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EVALUATION OF SORGHUM GENOTYPES FOR THEIR RSISTANCE TO SHOOT FLY *ATHERIGONA SOCCATA*

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ABSTRACT

An experiment with sixteen sorghum genotypes including two checks was conducted to evaluate their reaction against shoot fly at Akola, during *kharif* 2016-17. Observations were made on the eggs, deadhearts, seedling vigour, leaf glossiness, trichome density, chlorophyll content and bricks index. The results revealed that the seedling leaf glossiness score (SLGS) range was 1.67 to 4.67 and was significantly positively related with oviposition and with deadhearts. Seedling vigour score (SVS) also was observed with a positive significant association with eggs and deadhearts on 14th and 28th days after emergence. The trichomes on abaxial (lower) surface was observed to be maximum with the resistant check IS-18551, and this showed a significant negative association with oviposition and deadhearts. Chlorophyll index had highly significant positive impact on the oviposition and deadhearts. Low bricks indices were observed in the resistant lines.

Key words: *Sorghum bicolor*, *Atherigona soccata*, host resistance, eggs, deadhearts, seedling vigour, leaf glossiness, trichomes, chlorophyll index, bricks index

Sorghum [*Sorghum bicolor* (L.) Monech] is an important cereal crop. Sorghum shoot fly, *Atherigona soccata* (Rondani) is an important pest of sorghum, and attacks the sorghum seedlings during 5-25 days after emergence. It lays elongated cigar shaped eggs on third to sixth basal leaves parallel to the leaf midrib (Padmaja et al. 2010). The egg hatches into a maggot in 1-2 days, the maggot crawls along the leaf sheath, and reaches the central whorl of the plant, where it makes an incision on the central leaf, which causes desiccation and death of whorl leaf and forms a typical dead heart (Deeming, 1972). In sorghum, shoot fly infestation decreases plant stand, and causes severe yield losses. Increase in shoot fly deadhearts by 1% results in a loss of 143 kg grain yield/ ha (Chundurwar and Karanjkar, 1979; Dhaliwal et al., 2004). The worldwide yield loss due to shoot fly has been estimated to be over 274 million US$ (Sharma, 2006).

Host plant resistance is an important component for the management of this pest. Sorghum seedling characters are associated with resistance; physicochemical traits viz., leaf glossiness, trichome density are associated with resistance and chlorophyll content, seedling vigour are important (Dhillon et al., 2005). The deadhearts, plants with eggs, leaf glossiness, trichomes on the abaxial surface of the leaf can be used as marker traits. Losses due to damage can be reduced by using resistant varieties (Sharma, 1985), and to keep the populations below the economic threshold levels (Sharma, 1985; Riyazuddin et al., 2015). Therefore, this study evaluates various sorghum lines for their physicochemical traits and its impact on shoot fly resistance.

MATERIAL AND METHODS

The study was carried out at the Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *kharif* 2016-17. The morphological traits associated with sorghum and important resistance contributing parameters for shoot fly reaction were observed. The experiment was laid out in Randomized Block Design with 16 treatments -14 sorghum lines and two checks in three replications in gross plot size was 2.0 x 2.70 m at spacing 45 x 15 cm. Number of plants/ plot in six rows of 4 m each/ replication were observed 12 days after emergence (DAE). The leaf glossiness and seedling vigour in the scale 1 to 5 were observed at 12 DAE (Sharma et al. 1997). The number of eggs/ plant were counted on five randomly selected plants in each plot at 7, 14 and 21 DAE. The deadhearts were observed at 14, 21 and 28 DAE. The trichome density on abaxial and adaxial surfaces of leaf blade was observed under stereozoom microscope at 10x magnification (Sharma et al., 1997). The sixth leaves from apical point in each replication of each line were collected at 14th DAE and kept overnight in to 20 ml acetic acid: alcohol (2:1) and were preserved in 90% lactic acid for measuring the trichome density.

