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Field Screening of Sorghum Genotypes against Shoot fly

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ABSTRACT

The present experiment was conducted to evaluate 30 sorghum genotypes including two resistant checks against shoot fly under unprotected and protected conditions at the Agricultural College Farm, Bapatla during *kharif* 2017-18. Infestation in the form of dead hearts caused by shoot fly ranged from 2.54 to 35.56% and 0.00 to 8.14% under unprotected and protected conditions respectively. Biophysical characters *viz.,* trichomes and leaf glossiness responsible for resistance were also studied under both unprotected and protected conditions and the data revealed that the highest number of trichomes of adaxial surfaces and abaxial surface were recorded in the highly resistant genotypes R-68 and Mahalakshmi, whereas lowest number in susceptible genotype 4993 when compared to the resistant checks IS 2205 and IS 18551. The genotypes R-68, Mahalakshmi and I 33 were found to be glossy in nature, while the susceptible genotypes R-91014 and 4993 were non-glossy in nature compared to resistant checks IS 2205 and IS 18551. The trichome density on adaxial and abaxial leaf surface was significantly and negatively correlated with dead hearts. With regard to the infestation of shoot fly, the genotypes I 33, Mahalakshmi and R-68 were found to be highly resistant when compared to resistant checks IS 2205 (C) and IS 18551 (C).

Keywords: *Dead hearts, Genotypes, Leaf glossiness, Shoot fly, Sorghum, Trichomes*

Sorghum (*Sorghum bicolor* L. Moench) is one of the most important cereal crops of the world. Sorghum ranks fourth, among the world cereals in the order of wheat, maize and rice. It is the major source of food and fodder for millions of people in tropics and semi-arid tropics. Sorghum originated in tropical Africa and it is a crop with extreme genetic diversity. It is cultivated under diverse agro-ecosystems and its grain yield is influenced by various biotic and abiotic factors which constitutes a major constraint for its production. Over 150 insect species have been reported to damage sorghum in different agro-ecosystems.

Sorghum shoot fly (*Atherigona soccata* Rondani) is one of the major constraints during the seedling stage (Aruna and Padmaja, 2009). It infests the sorghum seedlings at seven days after emergence (DAE) and continues till 30 DAE of the crop (Vadariya, 2014) and its infestation goes up to 80 per cent. The adult fly lays white, elongated, cigar shaped eggs singly on the under surface of the leaves, parallel to the midrib. After hatching of the eggs, 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 the formation of dead hearts (Dhillon *et al.,* 2005) and causing 29-72 per cent yield loss under varied agroclimatic conditions (Puri and Mote, 2003). It has been estimated that shoot fly causes maximum yield losses of 75.6% in grain and 68.6% in fodder crop of sorghum (Pawar *et al.,* 1984).

For the management of shoot fly in the sorghum, farmers mostly depend on the expensive chemical control, but continuous use of wide range of chemical insecticides has caused many side effects, including loss of biodiversity, the problem of secondary pests and the resurgence of insect pests, insecticide resistance, residual toxicity and environmental pollution. Insecticides are hazardous to many target and non-target species which lead to disturbance in crop ecosystem (Balikai, 2003).

Therefore, adoption of some important components of safer, cost effective alternatives of integrated pest management (IPM) like host plant resistance (HPR) required to keep the pest population below the economic threshold levels (Riyazaddin *et al.,* 2015) which is economical compared to other methods of pest control. Adoption of HPR is not only reduces the need of pesticides, but also enhance the effectiveness of natural enemies (Sharma *et al.,* 1993). Resistance of plants to insects enables a plant to inhibit host selection, oviposition, feeding and survival and insect development. Hence, it is necessary to identify the resistance source with high yield in sorghum breeding programmes.

MATERIAL AND METHODS

The experiment was laid out in RBD at Agricultural College Farm, Bapatla and the 30 genotypes including two resistant checks were replicated twice. Two sets of experiment maintained under unprotected and protected conditions. The crop protection was taken up with the recommended pesticides in protected plots only, but not in unprotected plots. The crop was raised by following all the recommended package of practices prescribed by ANGRAU.

Data collected on the number of shoot fly dead hearts at 14, 21 and 28 days after emergence and per cent dead hearts was calculated as per the given formula

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

Based on 1-9 scale for shoot fly infestation, the 30 genotypes were categorized as follows (Gomashe *et al*., 2010)

Scale	% infestation	Reaction
1	$\leq$ 10 %	Highly resistant
3	10 to 20%	Resistant
5	20 to 35%	Moderately resistant
7	35 to 50%	Susceptible
9	$\geq$ 50 %	Highly susceptible

Data on biophysical factors viz., trichome density and leaf glossiness was recorded by following the standard protocols. The density of trichomes were measured on the central portion of the 5th leaf taken from the base and samples were 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). The leaf sections were mounted on a glass slide in a drop of lactic acid and magnified at 10 X under a trinocular microscope. Images were taken with the help of Image analyzer (MICAPS software- Microview) in the system.

Intensity of the leaf glossiness was recorded at 10 DAE in the morning hours when there was maximum reflection of light from the leaf surfaces by using 1-5 scale (1= highly glossy- light green, shiny, narrow and erect leaves and 5= non-glossy-dark green, dull, broad and drooping leaves) (Dhillon *et al.,* 2005).

STATISTICAL ANALYSIS

Data obtained in the present investigations were subjected to statistical analysis. The data in each treatment was recorded separately and subjected to analysis of variance and estimated correlation between shoot fly infestation with trichomes, leaf glossiness and yield.

RESULTS AND DISCUSSION

The shoot fly infestation observed from 14 days after emergence (DAE). There is a significant variation among the genotypes. At 14 DAE, the data recorded on number of dead hearts ranged from 0.00 to 5.00 and 0.00 to 2.00 under unprotected and protected condition respectively (Table 1).

Among the 30 genotypes screened, the highest number of dead hearts recorded in genotypes R-149 (5.00), R-91019 (5.00) followed by R-91014 (4.00) and R-75 (4.00), while the lowest number of dead hearts recorded in genotypes ICSR 172 (0.50), ICSR 96 (1.00), 73902-2-7 (1.00), R-68 (1.00) and ICSR 98 (1.00), but the genotypes 73902-4-1-2, 81-52-4, I33, 4019, R-49 and 4993 were free of infestation when compared to the resistant checks IS 2205 (C) and IS 18551 (C) at 14 DAE.

Regarding the data recorded under protected condition, the highest number of dead hearts recorded in genotypes 73904-1-1 (2.00), R-149 (2.00), 81-1-1 & R 75 (2.00) and NJ 2446 (2.00), whereas the lowest number of dead hearts recorded in genotypes R-91014 (0.50), 4993, 73903-1-2-1, 73902-2-5 and R 68 (1.00), but dead hearts not observed in genotypes 73902-4-2-1, Mahalakshmi, R-49, ICSR 96, 4019, I 33, R-91019, 73902-4-1-2, 81-52-4 and ICSR 98 when compared to the resistant checks IS 18551(C).

