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Screening of different sorghum genotypes against sorghum shoot fly, *Atherigona soccata* Rondani

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Abstract
Sorghum (*Sorghum bicolor* L.) is one of the main staples for the world's poorest and most food-secure people commonly known as jowar in the Indian sub-continent, it grows well in both summer and winter, and is thus both a *Rabi* and *Kharif* crop. In this experiment, eighteen sorghum genotypes including local, susceptible and resistant checks were evaluated for shoot fly at Main Sorghum Research Station, Navsari Agricultural University, Athwa Farm, Surat. The results showed that, shoot fly dead heart per cent at 14 DAE, resistant check IS 2205 (12.52%) was recorded significantly lowest damaged. The shoot fly dead heart per cent at 28 DAE was found significantly lower in resistant check IS 2205 (20.47%), whereas susceptible check Swarna recorded 35.23 and 61.21 per cent at 14 and 28 DAE of crop respectively.

Keywords: Sorghum genotypes, sorghum shoot fly, *Atherigona soccata* Rondani

Introduction
Sorghum (Sorghum bicolor) is one of the most important cereal crops grown in Africa, Asia, United States of America, Australia and Latin America. It is widely grown for food, feed, fodder, forage and fuel in the semi-arid tropics (SAT) of Asia, Africa, the Americas and Australia. It's importance after wheat, maize, rice and barley is because of its good adaptation to a wide range of ecological conditions, low input cultivation and diverse uses (Aruna *et al*., 2011) [1]. In India, sorghum is grown on an area of 6.18 million ha with annual production of 5.28 million tonnes with productivity 845.4 kg/ha in *kharif* and 674.7 kg/ha in *rabi* season (FAO, 2014) [6]. Gujarat, Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh and Rajasthan are the major states of the country gaining the sorghum.
Insect pests are the major biotic constraints for production and productivity of sorghum causing economic losses over US$1 billion annually in the SAT. Nearly 150 insect species have been reported as pest on sorghum out of which twenty two are of potential economic importance. Among these, shoot fly (*Atherigona soccata*) is a major grain yield restrictive factor that causes damage under delayed sowings in rainy season. Shoot fly infestation decreases plant stand, and also causes severe losses in grain and fodder yield. Increase in shoot fly dead hearts by 1% results in a loss of 143 kg grain yield/ha, and an overall loss of 90-100% was reported under delayed sowings (Dhaliwal *et al.*, 2004) [5]. The worldwide yield loss due to shoot fly has been estimated to be over 274 million US$ (Sharma 2006) [9]. The early-sown sorghum crop escapes from shoot fly damage but in most cases the late-sown crop is affected. Shoot fly infestation is high when sorghum sowings are spread over a period of time due to unreliable rainfall distribution which is common in the state. Early sowing is not for all time practicable as the sowing window is short in rainfed situations and there exists a competition with other crops for sowing. For shoot fly management, strategies such as agronomic practices, natural enemies, synthetic insecticides and host plant resistance have been employed for minimizing the pest losses. Host plant resistance can play a most important role in putting down the extent of losses and is companionable with other tactics of pest management, including the use of natural enemies and chemical control. The host plant resistance (HPR) can be exploited as one of the most effective means of keeping insect pests below the economic threshold levels (Mohammed *et al.*, 2015) [7].

Materials and Methods
The trial was sown in randomized block design having 18 sorghum genotypes including local, susceptible and resistant checks were evaluated for shoot fly resistance at Main Sorghum Research Station, Navsari Agricultural University, Athwa Farm Surat. Plant population in each

entry was counted at 12 days after emergence of crop. Shoot fly incidence was recorded in term of dead heart formation. Dead heart percentage was recorded at 14 and 28 days after emergence of crop. The number of dead heart caused by shoot fly and total numbers of plants were counted from each genotype/entry at 14 and 28 days after emergence of crop and percentage of dead heart were calculated by using following formula.

$$\text{Dead hearts (\%)} = \frac{\text{No. of dead heart plants}}{\text{Total numbers of plants}} \times 100$$

Result and Discussion

Dead heart percentage was recorded at 14 and 28 days after emergence of crop. The number of dead heart caused by shoot fly and total numbers of plants were counted from each genotype at 14 and 28 days after emergence of crop and percentage of dead heart were calculated.