The chlorophyll index of five randomly selected leaves/ was measured at 14 DAE using SPAD-502 plus meter. Bricks indices were measured at 14, 21 and 28, DAE with a hand refractometer. Plant height of five plants selected at random/ replication was measured from the ground level to the tip of earhead at the time of harvest. These data were subjected to appropriate transformations and subjected to statistical analysis to test the level of significance. Moreover, the data thus collected on morphological parameters were correlated with infestation.

RESULTS AND DISCUSSION

Leaf glossiness

Seedling leaf glossiness score (SLGS) was observed to range between 1.67 to 4.67; lower the score higher was the glossiness and vice-versa (Table 1). The lower SLGS was in resistant check IS-18551 and test lines viz., IC-289172 and IC-289109 which had 1.67 SLGS indicating these lines were glossier. Whereas, higher score 4.67 was observed in susceptible check Swarna, test lines IC-288539 and IC-288619 indicating that the lines are less glossy. The SLGS of IC-289109,

Table 1. Seedling glossiness and vigour score, shoot fly eggs and deadhearts of sorghum genotypes (*kharif* 2016)

S. No.	Sorghum genotypes	Plant stand	SLGS	SVS	Eggs/ plant			Deadhearts (%)		
					7 DAE	14 DAE	21 DAE	14 DAE	21 DAE	28 DAE
1	IC-288412	178.00	2.67	2.67	8.67 (2.92)	7.67 (2.76)	13.33 (3.64)	21.85 (27.52)	28.71 (32.25)	29.51 (32.85)
2	IC-288477	315.67	2.67	2.67	8.67 (2.92)	8.00 (2.82)	8.33 (2.85)	11.44 (19.64)	17.31 (24.02)	18.44 (25.09)
3	IC-288539	71.00	4.67	4.67	13.00 (3.60)	10.33 (3.17)	8.33 (2.77)	37.05 (37.44)	40.66 (39.35)	45.42 (42.24)
4	IC-288605	112.33	4.33	4.00	12.00 (3.46)	11.00 (3.27)	14.67 (3.81)	33.89 (35.50)	38.95 (38.61)	40.05 (39.26)
5	IC-288619	76.00	4.67	3.00	15.00 (3.79)	10.00 (3.14)	10.33 (3.19)	27.72 (31.64)	44.64 (41.86)	54.92 (47.95)
6	IC-288631	81.33	4.33	3.00	14.67 (3.83)	16.67 (3.95)	13.67 (3.69)	46.71 (43.11)	51.88 (46.08)	59.02 (50.32)
7	IC-288634	69.00	3.67	4.00	10.33 (3.18)	11.67 (3.37)	12.33 (3.51)	36.17 (36.55)	40.45 (39.35)	52.46 (46.41)
8	IC-288919	294.00	2.33	4.00	5.67 (2.35)	5.67 (2.33)	11.00 (3.31)	8.68 (17.04)	20.83 (27.11)	23.29 (28.85)
9	IC-289087	152.00	3.00	3.67	8.67 (2.94)	8.33 (2.86)	8.00 (2.82)	18.37 (25.20)	29.78 (32.08)	33.16 (34.39)
10	IC-289109	154.00	1.67	2.00	7.00 (2.63)	7.67 (2.74)	8.67 (2.94)	12.38 (20.35)	26.94 (30.81)	28.58 (31.95)
11	IC-289124	118.67	2.33	1.33	9.33 (3.05)	6.00 (2.45)	6.00 (2.44)	19.58 (26.11)	36.15 (36.89)	38.21 (38.13)
12	IC-289161	112.00	2.33	2.33	14.67 (3.68)	6.00 (2.43)	8.67 (2.93)	30.47 (33.49)	36.16 (36.77)	39.58 (38.89)
13	IC-289172	213.33	1.67	2.00	5.67 (2.35)	7.00 (2.60)	9.00 (3.00)	11.21 (19.50)	16.27 (23.57)	20.21 (26.42)
14	IC-289741	103.00	2.00	2.67	10.33 (3.17)	8.00 (2.82)	7.00 (2.63)	21.69 (27.65)	37.11 (37.52)	42.26 (40.53)
15	IS-18551 (Rc)	148.00	1.67	1.33	10.67 (3.25)	6.00 (2.43)	13.00 (3.60)	6.08 (14.24)	14.32 (21.50)	15.69 (23.02)
16	Swarna (sc)	83.67	4.67	4.33	12.67 (3.48)	13.67 (3.51)	15.67 (3.87)	39.60 (38.94)	50.11 (45.06)	65.97 (54.38)
	CD (at 5%)				0.86	0.93	0.77	7.14	9.87	9.16
	CV (%)				16.31	19.26	14.61	15.16	17.21	14.70