The results revealed that there is an increasing trend in shoot fly infestation from 21 DAE. The data on the number of dead hearts recorded ranged from 0.00 to 11.00 and 0.00 to 3.00 under unprotected and protected condition respectively. The highest number of dead hearts were recorded in genotypes R-91014 (11.00), 4993 (10.50) followed by 73902-2-7 (8.50), R 75 (7.50) and 4109 (7.00), while the lowest were recorded in genotypes 81-52-4 (0.00) and ICSR 96 (1.00) when compared to the resistant checks IS 2205 (0.00) and IS 18551 (1.00) at 21 DAE.

Under protected condition, the genotypes NJ 2446 (3.00) and R 149 (3.00) recorded the highest number of dead hearts, whereas the lowest number of dead hearts recorded in genotypes ICSR 96 and I 33 (0.50), but dead hearts were not found in genotypes 73904-2-1, 73902-4-1-2, R-91019, 4019 and Mahalakshmi when compared to the resistant checks IS 2205 (C) and IS 18551 (C). The change in the weather parameters like relative humidity (RH) in the environment during crop growth period might be the reason for the shoot fly infestation after 21 DAE. Sable *et al.* (2009) reported that high RH was favourable for shoot fly infestation and dead hearts formation.

At 28 DAE, the number of dead hearts ranged from 0.00 to 11.50 and 0.00 to 4.00 under unprotected and protected condition respectively. The highest number of dead hearts recorded in genotypes R-91014

(11.50), 4993 (11.00) followed by 73902-2-7 (9.50) and R 75 (9.00), while the lowest number of dead hearts were recorded in genotypes R 68 (2.00), Mahalakshmi (2.50) and NJ 2647 (2.50) when compared with resistant checks IS 2205 (C) (0.00) and IS 18551(C) (1.00).

Under protected condition, the data on number of dead hearts revealed that the genotypes R 75 (4.00) followed by 73904-1-1 and 81-1-1 (3.00) and NJ 2446 (3.00) recorded the highest number of dead hearts, whereas the lowest number of dead hearts were recorded in genotypes 73911-3-2-30 (1.00), 73902-8-2-2 (1.00) and 4109 (1.00), but in the genotypes 73904-2-1, 73902-4-1-2, R-91019, 4019, 73902-2-7 and Mahalakshmi were free of infestation when compared to the resistant checks IS 2205 (C).

The cumulative mean data on number of dead hearts ranged from 0.67 to 8.83 and 0.00 to 2.67 under unprotected and protected conditions respectively. The highest number of dead hearts recorded in genotypes R-91014 (8.83), 4993 (7.17) followed by R 75 (6.83) and 73902-2-7 (6.33) and 4109 (5.83), while the lowest number of dead hearts recorded in genotypes 81-52-4 (1.50), R 68 (1.67) and I 33 (1.83) when compared to the resistant checks IS 18551 (0.67) and IS 2205 (0.83).

Under protected condition, the genotypes R 75 (2.67), NJ 2446 (2.67) and R 149 (2.67) recorded the highest number of dead hearts, whereas the lowest number of dead hearts recorded in genotypes 73904-2-1 (0.33), I 33 (0.83) and ICSR 96 (0.83), but dead hearts were not recorded in genotypes 73902-4-1-2, R-91019, 4019 and Mahalakshmi when compared to the resistant checks IS 18551 (C) (0.17) and IS 2205 (C) (0.00) (Table 1).

At 14 DAE, the data recorded on per cent dead hearts ranged from 0.00 to 16.15 % and 0.00 to 6.67% under unprotected and protected condition respectively.

Under unprotected condition, the highest per cent dead hearts recorded in genotypes R-149 (16.15%), R-91019 (14.76%) followed by R-91014 (13.33%) and R-75 (12.92%), while the lowest per cent dead hearts recorded in genotypes ICSR 172 (1.67%), ICSR 96 (2.86%), 73902-2-7 (3.14%), R-68 (3.18%) and ICSR 98 (3.33%), but the genotypes 73902-4-1-2, 81-52-4, I33, 4019, R-49 and 4993 were free of infestation when compared to the resistant checks IS 2205 (C) and IS 18551 (C) at 14 DAE.

Under protected condition, the highest per cent dead hearts recorded in genotypes 73904-1-1 (6.67%), R-149 (6.25%), 81-1-1 & R 75 (6.16%) and NJ 2446 (6.06%), whereas the lowest per cent dead hearts recorded in genotypes R-91014 (1.43%), 4993 & 73903-1-2-1 (2.70%), 73902-2-5 (2.74%) and R 68 (2.86%), but dead hearts not observed in genotypes 73902-4-2-1, Mahalakshmi, R-49, ICSR 96, 4019, I 33, R-91019, 73902-4-1-2, 81-52-4 and ICSR 98 when compared to the resistant checks IS 18551(C) at 14 DAE.

At 21 DAE, the data on per cent dead hearts recorded ranged from 0.00 to 36.67% and 0.00 to 8.83% under unprotected and protected conditions respectively. The highest per cent dead hearts were recorded in genotypes R-91014 (36.67%), 4993 (33.87%) followed by 73902-2-7 (26.76%), R 75 (24.17%) and 4109 (23.33%), while the lowest were recorded in genotypes 81-52-4 (0.00%) and ICSR 96 (3.10%) when compared to the resistant checks IS 2205 (C) (0.00%) and IS 18551 (C) (3.03%).

Under protected condition, the genotypes NJ 2446 (8.83%) and R 149 (8.53%) recorded the highest per cent dead hearts, whereas the lowest per cent dead hearts recorded in genotypes ICSR 96 and I 33 (1.61%), but dead hearts were not found in genotypes 73904-2-1, 73902-4-1-2, R-91019, 4019 and Mahalakshmi when compared to the resistant checks IS 2205 (C) and IS 18551 (C).

At 28 DAE, the per cent dead hearts ranged from 0.00 to 40.00% and 0.00 to 12.12% under unprotected and protected condition respectively. The highest per cent dead hearts recorded in genotypes R-91014 (40.00%), 4993 (35.48%) followed by 73902-2-7 (29.71%) and R 75 (29.06%), while the lowest per cent dead hearts were recorded in genotypes R 68 (6.36%), Mahalakshmi (8.82%) and NJ 2647 (12.31%) when compared with resistant checks IS 2205 (C) (0.00%) and IS 18551(C) (3.03%).

Under protected condition, data on per cent dead hearts revealed that the genotypes R 75 (12.12%) followed by 73904-1-1 and 81-1-1 (9.38%) and NJ 2446 (9.09%) recorded the highest per cent dead hearts, whereas the lowest per cent dead hearts were recorded in genotypes 73911-3-2-30 (2.95%), 73902-8-2-2 (3.13%) and 4109 (3.28%), but in the genotypes 73904-2-1, 73902-4-1-2, R-91019, 4019, 73902-2-7 and Mahalakshmi were free of infestation when compared to the resistant checks IS 2205 (C).