Dead hearts (*Kharif* 2020)

During *Kharif* 2020 season at 14 days after emergence of crop lowest dead heart percentage was recorded in genotype IS-2205 (11.12%) and it was statistically at par with GNJ-1 (11.92%), SR-3019 (11.99%), SR-3048 (12.40%), SR-3012(12.68%), SR-2980 (12.77%), SR-2957 (13.96%), DS-189 (15.41%), DS-200 (15.54%), SR-2985 (14.57%), SR-3049 (15.67%) and DS-172 (16.78%). The highest dead heart percentage was recorded in genotype Swarna (35.83%). It was followed by DS-184 (20.92%), SR-3040 (20.55%), DS-156 (19.44%) and CSV-20 (18.47%). At 28 days after emergence of crop lowest dead heart percentage as compared to other genotypes was recorded in genotype IS-2205 (20.77%). It was statistically at par with sorghum genotypes SR-3019, SR-2957, SR-2980, SR-3048, SR-3012 and GNJ-1 in with dead heart formation was recorded as 22.55, 24.79, 24.01, 24.04, 24.65 and 25.29 per cent respectively. Sorghum genotype Swarna recorded highest dead heart percentage (69.86%). Other entries recorded dead heart percentage as SR-3049 (28.32%), GJ-43 (30.93%), DS-200 (31.09%), DS-172 (31.76%), DS-189 (32.20%), CSV-20 (35.48%), SR-2985 (36.02%), SR-3040 (37.77%), DS-156 (38.38%) and DS-184 (39.04%). Pooled mean over two periods at 14 and 28 days after emergence of crop during *Kharif* 2020 the minimum shoot fly incidence was recorded in genotype IS-2205 (15.65%) and it was statistically at par with SR-3019 (16.93%), SR-3048 (17.85%), SR-2980 (18.05%), GNJ-1 (18.12%), SR-3012 (18.29%) and SR-2957 (18.82%). Significantly highest dead heart percentage was recorded in genotype Swarna (53.21%) and it was followed by DS-184 (29.57%), SR-3040 (28.77%), DS-156 (28.41%), CSV-20 (26.53%), SR-2985 (24.49%), DS-172 (23.86%), GJ-43 (23.43%), DS-189 (23.25%), DS-200 (22.84%) and SR-3049 (21.67%) (Table 1 and Fig. 1).

Table 1: Dead hearts formation in different sorghum genotypes due to sorghum shoot fly at 14 and 28 DAE (*Kharif*, 2020)

Sr. No.	Genotypes	Mean dead heart (%)		
		14 DAE	28 DAE	Pooled
1	SR-2957	21.94 (13.96)	29.19 (23.79)	25.71^{abcd} (18.82)
2	SR-2980	20.94 (12.77)	29.34 (24.01)	25.14^{abc} (18.05)
3	SR-2985	22.44 (14.57)	36.88 (36.02)	29.66^{efg} (24.49)
4	SR-3012	20.86 (12.68)	29.77 (24.65)	25.32^{abcd} (18.29)
5	SR-3019	20.26 (11.99)	28.35 (22.55)	24.30^{ab} (16.93)
6	SR-3040	26.96 (20.55)	37.92 (37.77)	32.44^{bcde} (28.77)
7	SR-3048	20.62 (12.40)	29.36 (24.04)	24.99^{fg} (17.85)
8	SR-3049	23.32 (15.67)	32.15 (28.32)	27.74^{ef} (21.67)
9	DS-156	26.16 (19.44)	38.28 (38.38)	32.21^{g} (28.41)
10	DS-172	24.18 (16.78)	34.30 (31.76)	29.24^{de} (23.86)
11	DS-184	27.22 (20.92)	38.67 (39.04)	32.94^{cde} (29.57)
12	DS-189	23.11 (15.41)	34.57 (32.20)	28.83^{de} (23.25)
13	DS-200	23.22 (15.54)	33.89 (31.09)	28.55^{abc} (22.84)
14	GJ-43	24.10 (16.67)	33.79 (30.93)	28.95^{de} (23.43)
15	GNJ-1	20.20 (11.92)	30.19 (25.29)	25.19^{abc} (18.12)
16	CSV-20	25.45 (18.47)	36.56 (35.48)	31.00^{efg} (26.53)
17	IS-2205	19.48 (11.12)	27.11 (20.77)	23.30^{a} (15.65)
18	Swarna	36.77 (35.83)	56.91 (70.19)	46.84^{h} (53.21)
S. Em. (±)		1.86	1.45	1.24
C.D. at 5%		5.36	4.17	3.51
S. Em. (±) (Y X T)		--	--	1.66
C.D. at 5% (Y X T)		--	--	NS
C.V. (%)		13.60	7.32	9.96

