV 26, CSV 29R, CSH 30, CSH 14R, CSH 13, NTJ-1 (C) and NLCW-12 were found to be resistant and placed under scale 3 as they recorded with 10.13 (CSV 14R) to 19.79 (NLCW-12) per cent dead hearts.

Eighteen genotypes including popular local check Mahalaxmi 296, CSV 24SS, CSH 22SS, CSV 23, SSV 84, CSV 216R, CSV 15, CSH 14, CSH 23, CSH 25, NTJ-2 (C), NTJ-3 (C), NTJ-4 (C), N-13, N-14, BRJ-358, NLCW-6 and NLCW-12 were placed under moderately resistant with scale 5 as they recorded 20.51 (CSH 25) to 28.89 and the genotype CSH 20MF was found to be susceptible by recording 35.58 % dead hearts, hence categorized under sale-7 (Table: 3).

Table 3: Evaluation of Sorghum genotypes based on 1-9 scale for Shoot fly infestation

S. No.	Genotype	Per cent dead hearts by shoot fly #			Reaction	Scale (1-9)
		21 DAE	28 DAE	35 DAE		
1	CSV 24SS	2.27 (6.16)	9.51 (17.96)	27.81 (35.25)	MR	5
2	CSH 22SS	0.96 (3.99)	18.62 (25.57)	28.58 (31.34)	MR	5
3	CSV 23	3.00 (7.09)	14.86 (22.67)	25.67 (32.77)	MR	5
4	CSH 20MF	2.27 (6.16)	21.54 (27.48)	35.58 (29.64)	S	7
5	CSH 24MF	0.00 (0.00)	13.42 (21.50)	18.11 (23.55)	R	3
6	CSV 17	1.96 (5.71)	12.00 (20.28)	16.01 (26.28)	R	3
7	SSV 84	0.96 (3.99)	13.46 (21.33)	26.92 (29.15)	MR	5
8	CSV 216R	0.00 (0.00)	23.91 (28.92)	27.57 (34.63)	MR	5
9	CSV 15	0.00 (0.00)	10.62 (19.01)	28.58 (31.69)	MR	5
10	CSH 14	0.00 (0.00)	5.67 (13.61)	21.25 (21.59)	MR	5
11	CSV 22	1.22 (4.49)	12.54 (20.43)	14.50 (21.23)	R	3
12	CSV 26	0.00 (0.00)	8.88 (17.14)	11.06 (28.82)	R	3
13	CSH 23	2.00 (5.77)	9.68 (18.07)	32.91 (25.48)	MR	5
14	CSV 29R	5.99 (13.99)	7.01 (16.64)	10.66 (14.71)	R	3
15	CSH 30	2.04 (8.22)	8.95 (17.39)	11.42 (23.72)	R	3
16	CSV 14R	2.00 (5.77)	10.13(18.57)	10.13 (18.57)	R	5
17	CSH 13	3.04 (9.88)	13.22 (20.89)	14.82 (24.09)	R	3
18	CSH 25	1.06 (6.30)	10.45 (18.45)	20.51 (26.17)	MR	5
19	N-13	0.00 (0.00)	7.14 (11.11)	27.22 (30.12)	MR	5
20	N-14	3.57 (7.75)	15.48 (23.16)	26.19 (31.77)	MR	5
21	BRJ-358	3.48 (7.53)	21.21 (27.42)	25.91 (29.62)	MR	5
22	NLCW-6	4.76 (8.99)	18.90 (25.78)	21.28 (26.46)	MR	5
23	NLCW-8	3.49 (7.66)	16.79 (23.95)	22.66 (32.45)	MR	5
24	NLCW-12	3.94 (11.40)	8.33 (12.05)	19.79 (32.65)	R	3
25	Mahalaxmi 296 (C)	0.00 (0.00)	8.05 (15.90)	26.00 (33.33)	MR	5
26	CSH 16 (C)	1.92 (7.98)	13.18 (21.30)	20.00 (26.56)	R	5
27	NTJ-1 (C)	1.22 (4.99)	6.10 (10.22)	12.09 (20.84)	R	3
28	NTJ-2 (C)	5.19 (13.09)	20.70 (27.03)	28.89 (29.57)	MR	5
29	NTJ-3 (C)	2.00 (5.77)	14.74 (22.09)	21.96 (30.11)	MR	5
30	NTJ-4 (C)	7.83 (15.90)	22.35 (27.50)	30.30 (33.59)	MR	5
	G. Mean	6.13	20.22	27.94		
	SEm±	1.03	2.37	4.51		
	CD (0.05%)	2.97*	6.87*	13.03*		
	CV%	24	16.60	22.80		