The cumulative mean data on per cent dead hearts ranged from 2.54 to 35.56% and 0.00 to 8.14%) under unprotected and protected conditions respectively. The highest per cent dead hearts recorded in genotypes R- 91014 (35.56%), 4993 (29.03%) followed by R 75 (25.17%) and 73902-2-7 (25.26%) and 4109 (22.22%), while the lowest per cent dead hearts recorded in genotypes 81-52-4 (9.26%), R 68 (5.86%) and I 33 (8.47%) when compared to the resistant checks IS 18551 (2.54%) and IS 2205 (4.08%).

Table 1. Reaction of sorghum genotypes against shoot fly, *A. soccata* during *kharif* 2017-18

S. No.	Genotype	No. of dead hearts caused by shoot fly							
		14 DAE		21DAE		28 DAE		Cumulative mean	
		UP	P	UP	P	UP	P	UP	P
1	73903-1-2-1	3.00 (2.00)	1.00 (1.41)	4.00 (2.24)	2.00 (1.73)	7.00 (2.83)	3.00 (2.00)	4.67 (2.16)	2.00 (1.73)
2	73902-8-2-2	1.00 (1.41)	1.00 (1.41)	2.50 (1.87)	2.00 (1.73)	8.00 (3.00)	1.00 (1.41)	4.17 (2.04)	1.33 (1.53)
3	NJ2446	3.00 (2.00)	2.00 (1.73)	6.00 (2.65)	3.00 (2.00)	7.50 (2.91)	3.00 (2.00)	5.50 (2.34)	2.67 (1.91)
4	ICSR 98	1.00 (1.41)	0.00 (1.00)	3.00 (2.00)	1.00 (1.41)	7.50 (2.91)	2.00 (1.73)	3.83 (1.96)	1.00 (1.41)
5	73904-1-1	2.00 (1.73)	2.00 (1.73)	4.50 (2.34)	2.00 (1.73)	6.50 (2.74)	3.00 (2.00)	4.33 (2.08)	2.33 (1.83)
6	4109	3.00 (2.00)	1.00 (1.41)	7.00 (2.82)	2.00 (1.73)	7.50 (2.91)	1.00 (1.41)	5.83 (2.41)	1.33 (1.53)
7	73904-2-1	1.50 (1.57)	1.00 (1.41)	2.00 (1.73)	0.00 (1.00)	6.00 (2.65)	0.00 (1.00)	3.17 (1.78)	0.33 (1.15)
8	81-52-4	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	1.00 (1.41)	4.50 (2.34)	2.00 (1.73)	1.50 (1.22)	1.00 (1.41)
9	73911-3-2-30	2.00 (1.73)	1.00 (1.41)	6.00 (2.62)	2.00 (1.73)	7.00 (2.82)	1.00 (1.41)	5.00 (2.22)	1.33 (1.53)
10	IS 2205(C)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (0.00)	0.00 (1.00)	0.00 (0.00)	0.00 (1.00)
11	73902-4-1-2	0.00 (1.00)	0.00 (1.00)	6.50 (2.74)	0.00 (1.00)	7.00 (2.83)	0.00 (1.00)	4.50 (2.12)	0.00 (1.00)
12	81-1-1	3.00 (2.00)	2.00 (1.73)	3.00 (1.98)	2.00 (1.73)	7.50 (2.91)	3.00 (2.00)	4.50 (2.12)	2.33 (1.83)
13	R-91019	5.00 (2.45)	0.00 (1.00)	6.00 (2.65)	0.00 (1.00)	4.50 (2.34)	0.00 (1.00)	5.17 (2.27)	0.00 (1.00)
14	73902-2-7	1.00 (1.41)	1.00 (1.41)	8.50 (3.08)	2.00 (1.73)	9.50 (3.24)	0.00 (1.00)	6.33 (2.52)	1.00 (1.41)
15	I33	0.00 (1.00)	0.00 (1.00)	2.50 (1.87)	0.50 (1.21)	3.00 (1.98)	2.00 (1.73)	1.83 (1.34)	0.83 (1.35)
16	R 75	4.00 (2.24)	2.00 (1.73)	7.50 (2.91)	2.00 (1.73)	9.00 (3.16)	4.00 (2.24)	6.83 (2.61)	2.67 (1.91)
17	ICSR172	0.50 (1.21)	1.00 (1.41)	3.00 (1.98)	2.00 (1.73)	6.00 (2.65)	2.00 (1.73)	3.17 (1.78)	1.67 (1.63)
18	4019	0.00 (1.00)	0.00 (1.00)	2.00 (1.73)	0.00 (1.00)	4.50 (2.34)	0.00 (1.00)	2.17 (1.47)	0.00 (1.00)
19	R-68	1.00 (1.41)	1.00 (1.41)	2.00 (1.73)	2.00 (1.73)	2.00 (1.73)	2.00 (1.73)	1.67 (1.29)	1.67 (1.63)
20	R-29	2.00 (1.73)	1.00 (1.41)	2.00 (1.73)	2.00 (1.73)	7.50 (2.91)	2.50 (1.87)	3.83 (1.96)	1.83 (1.68)
21	ICSR 96	1.00 (1.37)	0.00 (1.00)	1.00 (1.41)	0.50 (1.21)	4.00 (2.24)	2.00 (1.73)	2.00 (1.41)	0.83 (1.35)
22	R-49	0.00 (1.00)	0.00 (1.00)	3.50 (2.12)	2.00 (1.73)	7.00 (2.83)	2.00 (1.73)	3.50 (1.87)	1.33 (1.53)
23	NJ 2647	2.00 (1.73)	1.00 (1.41)	3.00 (2.00)	1.00 (1.41)	2.50 (1.87)	2.00 (1.73)	2.50 (1.58)	1.33 (1.53)
24	Mahalakshmi	2.00 (1.73)	0.00 (1.00)	3.00 (2.00)	0.00 (1.00)	2.50 (1.87)	0.00 (1.00)	2.50 (1.58)	0.00 (1.00)

Table 1. cont...

