Biological Forum – An International Journal 14(4): 47-54(2022)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Screening of Shoot Fly Resistance in M_5 Generation of Sorghum (*Sorghum bicolor* (L.) Moench)

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(Received 26 July 2022, Accepted 17 September, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The present investigation was carried to screen 200 mutant lines against shoot fly incidence in augmented block design at Agricultural Research Station, Hagari. In sorghum production shoot fly incidence is the major biotic constraints, which attacks crop at the seedling stage and causes losses of yield and fodder. The screening results revealed that 32 mutant lines shown highly resistance reaction compared to resistant check IS-2312 (14.29), among them six mutant lines showed zero percentage of dead heart per cent. These mutant lines exhibited comparatively lower number of eggs per plant and minimum dead heart formation. 8 mutant lines shown highly resistance response to seedling vigour and 6 mutant lines shown highly resistance to glossiness score traits. In order to attain uniform shoot fly pressure under field conditions the interlard-fish meal technique was followed for present experiment. These resistant lines can be used for further confirmation and also for future resistant breeding programmes.

Keywords: Dead heart, Oviposition, Shoot fly, Sorghum.

INTRODUCTION

The fifth most important cereal crop in the world, Sorghum [*Sorghum bicolor* (L.) Moench], commonly known as Jowar, is a tropical cultivated diploid (2n = 20) cereal grass plant. It belongs to the Poaceae family and is a monocotyledon plant of tropical origin (Nagara, 2017). Among the major sorghum producing countries in the world, India ranks first in acreage and second in production next to United States of America. In India, it is grown over an area of almost 4.82 million ha, with a production of over 4.77 million tonnes and a productivity of 989 kg/ha. It is grown in 8.2 lakh ha in Karnataka, with a production of 9.8 lakh tonnes and a productivity of 1194 kg/ha (INDIASTAT, 2020). Kalaburgi, Raichur, Koppal, Belagavi, Ballari and Vijayapur are the major sorghum growing districts in Karnataka.

The process of mutation is recognized as one of the driving forces of evolution. Induced mutation breeding is a relatively quick method of creating variability in quantitatively inherited traits between plants (Camargo *et al.,* 2000). Both physical and chemical mutagens induce genetic variability, of which gamma radiation is an important tool for inducing mutants with potential to enhance yield and yield contributing traits (Thapa, 2004). Sorghum is treated with 1% sodium azide to improve germination rate, root length, shoot length, bold seeds, and yield attributing traits (Dahot *et al.,* 2011). The shoot fly is one of the most significant pests that reduces sorghum yield levels. In Asia, Africa and Mediterranean Europe, the shoot fly (Atherigona soccata Rond.) poses a major pest problem for sorghum. A maximum yield loss of 80-90 percent has been reported in grain and 68 percent in fodder (Kahate *et al.,* 2014). There was a higher incidence of this disease in late-planted crops during rainy and post-rainy seasons (*rabi*) due to the build up of shoot fly populations on early-planted crops (Balikai and Bhagwat 2009).

At the early stages of crop growth, shoot fly damages crops and causes a specific symptom called "dead heart". Since shoot fly control methods are not feasible for this crop, which is cultivated by poor and marginal farmers, and the pest damage ranges from 7-30 days after germination, there is very little or no time for control measures to be adopted. More importantly, this method pollutes the soil, water, food, and fodder. Therefore, the most realistic alternative method for reducing insect losses is the use of host plant resistance in mutants.

MATERIAL AND METHODS

Sorghum seeds from IS925 and Phule Vasudha varietals were sent to Bhabha Atomic Research Centre (BARC) Trombay, Mumbai. A total of 160 seeds of each line were irradiated with 300 Gy gamma rays, while 40 of the irradiated seeds were also treated with 0.1 % sodium azide at equilibrium moisture content of eight percent [for 160 Gamma irradiated and (40 Gamma irradiated + Chemically treated seeds)].

Each of the subsequent seasons M_1, M_2 M_3 and M_4 progenies were raised at ARS Hagari. As seed material for this study we selected from the M_4 generation 100 mutants from the IS925 variety (80 irradiated and 20 irradiated + chemical treated) and 100 mutants from the Phule Vasudha variety (80 irradiated and 20 irradiated + chemical treated). These mutants were used alongside with seven checks *viz.*, IS-2312, DJ-6514, M-35-1, SPV-86, DSV-4, E-36-1 and GS-23.