Note: # = Values in the parenthesis are arcsine transformed values; HR= Highly Resistant, MR= Moderately Resistant, R= Resistant, S=Susceptible. * = Significant

Yadav and Panickar (2015) [32] recorded significantly minimum mean 16.09 per cent dead hearts on sorghum variety CSV 21 at every intervals of observation followed by CSV 15 (21.95) which was at par with SPV-1616. Kushwaha and Kapoor (1995) [16] at Hissar and Garg and Singh (2003) [9] at Gwalior also reported that the variety CSV-15 was found resistant against *A. soccata*.

Influence of Trichomes Density on Shoot fly Infestation

The data on trichomes density recorded at 12 DAE revealed that there is a highly significant variation among the genotypes (Table: 4). The number of trichomes on the adaxial leaf surface ranged from 0.00 to 177. The susceptible genotype CSH 20MF and moderately resistant genotype CSH 23 were free from trichomes. The highest number of trichomes recorded in the resistant genotypes CSV 14 R (177), followed by CSH 30 (164), CSV 29R (154), CSV 26 (153), NTJ-1 (C) (147) and CSV 22 (145) which recorded 10.13 to 14.50% dead hearts. The lowest number of trichomes was recorded in the genotypes CSH 22SS, NTJ-2 (C) and NTJ-4 (C) (2.0) followed by CSV 15 (3.0), CSV 24SS (8.0) and CSV 216R (23.0) which recorded with 27.57 to 32.91 per cent dead hearts compared to the popular check Mahalaxmi 296 (99) and resistant check CSH 16 (122) and the other checks NTJ-3 (114) and NTJ-4 (2.0).

The number of trichomes on the abaxial leaf surface ranged from 0.00 to 113. The highest number of trichomes was recorded in the genotypes CSH 13 (113) followed by CSV 22 (107), CSV 29R (103), CSV 14R (101) and CSV 26 (100) whereas the lowest number *i.e.,* 2.0 was recorded in the moderately resistant genotypes, CSH 22SS, CSV 15, NTJ-2 (C) and NTJ-4 (C) followed by SSV 84 (15.0) and CSV 216R (17.0) which recorded 21.96 to 32.91 percent dead hearts compared to the checks NTJ-1 (102) and NTJ-3 (66).

Table 4: Biophysical characters of Sorghum genotypes evaluated against Shoot fly, *Atherigona soccata* infestation

