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Screening of M_4 Sorghum (*Sorghum bicolor* (L.) Moench) Mutant Lines Against Shoot Fly (*Atherigona soccata* Rondani)

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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 29 mutant lines shown highly resistance reaction compared to resistant check IS-2312 (15.78), among them seven 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. 10 mutant lines shown highly resistance response to seedling vigour and 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

Sorghum [*Sorghum bicolor* (L.) Moench], is popularly known as “Jowar” a cultivated diploid (2n = 20) tropical cereal C_4 grass plant, is the fifth most important cereal crop grown in the world. It is a monocotyledon plant of tropical origin, belonging to Poaceae family (Nagara, 2017). India is a major sorghum growing country in the world, ranks first in acreage and second in production next to United States of America. It is grown in India in an area about 4.09 m ha with production of 3.48 m tonnes and productivity of 845 kg/ha. In Karnataka, it is grown in 0.94 m ha with production of 0.89 million tonnes and productivity of 945 kg/ha (INDIASTAT, 2019). Major sorghum growing districts of Karnataka are Kalaburgi, Raichur, Koppal, Belagavi, Ballari and Vijayapur.

Mutation is recognized as one of the driving forces of evolution. Induced mutation breeding is relatively quicker method to create variability for quantitatively inherited traits in different plants (Camargo *et al*., 2000). It is induced through both physical and chemical mutagens, in which gamma radiation is an important tool for inducing the genetic variability, which intern throw potential mutants for enhancing yield and yield contributing traits (Thapa, 2004). One per cent sodium azide is utilized as induced mutation in sorghum for enhancing germination rate, root length, shoot length, bold seeds and yield attributing traits.

Insect pests cause much reduction in sorghum yield levels, among which shoot fly is a major one. Shoot fly (*Atherigona soccata* Rond.) is an important pest of sorghum in Asia, Africa and Mediterranean Europe. Maximum yield losses of 80-90 per cent in grain and 68 per cent in fodder have been reported (Kahate *et al.*, 2014). Its incidence was higher in late-sown crops in the rainy and post rainy (*rabi*) seasons because of buildup of shoot fly populations on the early-sown crops (Balikai and Bhagwat, 2009).

Shoot fly damages crop at initial stage of crop growth ranges from 7-30 days after germination and causes specific symptom called “dead heart”. Adoption of chemical control methods for shoot fly control is not feasible because it is cultivated by poor and marginal farmers as well as pest damages of crop ranges from 7-30 days after germination, hence very little or no time to take control measures. More over this method is polluting soil, water, food and fodder. Therefore, utilization of host plant resistance in mutants is the most realistic alternative method for reducing losses caused by the insect pests.

MATERIAL AND METHODS

Two varietal seeds *viz*., IS925 and Phule Vasudha of sorghum lines were sent to Bhabha Atomic Research Centre (BARC) Trombay, Mumbai. The 160 seeds of both the lines were irradiated with 300 Gy gamma rays and 40 irradiated seeds were also treated with 0.1 %

Sodium azide [160 Gamma irradiated and (40 Gamma irradiated + chemical treated)] at equilibrium moisture content of eight per cent.

The each subsequent seasons M_1, M_2 and M_3 progenies were raised at ARS Hagari. 100 mutants from IS925 variety (80 irradiated and 20 irradiated + chemical treated) and 100 mutants from Phule Vasudha variety (80 irradiated and 20 irradiated + chemical treated) were selected from the M_3 generation and used as seed material along with checks *viz*., IS-2312, DJ-6514, M-35-1, SPV-86, DSV-4, E-36-1 and GS-23 for present investigation (M_4 generation).

To attain uniform shoot fly pressure under field conditions the interlard-fish meal technique (Nwanze, 1997) was followed for screening resistance (Plate 1). Two rows of a susceptible cultivar (DJ-6514) were sown 20 days before sowing the test material. This was done to allow for multiplication of shoot fly for one generation. Seven days after seedlings emergence, moistened fish meal was spread uniformly in four blocks covering all the test material to attract the emerging shoot flies from infester rows. The plant protection measures were avoided until the shoot fly infestation period was complete.