S. No.	Genotype	No. of dead hearts caused by shoot fly							
		14 DAE		21DAE		28 DAE		Cumulative mean	
		UP	P	UP	P	UP	P	UP	P
25	R-149	5.00 (2.45)	2.00 (1.73)	5.00 (2.45)	3.00 (2.00)	6.50 (2.74)	3.00 (2.00)	5.50 (2.34)	2.67 (1.91)
26	R-91014	4.00 (2.24)	0.50 (1.21)	11.00 (3.46)	1.00 (1.41)	11.50 (3.53)	2.00 (1.73)	8.83 (2.97)	1.17 (1.47)
27	73902-4-2-1	2.00 (1.73)	0.00 (1.00)	6.00 (2.62)	1.00 (1.41)	6.50 (2.72)	2.00 (1.73)	4.83 (2.18)	1.00 (1.41)
28	73902-2-5	2.00 (1.73)	1.00 (1.41)	4.00 (2.22)	2.00 (1.73)	8.50 (3.08)	2.00 (1.73)	4.83 (2.20)	1.67 (1.63)
29	IS 18551(C)	0.00 (1.00)	0.00 (1.00)	1.00 (1.41)	0.00 (1.00)	1.00 (1.41)	0.50 (1.21)	0.67 (0.82)	0.17 (1.08)
30	4993	0.00 (1.00)	1.00 (1.41)	10.50 (3.38)	2.00 (1.73)	11.00 (4.36)	3.00 (2.00)	7.17 (2.67)	2.00 (1.73)
	GM	1.59	1.29	2.19	1.49	2.63	1.59	1.94	1.47
	SEm±	0.08	0.04	0.15	0.05	0.11	0.05	0.1	0.02
	CD (P = 0.05)	0.24	0.11	0.43	0.15	0.32	0.13	0.28	0.07
	CV%	7.38	4.13	9.69	4.98	5.91	4.08	7.15	2.38

Note: UP= Unprotected, P= Protected Values in the parenthesis are square root transformed values

Under protected condition, the genotypes R 75 (8.14%), NJ 2446 (7.99%) and R 149 (7.49%) recorded the highest per cent dead hearts, whereas the lowest per cent dead hearts recorded in genotypes 73904-2-1 (1.08%), I 33 (2.65%) and ICSR 96 (2.72%), but dead hearts were not recorded in genotypes 73902-4-1-2, R-91019, 4019 and Mahalakshmi when compared to the resistant checks IS 18551 (C) (0.49%) and IS 2205 (C) (0.00%) (Table 2).

The field screened 30 genotypes were categorized based on 1-9 scale for shoot fly dead heart infestation *viz*., highly resistant (1 = d" 10% infestation), resistant (3 = 10 to 20%), moderately resistant (5 = 20 to 35%), susceptible (7 = 35 to 50% infestation) and highly susceptible (9 = e" 50% infestation) and found that genotypes five namely, IS 2205, I 33, IS 18551, Mahalakshmi and R-68 were highly resistant (scale 1) with 3.33 to 9.58% dead hearts (DH).

Ten genotypes namely, ICSR 172, 4019, ICSR 96, NJ 2647, R-149, 73902-4-2-1, 73904-2-1, 81-52-4, 73902-4-1-2 and R- 91019 grouped under scale 3 were found to be the resistant with 12.31 to 20.00% DH. This might be due to antibiosis, as maggot could not feed fully and also could not survive on shoot (Jadhav and Mote, 1986). The larvae on the resistant varieties were sick and smaller as compared to those on susceptible sorghum varieties.

Thirteen genotypes namely, 73902-2-1, 73902-8-2-2, NJ 2446, ICSR 98, 73904-1-1, 4109, 73911-3-2-30, 81-1-1, 73902-2-7, R-75, R-29, R-49, 73902-1-2-1 were placed under moderately resistant (scale 5) with 20.67 to 29.71% DH. The two genotypes R-91014 and 4993 found to be susceptible (scale 7) with 35.48 to 40.00% DH.

The results of the present studies are in conformity with Mohammed *et al.* (2015), Neelesh *et al.* (2016), Sharma *et al.* (2016), Khandare and Patil (2010) who reported that resistant checks IS 18551 and IS 2205 recorded significantly minimum number of shoot fly eggs per plant and per cent dead hearts. Chamarthi *et al.* (2011) also reported that sorghum genotypes IS 2205, IS 2312, IS 2312 and IS 18551 exhibited antixenosis for oviposition and dead hearts formation by sorghum shoot fly, *Atherigona soccata.*

Biophysical parameters of sorghum genotypes Trichome Density on Shoot fly infestation

Data on trichome density recorded both under unprotected and protected conditions and that there was a significant difference among the genotypes. The number of trichomes on adaxial leaf surface and abaxial leaf surface varied from 0.00 to 104.25 and 0.00 to 81.33 respectively under unprotected condition (Table 3).

The highest number of trichomes on adaxial leaf surface was observed in the genotypes JMLT-26

Table 2. Reaction of sorghum genotypes against shoot fly infestation during *kharif*, 2017-18