S. No.	Genotype	Reaction	Trichome density (No./mm^2) ¥		% Dead hearts	Leaf glossiness (1-5 scale) ¥ 1=highly glossy 5= non glossy
			Adaxial leaf surface	Abaxial leaf surface		
1	CSV 24SS	MR	8.00 (3.07)	20.00 (4.55)	27.81 (35.25)	2.20 (1.48)
2	CSH 22SS	MR	2.00 (1.72)	2.00 (1.72)	28.58 (31.34)	4.10 (2.02)
3	CSV 23	MR	86.00 (9.32)	31.00 (5.67)	25.67 (32.77)	3.30 (1.82)
4	CSH 20MF	S	0.00 (1.00)	0.00 (1.00)	35.58 (29.64)	3.10 (1.76)
5	CSH 24MF	R	143.00 (12.00)	94.00 (9.76)	18.11 (23.55)	2.95 (1.72)
6	CSV 17	R	145.00 (12.10)	90.00 (9.55)	16.01 (26.28)	2.05 (1.43)
7	SSV 84	MR	35.00 (5.99)	15.00 (3.99)	26.92 (29.15)	1.80 (1.34)
8	CSV 216R	MR	23.00 (4.86)	17.00 (4.20)	27.57 (34.63)	1.70 (1.30)
9	CSV 15	MR	3.00 (1.98)	2.00 (1.72)	28.58 (31.69)	2.05 (1.43)
10	CSH 14	MR	119.00 (10.96)	76.00 (8.76)	21.25 (21.59)	1.55 (1.24)
11	CSV 22	R	145.00 (12.10)	107.00 (10.39)	14.50 (21.23)	3.70 (1.92)
12	CSV 26	R	153.00 (12.40)	100.00 (10.07)	11.06 (28.82)	1.70 (1.30)
13	CSH 23	MR	0.00 (1.00)	0.00 (1.00)	32.91 (25.48)	1.40 (1.11)
14	CSV 29R	R	154.00 (12.46)	103.00 (10.19)	10.66 (14.71)	2.00 (1.41)
15	CSH 30	R	164.00 (12.83)	97.00 (9.89)	11.42 (23.72)	3.70 (1.92)
16	CSV 14R	R	177.00 (13.35)	101.00 (10.07)	10.13 (18.57)	1.15 (1.07)
17	CSH 13	R	145.00 (12.07)	113.00 (10.70)	14.82 (24.09)	2.05 (1.43)
18	CSH 25	MR	125.00 (11.22)	67.00 (8.25)	20.51 (26.17)	1.70 (1.30)
19	N-13	MR	83.00 (9.16)	34.00 (5.91)	27.22 (30.12)	1.80 (1.34)
20	N-14	MR	111.00 (10.59)	69.00 (8.39)	26.19 (31.77)	1.50 (1.22)
21	BRJ-358	MR	109.00 (10.47)	82.00 (9.10)	25.91 (29.62)	2.20 (1.48)
22	NLCW-6	MR	124.00 (11.17)	82.00 (9.10)	21.28 (26.46)	1.90 (1.38)
23	NLCW-8	MR	145.00 (12.10)	90.00 (9.55)	22.66 (32.45)	1.75 (1.32)
24	NLCW-12	R	138.00 (11.79)	93.00 (9.69)	19.79 (32.65)	2.00 (1.41)
25	Mahalaxmi 296 (C)	MR	99.00 (9.99)	74.00 (8.66)	26.00 (33.33)	3.90 (1.97)
26	CSH 16 (C)	R	122.00 (11.09)	91.00 (9.61)	20.00 (26.56)	1.55 (1.24)
27	NTJ-1 (C)	R	147.00 (12.17)	102.00 (10.17)	12.09 (20.84)	1.80 (1.34)
28	NTJ-2 (C)	MR	2.00 (1.72)	2.00 (1.72)	28.89 (29.57)	2.10 (1.45)
29	NTJ-3 (C)	MR	114.00 (10.74)	66.00 (8.21)	21.96 (30.11)	1.75 (1.32)
30	NTJ-4 (C)	MR	2.00 (1.72)	2.00 (1.72)	30.30 (33.59)	2.90 (1.70)
	G. Mean		8.70	7.06	27.94	1.47
	SEm±		0.63	0.56	2.49	0.12
	CD (0.05%)		1.81*	1.62*	7.21*	0.35*
	CV%		10.2	11.2	12.62	11.8

Note: ¥ = Values in the parenthesis are square root transformed values. HR= Highly Resistant
MR= Moderately Resistant, R= Resistant, S=Susceptible. * = Significant

Generally trichomes are present on both surfaces of the leaf, but were more abundant on the adaxial surface. Trichomes may contribute to the expression of antibiosis to shoot fly by limiting the insect contact with the plant by playing a role as a physical barrier to the movement of newly hatched larvae to the base of the whorl. The cultivars having more number of trichomes could be considered as sources of resistance for using in the varietal improvement programmes.