The following parameters were recorded to assess shoot fly incidence:

1. Glossiness. Intensity of glossiness was recorded at 7 days after emergence (DAE) on 1 to 5 scale where 5 = high intensity of glossiness and 1 = non-glossy. Leaf glossiness was scored in the morning hours when there was maximum reflection of light (Kamatar *et al.*, 2010).

2. Oviposition. Total number of plants with eggs in each entry was recorded at 7 DAE (Plate 2). The observations on units were expressed in terms of percentage (Kamatar *et al.* 2010).

$$\text{Oviposition (\%)} = \frac{\text{Number of plants with eggs}}{\text{Total number of plants}}$$

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

$$\text{Dead heart (\%)} = \frac{\text{No. of shoots with dead heart}}{\text{Total no. of shoots}} \times 100$$

The shoot fly incidence (dead hearts percentage) was recorded on 21days after emergence of plants. The following rating scale was used to classify the genotypes into different categories, (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

Seven mutant lines *viz.*, PV-RD-29, PV-RD-30, PV-RD-13, PV-RD-41, PV-RD-33, PV-9 and PV-RD-47 showed 0 percentage of dead heart, whereas IS-2312 resistant check showed 15.78 percentage of dead heart. These 3 mutants IS 925-6 (71.42%), IS925-9 (68.18%) and IS925-22 (65%) showed highest amount of dead hearts, whereas susceptible check DJ-6514 showed 71.42% percentage of dead heart.

Among 200 mutant lines were screened for shoot fly, in that 29 lines shown highly resistant (0-10%) reaction, 57 lines shown resistant (11-20%) reaction, 51 lines shown moderately resistance (21-30%) reaction, 56 lines shown susceptible (30-50%) reaction, 14 lines shown highly susceptible (>50%) reaction, these lines are presented in Table 1 and these results were comparable with the Kiran, (2014); Navinkumar *et al.*, (2020).

Table 1: Classification of 200 sorghum mutant lines along with checks based on per cent dead heart formed due to shoot fly incidence.

	Genotypes	
Reaction	**IS925**	**Phule Vasudha**
Highly resistance (0-10%)	IS925-58, IS925-RD-98, IS925-RV-4, IS925-85, IS925-117, IS925-83, IS925-132, IS925-20.	PV-3, PV-RD-7, PV-RD-22, PV-RD-30, PV-RD-54, PV-RD-25, PV-RD-29, PV-RD-13, PV-RD-62, PV-1, PV-RD-41,PV-RD-20, PV-RD-33, PV-9, PV-RD-51, PV-23, PV-RD-47, PV-RD-6, PV-RD-53, PV-13, PV-37.
Resistance (11–20 %)	IS925-23, IS925-7, IS925-14, IS925-RD-50, IS925-105, IS925-RD-61, IS925-RD-71, IS925-54, IS925-124, IS925-34, IS925-90, IS925-134, IS925-3, IS925-RV-7, IS925-4, IS925-120, IS925-138, IS925-RD-74, IS-2312.	PV-RD-68, PV-6E, PV-12, PV-33, PV-RD-31, PV-RD-49, PV-RD-15, PV-RD-40, PV-RD-44, PV-52, PV-6, PV-57, PV-60, PV-10, PV-RD-35, PV-2, PV-41, PV-RD-21, PV-RD-27, PV-RD-50, PV-RD-14, PV-RD-45, PV-RD-18, PV-RD-43, PV-RD-10, PV-38, PV-RD-46, PV-14, PV-26, PV-1, PV-17-1, PV-13, PV-7, PV-22, PV-16, PV-19, PV-24, PV-11.
Moderately resistance (21 – 30%)	IS925-11, IS925-1, IS925-24, IS925-16, IS925-2, IS925-2-1, IS925-113, IS925-RD-48, IS925-RV-3, IS925-RD-30, IS925-80, IS925-RD-15, IS925-RD-53, IS925-70, IS925-39, IS925-RD-47, IS925-RD-65, IS925-RD-46, IS925-130, IS925-RD-21, IS925-46, IS925-RD-19, IS925-110, IS925-127, IS925-28, IS925-RD-76, IS925-38, IS925-109, IS925-RD-34, IS925-RD-8, GS-23, M-35-1, SPV-86.	PV-17, PV-RD-57, PV-RD-3, PV-RD-19, PV-18, PV-RD-36, PV-47, PV-48, PV-20, PV-53, PV-RD-4, PV-RD-20, PV-RD-5, PV-50, PV-11, PV-5, PV-17, PV-18.
Susceptible (30 – 50 %)	IS925-19, IS925-10, IS925-21, IS925-5, IS925-17, IS925-21-1, IS925-7-1, IS925-131, IS925-RV-6, IS925-RV-8, IS925-108, IS925-64, IS925-128, IS925-72, IS925-7, IS925-RV-13, IS925-101, IS925-RD-41, IS925-116, IS925-16, IS925-115, IS925-44, IS925-102, IS925-RD-25, IS925-96, IS925-118, IS925-23, IS925-144, IS925-123, IS925-133, IS925-41, IS925-82, E-36-1, DSV-4.	PV-RD-28, PV-RD-1, PV-58, PV-61, PV-16, PV-RD-32, PV-RD-34, PV-RD-87, PV-RD-11, PV-RD-48, PV-RD-52, PV-22, PV-RD-38, PV-45, PV-RD-9, PV-44, PV-49, PV-6, PV-7-1, PV-23, PV-8, PV-9.
Highly susceptible (>50%)	IS925-8, IS925-22, IS925-6, IS925-9, IS925-RD-44, IS925-87, IS925-RD-101, IS925-RD-16, IS925-RV-16, IS925-RD-37, IS925-37, IS925-RV-2, DJ-6514	PV-35.