*Figures in parentheses arc sine transformed values.*Figures in parentheses square root transformed values; DAE= Days after emergence; SLGS- Seedling leaf glossiness score; SVS- seedling vigour score

IC-289172 and IC-289741 were comparable with glossiness of resistant check IS-18551 (1.67). Similar type of results was observed by Dhillon et al. (2005) who reported 1.4 glossiness score in resistant check IS-18551. Bhagwat et al. (2011) also observed comparative glossiness in four lines with resistant checks. Raut et al. (2015) reported low values of glossiness score for shoot fly resistance lines. The SLGS positively significant with oviposition 7 (0.685**) and 14 DAE (0.797**) indicating non preference for oviposition on glossy seedling (Table 3). Dhillon et al. (2005) observed positive significant association of oviposition with leaf glossiness. Seedling glossiness score highly positively associated with shoot fly deadhearts 14th, 21st and 28th DAE (Table 3). The intensity of leaf glossiness at seedling stage reported highly significant positive association with shoot fly deadhearts at 28 DAE (Dhillon et al. 2006; Gomashe et al., 2010; Sonalkar and Pagire, 2017). While, Nawalkar et al. (2017) reported positive significant association between leaf glossiness and shoot fly deadhearts.

Seedling vigour

Seedling vigour score (SVS) varied in the lines indirectly influencing the pest attack. Least SVS was showed by the resistant check IS-18551 and test line IC-289124 with score 1.33 each indicating these lines are more vigorous (Table 1). The highest SVS i.e. 4.67 was showed by test line susceptible check Swarna indicating least vigourous seedlings. Least is the SVS, more was the vigour and more was the SVS, least vigorous were the seedling. The present findings confirmed by the findings of Singh et al. (2011) who reported minimum SVS in IS-21444 and highest in two sorghum genotypes. Similarly, low values of SVS was observed in four sorghum lines including one resistant check by Prasad et al. (2015);

Table 2. Trichome density, chlorophyll index and bricks index in sorghum genotypes (*kharif* 2016).

S. No.	Sorghum genotypes	Trichome density (14 DAE)		Chlorophyll Index (14 DAE)	Bricks index at crop stages		
		Adaxial (Upper)	Abaxial (Lower)		14 DAE	21 DAE	28 DAE
1	IC-288412	94.11 (9.70)	37.56 (6.12)	28.93	6.43	9.73	8.17
2	IC-288477	101.67 (10.07)	35.11 (5.92)	27.73	8.93	11.27	9.20
3	IC-288539	84.89 (9.20)	15.66 (3.95)	36.90	7.60	9.70	8.17
4	IC-288605	66.78 (8.16)	14.67 (3.82)	32.63	7.70	10.60	9.27
5	IC-288619	72.22 (8.48)	21.22 (4.60)	29.63	7.33	10.17	8.53
6	IC-288631	65.33 (8.08)	15.22 (3.89)	37.00	7.30	10.63	8.80
7	IC-288634	72.45 (8.49)	18.11 (4.24)	31.00	8.77	9.93	8.07
8	IC-288919	135.45 (11.63)	38.66 (6.19)	30.67	8.03	11.53	9.53
9	IC-289087	99.56 (9.97)	38.89 (6.23)	30.33	8.07	11.00	8.90
10	IC-289109	107.89 (10.38)	30.44 (5.49)	33.67	6.60	10.60	9.20
11	IC-289124	97.67 (9.88)	38.00 (6.16)	31.67	6.90	10.60	9.23
12	IC-289161	112.22 (10.59)	41.11 (6.41)	32.00	7.70	10.83	9.50
13	IC-289172	125.56 (11.20)	41.56 (6.44)	29.00	7.00	9.73	8.30
14	IC-289741	114.11 (10.67)	40.78 (6.38)	31.00	7.17	11.60	9.57
15	IS-18551 (RC)	133.44 (11.55)	46.00 (6.78)	29.67	7.83	10.50	8.60
16	Swarna (SC)	31.67 (5.60)	9.78 (3.12)	34.67	7.97	10.57	8.17
	CD at (5%)	0.83	0.60	5.74	1.25	1.19	1.03
	CV (%)	5.20	6.71	10.93	9.92	6.81	7.44