For screening resistance, the interlard-fish meal technique (Nwanze, 1997) was followed (Plate 1). 20 days before sowing the test material, two rows of a susceptible cultivar (DJ-6514) were sown. The purpose of this was to allow the shoot fly to multiply for one generation. The test material was uniformly covered with moistened fish meal seven days after seedling emergence to attract emerging shoot flies from infester rows. Until the shoot fly infestation period was over, plant protection measures were avoided.

The following parameters were recorded to assess shoot fly incidence:

1. Glossiness. On a scale of 1-5, glossiness intensity was recorded at 7 days after emergence (DAE), where 5=high glossiness and 1=non-glossy. During the morning hours, there is maximum reflection of light on the leaves, which is the ideal time to score their glossiness (Kamatar *et al.*, 2010).

2. Oviposition. At 7 DAE, the total number of plants with eggs in each entry was recorded (Plate 2). A percentage was used to express the observations on units (Kamatar *et al.*, 2010).

Oviposition (%) = Number of plants with eggs / Total number of plants

3. Seedling vigour. Seedling vigour (height, leaf growth and robustness) was scored at 16 DAE on a 1-5 scale where 5 = high vigour (plants showing maximum height, leaf expansion and robustness) and 1 = low vigour (plants showing minimum growth, less leaf expansion and poor adaptation) (Kamatar *et al.*, 2010).

4. Dead heart. At 21 days after emergence, dead heart counts were recorded (Plate 3). Dead heart was expressed in terms of percentage (Nimbalkar and Bapat, 1987).

Dead heart (%) = No. of shoots with dead heart/Total no. of shoots ×100. Shoot fly incidence (dead hearts percentage) was determined 21 days after plants emerged. The genotypes were classified into different categories using the following rating scale (Nimbalkar and Bapat 1987).

Rating	Reaction
0 – 10% dead heart	Highly resistant
10 – 20% dead heart	Resistant
20 – 30% dead heart	Moderately resistant
30 – 50% dead heart	Susceptible
Above 50% dead heart	Highly susceptible

RESULTS AND DISCUSSION

PV-RD-33, PV-RD-30, PV-RD-29, PV-RD-41, PV-RD-13 and PV-9 mutant lines all showed zero per cent dead heart, whereas the IS-2312 resistant check showed 14.29 per cent dead heart. A further three mutants, namely IS925-6 (72.22%), IS925-22 (68.42%) and IS925-9 (63.64%), showed highest rates of dead hearts, while susceptible check DJ-6514 had a dead heart rate of 69.57 per cent.

Among the 200 mutant lines, 32 showed Highly resistant (0-10%) reaction, 57 showed Resistant (11-20%) reaction, 57 showed Moderately resistant (21-30%) reaction, 49 showed Susceptible (30-50%) reaction and 12 showed Highly susceptible (˃ 50%) reaction, these lines are presented in Table 1 and Kiran (2014); Navinkumar *et al.* (2020b); Shid *et al.* (2021) all reported similar results.

Compared to the resistant check IS-2312 (23.81%), not a single egg was observed in PV-RD-33 (0%), PV-RD-30 (0%), PV-RD-29 (0%), PV-RD-41 (0%), PV-RD-13 (0%) and PV-9 (0%) during this investigation. In comparison to DJ-6514 (78.26%), IS925-21 (85.71%), IS925-34 (80.95%), IS925-123 (80.00%), PV-21 (77.78%), IS925-10 (76.47%) and IS925-RD-101 (75.00%) had the highest number of eggs. It is in accordance with the findings of Chandra *et al.* (2018); Shid *et al.* (2021).

Seedling vigour observation is taken at 16 days after emergence and rated on a 1-5 scale. From 200 mutants tested, only 8 mutants had a high vigorous score (5), 85 mutants had a score (4), 85 mutants had a score (3), 23 mutants had a score (2) and 6 mutants had a score (1). This is shown in Table 2.

Mutants with a seedling vigour score of 1, which is the lowest possible score, were susceptible to shoot fly attack. As reported by Prasad *et al*. (2015), greater sorghum seedling vigour contributed to the plants ability to resist the shoot fly. Sharma and Nwanze (1997) as well as Cheema *et al.* (2021), have also observed that seedling vigour is a crucial morphological characteristic for manifesting resistance to shoot fly.

Based on a scale of 1 to 5, the intensity of glossiness was scored at 7 DAE on a 1 to 5 scale. From 200 mutants, 6 mutants scored high in glossiness (5), 92 mutants scored well (4), 81 mutants scored well (3), 21 mutants scored well (2) and 7 mutants scored well (1). This is shown in Table 3. Mean performances of 200 M_5 sorghum mutant lines for shoot fly incidence is represented in Table 4.