Low amount of eggs were present in PV-RD-30 (0%), PV-RD-29 (0%), PV-RD-13 (0%) and PV-9 (0%) compared to the resistant check IS-2312 (31.57%). Highest number of eggs were present in IS925-21 (87.5%), IS925-118 (85%), IS925-RV-16 (83.33%) and IS925-6 (82.35%) compared to the susceptible check DJ-6514 (85.71%). These results were coincides with the findings of Chandra *et al*., (2018).

The seedling vigour observation is taken after 16 DAE and was scored on a 1-5 scale. Out of 200 mutants screened only 10 mutants shown high vigorous score (5), 80 mutants shown score (4), 77 mutants shown score (3), 33 mutants shown score (2) and 7 mutants shown score (1). This is shown in Table 2.

The lowest seedling vigour score in mutants was 1 and those mutants showing 1 as a score were categorized as shoot fly susceptible mutants. These findings were registered earlier by Prasad *et al*., (2015). Who observed that higher seedling vigour in sorghum was responsible for showing resistance to shoot fly. Similarly, Sharma and Nwanze (1997) also observed that seedling vigour as an important morphological trait for showing resistance to shoot fly.

The intensity of glossiness was scored at 7 DAE on 1 to 5 scale. Out of 200 mutants screened, 10 mutants shown high glossiness score (5), 84 mutants shown score (4), 69 mutants show score (3), 37 mutants shown score (2) and 7 mutants shown score (1). This is shown in Table 3. Mean performances of 200 M_4 sorghum mutant lines for shoot fly incidence is represented in Table 4.