The results of the present studies also corroborate with the reports of Singh and Rana (1996) [26], Padmaja *et al.* (2010) [18], Gomashe *et al.* (2010) [10] and Chickkarugi and Balikai (2011) [5]. The presence of unicellular and pointed trichomes on both the leaf surfaces in resistant genotypes might be the reason for low shoot fly infestation as their presence on the adaxial surface of leaf impedes the larval movement towards the growing apex and deters the oviposition by shoot fly. The susceptibility in genotypes might be due to the presence of bicellular and blunt trichomes. Hence, the trichome morphology may be used as a morphological marker associated positively with shoot fly resistance.

Although trichome density is significantly and negatively correlated with dead hearts, it does not have direct role in reducing dead hearts but through other traits. In addition, glandular trichomes can contribute to insect resistance by producing toxic compounds, which poison the insect through contact, ingestion, and/or inhalation, and by producing gummy, sticky or polymerizing chemical exudates, which impede the insect movement (David and Easwaramoorthy, 1988) [6].

Influence of Leaf Glossiness on Shoot fly Infestation

The leaf glossiness ranged from 1.15 to 4.10. The genotypes with highest leaf glossiness values were found as non-glossy, they were CSH 22SS (4.10), Mahalaxmi 296 (3.90), CSV 22 (3.70), CSH 30 (3.70), CSV 23 (3.30) and CSH 20MF (3.10) while the genotypes with the lowest leaf glossiness values were glossy, they were CSV 14R (1.15), CSH 23 (1.40), CSH 16 (C) (1.55), CSH 14 (1.55), CSV 216R (1.70), CSV 26 (1.70) and CSH 25 (1.70).

Expression of leaf glossiness in seedlings is an important trait for identifying shoot fly resistance in sorghum. It is clearly manifested during the seedling stage and gradually disappears as the seedling grows. The glossy appearance of the leaf is due to change in the structure of epicuticular wax on the leaf surface rather than the dense mat of vertical tubes of normal wax (non-glossy) (Tarumoto, 2005) [28].

Glossiness affects the quality of light reflected from leaves, which inturn influences the orientation of insects towards

their host plants (Prokopy *et al.*, 1983) [20]. The intensity of leaf glossiness of the leaves during seedling stage is associated with resistance to shoot fly (Sharma *et al.*, 1997; Vijayalakshmi, 1993) [22, 23, 30].

The highest number of trichomes was recorded in glossy, resistant line IS 18551 and the least in non glossy, susceptible line-296B. Glossiness and trichome traits together contribute to shoot fly resistance. The presence of trichomes in glossy leaf surface imparts resistance to shoot fly attack (Padmaja *et al.* (2010) [18]. The trichome shape was different in glossy and non-glossy genotypes. The glossy genotypes showed unicellular and pointed trichomes whereas in the non-glossy genotypes trichomes were bicellular and blunt in shape.

In highly resistant, moderately resistant genotypes resistance against shoot fly might be due to the physico-morphological and biochemical factors associated with resistance to shoot fly. This nature was influenced by factors like presence of irregularly shaped silica bodies in plant tissue, lignifications, silica deposition, nitrogen, reducing sugars, total sugars, moisture, chlorophyll, lysine, amino acids, phenol and phosphorus have been found to be associated with resistance to shoot fly (Sharma and Nwanze, 1997) [22, 23].

Correlation between biophysical parameters of sorghum genotypes and shoot fly infestation

The interactions between the shoot fly infestation and trichomes on adaxial surface revealed negative significant correlation (r= -0.7373), shoot fly infestation and trichomes on abaxial surface revealed negative significant correlation (r= -0.7141), but it was positive non-significant with leaf glossiness (r= 0.1384) and yield (r=0.2403) (Table: 5). Although trichome density is significantly and negatively correlated with dead hearts, it does not have direct role in reducing dead hearts, but contributes to shoot fly resistance mainly through other traits (Karanjkar *et al.*, 1992) [12].