As a result of the glossiness of leaves, egg laying is not preferred in the host, which minimizes the percentage of dead heart. Adaxial and abaxial surfaces of leaves have glossy surfaces that allow eggs to fall on the ground before hatching, thus reducing heart death. Aruna *et al.* (2011); Sonalkar and Pagire (2017) also reported similar findings.

Shoot fly resistance was greater in mutants with high seedling vigour and glossiness ratings due to olfactory or gustatory responses to the insect. Mutants with low score ratings are more susceptible to shoot fly attack because low vigour plants produce higher levels of chemicals. Maggots hatching on the seedlings take longer time to reach meristematic tissues due to their vigour and glossiness. They serve as a barrier in the stem core, preventing maggots from entering the core of the stem and causing the symptoms of dead hearts in plants.

Plate 1. Fish meal application to attract shoot fly.

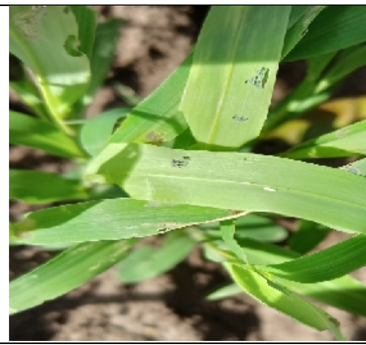

Plate 2. Cigar shaped eggs of Shoot fly.

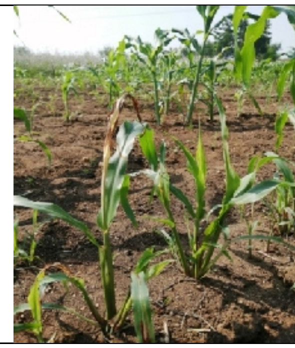

Plate 3. Shoot fly infected infected plant with maggot.

Table 1: Classification of M_5 sorghum mutant lines along with checks based on per cent dead heart due to shoot fly incidence.

		GENOTYPES	
Reaction	**Total mutants**	**IS925**	**Phule Vasudha**
Highly resistance (0-10%)	**10+22**	IS925-58, IS925-RV-4, IS925-RD-98, IS925-20, IS925-120, IS925-85, IS925-137, IS925-83, IS925-117, IS925-132.	PV-RD-6, PV-RD-62, PV-RD-22, PV-RV-62, PV-RD-25, PV-RV-22, PV-13, PV-RD-20, PV-RD-54, PV-33, PV-RD-33, PV-RD-30, PV-RD-29, PV-RD-41, PV-RD-7, PV-RV-6, PV-37, PV-RD-53, PV-1, PV-RD-13, PV-RD-51, PV-9.
Resistance (11–20 %)	**17+40**	IS925-14, IS925-54, IS925-34, IS925-15, IS925-RD-140, IS925-89, IS925-138, IS925-RD-71, IS925-RD-84, IS925-3, IS925-90, IS925-105, IS925-109, IS925-134, IS925-124, IS925-RD-6, IS-2312.	PV-19, PV-14, PV-22, PV-7, PV-11-1, PV-26, PV-24, PV-16-1, PV-1-1, PV-17-1, PV-13-1, PV-RD-45, PV-RD-27, PV-RD-21, PV-RD-68, PV-RD-35, PV-RD-18, PV-RD-43, PV-12, PV-6E, PV-10, PV-60, PV-RD-40, PV-2, PV-RV-95, PV-RD-60, PV-RD-44, PV-52, PV-2-1, PV-RD-31, PV-RD-10, PV-RD-115, PV-RD-49, PV-30, PV-62, PV-RD-4, PV-3, PV-RD-14, PV-RD-15, PV-29.
Moderately resistance (21 – 30%)	**40+17**	IS925-7-1-1, IS925-23-1, IS925-16-1, IS925-24, IS925-21-1, IS925-1, IS925-11, IS925-2-1, IS925-46, IS925-70, IS925-114, IS925-RD-45, IS925-29, IS925-136, IS925-RD-2, IS925-RD-31, IS925-113, IS925-RD-34, IS925-RD-53, IS925-31, IS925-97, IS925-RV-3, IS925-RD-49, IS925-RD-50, IS925-RD-30, IS925-RV-6, IS925-130, IS925-RD-21, IS925-41R, IS925-RV-8, IS925-38, IS925-RD-19, IS925-RD-48, IS925-RD-65, IS925-39, IS925-RD-15, IS925-RV-13, SPV-86, M-35-1, GS-23.	PV-5, PV-21, PV-17-1-1, PV-18, PV-RD-48, PV-48, PV-RD-36, PV-RD-19, PV-RD-3, PV-17, PV-50, PV-18-1, PV-RD-5, PV-61, PV-57, PV-RD-57, PV-38.
Susceptible (31 – 50 %)	**29+20**	IS925-19, IS925-17, IS925-2, IS925-7, IS925-10, IS925-5, IS925-41, IS925-131, IS925-RD-16, IS925-101, IS925-RV-41, IS925-RD-100, IS925-RD-60, IS925-RV-11, IS925-RD-42, IS925-82, IS925-96, IS925-64, IS925-133, IS925-108, IS925-80, IS925-128, IS925-RD-25, IS925-44, IS925-123, IS925-144, IS925-7-1, E-36-1, DSV-4.	PV-8, PV-7-1, PV-9-1, PV-6-1, PV-23-1, PV-RD-11, PV-RD-38, PV-RD-34, PV-58, PV-16, PV-RD-32, PV-RD-1, PV-RD-9, PV-RD-87, PV-RV-5, PV-RD-28, PV-39, PV-22-1, PV-49, PV-45.
Highly susceptible (>50%)	**11+1**	IS925-21, IS925-9, IS925-8, IS925-22, IS925-6, IS925-RV-2, IS925-87, IS925-RD-44, IS925-37, IS925-RD-101, DJ-6514.	PV-35.