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

	Genotypes	
Reaction	**IS925**	**Phule Vasudha**
Highly resistance (5)	IS925-RD-98, IS-2312.	PV-RD-7, PV-RD-30, PV-RD-29, PV-RD-13, PV-RD-41, PV-RD-33, PV-RD-51, PV-RD-47.
Resistance (4)	IS925-16-1, IS925-14, IS925-2-1, IS925-58, IS925-RD-48, IS925-RV-3, IS925-105, IS925-RD-71, IS925-RV-4, IS925-85, IS925-117, IS925-83, IS925-124, IS925-34, IS925-90, IS925-134, IS925-132, IS925-20, IS925-3, IS925-RV-7, IS925-28, IS925-RD-76, IS925-4, IS925-120, IS925-138, IS925-RD-74. GS-23, M-35-1,SPV-86.	PV-14, PV-26, PV-1-1, PV-13-1, PV-7, PV-22, PV-16-1, PV-19, PV-24, PV-11-1, PV-3, PV-17-1-1, PV-21, PV-RD-68, PV-6-E, PV-RD-22, PV-33, PV-RD-31, PV-RD-49, PV-RD-54, PV-RD-62, PV-RD-15, PV-RD-40, PV-RD-44, PV-1, PV-RD-20, PV-57, PV-9, PV-60, PV-10, PV-RD-35, PV-2, PV-48, PV-20, PV-41, PV-RD-21, PV-RD-27, PV-23, PV-RD-6, PV-RD-50, PV-RD-14, PV-RD-4, PV-RD-53, PV-50, PV-RD-18, PV-13, PV-RD-43, PV-37, PV-11, PV-38, PV-RD-46.
Moderately resistance (3)	IS925-19, IS925-11, IS925-23-1, IS925-10, IS925-1, IS925-24, IS925-17, IS925-7-1-1, IS925-2, IS925-21-1, IS925-7-1, IS925-131, IS925-RD-50, IS925-113, IS925-RD-61, IS925-RV-8, IS925-RD-30, IS925-54, IS925-80, IS925-RD-15, IS925-RD-53, IS925-70, IS925-RD-8, IS925-39, IS925-RD-47, IS925-RD-65, IS925-RD-46, IS925-RV-13, IS925-130, IS925-RD-21, IS925-46, IS925-RD-19, IS925-RD-16, IS925-116, IS925-110, IS925-16, IS925-127, IS925-96, IS925-118, IS925-23, IS925-144, IS925-38, IS925-109, IS925-RD-34, IS925-29, E-36-1, DSV-4.	PV-6-1, PV-7-1, PV-23-1, PV-17-1, PV-9-1, PV-5, PV-RD-28, PV-17, PV-12, PV-RD-57, PV-RD-25, PV-RD-3, PV-RD-19, PV-18, PV-52, PV-6, PV-RD-36, PV-61, PV-53, PV-RD-34, PV-RD-87, PV-RD-45, PV-RD-20, PV-RD-5, PV-RD-48, PV-RD-10, PV-RD52, PV-22, PV-44, PV-49.
Susceptible (2)	IS925-8, IS925-21, IS925-5, IS925-RD-44, IS925-RV-6, IS925-108, IS925-64, IS925-128, IS925-87, IS925-72, IS925-7, IS925-101, IS925-RD-41, IS925-RV-16, IS925-115, IS925-44, IS925-102, IS925-RD-25, IS925-123, IS925-133, IS925-41, IS925-RV-2.	PV-8, PV-RD-1, PV-58, PV-47, PV-35, PV-16, PV-RD-32, PV-RD-11, PV-RD-38, PV- PV-45, PV-RD-9.
Highly susceptible (1)	IS925-22, IS925-6, IS925-9, IS925-RD-101, IS925-RD-37, IS925-37, DJ-6514.	-