S. No.	Genotype	Per cent dead hearts caused by shoot fly									
		14 DAE		21DAE		28 DAE		Cumulative		Reaction	Scale (1-9)
		UP	P	UP	P	UP	P	UP	P		
1	73903-1-2-1	9.05 (17.00)	2.70 (9.30)	12.50 (20.01)	5.71 (13.52)	20.59 (25.68)	8.34 (16.34)	17.48 (23.56)	5.59 (13.37)	MR	5
2	73902-8-2-2	6.67 (14.61)	3.13 (10.00)	8.33 (16.25)	6.25 (14.14)	23.53 (27.45)	3.13 (10.00)	17.91 (23.64)	4.17 (11.55)	MR	5
3	NJ2446	9.69 (17.61)	6.06 (13.93)	20.00 (25.31)	8.83 (16.81)	25.00 (28.28)	9.09 (17.06)	21.01 (25.90)	7.99 (16.00)	MR	5
4	ICSR 98	3.33 (10.33)	0.00 (0.00)	10.00 (17.89)	3.33 (10.33)	25.00 (28.28)	6.67 (14.61)	19.44 (24.50)	3.33 (10.33)	MR	5
5	73904-1-1	6.35 (14.26)	6.67 (14.61)	14.26 (21.35)	6.67 (14.61)	20.67 (25.70)	9.38 (17.32)	18.06 (23.86)	7.57 (15.57)	MR	5
6	4109	10.00 (17.89)	3.28 (10.25)	23.33 (27.27)	6.56 (14.49)	25.00 (28.28)	3.28 (10.25)	22.22 (26.67)	4.37 (11.83)	MR	5
7	73904-2-1	4.61 (12.03)	3.23 (10.17)	6.67 (14.61)	0.00 (0.00)	18.82 (24.54)	0.00 (0.00)	13.82 (20.83)	1.08 (5.87)	R	3
8	81-52-4	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	3.18 (10.08)	13.07 (20.41)	6.35 (14.26)	9.26 (16.37)	3.18 (10.08)	R	3
9	73911-3-2-30	6.25 (14.14)	3.33 (10.33)	18.75 (24.15)	5.90 (13.71)	21.88 (26.40)	2.95 (9.69)	18.75 (24.15)	4.06 (11.39)	MR	5
10	IS 2205 (C)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	HR	1
11	73902-4-1-2	0.00 (0.00)	0.00 (0.00)	18.06 (24.03)	0.00 (0.00)	19.44 (24.95)	0.00 (0.00)	15.74 (22.29)	0.00 (0.00)	R	3
12	81-1-1	9.23 (17.19)	6.16 (14.04)	9.28 (16.97)	6.25 (14.14)	23.11 (27.18)	9.38 (17.32)	18.56 (24.00)	7.26 (15.24)	MR	5
13	R-91019	14.76 (21.73)	0.00 (0.00)	18.75 (24.50)	0.00 (0.00)	13.37 (20.61)	0.00 (0.00)	13.89 (20.98)	0.00 (0.00)	R	3
14	73902-2-7	3.14 (10.02)	3.33 (10.33)	26.76 (29.23)	6.67 (14.61)	29.71 (30.85)	0.00 (0.00)	25.26 (28.35)	3.33 (10.33)	MR	5
15	I33	0.00 (0.00)	0.00 (0.00)	8.02 (15.97)	1.61 (5.08)	9.58 (17.31)	6.35 (14.26)	8.47 (15.97)	2.65 (9.16)	HR	1
16	R 75	12.92 (20.33)	6.16 (14.04)	24.17 (27.82)	6.16 (14.04)	29.06 (30.51)	12.12 (19.70)	25.17 (28.35)	8.14 (16.15)	MR	5
17	ICSR172	1.67 (5.16)	3.33 (10.33)	10.00 (17.63)	6.27 (14.17)	20.00 (25.31)	6.67 (14.61)	15.00 (21.60)	5.42 (13.18)	R	3
18	4019	0.00 (0.00)	0.00 (0.00)	6.11 (13.97)	0.00 (0.00)	13.61 (20.87)	0.00 (0.00)	10.28 (17.85)	0.00 (0.00)	R	3
19	R-68	3.18 (10.09)	2.86 (9.57)	6.36 (14.27)	5.72 (13.53)	6.36 (14.27)	5.72 (13.53)	5.86 (13.66)	4.77 (12.35)	HR	1
20	R-29	6.16 (14.04)	3.23 (10.17)	6.25 (14.14)	6.67 (14.61)	23.06 (27.17)	8.13 (16.02)	17.03 (23.11)	6.01 (13.85)	MR	5
21	ICSR 96	2.86 (6.76)	0.00 (0.00)	3.10 (9.95)	1.61 (5.08)	12.38 (19.89)	6.56 (14.49)	8.49 (16.23)	2.72 (9.30)	R	3
22	R-49	0.00 (0.00)	0.00 (0.00)	11.25 (18.95)	6.67 (14.61)	22.60 (26.90)	6.67 (14.61)	16.49 (22.66)	4.44 (11.93)	MR	5
23	NJ 2647	6.16 (14.04)	3.18 (10.08)	9.23 (17.19)	3.18 (10.08)	12.31 (19.85)	6.35 (14.26)	10.80 (18.53)	4.23 (11.64)	R	3
24	Mahalakshmi	5.80 (13.62)	0.00 (0.00)	8.70 (16.69)	0.00 (0.00)	8.82 (16.81)	0.00 (0.00)	8.26 (16.25)	0.00 (0.00)	HR	1

Table 2. cont...

S. No.	Genotype	Per cent dead hearts caused by shoot fly									
		14 DAE		21DAE		28 DAE		Cumulative		Reaction	Scale (1-9)
		UP	P	UP	P	UP	P	UP	P		
25	R-149	16.15 (22.73)	6.25 (14.14)	16.67 (23.10)	8.53 (16.51)	19.46 (24.96)	7.69 (15.69)	18.54 (24.34)	7.49 (15.48)	R	3
26	R-91014	13.33 (20.66)	1.43 (4.78)	36.67 (34.24)	2.74 (9.37)	40.00 (35.80)	5.49 (13.25)	35.56 (33.69)	3.22 (10.11)	S	7
27	73902-4-2-1	6.36 (14.27)	0.00 (0.00)	17.48 (23.49)	3.24 (10.14)	19.14 (24.71)	5.26 (12.98)	16.55 (23.02)	2.83 (9.52)	R	3
28	73903-1-2-1	6.17 (14.05)	2.74 (9.37)	12.19 (19.65)	5.49 (13.25)	26.14 (28.93)	5.71 (13.52)	20.75 (25.58)	4.65 (12.20)	MR	5
29	IS 18551 (C)	0.00 (0.00)	0.00 (0.00)	3.03 (9.85)	0.00 (0.00)	3.03 (9.85)	1.47 (4.85)	2.54 (8.96)	0.49 (2.80)	HR	1
30	4993	0.00 (0.00)	2.70 (9.30)	33.87 (32.86	5.41 (13.16	35.48 (33.68)	7.89 (15.90)	29.03 (30.45)	5.34 (13.07)	S	7
	GM	10.75	6.49	19.04	9.67	24.35	10.82	21.89	9.74		
	SEm ±	1.63	0.88	1.57	1.33	1.06	0.97	1.6	0.62		
	CD (P = 0.05)	4.71	2.54	4.53	3.86	3.07	2.81	4.63	1.79		
	CV%	21.4	19.1	11.6	19.5	6.17	12.7	10.3	8.96		

Note: Values in the parenthesis are arcsine transformed values; UP = Unprotected, P = Protected, HR= Highly Resistant, MR= Moderately Resistant, R= Resistant, S= Susceptible.

(104.25), followed by R-68 (92.75), 4019 (91.50), Mahalakshmi (88.00) and IS 18551 (C) (87.50), whereas the lowest number of trichomes were observed in genotypes 73902-2-7 (9.75), 4109 (10.75), 73902-4-1-2 (11.00) and 73903-1-2-1 (11.25).

On abaxial leaf surface, the highest number of trichomes observed in genotypes NJ 2647 (81.33), 73911.3-2-30 (80.33) followed by IS 18551 (C) (79.67), IS 2205 (C) (74.33) and ICSR 96 (71.33), while minimum number of trichomes recorded in genotypes R 29 (12.67), 4109 (12.17), NJ 2446 (10.00) and 73902-2-7 (8.17) (Table 3).

The similar observations were recorded under protected condition also. The number of trichomes on adaxial leaf surface and abaxial leaf surface varied from 0.00 to 100.1 and 0.00 to 81.00 respectively. The highest number of trichomes on adaxial leaf surface was observed in genotypes NJ 2647 (100.10) followed by IS 18551 (87.00), Mahalakshmi (83.00) and 73911-3-2-30 (81.00), whereas the lowest number of trichomes were observed in genotype ICSR 98 (0.00), 73902-2-7 (10.25) followed by 73903-1-2-1 (11.50) and 73902-4-1-2 (11.50) (Table 3).

The present investigation results are in close conformity with the findings of Dhillon *et al.* (2005) who reported that the number of trichomes on the adaxial leaf surfaces were greater as compared to the abaxial leaf surface which varied from 78.7 to 115.8 (abaxial) and 112.1 to 166.8 (adaxial) and susceptible check Swarna showed few trichomes on abaxial (7.9 trichomes) and adaxial (18.5 trichomes) leaf surfaces.