Note:

1) DAE- Days after emergence

2) Figures in parentheses are retransformed value, while those outside are arcsine transformed value.

3) Treatment means with the common super scripts letters are non-significant by DNMRT at 5% level of significance.

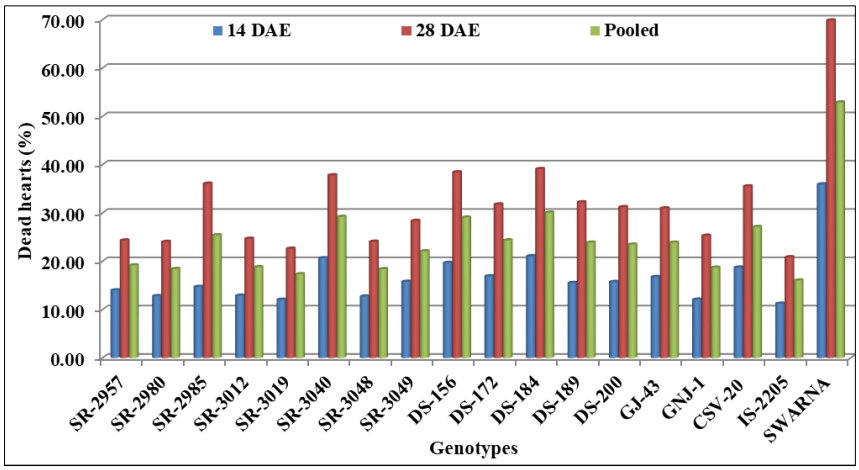

Fig 1: Dead hearts formation in different sorghum genotypes due to sorghum shoot fly at 14 and 28 DAE (*Kharif*, 2020)

Dead hearts (*Kharif* 2021)

During the year *Kharif* 2021 shoot fly incidence was ranged from 14.00 per cent to 34.62 percent at 14 days after emergence of crop. At that time significantly lowest dead heart percentage among all eighteen sorghum genotypes was recorded in genotype IS-2205 (14.00%) and it was statistically at par with SR-3019 (14.11%), SR-3048 (15.65%), SR-2957 (17.37%), SR-2980 (17.37%), GNJ-1 (17.70%), SR-3012(18.24%), SR-2985 (20.72%) and SR-3040 (20.79%). Susceptible check Swarna recorded highest dead heart percentage (34.62%). It was followed by CSV-20 (25.26%), DS-200 (24.08%), DS-189 (23.59%), GJ-43(23.39%), DS-172 (23.39%), DS-184 (21.68%), SR-3049 (21.19%) and DS-156 (21.19%). At 28 days after emergence of crop shoot fly incidence was ranged from 20.19 per cent to 51.81 per cent. During this period significantly lowest dead heart percentage was recorded in genotype IS-2205 (20.19%) and it was found statistically at par with sorghum genotypes SR-3048, SR-3019, SR-2957, SR-3012 and SR-3049 in with dead heart formation was recorded as 23.25, 25.93, 27.08, 27.47 and 27.57 per cent respectively. Shoot fly attack in terms of dead heart was observed highest in genotype Swarna (51.84%). Other entries recorded dead heart percentage as SR-2980 (28.95%), GNJ-1 (29.07%), DS-200 (29.34%), GJ-43 (31.79%), DS-189 (32.72%), DS-172 (33.72%), SR-3040 (34.88%), SR-2985 (36.20%), CSV-20 (36.27%), DS-156 (37.53%) and DS-184 (40.17%). Pooled mean over two periods at 14 and 28 days after emergence of crop during *Kharif* 2021 the significantly minimum shoot fly incidence in terms of dead heart as compared to other sorghum genotypes was recorded in genotype IS-2205 (17.02%) and it was observed statistically at par with SR-3048 (19.30%), SR-3019 (19.37%) and SR-2957 (22.03%). The highest dead heart percentage was recorded in susceptible check Swarna as 43.27 per cent. It was followed by other sorghum genotypes *viz.*, DS-184 (30.53%), CSV-20 (30.62%), DS-156 (29.03%), DS-172 (28.41%), SR-2985 (28.13%), DS-189 (28.05%), SR-3040 (27.55%), GJ-43 (27.49%), DS-200 (26.67%), SR-3049 (24.31%), GNJ-1 (23.14%), SR-2980 (22.90%) and SR-3012 (22.69%) (Table 2 and Fig. 2).