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

	Genotypes	
Reaction	**IS925**	**Phule Vasudha**
Highly resistance (5)	-	PV-RD-30, PV-RD-25, PV-RD-29, PV-RD-13, PV-RD-41, PV-RD-33, PV-9, PV-RD-51, PV-23, PV-RD-47.
Resistance (4)	IS925-23-1, IS925-1, IS925-24, IS925-6-1, IS925-14. IS925-2, IS925-2-1, IS925-58, IS925-RD-50, IS925-105, IS925-RD-61, IS925-RD-98, IS925-RV-4, IS925-85, IS925-117, IS925-83, IS925-RD-53, IS925-70, IS925-124, IS925-RD-65, IS925-90, IS925-134, IS925-132, IS925-46, IS925-20, IS925-28, IS925-RD-76, IS925-120, IS925-138, IS925-109, IS925-RD-74, IS-2312, GS-23, M-35-1.	PV-14, PV-26, PV-1-1, PV-17-1, PV-13-1, PV-7, PV-22, PV-16-1, PV-19, PV-24, PV-11-1, PV-3, PV-17-1-1, PV-RD-68, PV-RD-7, PV-6-E, PV-RD-22, PV-12, PV-33, PV-RD-31, PV-RD-49. PV-RD-54, PV-RD-62, PV-RD-15, PV-RD-40, PV-RD-44, PV-1, PV-RD-20, PV-6, PV-RD-36, PV-57, PV-10, PV-RD-35, PV-2, PV-48, PV-20, PV-41, PV-RD-21, PV-RD-27, PV-RD-6, PV-RD-50, PV-RD-4, PV-RD-45, PV-RD-20, PV-RD-53, PV-50, PV-RD-18, PV-13, PV-RD-10, PV-37.
Moderately resistance (3)	IS925-19, IS925-11, IS925-10, IS925-17, IS925-7-1-1, IS925-21-1, IS925-7-1, IS925-113, IS925-RD-48, IS925-RV-3, IS925-RD-71, IS925-RV-8, IS925-RD-30, IS925-54, IS925-80, IS925-RD-15, IS925-128, IS925-RD-8, IS92534, IS925-72, IS925-RD-47, IS925-RD-46, IS925-RV-13, IS925-130, IS925-RD-21, IS925-101, IS925-RD-41, IS925-RD-19, IS925-3, IS925-110, IS925-16, IS925-115, IS925-127, IS925-RV-7, IS925-96, IS925-4, IS925-144, IS925-38, IS925-RD-34, IS925-29, SPV-86.	PV-6-1, PV-7-1, PV-23-1, PV-9-1, PV-5, PV-21, PV-17, PV-RD-57, PV-3, PV-RD-19, PV-18, PV-52, PV-47, PV-60, PV-61, PV-53, PV-RD-32, PV-RD-34, PV-RD-87, PV-RD-14, PV-RD-5, PV-RD-11, PV-RD-48, PV-RD-43, PV-22, PV-11, PV-38, PV-RD-46.
Susceptible (2)	IS925-8, IS925-21, IS925-5, IS925-131, IS925-RV-6, IS925-108, IS925-64, IS925-87, IS925-39, IS925-7, IS925-RD-16, IS925-116, IS925-RV-16, IS925-44, IS925-102, IS925-RD-25, IS925-37, IS925-118, IS925-23, IS925-123, IS925-133, IS925-41, IS925-RV-2, E-36-1, DSV-4.	PV-8, PV-RD-28, PV-RD-1, PV-58, PV-35, PV-16, PV-RD-52, PV-RD-38, PV-45, PV-RD-9, PV-44, PV-49.
Highly susceptible (1)	IS925-22, IS925-6, IS925-9, IS925-RD-44, IS925-RD-10, IS925-RD-37, DJ-6514.	-

The glossiness in leaves influences the non-preference of egg laying in the host and it minimizes the dead heart percentage. Glossy surface present on adaxial and abaxial surface in leaves causes the fall down of eggs to soil earlier than hatching and decreases the dead heart percentage. These findings match with the results of Kamatar *et al.,* (2010); Sonalkar and Pagire, (2017).

The mutants which were having high score rating of seedling vigour and glossiness were showing high resistance to the shoot fly, it is due to responses of olfactory or gustatory to the insect. Those mutants are having low score rating were more vulnerable to the shoot fly attack, because low vigour plants produces higher dose of chemicals and attracted by the shoot fly. The maggots which hatch on the vigourus seedlings, takes more time to reach meristematic tissues, it was because of seedling vigour and glossiness traits. These two characters serves as obstacle for maggots to reach the centre of the stem and to form dead heart symptom in plants.

Mean performances of M_4 sorghum mutant lines for shoot fly incidence.