Table 2: Classification of M_5 sorghum mutant lines along with checks based on seedling vigour score.

		GENOTYPES	
Reaction	**Total mutants**	**IS925**	**Phule Vasudha**
Highly resistance (5)	**2+6**	IS925-RD-98, IS2312.	PV-33, PV-RD-29, PV-RD-30, PV-RD-33, PV-RD-41, PV-RD-13.
Resistance (4)	**30+55**	IS925-14, IS925-2-1, IS925-58, IS925-54, IS925-34, IS925-15, IS925-RD-140, IS925-89, IS925-113, IS925-138, IS925-RD-71, IS925-RD-84, IS925-RV-4, IS925-20, IS925-120, IS925-85, IS925-137, IS925-3, IS925-90, IS925-83, IS925-117, IS925-105, IS925-109, IS925-132, IS925-134, IS925-124, IS925-RD-6, SPV-86, GS-23, M-35-1.	PV-19, PV-14, PV-22, PV-5, PV-7, PV-11-1, PV-21, PV-26, PV-17-1-1, PV-24, PV-16-1, PV-1-1, PV-17-1, PV-13-1, PV-RD-45, PV-RD-27, PV-RD-6, PV-RD-21, PV-RD-62, PV-RD-68, PV-RD-22, PV-RV-62, PV-RD-18, PV-RD-25, PV-RV-22, PV-RD-43, PV-13, PV-RD-20, PV-6E, PV-10, PV-60, PV-RD-54, PV-RD-40, PV-2, PV-RD-60, PV-RD-44, PV-18-1, PV-52, PV-2-1, PV-RD-10, PV-RD-115, PV-RD-49, PV-30, PV-RD-7, PV-RV-6, PV-37, PV-RD-4, PV-RD-53, PV-1, PV-3, PV-RD-14, PV-RD-51, PV-9, PV-RD-15, PV-29.
Moderately resistance (3)	**53+32**	IS925-23-1, IS925-16-1, IS925-24, IS925-21-1, IS925-1, IS925-11, IS925-7, IS925-46, IS925-131, IS925-RD-16, IS925-101, IS925-70, IS925-114, IS925-RV-41, IS925-RD-45, IS925-29, IS925-136, IS925-RD-100, IS925-RD-60, IS925-RV-11, IS925-RD-2, IS925-RD-42, IS925-RD-131, IS925-82, IS925-96, IS925-RD-34, IS925-RD-53, IS925-31, IS925-97, IS925-RV-3, IS925-RD-49, IS925-RD-50, IS925-RD-30, IS925-RV-6, IS925-130, IS925-64, IS925-108, IS925-RD-21, IS925-41R, IS925-80, IS925-RV-8, IS925-128, IS925-38, IS925-44, IS925-RD-19, IS925-RD-48, IS925-RD-65, IS925-39, IS925-RD-15, IS925-144, IS925-RV-13, E-36-1, DSV-4.	PV-7-1, PV-9-1, PV-18, PV-RD-11, PV-RD-34, PV-RD-58, PV-RD-48, PV-RD-16, PV-RD-1, PV-48, PV-RD-36, PV-RD-35, PV-RD-19, PV-RD-3, PV-12, PV-RV-95, PV-17, PV-50, PV-RD-31, PV-RD-5, PV-RD-87, PV-RV-5, PV-RD-28, PV-39, PV-61, PV-62, PV-57, PV-RD-57, PV-22-1, PV-49, PV-38, PV-45.
Susceptible (2)	**16+7**	IS925-7-1-1, IS925-19, IS925-17, IS925-2, IS925-21, IS925-8, IS925-10, IS925-5, IS925-41, IS925-RV-2, IS925-87, IS925-133, IS925-RD-44, IS925-RD-25, IS925-123, IS925-7-1.	PV-8, PV-6-1, PV-23-1, PV-RD-38, PV-RD-32, PV-RD-9, PV-35.
Highly susceptible (1)	**6+0**	IS925-9, IS925-22, IS925-6, IS925-37, IS925-RD-101, DJ-6514.	-