*Square root transformed values; RC-Resistant check; SC- Susceptible check; DAE = Days after emergence

Table 3. Association of plant characters with shoot fly oviposition and deadhearts

Parameters	Eggs			Dead heart (%)		
	7 DAE	14 DAE	21 DAE	14 DAE	21 DAE	28 DAE
Seedling Glossiness score	0.685**	0.797**	0.470	0.825**	0.786**	0.791**
Seedling vigour score	0.227	0.534*	0.368	0.559*	0.471	0.505*
Chlorophyll index	0.488	0.634**	0.207	0.706**	0.682**	0.625**
Bricks index 14 DAE	-	0.156	-	0.074	-	-
Bricks index 21 DAE	-	-	-0.247	-	-0.140	-
Bricks index 28 DAE	-	-	-	-	-	-0.234
Trichome density (Adaxial)	-0.191	-0.229	-0.252	-0.237	-0.171	-0.149
Trichome density (Abaxial)	-0.546*	-0.868**	-0.531*	-0.822**	-0.774**	-0.791**

*Correlation coefficients significant at p=0.05 (r=0.497); **highly significant at p= 0.01 (r=0.623)

Raut et al. (2015) also reported less than 1.68 SVS in three sorghum lines. Seedling vigour score had positive significant association with eggs (Table 3) observed on 14th DAE (0.534*) indicates that vigorous lines non-preferred by shoot fly for egg laying. Similar types of observations were noted by Gomashe et al. (2010) who observed positive significant association of oviposition on 14 and 21 DAE with seedling vigour. However, Dhillon et al. (2005) and Dhillon et al. (2006) observed positive but non-significant correlation of seedling vigour and egg number. Seedling vigour score had significant positive impact on shoot fly deadhearts 14th and 28th DAE indicating vigorous seedlings are less vulnerable to shoot fly deadhearts. Gomashe et al. (2010) reported that the seedling vigour had positively and highly significant association with shoot fly deadhearts.

Eggs

The eggs 7 DAE on five plants varied from 5.67 to 15.00 with least i.e. 5.67 were noted on test entry viz., IC-288919 and IC-289172 each (Table 1). The highest egg count was on IC-288619 (15.00) followed on IC-289161, IC-288631, IC-288539, Swarna and IC-288605. Khandare et al. (2013) reported low level egg laying 7 DAE by shoot fly on sorghum. Minimum eggs (5.67) 14 DAE were on IC-288919 which was on par with eggs on lines IC-289161, IS-18551, IC-289124, IC-289172, IC-289109, IC-288412, IC-288477, IC-289741, IC-289087, IC-288619, IC-288539 and IC-288605. The highest eggs (16.67) were on IC-288631 followed on Swarna (13.67) and IC-288634 (11.67). Patel et al. (2015) studied the egg laying by shoot fly on 12 genotypes and reported on par eggs on three sorghum lines with resistant checks. Similarly, Siva kumar et al. (2008) observed shoot fly eggs on thirteen lines along with two checks and reported least eggs on nine sorghum lines. The minimum eggs 21 DAE were on IC-289124 and it was on par with eggs on IC-289741, IC-289087, IC-288477, IC-288539, IC-289161, IC-289109, IC-289172 and IC-288619 (Table 1). However, eggs on later two were statistically equal with highest eggs (15.67) noted on Swarna being statistically equal on IC-288605 (14.67), IC-288631, IC-288412, IS-18551, IC-288634 and IC-288919. Dhillon et al. (2005) reports 4.25 to 5.40 eggs/ five plants (8.5 to 10.8 / 10 plants). Similarly, Khandare et al. (2013) reports low range of egg laying on sorghum lines.