Table 5: Correlation between Shoot fly infestation and Trichomes on leaf surface in different sorghum genotypes

Parameter	Trichomes on Adaxial surface	Trichomes on Abaxial surface	Leaf glossiness	Yield
DH % by Shoot fly	-0.7374*	-0.7142*	0.1384	0.2403

*Significant at 5% r table value = 0.361 Number of observations = 30

Kumar *et al*. (2008) [15] reported that there was significant and positive correlation between shoot fly dead hearts and grain yield (r = 0.42*) and negative correlation between shoot fly dead hearts and time to 50% flowering (r = −0.49**). Grain yield also showed significant negative correlation with time to 50% flowering (r = −0.50**). These results, therefore, suggested that resistant genotypes though infected with shoot fly recovered from the damage and produced tillers. Tillers, which delayed crop maturity but higher grain yield was produced like normal crop. Host plant resistance is one of the most effective means of pest management in sorghum.

There is a positive and significant correlation between leaf glossiness and oviposition by *A. soccata* on percent dead hearts. The higher level of resistance to shoot fly will exhibit when the leaf glossiness and trichomes occurred together in a genotype. Shoot fly females lay eggs on non preferred cultivars only after laying several eggs on the seedlings of susceptible cultivars. Resistance to shoot fly was associated with leaf glossiness, trichome density, leaf sheath pigmentation and waxy bloom. Leaf glossiness, trichome density on both leaf surfaces, leaf sheath pigmentation and waxy bloom were significantly and positively correlated. Chlorophyll content showed significant and negative association with leaf glossiness, trichome density and waxy bloom.

Non preference for oviposition in sorghum is relative. The shoot fly adult is unable to attach itself on to the leaf surface of the glossy genotypes for oviposition due to their smooth amorphous epicuticular wax, while in the non-glossy genotypes the crystalline wax may give support for attachment and their oviposition. Leaf surface microroughness is caused by epicuticular wax crystals, cell surface, contours, leaf venation and trichomes. Rapid growth of seedlings, greater seedling height and hardness may retard the first instar larvae from reaching the growing tip. In contrast slow growth due to the poor seedling vigour, low fertility or environmental stress increases shoot fly damage.

In highly resistant, moderately resistant genotypes the resistance against shoot fly might be due to the physico-morphological and biochemical factors associated with resistance to shoot fly influenced by factors like presence of irregularly shaped silica bodies in plant tissue, lignifications, silica deposition, nitrogen, reducing sugars, total sugars, moisture, chlorophyll, lysine, amino acids, phenol and phosphorus have been found to be associated with resistance to shoot fly (Sharma and Nwanze, 1997) [22, 23].

Conclusions

The infestation interms of dead hearts caused by shoot fly ranged from 0.10 to 35.58%. As per 1-9 scale, for shoot fly infestation interms of dead hearts among the 30 evaluated genotypes, eleven namely CSH 16 (C), CSH 24MF, CSV 17, CSV 22, CSV 26, CSV 29R, CSH 30, CSH 14R, CSH 13, NTJ-1 (C) and NLCW-12 were found to be resistant, eighteen genotypes including popular local check Mahalaxmi 296, CSV 24SS, CSH 22SS, CSV 23, SSV 84, CSV 216R, CSV 15, CSH 14, CSH 23, CSH 25, NTJ-2 (C), NTJ-3 (C), NTJ-4 (C), N-13, N-14, BRJ-358, NLCW-6 and NLCW-12 were moderately resistant with scale 5 and the genotype CSH 20MF was found to be susceptible under sale-7.