Table 2: Dead hearts formation in different sorghum genotypes due to sorghum shoot fly at 14 and 28 DAE (*Kharif*, 2021)

Sr. No.	Genotypes	Mean dead heart (%)		
		14 DAE	28 DAE	Pooled
1	SR-2957	24.63 (17.37)	31.36 (27.08)	27.99^{abc} (22.03)
2	SR-2980	24.63 (17.37)	32.55 (28.95)	28.59^{bcde} (22.90)
3	SR-2985	27.08 (20.72)	36.99 (36.20)	32.03^{efg} (28.13)
4	SR-3012	25.28 (18.24)	31.61 (27.47)	28.45^{bcd} (22.69)
5	SR-3019	22.06 (14.11)	30.61 (25.93)	26.11^{ab} (19.37)
6	SR-3040	27.13 (20.79)	36.20 (34.88)	31.66^{bcdef} (27.55)
7	SR-3048	23.30 (15.65)	28.83 (23.25)	26.06^{ab} (19.30)
8	SR-3049	27.41 (21.19)	31.67 (27.57)	29.54^{bcdef} (24.31)
9	DS-156	27.41 (21.19)	37.78 (37.53)	32.60^{fg} (29.03)
10	DS-172	28.92 (23.39)	35.50 (33.72)	32.21^{efg} (28.41)
11	DS-184	27.75 (21.68)	39.33 (40.17)	33.54^{g} (30.53)
12	DS-189	29.06 (23.59)	34.89 (32.72)	31.98^{defg} (28.05)
13	DS-200	29.39 (24.08)	32.80 (29.34)	31.09^{cdefg} (26.67)
14	GJ-43	28.92 (23.39)	34.32 (31.79)	31.62^{cdefg} (27.49)
15	GNJ-1	24.88 (17.70)	32.63 (29.07)	28.75^{bcde} (23.14)
16	CSV-20	30.17 (25.26)	37.03 (36.27)	33.60^{g} (30.62)
17	IS-2205	21.97 (14.00)	26.70 (20.19)	24.36^{a} (17.02)
18	Swarna	36.04 (34.62)	46.04 (51.81)	41.04^{h} (43.11)
S. Em. (±)		1.89	1.98	1.32
C.D. at 5%		5.44	5.70	3.73
S. Em. (±) (Y X T)				1.93
C.D. at 5% (Y X T)				NS

C.V. (%)	12.13	10.00	10.95

Note:
1) DAE- Days after emergence
2) Figures in parentheses are retransformed value, while those outside are arcsine transformed value.
3) Treatment means with the common super scripts letters are non-significant by DNMRT at 5% level of significance.