Table 3: Classification of M_5 sorghum mutant lines along with checks based on glossiness score.

		GENOTYPES	
Reaction	**Total mutants**	**IS925**	**Phule Vasudha**
Highly resistance (5)	**0+6**	-	PV-33, PV-RD-29, PV-RD-41, PV-RD-33, PV-RD-30, PV-RD-13.
Resistance (4)	**35+57**	IS925-23-1, IS925-14, IS925-16-1, IS925-2, IS925-1, IS925-11, IS925-2-1, IS925-58, IS925-54, IS925-34, IS925-136, IS925-RD-100, IS925-15, IS925-RD-140, IS925-89, IS925-113, IS925-138, IS925-RD-84, IS925-31, IS925-RD-50, IS925-RV-4, IS925-RD-98, IS925-108, IS925-20, IS925-120, IS925-85, IS925-44, IS925-137, IS925-90, IS925-83, IS925-117, IS925-RD-6, IS925-39, E-36-1, DSV-4.	PV-19, PV-22, PV-7, PV-11-1, PV-21, PV-26, PV-24, PV-16-1, PV-13-1, PV-RD-45, PV-RD-27, PV-RD-34, PV-58, PV-RD-6, PV-RD-21, PV-RD-62, PV-48, PV-RD-36, PV-RD-68, PV-RD-22, PV-RV-62, PV-RD-18, PV-RD-19, PV-RD-25, PV-RV-22, PV-RD-43, PV-13, PV-RD-20, PV-6E, PV-10, PV-60, PV-RD-54, PV-RD-40, PV-2, PV-RV-95, PV-RD-60, PV-RD-44, PV-52, PV-2-1, PV-RD-31, PV-RD-10, PV-RD-115, PV-RD-49, PV-30, PV-RD-7, PV-RV-6, PV-37, PV-RD-4, PV-RD-53, PV-62, PV-57, PV-1, PV-3, PV-RD-14, PV-RD-51, PV-9, PV-29.
Moderately resistance (3)	**52+29**	IS925-7-1-1, IS925-24, IS925-19, IS925-17, IS925-21-1, IS925-7, IS925-5, IS925-10, IS925-46, IS925-131, IS925-101, IS925-70, IS925-114, IS925-RV-41, IS925-RD-45, IS925-29, IS925-RD-60, IS925-RV-11, IS925-RD-2, IS925-RD-42, IS925-RD-31, IS925-82, IS925-RD-34, IS925-RD-53, IS925-RD-71, IS925-97, IS925-RV-3, IS925-RD-49, IS925-RD-30, IS925-RV-6, IS925-130, IS925-64, IS925-RD-21, IS925-41R, IS925-80, IS925-RV-8, IS925-128, IS925-38, IS925-3, IS925-RD-19, IS925-105, IS925-109, IS925-132, IS925-134, IS925-RD-48, IS925-RD-65, IS925-124, IS925-RD-15, IS925-144, IS925-RV-13, IS925-7-1, SPV-86.	PV-14, PV-5, PV-7-1, PV-9-1, PV-17-1-1, PV-1-1, PV-17-1, PV-6-1, PV-23-1, PV-18, PV-RD-11, PV-RD-48, PV-RD-1, PV-RD-35, PV-3, PV-RD-12, PV-17, PV-50, PV-18-1, PV-RD-5, PV-RV-5, PV-RD-28, PV-39, PV-61, PV-RD-57, PV-22-1, PV-49, PV-RD-15, PV-38.
Susceptible (2)	**13+8**	IS925-8, IS925-41, IS925-RD-16, IS925-RV-2, IS925-96, IS925-87, IS925-133, IS925-RD-44, IS925-RD-25, IS925-123, M-35-1, GS-23, IS-2312.	PV-8, PV-RD-38, PV-16, PV-RD-32, PV-RD-9, PV-35, PV-RD-87, PV-45.
Highly susceptible (1)	**7+0**	IS925-21, IS925-9, IS925-22, IS925-6, IS925-37, IS925-RD-101, DJ-6514.	-

Table 4: Mean performances of M_5 mutant lines for shoot fly incidence.