Sr.No.	Mutants	DH%	OP %	SV	Glossiness
	P+C (IS925)				
1.	IS925-19	31.57	54.54	3	3
2.	IS925-11	23.52	47.05	3	3
3.	IS925-8	52.38	71.42	2	2
4.	IS925-23-1	18.18	45.45	3	4
5.	IS925-10	33.33	72.22	3	3
6.	IS925-1	28.57	57.14	3	4
7.	IS925-22	65	75	1	1
8.	IS925-24	27.27	54.54	3	4
9.	IS925-21	50	87.5	2	2
10.	IS925-5	50	61.11	2	2
11.	IS925-17	33.33	55.56	3	3
12.	IS925-16-1	25	50	4	4
13.	IS925-6	71.42	82.35	1	1
14.	IS925-7-1-1	16.66	33.33	3	3
15.	IS925-14	20	20	4	4
16.	IS925-9	68.18	68.18	1	1
17.	IS925-2	28.57	50	3	4
18.	IS925-21-1	41.67	50	3	3
19.	IS925-2-1	25	50	4	4
20.	IS925-7-1	37.5	50	3	3
	P+C(PV)				
1.	PV-6-1	44.44	44.44	3	3
2.	PV-14	20	20	4	4
3.	PV-26	18.18	27.27	4	4
4.	PV-1-1	12.5	12.5	4	4
5.	PV-7-1	38	46.15	3	3
6.	PV-23-1	36.36	45.45	3	3
7.	PV-17-1	16	32	3	4
8.	PV-8	42.85	42.85	2	2
9.	PV-13-1	12	20	4	4
10.	PV-9-1	38.09	47.61	3	3
11.	PV-7	15.38	23.07	4	4
12.	PV-22	13.33	13.33	4	4
13.	PV-5	28.57	33.33	3	3
14.	PV-16-1	15.38	32.5	4	4
15.	PV-19	15.38	23.07	4	4
16.	PV-24	13.33	20	4	4
17.	PV-11-1	11.11	22.22	4	4
18.	PV-3	7.69	15.38	4	4
19.	PV-17-1-1	23.52	35.29	4	4
20.	PV-21	25	75	4	3
	P(IS925)				
1.	IS925-RD-44	61.9	71.42	2	1
2.	IS925-131	30.76	46.15	3	2
3.	IS925-58	10	20	4	4
4.	IS925-RD-50	20	40	3	4
5.	IS925-113	22.22	72.2	3	3
6.	IS925-RD-48	21.42	50	4	3
7.	IS925-RV-3	21.05	36.84	4	3
8.	IS925-105	15.78	42.1	4	4
9.	IS925-RV-6	40	33.33	2	2
10.	IS925-RD-61	19.04	23.8	3	4
11.	IS925-RD-98	5.56	11.11	5	4
12.	IS925-RD-71	14.28	21.42	4	3
13.	IS925-RV-8	31.25	37.5	3	3
14.	IS925-RV-4	8.33	16.67	4	4
15.	IS925-85	9.09	27.27	4	4
16.	IS925-RD-30	23.07	30.76	3	3
17.	IS925-108	41.17	41.17	2	2
18.	IS925- 117	6.25	25	4	4
19.	IS925-83	9.09	18.18	4	4
20.	IS925-64	37.5	43.75	2	2
21.	IS925-54	15.78	21.05	3	3
22.	IS925-80	29.16	37.5	3	3
23.	IS925-RD-15	25	65	3	3