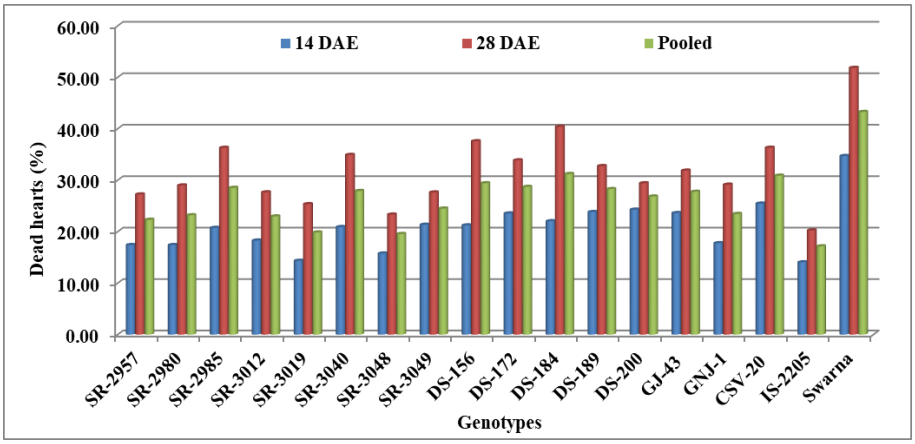

Fig 2: Dead hearts formation in different sorghum genotypes due to sorghum shoot fly at 14 and 28 DAE (*Kharif*, 2021)

Overall Pooled

Pooled mean over two seasons at 14 days after emergence of crop the significantly minimum shoot fly incidence was recorded in genotype IS-2205 (12.52%) and it was found statistically at par with SR-3019 (13.03%), SR-3048 (13.98%), GNJ-1 (14.69%), SR-2980 (15.00%), SR-3012 (15.36%) and SR-2957 (15.62%). Significantly the highest dead heart percentage was recorded in genotype Swarna (35.23%) and it was followed by sorghum genotypes CSV-20, DS-184, SR-3040, DS-156, DS-172, GJ-43, DS-200, DS-189, SR-3049 and SR-2985 in which per cent dead heart recorded as 21.77, 21.29, 20.68, 20.30, 19.98, 19.92, 19.63, 19.33, 18.36 and 17.54 per cent, respectively. During 28 days after emergence of crop pooled mean over two seasons minimum shoot fly incidence was observed in resistant check genotype IS-2205 (20.47%) and it was statistically at par with SR-3048 (23.65%), SR-3019 (23.88%), SR-2957 (25.65%), SR-3012 (26.05%) and SR-2980 (26.43%). Susceptible check Swarna recorded higher incidence of shoot fly in term of dead heart as 61.21 per cent. Other genotypes recorded dead heart per cent in merit were GNJ-1 (27.16%), SR-3049 (27.99%), DS-200 (30.21%), GJ-43 (31.35%), DS-189 (32.46%), DS-172 (32.74%), CSV-20 (35.88%), SR-2985 (36.12%), SR-3040 (36.32%), DS-156 (37.97%) and DS-184 (39.60%). Pooled mean over two seasons at 14 and 28 days after emergence of crop during *Kharif* 2020 and *Kharif* 2021 the incidence of shoot fly was ranged from 16.30 to 48.15 per cent and significantly minimum incidence was recorded in genotype IS-2205 (16.30%) and it was statistically at par with SR-3019 and SR-3048 in with dead heart formation was recorded as 18.14 and 18.57 per cent, respectively. Other genotypes recorded dead heart per cent as SR-2957 (20.41%), SR-2980 (20.43%), SR-3012 (20.44%), GNJ-1 (20.57%), SR-3049 (22.97%), DS-200 (24.73%), GJ-43 (25.42%), DS-189 (25.62%), DS-172 (26.11%), SR-2985 (26.28%), SR-3040 (28.16%), CSV-20 (28.55%), DS-156 (28.73%) and DS-184 (30.05%). Whereas, significantly highest dead heart percentage was recorded in genotype Swarna (48.15%) (Table 3 and Fig. 3). The interaction effects were non-significant and hence data for two years showed similar trend. Similar outcomes were also reported by Chamarthi *et al.* (2010) [4], Bhagwat *et al.* (2011) [2], Sonalkar and Pagire (2017) [11], Bhagyashree Ojha and Choudhary (2018) [3], Patidar *et al.* (2019) [8], Sonalkar *et al.* (2019) [12] and Shid *et al.* (2021) [10] at different locations amoung country.