Leaf Glossiness on Shoot fly infestation

Data on leaf glossiness varied from 1.00 to 3.00 and 1.17 to 3.83 under unprotected and protected conditions respectively. The higher leaf glossiness values recorded in the genotypes R 75 (3.50), R-91014 (3.33) and 73902-2-7 (3.33), whereas lower values in genotypes Mahalakshmi (1.17), 73904-2-1 (1.17), 73911-3-2-30 (1.17) and R 68 (1.17) when compared to the resistant checks IS 2205 (1.33) and IS 18551 (1.33) (Table 3).

The present investigation results are in conformity with the findings of Wagh *et al.* (2016) and Patil and Bagde (2017). Chamarathi *et al.* (2011) reported that the genotypes IS 1054, IS 2205, IS 2312, IS 2416 and IS 18551 had lower leaf surface wetness, more number of trichomes, high leaf glossiness intensity as compared to the susceptible check, Swarna.

Correlation between biophysical parameters of sorghum genotypes and shoot fly infestation

The data on trichomes density (adaxial and abaxial leaf surface), leaf glossinesss, per cent dead hearts and yield under unprotected and protected conditions were subjected to the correlation analysis and it was significant. The per cent dead hearts was

Table 3 Biophysical characters of sorghum genotypes evaluated against shoot fly, *A. soccata* infestation

S. No	Genotype	Reaction	Trichome density (No/mm^2)				Dead hearts (%)		Leaf glossiness (1-5 scale) 1= highly 5=non glossy	
			Adaxial leaf		Abaxial leaf					
			UP	P	UP	P	UP	P	UP	P
1	73903-1-2-1	MR	11.25 (3.35)	11.50 (3.39)	17.17 (4.14)	17.00 (4.12)	20.59 (25.68)	8.34 (16.34)	2.33 (1.53)	2.33 (1.52)
2	73902-8-2-2	MR	13.25 (3.64)	12.00 (3.46)	15.00 (3.87)	13.17 (3.63)	23.53 (27.45)	3.13 (10.00)	1.83 (1.34)	2.67 (1.63)
3	NJ2446	MR	13.25 (3.63)	12.00 (3.46)	10.00 (3.16)	9.67 (3.10)	25.00 (28.28)	9.09 (17.06)	2.17 (1.47)	2.67 (1.63)
4	ICSR 98	MR	14.00(3.73)	14.00 (3.73)	11.50 (3.39)	11.50 (3.39)	25.00 (28.28)	6.67 (14.61)	1.83 (1.35)	2.00 (1.41)
5	73904-1-1	MR	30.00 (5.48)	29.25 (5.41)	13.83 (3.72)	12.83 (3.58)	20.67 (25.70)	9.38 (17.32)	2.83 (1.68)	3.17 (1.77)
6	4109	MR	10.75 (3.28)	11.75 (3.42)	12.17 (3.49)	11.50 (3.39)	25.00 (28.28)	3.28 (10.25)	3.00 (1.73)	3.00 (1.73)
7	73904-2-1	R	65.75 (8.11)	61.5 (7.84)	52.83 (7.27)	50.83 (7.13)	18.82 (24.54)	0.00 (0.00)	1.17 (1.08)	1.33 (1.15)
8	81-52-4	R	69.00 (8.31)	65.00 (8.06)	61.00 (7.81)	61.00 (7.81)	13.07 (20.41)	6.35 (14.26)	1.50 (1.22)	1.17 (1.08)
9	73911-3-2-30	MR	82.00 (9.05)	81.00 (9.00)	80.33 (8.96)	81.00(9.00)	21.88 (26.40)	2.95 (9.69)	1.17 (1.08)	1.33 (1.15)
10	IS 2205 (C)	HR	80.75 (8.99)	79.75 (8.93)	74.33 (8.62)	72.17 (8.47)	7.11 (14.94)	0.00 (0.00)	1.33 (1.15)	1.33 (1.15)
11	73902-4-1-2	R	11.00 (3.29)	11.50 (3.39)	14.00 (3.73)	15.83 (3.97)	19.44 (24.95)	0.00 (0.00)	3.00 (1.73)	3.33 (1.83)
12	81-1-1	MR	23.50 (4.85)	21.75 (4.66)	14.00 (3.73)	14.00 (3.74)	23.11 (27.18)	9.38 (17.32)	2.83 (1.68)	3.33 (1.82)
13	R-91019	R	77.25 (8.79)	74.00 (8.60)	58.00 (7.61)	54.50 (7.38)	13.37 (20.61)	0.00 (0.00)	1.33 (1.15)	1.17 (1.08)
14	73902-2-7	MR	9.75 (3.12)	10.25 (3.20)	8.17 (2.85)	11.33 (3.65)	29.71 (30.85)	0.00 (0.00)	3.33 (1.83)	3.67 (1.91)
15	I33	HR	40.50 (6.36)	40.25 (6.34)	34.83 (5.90)	31.83 (5.64)	9.58 (17.31)	6.35 (14.26)	1.67 (1.26)	1.33 (1.15)
16	R 75	MR	26.75 (5.17)	24.25 (4.92)	19.67 (4.42)	17.17 (4.14)	29.06 (30.51)	12.12 (19.70)	3.50 (1.87)	3.67 (1.91)
17	ICSR172	R	50.25 (7.05)	52.5 (7.24)	25.67 (5.07)	22.50 (4.74)	20.00 (25.31)	6.67 (14.61)	2.67 (1.63)	3.00 (1.72)
18	4019	R	91.50 (9.57)	92.00 (9.59)	58.83 (7.67)	57.50 (7.58)	13.61 (20.87)	0.00 (0.00)	1.33 (1.15)	1.33 (1.15)
19	R-68	HR	92.75 (9.63)	82.75 (9.10)	65.33 (8.08)	62.00 (7.86)	6.36 (14.27)	5.72 (13.53)	1.00 (1.00)	1.33 (1.15)
20	R-29	MR	22.25 (4.72)	22.75 (4.77)	12.67 (3.55)	13.17 (3.63)	23.06 (27.17)	8.13 (16.02)	2.33 (1.53)	2.67 (1.63)
21	ICSR 96	R	76.00 (8.72)	73.00 (8.54)	71.33 (8.44)	68.17 (8.22)	12.38 (19.89)	6.56 (14.49)	2.00 (1.39)	1.33 (1.15)
22	R-49	MR	25.25 (5.02)	24.25 (4.92)	16.00 (3.99)	20.16 (4.48)	22.60 (26.90)	6.67 (14.61)	2.83 (1.66)	3.33 (1.83)
23	NJ 2647	R	104.25 (109)	100.1 (10.00)	81.33 (9.01)	77.17 (8.78)	12.31 (19.85)	6.35 (14.26)	1.33 (1.15)	1.17 (1.08)

Table 3. cont...