Sr. No.	MUTANTS	OP %	GLOSSINESS	SV	DH %
	P+C (IS925)				
1	IS925-7-1-1	44.44	3	2	33.33
2	IS925-23-1	47.62	4	3	28.57
3	IS925-14	22.22	4	4	11.11
4	IS925-16-1	50.00	4	3	28.57
5	IS925-24	56.52	3	3	26.09
6	IS925-19	47.37	3	2	36.84
7	IS925-17	62.50	3	2	37.50
8	IS925-2	50.00	4	2	33.33
9	IS925-21	85.71	1	2	57.14
10	IS925-21-1	50.00	3	3	25.00
11	IS925-1	53.33	4	3	26.67
12	IS925-9	63.64	1	1	63.64
13	IS925-11	47.37	4	3	26.32
14	IS925-7	33.33	3	3	33.33
15	IS925-8	72.73	2	2	54.55
16	IS925-22	73.68	1	1	68.42
17	IS925-6	50.00	1	1	72.22
18	IS925-10	76.47	3	2	35.29
19	IS925-5	52.63	3	2	47.37
20	IS925-2-1	53.85	4	4	23.08
Sr. No.	**MUTANTS**	**OP %**	**GLOSSINESS**	**SV**	**DH %**
	P+C (PV)				
1	PV- 19	14.29	4	4	14.29
2	PV-8	46.67	2	2	46.67
3	PV-14	30.00	3	4	20.00
4	PV- 22	20.00	4	4	20.00
5	PV- 5	33.33	3	4	23.81
6	PV- 7	21.43	4	4	14.29
7	PV-7-1	42.86	3	3	35.71
8	PV-9-1	36.36	3	3	31.82
9	PV-11-1	27.27	4	4	18.18
10	PV- 21	77.78	4	4	22.22
11	PV- 26	21.43	4	4	14.29
12	PV-17-1-1	40.00	3	4	30.00
13	PV- 24	20.00	4	4	13.33
14	PV-16-1	35.71	4	4	14.29
15	PV-1-1	46.67	3	4	13.33
16	PV-17-1	33.33	3	4	18.52
17	PV-6-1	50.00	3	2	44.44
18	PV-13-1	16.67	4	4	12.50
19	PV-23-1	46.67	3	2	40.00
20	PV-18	21.43	3	3	28.57
Sr. No.	**MUTANTS**	**OP %**	**GLOSSINESS**	**SV**	**DH %**
	P (IS925)				
1	IS925- 46	31.25	3	3	25.00
2	IS925- 58	16.67	4	4	8.33
3	IS925-41	64.71	2	2	47.06
4	IS925- 131	40.00	3	3	33.33
5	IS925- RD-16	47.06	2	3	41.18
6	IS925- 101	45.45	3	3	31.82
7	IS925-54	21.05	4	4	15.79
8	IS925- 34	80.95	4	4	14.29
9	IS925- 70	40.00	3	3	26.67
10	IS925-RV-2	61.90	2	2	52.38
11	IS925-114	52.94	3	3	29.41
12	IS925- RV-41	42.11	3	3	31.58
13	IS925-RD-45	38.10	3	3	28.57
14	IS925-29	41.18	3	3	29.41
15	IS925-136	26.32	4	3	21.05
16	IS925-RD-100	60.00	4	3	33.33
17	IS925-RD-60	41.18	3	3	35.29
18	IS925-RV-11	41.67	3	3	33.33
19	IS925-RD-2	33.33	3	3	27.78
20	IS925-RD-42	56.25	3	3	31.25
21	IS925-15	25.00	4	4	16.67
22	IS925-RD-31	35.29	3	3	23.53
23	IS925-RD-140	27.78	4	4	16.67
24	IS925-89	29.41	4	4	17.65
25	IS925-113	68.42	4	4	21.05
26	IS925-82	42.86	3	3	33.33
27	IS925- 138	52.17	4	4	13.04
28	IS925- 96	56.25	2	3	43.75
29	IS925- RD-34	28.57	3	3	23.81
30	IS925-RD- 53	52.38	3	3	23.81