Deadhearts

The least deadhearts 14 DAE (Table 1) were in IS-18551(6.08 %) followed in IC-288919 (8.68 %). The maximum deadhearts i.e. 46.71% observed in IC-288631 does not differ statistically from that of Swarna (39.60), IC-288539 (37.05), IC-288634 (36.17) and IC-288605 (33.89). Fourteen days after emergence the deadhearts in resistant and susceptible checks were 6.08 and 39.60%, respectively. Whereas, Dhillon et al. (2005) reported 33.4 and 78.60% deadhearts in resistant and susceptible checks, respectively. The least deadhearts i.e. 14.32% at 21 DAE were noted in IS-18551(Table 1); however, these were statistically at par with that of IC-289172 (16.27), IC-288477 (17.31), IC-288919 (20.83), IC-289109 (26.94) and IC-289087 (29.78). The test entry IC-288631 (51.88) shown highest deadhearts expressing susceptibility to shoot fly and were at par with deadhearts in Swarna (50.11%), IC-288619 (44.64%), IC-288539 (40.66%), IC-288634 (40.45%), IC-288605 (38.95 %), IC-289741 (37.11 %) and IC-289124 (36.15%). In check entry IS 18551 14.32% deadhearts were noted which were on par to deadhearts in five test entries.

Similar results were obtained by Apotikar et al. (2011) who reported 15.00% deadhearts whereas,

Khandare et al. (2013) reports 7.98% deadhearts. Amongst all entries, IS-18551 (15.69) was the most effective for shoot fly reaction 28 DAE (Table 1). Of the test entries IC-288477 recorded minimum deadhearts i.e. 18.44 % being statistically at par with that of IS-18551 and in IC-289172 (20.21%), IC-288919 (23.29%) and IC-289109 (28.58%). Swarna showed maximum deadhearts (65.97%) and entries viz., IC-288631, IC-288619 and IC-288634 expressed susceptibility recording 59.02, 54.92 and 52.46% deadhearts, respectively. Present findings confirm the results of Bhagwat et al. (2011) who reported 37.40 to 41.2 % shoot fly deadhearts on resistant checks; also corroborate with those of Khandare et al. (2013). However, Patel et al. (2015) noted 10.13% deadhearts on resistant check under low pest pressure. Sonalkar and Pagire (2017) observed less deadhearts not exceeding 5% on resistant checks under high pest pressure.

Leaf trichome density (14 DAE)

Significantly, highest numbers of trichomes were recorded on leaves of IC-288919 and were statistically equal with trichomes on IS-18551 (133.44) and test lines viz., IC-289172 (125.56) and IC-289741 (114.11) (Table 2). Minimum trichomes were noted on susceptible check Swarna (31.67); trichomes on these were significantly less than all the genotypes studied. Among the test lines, IC-288631 reported minimum (65.33) trichomes which were on par to trichomes on IC-288605 (66.78), IC-288619 (72.22), IC-288634 (72.45) and IC-288539 (84.89). Present findings are partially in agreement with those of Dhillon et al. (2005) who reported trichome range 112.1 to 166.8 in a 10x microscopic field. However, Mohammed et al. (2016a) reported trichome range 120.4 to 165.0 . The highest trichomes on abaxial (lower) surface were on resistant check IS-18551 (46.00) followed with 41.56 on test line IC-289172 (Table 2); however, trichomes on former were on par with trichomes on IC-289161 (41.11), IC-289741 (40.78), IC-289087 (38.89) and IC-288919 (38.66). Least trichomes count was on Swarna which had 9.78 trichomes followed on test line IC-288605 (14.67). In present study highest and lowest trichomes on abaxial leaf surface were observed on resistant and susceptible checks, respectively and the range was 9.78 and 46.0. Whereas, Dhillon et al. (2005) reports trichome range 78.7 to 115.8; they also reported few trichomes on susceptible check Swarna.