S. No	Genotype	Reaction	Trichome density (No/mm^2)				Dead hearts (%)		Leaf glossiness (1-5 scale) 1= highly 5=non glossy	
			Adaxial leaf		Abaxial leaf					
			UP	P	UP	P	UP	P	UP	P
24	Mahalakshmi	HR	88.00 (9.68)	83.00 (9.11)	68.67 (8.28)	61.67 (7.85)	8.82 (16.81)	0.00 (0.00)	1.17 (1.08)	1.17 (1.08)
25	R-149	R	32.00 (5.66)	33.5 (5.79)	24.17 (4.92)	27.00 (5.17)	19.46 (24.96)	7.69 (15.69)	2.67 (1.63)	3.17 (1.78)
26	R-91014	S	31.50 (5.61)	30.5 (5.52)	28.00 (5.29)	25.50 (4.99)	40.00 (35.80)	5.49 (13.25)	3.33 (1.83)	3.83 (1.96)
27	73902-4-2-1	R	17.25 (4.15)	20.50 (4.53)	14.83 (3.85)	15.00 (3.79)	19.14 (24.71)	5.26 (12.98)	2.83 (1.68)	3.50 (1.87)
28	73902-2-5	MR	21.50 (4.64)	18.75 (4.33)	23.00 (4.80)	21.83 (4.67)	26.14 (28.93)	5.71 (13.52)	2.67 (1.63)	3.00 (1.73)
29	IS 18551(C)	HR	87.50 (9.35)	87.00 (9.33)	79.67 (8.92)	76.50 (8.73)	3.03 (9.85)	1.47 (4.85)	1.33 (1.15)	1.17 (1.08)
30	4993	S	15.25 (3.89)	17.00 (4.12)	17.17 (4.13)	19.67 (4.42)	35.48 (33.68)	7.89 (15.90)	3.00 (1.73)	3.33 (1.83)
	GM		6.1	6.03	5.51	5.45	24.35	10.82	1.45	1.5
	SEm±		0.22	0.14	0.22	0.31	1.06	0.97	0.11	0.1
	CD (P= 0.05)		0.62*	0.39*	0.63*	0.89*	3.07*	2.81*	0.30*	0.28*
	CV%		5	3.17	5.61	7.98	6.17	12.7	10.3	9.05

Note: Values in the parenthesis are square root transformed values; UP = Unprotected, P= Protected, HR= Highly Resistant, MR= Moderately Resistant, R= Resistant, S= Susceptible.

Table 4. Correlation between shoot fly dead hearts, biophysical factors and yield of different sorghum genotypes

Parameter	Trichomes on Adaxial leaf surface	Trichomes on abaxial leaf surface	Leaf glossiness	Yield
DH % by Shoot fly (Unprotected)	-0.7179*	-0.6972*	-0.4349*	-0.0944
Protected	-0.4101*	-0.4388*	-0.0828*	-0.0578

*Significant at 5% r table value = 0.361 No of observation= 30

negatively negatively correlated with trichomes density (adaxial (r= -0.7179) and abaxial leaf surface (r= -0.6972), leaf glossiness (r = -4349) and yield (-0.0944). Similar results were obtained under protected conditions also (Table 4).

These results are in conformity with the findings of Folane *et al.* (2014) who reported that trichome density on abaxial leaf surfaces showed negative correlation with shoot fly dead hearts. The number of trichomes on lower surfaces of leaf lamina and leaf glossiness contributed resistance to shoot fly.

Yield attributes

Days to 50% flowering

Based on days to 50% flowering, the 30 genotypes categorized as early (56-65 days), medium (66-75 days) and late duration (76-85 days).

Medium duration genotypes

73903-1-2-1 (72.50), 4109 (74.50), 81-52-4 (72.50), 73911-3-2-30 (72.00), 81-1-1 (72.00), R-91019 (73.00), R 75 (71.50), ICSR 172 (75), 4019 (70.00), R 29 (72.00), R-49 (72.00), Mahalakshmi (70.50), R-91014 (71.50), 73902-2-5 (72.00), R-149 (74.00) and R-68 (74.00).

Table 5. Yield attributes and yield of sorghum genotypes during *kharif* 2017-18

S. No	Genotype	Days to 50% flowering		Crop duration (Days)		Grain yield (kg ha-1)		Avoidable losses
		UP	P	UP	P	UP	P	
1	73903-1-2-1	72.50	72.50	99.50	99.50	1254.00	1880.00	26.11
2	73902-8-2-2	80.00	80.00	107.00	107.00	1713.00	1759.00	5.26
3	NJ2446	78.50	78.50	105.50	105.50	1204.00	2500.00	55.56
4	ICSR 98	80.50	80.00	107.50	107.00	1759.00	3704.00	55.00
5	73904-1-1	80.00	80.50	107.00	107.50	1324.00	1759.00	17.89
6	4109	74.50	75.00	101.50	102.00	1389.00	2037.00	36.36
7	73904-2-1	77.00	77.00	104.00	104.00	991.00	1898.00	48.29
8	81-52-4	72.50	72.50	99.50	99.50	2870.00	3806.00	22.14
9	73911-3-2-30	72.00	71.50	99.00	98.50	1426.00	1778.00	32.29
10	IS 2205 (C)	76.00	76.50	103.00	103.50	1954.00	2778.00	30.00
11	73902-4-1-2	75.50	75.00	102.50	102.00	3148.00	3889.00	23.81
12	81-1-1	72.00	71.50	99.00	98.50	3519.00	3981.00	6.98
13	R-91019	73.00	73.00	100.00	100.00	1667.00	1944.00	4.76
14	73902-2-7	75.50	75.50	102.50	102.50	1926.00	2685.00	28.97
15	I33	78.00	78.00	105.00	105.00	2037.00	2685.00	31.03
16	R 75	71.50	71.50	98.50	98.50	1389.00	2130.00	39.13
17	ICSR172	74.50	75.00	101.50	102.00	1833.00	2046.00	9.50
18	4019	70.50	70.00	97.50	97.00	1556.00	1852.00	22.00
19	R-68	74.00	74.00	101.00	101.00	833.00	1667.00	44.44
20	R-29	72.50	73.00	99.50	100.00	2130.00	2870.00	29.03
21	ICSR 96	80.50	80.00	107.50	107.00	1065.00	1815.00	48.98
22	R-49	72.00	72.00	99.00	99.00	1856.00	4168.00	60.00
23	NJ 2647	79.00	78.00	106.00	105.00	1296.00	2037.00	63.64
24	Mahalakshmi	70.50	70.00	97.50	97.00	1083.00	2685.00	57.24
25	R-149	74.00	73.50	101.00	100.50	833.00	1574.00	41.18
26	R-91014	71.50	72.00	98.50	99.00	926.00	2222.00	58.33
27	73902-4-2-1	76.00	77.00	103.00	104.00	1491.00	1880.00	26.11
28	73902-2-5	72.00	72.00	99.00	99.00	1157.00	1667.00	44.44
29	IS 18551(C)	75.50	75.00	102.50	102.00	1759.00	1870.00	10.89
30	4993	76.00	76.00	103.00	103.00	1481.00	2407.00	46.15
	GM	74.92	74.87	101.92	101.87	1628.83	2399.07	31.08
	SEm±	0.83	0.99	1.26	0.99	152.45	143.97	7.43
	CD (P= 0.05)	0.44	0.34	0.44	0.34	440.95	416.42	21.50
	CV%	1.26	0.64	0.61	0.47	13.20	8.49	33.80