Sr.No.	Mutants	DH%	OP %	SV	Glossiness
24.	IS925-RD-53	28.57	57.14	3	4
25.	IS925-128	31.25	50	2	3
26.	IS925-87	55.56	55.56	2	2
27.	IS925-70	21.42	42.85	3	4
28.	IS925-124	15.38	38.46	4	4
29.	IS925-RD-8	23.52	41.17	3	3
30.	IS925-RD-101	64.28	71.42	1	1
31.	IS925-39	21.05	36.84	3	2
32.	IS925-34	19.04	80.95	4	3
33.	IS925-72	41.17	41.17	2	3
34.	IS925-7	40	66.67	2	2
35.	IS925-RD-47	23.52	23.52	3	3
36.	IS925-RD-65	23.52	23.52	3	4
37.	IS925-90	20	40	4	4
38.	IS925-134	12.5	12.5	4	4
39.	IS925-RD-46	30	30	3	3
40.	IS925-RV-13	31.25	62.5	3	3
41.	IS925-130	26.31	47.36	3	3
42.	IS925-RD-21	23.8	42.85	3	3
43.	IS925-132	6.67	20	4	4
44.	IS925-101	31.81	31.81	2	3
45.	IS925-46	28.57	28.57	3	4
46.	IS925-RD-41	33.33	38.89	2	3
47.	IS925-RD-19	23.52	64.7	3	3
48.	IS925-RD-16	53.33	53.33	3	2
49.	IS925-20	6.25	31.25	4	4
50.	IS925-3	18.18	36.36	4	3
51.	IS925-116	35.71	35.71	3	2
52.	IS925-110	27.27	54.54	3	3
53.	IS925-RV-16	58.33	83.33	2	2
54.	IS925-16	38.09	38.09	3	3
55.	IS925-115	37.5	68.75	2	3
56.	IS925-44	40	33.33	2	2
57.	IS925-127	22	22.22	3	3
58.	IS925-RV-7	16	16.66	4	3
59.	IS925-102	36.36	54.54	2	2
60.	IS925-RD-25	50	62.5	2	2
61.	IS925-RD-37	61.11	77.78	1	1
62.	IS925-37	60.86	73.91	1	2
63.	IS925-28	29.41	64.7	4	4
64.	IS925-96	40	60	3	3
65.	IS925-118	50	85	3	2
66.	IS925-RD-76	25	75	4	4
67.	IS925-23	36.84	68.42	3	2
68.	IS925-4	17.39	34.78	4	3
69.	IS925-144	38.46	50	3	3
70.	IS925-123	45.45	81.81	2	2
71.	IS925-120	13.63	13.63	4	4
72.	IS925-38	30	35	3	3
73.	IS925-138	14.28	57.14	4	4
74.	IS925-109	25	25	3	4
75.	IS925-RD-34	25	30	3	3
76.	IS925-RD-74	18.75	31.25	4	4
77.	IS925-133	45	50	2	2
78.	IS925-41	50	62.5	2	2
79.	IS925-RV-2	54.54	36	2	2
80.	IS925-29	36.8	47	3	3
	P(PV)				
1.	PV-RD-28	38.46	46.15	3	2
2.	PV-RD-1	44.44	44.44	2	2
3.	PV-RD-68	12.5	12.5	4	4
4.	PV-RD-7	6.25	12.5	5	4
5.	PV-17	26.31	31.57	3	3
6.	PV-6-E	11.76	17.64	4	4
7.	PV-RD-22	7.69	23.07	4	4
8.	PV-12	18.18	27.27	3	4
9.	PV-33	16.16	33.33	4	4
10.	PV-RD-31	18.75	31.25	4	4
11.	PV-RD-30	0	0	5	5
12.	PV-RD-49	14.28	21.42	4	4
13.	PV-RD-57	23.07	38.46	3	3
14.	PV-RD-54	7.69	15.38	4	4
15.	PV-RD-25	6.25	12.5	3	5
16.	PV-RD-3	26.31	42.1	3	3
17.	PV-RD-29	0	0	5	5
18.	PV-RD-13	0	0	5	5
19.	PV-RD-19	27.27	27.27	3	3
20.	PV-RD-62	8.33	16.67	4	4
21.	PV-RD-15	12.5	12.5	4	4
22.	PV-18	26.31	47.36	3	3
23.	PV-RD-40	11.7	29.41	4	4
24.	PV-58	38	46	2	2