The findings of Apotikar et al. (2011) who observed 31.00 trichomes on abaxial leaf surface confirm the present study. Mohammed et al. (2016) reports trichomes range 46.4 to 78.9 per 10 x microscopic field. Trichome on leaf lamina is one of the major morphological characters that affect the oviposition by shoot fly (Table 3). Trichome on abaxial (Lower) leaf surface had significant negative association 7th and 21st DAE and highly significant negative correlation with oviposition 14th DAE and highly significant negative correlation with shoot fly deadhearts 14th (-0.822**), 21st (-0.774**) and 28th (-0.791**) DAE. Earlier it is reported that trichome on adaxial leaf surface had negative non-significant association with oviposition and on abaxial leaf surface had negatively and highly significant association with shoot fly deadhearts at 14 and 21DAE (Anandan et al. 2009); and the trichomes on abaxial leaf surface had negatively and highly significant association with shoot fly oviposition (Nawalkar et al.,2017) further they noted negative non significant association with shoot fly deadhearts in back cross (BC1); but, negative highly significant association in BC2 at 14 and 21 DAE.

Chlorophyll index (14 DAE)

The chlorophyll index indicates significant differences with highest (37.00) in IC-288631 followed in IC-288539, Swarna, IC-289109, IC-288605, IC-289161 and IC-289124 (Table 2). Minimum chlorophyll index was 27.73 observed in IC-288477 followed in IC-288412, IC-289172 and IC-288619. Low chlorophyll indices were in resistant check and higher in susceptible check. Similar, type of results were obtained earlier by Dhillon et al. (2005), Sonone et al. (2015) and Sridhar et al. (2015) confirms the present findings. Chlorophyll index had highly significant positive impact (Table 3) on shoot fly oviposition 14th DAE (0.634*) and deadhearts 14th (0.706**), 21st (0.682**) and 28th DAE (0.625**). Similar types of results noted by Dhillon et al. (2006) who reported the chlorophyll in sorghum seedlings at 14 DAE highly significant and positively associated with the shoot fly eggs and shoot fly deadhearts.

Bricks index

The highest bricks index 14 DAE noted in IC-288477 (8.93) (Table 2) follows in sorghum lines viz., IC-288634, IC-289087, IC-288919, Swarna , IS-18551, IC-288605 and IC-289161. The least bricks index i.e. 6.43 was in IC-288412 which was statistically equal in IC-289109, IC-289124, IC-289172, IC-289741, IC-288631, IC-288619, IC-288539, IC-289161 and IC-288605. Highest bricks index (11.60) 21 DAE was observed in IC-289741 followed in IC-288919, IC-288477 and IC-289087. Minimum i.e. 9.70 were in IC-288539 followed with 9.73 noted in IC-288412 and

IC-289172 each. Maximum bricks index i.e. 9.27 was in IC-289741 28 DAE followed with 9.53 in IC-288919. Least bricks index in (8.07) was in IC-288634 followed with 8.17 noted in each IC-288412, IC-288539 and Swarna. Low bricks indices observed in resistant lines and somewhat increased bricks indices in susceptible lines. Such types of results were reported by earlier workers (Patel et al. 2015 and Sonone et al. 2015). Bricks index reading had non-significant association with ovipositional preference (Table 3). Singh et al. (2004) also reported that the chlorophyll content and bricks index had positive and non-significant impact on shoot fly egg laying and deadhearts at 21 DAE. Bricks index reading at 14th (0.074) and 21st DAE (-0.140) had non-significant association with shoot fly deadhearts. The studies reveal that the morphological characters like seedling leaf glossiness, seedling vigour, trichomes on leaves play the role in imparting the resistance or susceptibility of sorghum line to shoot fly. Similarly, chlorophyll and brix index also responsible to certain extent for shoot fly incidence.

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