The number of trichomes on adaxial leaf surface ranged from 0.00 to 177. The susceptible genotype CSH 20MF and moderately resistant genotype CSH 23 were free from trichomes. The highest number of trichomes recorded in the resistant genotypes CSV 14 R (177), followed by CSH 30 (164), CSV 29R (154), CSV 26 (153), NTJ-1 (C) (147) and CSV 22 (145) which recorded 10.13 to 14.50% dead hearts. Non glossy genotypes with Scale=2.00 to 4.10 were NLCW-12 (2.00), CSV 29R (2.00), CSV 17 (2.05), CSV 15 (2.05), CSH 13 (2.05), NTJ-2 (C) (2.10), CSV 24SS (2.20), BRJ- 358 (2.20), NTJ-4 (C) (2.90), CSH 24MF (2.95), CSH 20MF (3.10), CSV 23 (3.30), CSV 22 (3.70), CSH 30 (3.70), Mahalaxmi 296 (C) (3.90), CSH 22SS (4.10) and glossy genotypes with Scale=1.15 to 1.90 were CSV 14R (1.15), CSH 23 (1.40), N-14 (1.50), CSH 16 (1.55), CSH 14 (1.55), CSH 25 (1.70), CSV 26 (1.70), CSV 216R (1.70), NLCW-8 (1.75), NTJ-3 (C) (1.75), NTJ-1 (C) (1.80), SSV 84 (1.80), N-13 (1.80), NLCW-6 (1.90).