Sr.No.	Mutants	DH%	OP %	SV	Glossiness
25.	PV-RD-44	12.5	25	4	4
26.	PV-1	7.14	21.42	4	4
27.	PV-RD-41	0	20	5	5
28.	PV-52	13.33	20	3	3
29.	PV-RD-20	7.69	15.38	4	4
30.	PV-RD-33	0	6.67	5	5
31.	PV-6	20	50	3	4
32.	PV-RD-36	29.41	35.29	3	4
33.	PV-57	20	26.67	4	4
34.	PV-47	38.89	77.78	2	3
35.	PV-9	0	0	4	5
36.	PV-60	15.38	15.38	4	3
37.	PV-10	15	40	4	4
38.	PV-61	30.43	43.47	3	3
39.	PV-RD-35	20	55	4	4
40.	PV-2	16.67	25	4	4
41.	PV-48	22.22	33.33	4	4
42.	PV-35	57.14	71.42	2	2
43.	PV-20	25	25	4	4
44.	PV-41	13	20	4	4
45.	PV-RD-21	15	15	4	4
46.	PV-RD-51	5	20	5	5
47.	PV-RD-27	16.67	25	4	4
48.	PV-53	30	60	3	3
49.	PV-16	33.33	33.33	2	2
50.	PV-23	6.25	18.75	4	5
51.	PV-RD-47	0	12.5	5	5
52.	PV-RD-6	6.25	18.75	4	4
53.	PV-RD-32	42.85	42.85	2	3
54.	PV-RD-50	11.76	35.29	4	4
55.	PV-RD-34	35.71	35.71	3	3
56.	PV-RD-87	33.33	41.67	3	3
57.	PV-RD-14	17.64	17.64	4	3
58.	PV-RD-4	28.57	28.57	4	4
59.	PV-RD-45	16.67	44.44	3	4
60.	PV-RD-20	26.67	33.33	3	4
61.	PV-RD-5	27.78	33.33	3	3
62.	PV-RD-11	33.33	40	2	3
63.	PV-RD-53	9.09	9.09	4	4
64.	PV-RD-48	30.43	39.13	3	3
65.	PV-50	21.42	42.85	4	4
66.	PV-RD-18	14.28	14.28	4	4
67.	PV-13	5.88	23.52	4	4
68.	PV-RD-43	15	20	4	3
69.	PV-RD-10	16.67	16.67	3	4
70.	PV-37	10	20	4	4
71.	PV-RD-52	44.44	55.55	3	2
72.	PV-22	33.33	33.33	3	3
73.	PV-RD-38	43.47	56.52	2	2
74.	PV-11	30	55	4	3
75.	PV-45	47.36	63.15	2	2
76.	PV-38	19.04	38	4	3
77.	PV-RD-9	44	52	2	2
78.	PV-44	33.33	66.67	3	2
79.	PV-49	31.57	52.94	3	2
80.	PV-RD-46	15.78	31.57	4	3
	CHECKS				
1.	DJ-6514 (S)	71.42	85.71	1	1
2.	IS-2312 (R)	15.78	31.57	5	4
3.	GS-23	25	37.5	4	4
4.	M-35-1	28.57	52.38	4	4
5.	SPV-86 (S)	25	33.33	4	3
6.	E-36-1 (R)	33.33	52.38	3	2
7.	DSV-4 (R)	42.85	57.14	3	2
	CD@5%				
	Ci-Cj	0.688	1.2518	0.766	0.8105
	BiVi-BiVj	1.3761	2.5036	1.532	1.6209
	BiVi-BjVj	1.4711	2.6764	1.637	1.7328
	Ci-Vl	1.163	2.1159	1.294	1.3699

P+C = Physical + chemical treated
P = Physical treated
PV = Phule Vasudha
DH% = Dead heart per cent
SV = Seedling vigour
OP% = Oviposition per cent
Ci-Cj = For two check means
BiVi-BiVj = For two test genotype means in same block
BiVi-BjVj = For any two entries means in the same block
Ci-Vl = For means between a check and a test genotype

Plate 1. Fish meal application to attract shoot fly.

Plate 2. Cigar shaped eggs of shoot fly.

Plate 3. Shoot fly infected plant with maggot in dead heart.

CONCLUSION

The present experiment was conducted to identify mutant lines, which were resistant to shoot fly attack. Study revealed that among 200 mutant lines seven lines *viz.*, PV-RD-29, PV-RD-30, PV-RD-13, PV-RD-41, PV-RD-33, PV-9 and PV-RD-47 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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