31	IS925- RD-71	26.67	3	4	13.33
32	IS925-RD-84	36.36	4	4	18.18
33	IS925-31	38.89	4	3	22.22
34	IS925- 87	57.89	2	2	52.63
35	IS925-97	42.86	3	3	28.57
36	IS925- RV-3	38.10	3	3	23.81
37	IS925-RD-49	46.15	3	3	30.77
38	IS925- RD-50	42.86	4	3	21.43
39	IS925-RD-30	37.50	3	3	25.00
40	IS925-RV-4	23.08	4	4	7.69
41	IS925- RV-6	38.46	3	3	30.77
42	IS925- 130	47.62	3	3	28.57
43	IS925- 64	41.18	3	3	35.29
44	IS925-133	47.37	2	2	42.11
45	IS925 –RD-98	12.50	4	5	6.25
46	IS925-108	42.11	4	3	36.84
47	IS925- RD-21	47.62	3	3	23.81
48	IS925- 20	35.29	4	4	5.88
49	IS925- RD-44	71.43	2	2	61.90
50	IS925-41R	33.33	3	3	23.81
51	IS925- 80	43.48	3	3	34.78
52	IS925- 37	70.83	1	1	62.50
53	IS925- RV-8	35.29	3	3	29.41
54	IS925- 128	47.37	3	3	31.58
55	IS925- RD-25	60.00	2	2	46.67
56	IS925- 120	14.29	4	4	9.52
57	IS925-85	25.00	4	4	8.33
58	IS925- 38	33.33	3	3	28.57
59	IS925- 44	40.00	4	3	33.33
60	IS925- 137	21.43	4	4	7.14
61	IS925- 3	38.46	3	4	15.38
62	IS925- 90	43.75	4	4	18.75
63	IS925- RD-19	47.37	3	3	21.05
64	IS925- 83	14.29	4	4	9.52
65	IS925-117	25.00	4	4	6.25
66	IS925- 123	80.00	2	2	40.00
67	IS925- 105	44.44	3	4	16.67
68	IS925- 109	25.00	3	4	16.67
69	IS925- 132	21.43	3	4	7.14
70	IS925- 134	23.53	3	4	17.65
71	IS925- RD-48	46.67	3	3	26.67
72	IS925- RD-65	23.53	3	3	23.53
73	IS925- 124	40.00	3	4	13.33
74	IS925- RD-101	75.00	1	1	62.50
75	IS925-RD-6	31.25	4	4	12.50
76	IS925- 39	33.33	4	3	23.81
77	IS925-RD-15	73.68	3	3	26.32
78	IS925- 144	51.85	3	3	40.74
79	IS925- RV-13	58.82	3	3	29.41
80	IS925-7-1	69.23	2	2	46.15
	P (PV)				
1	PV- RD-11	37.50	3	3	31.25
2	PV-RD-45	41.18	4	4	17.65
Sr. No.	**MUTANTS**	**OP %**	**GLOSSINESS**	**SV**	**DH %**
3	PV- RD-38	52.94	2	2	41.18
4	PV- RD-27	25.00	4	4	16.67
5	PV- RD-34	33.33	4	3	33.33
6	PV-58	47.06	4	3	35.29
7	PV- RD-48	34.78	3	3	30.43
8	PV- 16	30.77	2	3	38.46
9	PV- RD-32	50.00	2	2	42.86
10	PV- RD-6	18.75	4	4	6.25
11	PV- RD-21	19.05	4	4	14.29
12	PV- RD-1	38.89	3	3	33.33
13	PV- RD-62	15.38	4	4	7.69
14	PV- 48	31.58	4	3	21.05
15	PV- RD-36	27.78	4	3	22.22
16	PV- RD-68	17.65	4	4	11.76
17	PV-RD-35	52.38	3	3	19.05
18	PV- RD-9	52.17	2	2	43.48
19	PV-RD-22	26.67	4	4	6.67
20	PV- RV-62	14.29	4	4	7.14
21	PV- RD-18	18.75	4	4	12.50
22	PV- RD-19	26.09	4	3	21.74
23	PV- RD-25	14.29	4	4	9.52
24	PV-RV-22	26.67	4	4	6.67
25	PV- RD-43	18.18	4	4	13.64
26	PV-RD-3	36.84	3	3	21.05