UP= Unprotected P= Protected

Late duration varieties

73902-8-2-2 (80), NJ 2446 (78.50), ICSR 98 (80.50), 73904-1-1 (80), 73904-2-1 (77), IS 2205 (C) (76.50), 73902-2-7 (75.50), I 33 (78), ICSR 96 (80.50), NJ 2647 (79), 73902-4-2-1 (76), IS 18551 (C) (75.50) and 4993 (76), 73902-4-1-2 (75.50).

Crop Duration

The crop duration of the genotypes ranged from 97.5 to 107.5 days. The genotypes 73903-1-2-1 (99.5), 81-52-4 (99.5), 73911-3-2-30(99), 81-1-1 (99), R- 75 (98.5) and R-91014 (98.5) took lesser days to reach harvestable maturity, whereas 73904-1-1 (107), ICSR 98 (107.5) and ICSR 96 (107.5) took more days to reach maturity (Table 5).

Grain Yield

Data on grain yield revealed that there is significant variation among the genotypes, which ranged from 833.33 to 3518.52 and 1574 to 4166.67 kg ha^{-1} under unprotected and protected condition respectively. Under unprotected condition, the highest grain yield was recorded in genotypes 81-1-1 (3518.52 kg ha^{-1}) followed by 73902-4-1-2 (3148.15 kg ha^{-1}), 81-52-4 (2870.37 kg ha^{-1}), R-29 (2129.63 kg ha^{-1}), whereas the lowest grain yield recorded in R-68 (833.33 kg ha^{-1}), R-149 (833.33 kg ha^{-1}), R- 91014 (925.93 kg ha^{-1}) and 73904-2-1 (990.74 kg ha^{-1}) when compared to the resistant checks IS 18551 (1759 kg ha^{-1}) and IS 2205 (1954 kg ha^{-1}) respectively.

Under protected condition, the highest grain yield recorded in genotype R-49 (4166.67 kg ha^{-1}) followed by 81-1-1 (3981.48 kg ha^{-1}), 73902-4-1-2 (3888.89 kg ha^{-1}) and 81-52-4 (3805.56 kg ha^{-1}), whereas the lowest grain yield recorded in R-149 (1574.00 kg ha^{-1}), R-68 (1666.67 kg ha^{-1}), 73903-1-2-1 (1666.67 kg ha^{-1}), 73904-1-1 (1759.26 kg ha^{-1}), 73902-8-2-2 kg ha^{-1}) and 73911-3-2-30 (1777.78 kg ha^{-1}) when compared to the resistant checks IS 18551 (2407 kg ha^{-1}) and IS 2205 (2778 kg ha^{-1}) respectively (Table 5).

Avoidable losses (%)

Avoidable losses ranged from 4.76% to 63.64%. The highest avoidable losses were recorded in genotypes NJ 2647 (63.64%), R-49 (60%), R-91014 (58.33%), NJ 2446 (55.56) and ICSR 98 (55%) and lowest avoidable losses were observed in R-91019 (4.76%), 73902-8-2-2 (5.26%), 81-1-1 (6.98%), ICSR 172 (9.50%) when compared to the resistant check IS 18551(C) (10.89%) (Table 5).

Among the thirty screened sorghum genotypes, Mahalakshmi, I 33 and R-68 were found as highly resistant to shoot fly when compared to the resistant checks IS 2205 (C) and IS 18551 (C), which was highly resistant. Resistance in the above genotypes might be attributed to presence of trichomes, colour and glossiness of leaves and antibiosis mechanism.

The results indicated that oviposition non-preference (antixenosis) and antibiosis components of the resistance play major role in oviposition and dead heart formation. Growth and development of shoot flies were retarded and larval and pupal periods were extended by 8-15 days on resistant varieties (Singh and Jotwani, 1980).

Singh and Narayana, 1978 reported that highest fecundity and survivality of shoot fly was better on highly susceptible varieties.

The results showed that presence of more number of trichomes on both adaxial leaf surface and abaxial leaf surfaces in the highly resistant genotypes IS 2205 (80.75, 74.33), IS 18551 (87.50, 79.60), I 33 (40.50, 34.83), R 68 (92.75, 65.33) and Mahalakshmi (88.00, 68.67) respectively and the leaf glossiness of these genotypes (1.33, 1.17, 1.67, 1.00 and 1.17) were found to be very high compared to susceptible genotypes 4993 (3.00) and R-91014 (3.33). Susceptible genotypes 4993 and R-91014 have recorded a few number of trichomes on both adaxial and abaxial leaf surface (15.25 and 17.17) and (9.75 and 10.25) respectively.

Glossy trait is a characteristic feature of the most of the sorghum varieties associated with shoot fly resistance (Omori *et al*. 1988). The intensity of leaf glossiness at seedling stage is positively associated with the resistance to shoot fly (Sharma *et al*. 1997). Glossiness affects the quality of light reflected from the leaves, which in turn influences the orientation of insects towards their host plants (Prokopy *et al.* 1983).

The per cent dead hearts was negatively correlated with trichomes density (adaxial and abaxial leaf surface), leaf glossiness and yield. Glossiness exhibited significant positive correlation with trichome density and significant negative correlation with oviposition and dead hearts at 14 and 21 DAE (Apotikar *et al*. 2011).

Morphological traits like seedling leaf blade glossiness, trichome density on lower and upper leaf portions, leaf sheath pigmentation are negatively correlated with per cent shoot fly dead heart infestation and positively associated with the shoot fly resistance. Combined effects of trichome density on abaxial, adaxial and leaf glossiness have been found to reduce dead heart percentage and shoot fly resistance at higher level.

Among the highly resistant genotypes, I 33 found to be glossy with more number of trichomes and late durated recorded higher grain yield.

Ten genotypes were found as resistant to shoot fly. Among the resistant genotypes, 73902-4-1-2 found to be non-glossy with late duration recorded significantly higher grain yield.

The thirteen genotypes were grouped under moderately resistant to shoot fly. Among these, the genotypes 81-1-1, R 29 and 73902-2-7 were significantly recorded higher grain yields. Hence these type of genotypes can be utilized for resistant breeding programmes.

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