Reference

1. Agricultural Census. Proceedings in ICAR workshop on Global consultation on millets promotion for health and nutrition security conducted by Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India on 23-12-2013. 2013, 5.
2. Agricultural Statistics at a Glance - Andhra Pradesh. 2012-2013, 97-99.
3. Anonymous. ICRISAT (International Crops Research Institute for the Semi Arid Tropics). Medium – term plan. Patancheru Andhra Pradesh, India, 502-524, vii – viii.
4. Borad PK, Mittal VP. Assessment of losses of caused by pest complex to sorghum hybrid CSH-5. Indian Journal of Entomology. 1983; 15:271-278.
5. Chikkarugi NM, Balikai RA. Evaluation of sorghum genotypes in aphid and shoot bug nursery against major pests. International Journal of Plant Protection. 2011; 4(1):74-78.
6. David H, Eashwaramoorthy S. Physical resistance mechanisms in insect plant interaction, In: Dyanamics of insect-plant interaction: recent advances and future trends (Ananthkrishna, T, Raman, A. eds) Oxford IBH Publshing Co. New Delhi, India, 1988, 45-70.
7. Dhillon MK, Sharma HC, Singh R, Naresh JS. Mechanism of resistance to shoot fly (*Atherigona soccata*) in sorghum. Euphytica. 2005; 144(3):301-312.
8. Duale AH, Nwanze KF. Incidence and distribution in sorghum of the spotted stem borer *Chilo partellus* and associated natural enemies in farmers fields in Andhra Pradesh and Maharashtra states. International Journal of Pest Management. 1999; 45(1):3-7.
9. Garg VK, Singh UC. Relative susceptibility of some sorghum varieties against shoot fly, *Atherigona soccata*. Indian Journal of Tropical Biodiversity. 2003; 11(1):97-99.
10. Gomashe S, Misal MB, Ganapathy KN, Rakshit S. Correlation studies for shoot fly resistance traits in sorghum (*Sorghum bicolor* (L.) Moench). Electronic Journal of Plant Breeding. 2010; 1(4):899-902.
11. Hussian T, Vyas A K, Sumeriya HK, Ameta OP. Evaluation of breeder materials in advanced trails against major insect pests of sorghum. Annals of Agri-Bio Research. 2014; 19(1):85-89.
12. Karanjkar RR, Chundurwar RD, Borikar ST. Correlations and path analysis of shoot fly resistance in sorghum. Journal of Maharashtra Agricultural Universities. 1992; 17:389-391.
13. Khandare RP, Patil SP, Burghate SK, Kurhade K. Screening of advanced breeding material of sorghum against shoot fly (*Atherigona soccata*) (Rondani). Scholarly Journal of Agricultural Sciences. 2013; 3(8):305-307.
14. Kishore P, Babu SR, Singh U, Rai G. New sources of resistance against shoot fly, *Atherigona soccata* Rondani, stem borer, *Chilo partellus* (Swinhoe) and sugarcane leaf hopper, *Pyrilla perpusilla* Walker in newly developed sorghum varieties and hybrids. Journal of Entomological Research. 2002; 26(2):101-112.
15. Kumar AA, Reddy BVS, Sharma HC, Ramaiah B. Shoot fly (*Atherigona soccata*) resistance in improved grain sorghum hybrids. SAT e Journal. 2008; 6:1-4.
16. Kushwaha PS, Kapoor KN. Screening of sheet sorghum genotypes against shoot fly (*Atherigona soccata* Rond.). Crop Research. 1995; 10:226- 228.
17. Maiti RK, Bidinger FR. A simple approach to the identification of shoot fly tolerance in sorghum. Indian Journal of Plant Protection. 1979; 7:135-140.
18. Padmaja PG, Madhusudhana R, Seetharama N. Epicuticular wax and morphological traits associated with resistance to shoot fly, *Atherigona soccata* (Rondani) in Sorghum. Entomon. 2010; 34(3):137-146.
19. Pawar VM, Jadhav GD, Kadam BS. Compatibility of oncol 50 sp with different fungicides on sorghum (C53541) against shoot fly (*Atherigona soccata* Rondani). Pesticides. 1984; 8:9-10.
20. Prokopy RJ, Collier RH, Finch S. Leaf colour used by cabbage root flies to distinguish among host plants. Science. 1983; 221:190-192.
21. Sable KR, Kamble SK, Changule RB, Dhutraj DN. Seasonal incidence and weather correlation of sorghum shoot fly, *Atherigona soccata* (Rondani). Journal of Maharashtra Agricultural Universities. 2009; 34:243-44.
22. Sharma HC, Nwanze KF. Mechanisms of resistance to insects in sorghum and their usefulness in crop improvement. Information Bulletin no 45. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi - Arid Tropics. 1997, 56.
23. Sharma HC, Singh F, Nwanze KF. Plant resistance to insects in sorghum. International Crops Research Institute for the Semi Arid Tropics, Patancheru, 502 324, Andhra Pradesh, India. 1997, 35-72.
24. Sharma HC. Host plant resistance to insects in sorghum and its role in Integrated Pest Management. Crop Protection. 1993; 12:11-34.
25. Shekharappa. Evaluation of sorghum varieties against shoot fly, *Atherigona soccata* (Rondani). Karnataka Journal of Agricultural Sciences. 2007; 20(3):651-652
26. Singh BU, Rana BS. Resistance in sorghum to the shoot fly, *Atherigona soccata* (Rondani). Insect Science and its Application. 1996; 7(5):577-587.
27. Subbarayudu B, Shyam Prasad G, Kalaisekar A, Bhagawat VR, Elangovan M. Evaluation of Sorghum Genotypes for multiple resistance to shoot pests. Indian Journal of Plant Protection. 2011; 39(2):116-120.
28. Tarumoto I. Glossiness of leaf blades in sorghum (*Sorghum bicolor* L. Moench); Its visual and ultrastructural studies. Japan Agricultural Research Quarterly. 2005; 39:153-160.
29. Umakanth AV, Seetharama N, Kumar RM, Kumari VSSK. Evaluation of sorghum genotypes for their suitability in rice fallows in vertisols (in) Extended Summeries, International Symposium on Rice held during 4th-6th October at New Delhi, 2004, 317-8
30. Vijayalakshmi K. Study of the interrelationship of important traits contributing to the resistance of shoot fly in *Sorghum bicolor* (L.) Moench., Ph D Thesis. Andhra Pradesh Agricultural university, Hyderabad, 1993
31. Vyas AK, Hussian T, Sumeriya HK, Ameta OP. Response of various sorghum (*Sorghum bicolor* (L.) Moench) genotypes against major insects-pests in south Rajasthan conditions. Annals of Agri-Bio Research. 2014; 19(1):90-92.
32. Yadav SK, Panickar B. Reaction of different sorghum genotypes/varieties against shoot fly, *Atherigona soccata*. Pestology. 2015; 29(2):30-36.