Table 3: Dead hearts formation in different sorghum genotypes due to sorghum shoot fly (Pooled overall years)

Sr. No.	Genotypes	Mean dead heart (%)		
		14 DAE Pooled	28 DAE Pooled	Overall Pooled
1	SR-2957	23.28 (15.62)	30.43 (25.65)	26.86^{bc} (20.41)
2	SR-2980	22.79 (15.00)	30.94 (26.43)	26.87^{bc} (20.43)
3	SR-2985	24.76 (17.54)	36.94 (36.12)	30.84^{defgh} (26.28)
4	SR-3012	23.07 (15.36)	30.69 (26.05)	26.88^{bc} (20.44)
5	SR-3019	21.16 (13.03)	29.25 (23.88)	25.21^{ab} (18.14)
6	SR-3040	27.05 (20.68)	37.06 (36.32)	32.05^{efgh} (28.16)
7	SR-3048	21.96 (13.98)	29.10 (23.65)	25.53^{ab} (18.57)
8	SR-3049	25.37 (18.36)	31.94 (27.99)	28.64^{cd} (22.97)
9	DS-156	26.78 (20.30)	38.04 (37.97)	32.41^{fgh} (28.73)
10	DS-172	26.55 (19.98)	34.90 (32.74)	30.73^{defg} (26.11)
11	DS-184	27.48 (21.29)	39.00 (39.60)	33.24^{gh} (30.05)
12	DS-189	26.08 (19.33)	34.73 (32.46)	30.41^{def} (25.62)
13	DS-200	26.30 (19.63)	33.34 (30.21)	29.82^{de} (24.73)
14	GJ-43	26.51 (19.92)	34.05 (31.35)	30.28^{def} (25.42)

15	GNJ-1	22.54 (14.69)	31.41 (27.16)	26.97^{bc} (20.57)
16	CSV-20	27.81 (21.77)	36.80 (35.88)	32.30^{efgh} (28.55)
17	IS-2205	20.72 (12.52)	26.90 (20.47)	23.81^{a} (16.30)
18	Swarna	36.41 (35.23)	51.48 (61.21)	43.94^{i} (48.15)
S. Em. (±)		1.26	1.28	0.93
C.D. at 5%		3.75	3.62	2.57
S. Em. (±) (Y X T)		1.88	1.73	1.80
C.D. at 5% (Y X T)		NS	NS	NS
C.V. (%)		12.81	8.77	10.50

Note:
1) DAE- Days after emergence
2) Figures in parentheses are retransformed value, while those outside are arcsine transformed value.
3) Treatment means with the common super scripts letters are non-significant by DNMRT at 5% level of significance.

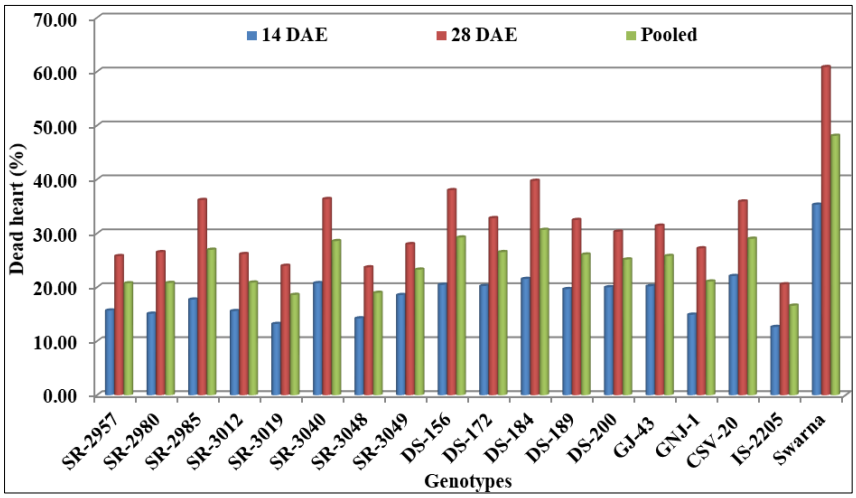

Fig 3: Dead hearts formation in different sorghum genotypes due to sorghum shoot fly (Pooled over years)

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