27	PV- 12	22.73	3	3	18.18
28	PV- 13	25.00	4	4	6.25
29	PV-RD-20	20.00	4	4	6.67
30	PV- 6E	21.05	4	4	15.79
31	PV- 10	22.73	4	4	18.18
32	PV-60	18.75	4	4	12.50
33	PV-RD-54	23.08	4	4	7.69
34	PV- 35	64.29	2	2	57.14
35	PV- RD-40	23.53	4	4	17.65
36	PV- 33	12.50	5	5	6.25
37	PV-2	23.08	4	4	15.38
38	PV- RV-95	29.41	4	3	17.65
39	PV-RD-60	20.00	4	4	13.33
40	PV- 17	36.84	3	3	26.32
41	PV- RD-44	31.25	4	4	18.75
42	PV- 50	46.67	3	3	26.67
43	PV- 18-1	52.63	3	4	21.05
44	PV-52	18.75	4	4	12.50
45	PV-2-1	23.08	4	4	15.38
46	PV-RD-33	0.00	5	5	0.00
47	PV- RD-31	33.33	4	3	20.00
48	PV- RD-10	19.05	4	4	14.29
49	PV- RD-5	31.82	3	3	22.73
50	PV- RD-30	0.00	5	5	0.00
51	PV- RD-115	29.41	4	4	17.65
52	PV- RD-49	18.75	4	4	12.50
53	PV-RD-87	45.45	2	3	36.36
54	PV-RV-5	36.84	3	3	31.58
55	PV- RD-29	0.00	5	5	0.00
56	PV- RD-41	0.00	5	5	0.00
57	PV- RD-28	46.67	3	3	33.33
58	PV- 39	42.11	3	3	31.58
59	PV- 61	47.83	3	3	26.09
60	PV- 30	30.77	4	4	15.38
61	PV- RD-7	14.29	4	4	9.52
62	PV- RV-6	17.65	4	4	5.88
63	PV- 62	33.33	4	3	19.05
64	PV- 37	14.29	4	4	9.52
65	PV- RD-4	31.82	4	4	13.64
66	PV- RD-53	12.50	4	4	6.25
67	PV- 57	23.53	4	3	23.53
68	PV- RD-57	33.33	3	3	25.00
69	PV-1	26.67	4	4	6.67
70	PV- RD-13	0.00	5	5	0.00
71	PV- 22-1	37.50	3	3	37.50
72	PV- 3	26.32	4	4	15.79
73	PV- RD-14	21.05	4	4	15.79
74	PV- RD-51	15.00	4	4	10.00
75	PV- 49	47.06	3	3	35.29
76	PV- 9	0.00	4	4	0.00
77	PV- RD-15	18.75	3	4	12.50
78	PV- 38	39.13	3	3	21.74
79	PV- 29	29.41	4	4	17.65
80	PV- 45	47.37	2	3	36.84
	CHECKS				
1	SPV-86	30.77	3	4	23.08
2	E-36-1	56.52	4	3	39.13
3	DSV-4	47.62	4	3	38.10
4	M 35-1	38.10	2	4	23.81
5	GS-23	35.29	2	4	23.53
6	IS-2312	23.81	2	5	14.29
7	DJ-6514	78.26	1	1	69.57
	CD@5%				
	Ci-Cj	0.003	0.001	0.002	0.026
	BiVi-BjVj	0.005	0.001	0.004	0.051
	BiVi-BjVj	0.006	0.001	0.005	0.055
	Ci-Vi	0.005	0.001	0.004	0.043

P+C = Physical + Chemical; **P** = Physical treated; **PV** = Phule Vasudha; **OP % =** Oviposition per cent; **SV =** seedling vigour; **DH %** = Dead; heart per cent; **Ci-Cj** = For two check means; **BiVi-BjVj** = For two test genotype means in same block; **BiVi-BjVj** = for any two entries means in the same block; **Ci-VI** = For means between a check and a test genotype

CONCLUSION

The present experiment was conducted to identify mutant lines, which were resistant to shoot fly attack. Study revealed that among 200 mutant lines six lines *viz*., PV-RD-33, PV-RD-30, PV-RD-29, PV-RD-41, PV-RD-13 and PV-9 showed resistant to shoot fly component characters *viz*., oviposition, dead heart, glossiness and seedling vigour compared to resistant check IS-2312 (Resistance) under interland fish-meal technique conditions. These six mutant lines were promising lines to reduce shoot fly infestation, so these lines can be used for further confirmation and future tolerance breeding programs.

Conflict of Interest. None.

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How to cite this article: Khaja Mohinuddin D., G. Girish, M.B. Ashok, Suvarna, L.N. Yogeesh, M.R. Govindappa, Anand Kumar V. and Ravi Kumar A. (2022). Screening of Shoot Fly Resistance in M_5 Generation of Sorghum (*Sorghum bicolor* (L.) Moench). *Biological Forum – An International Journal*, *14*(4): 47-54.