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Raosaheb Sawant, S. M. Pawar and Sangram Chavan

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Role of Leaf Glossiness in Sorghum [*Sorghum bicolor* (L.) Moench] Shoot Fly [*Atherigona soccata* Rondani] Resistance

Raosaheb Sawant*[1], S. M. Pawar[2] and Sangram Chavan[3]

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ABSTRACT

Higher crop production by cultivating climate smart crops and addressing their biotic and abiotic production constraints by eco-friendly way is required for sustainable development. Sorghum shoot fly is a major pest and causes economic losses to sorghum growers' through-out the world. 8 CMS lines were crossed with 8 testers in line x tester passion to investigate the role of glossy leaf character in imparting shoot fly resistance. All 16 parents, 64 crosses, maintainers of CMS lines and specific checks comprising total 112 genotypes were evaluated by infester row technique in randomized block design with three replications for two consecutive years in rainy season. Data were recorded on leaf glossiness, eggs per plant, percent egg laying and percent dead hearts at 14, 21 and 28 DAE (days after emergence). There was sufficient variability for all traits among the genotypes tested. Pooled data of two years was analyzed for mean performance, combining ability, correlation and genetic variance components. Strong, positive and highly significant correlation between leaf glossiness and percent egg laying (r = 0.837**), percent dead hearts at 14 DAE (r = 0.945**), percent dead hearts at 21 DAE (r = 0.880**), percent dead hearts at 28 DAE (r = 0.886**) was observed. All these traits were under the control of additive gene action and selection in early generation will be effective for improvement in these traits. Additive genetic control, high narrow sense heritability coupled with high genetic advance makes stable expression of glossy trait across the environments. It was found that the glossy trait acts through non-preference to oviposition. So, glossy trait can be used as morphological marker for selection and development of shoot fly resistant genotypes. Parents PA4, PR1, PR2 and crosses, PA4 X PR1, PA4 X PR7, PA7 X PR1, PA5 X PR3, and PA4 X PR2 may be evaluated further across more locations and used in breeding program for development of shoot fly resistant genotypes and commercial utilization.

Key words: General combining ability, Line × Tester analysis, Heritability, Genetic advance, *Sorghum bicolour* (L.) Moench, *Atherigona soccata* Rondani

Sorghum [*Sorghum bicolor* (L.) Moench] is a climate resilience crop mostly cultivated in the semi-arid tropic region of the world for food, feed, fodder, forage and fuel. Among the number of biotic and abiotic constraints, shoot fly is the major one which hampers the sorghum production. In a recent study in India, the losses due to shoot fly damage have been estimated to reach as high as 90 per cent of grain, and 45 per cent of fodder yield [1]. Shoot fly attacks sorghum crop from 7-30 days after seedling emergence and complete its life cycle in 17-21 days. A typical dead heart symptom is seen on damaged plant. To prevent the shoot fly damage lot of cultural and chemical measures are suggested by various researchers but they are not feasible practically, economically to resource poor farmers and possess serious health hazards and environmental pollution respectively. Development of host plant resistance is one of the best methods to overcome these problems and from this angle a study was undertaken to understand the role of leaf glossiness character in the shoot fly resistance development. Since farmer demands shoot fly resistant hybrids, it is important to know the heritability and gene action for shoot fly resistance traits to formulate appropriate breeding strategy.

* Raosaheb Sawant
raosahebshivdassawant@gmail.com

1,3 Hytech Seed India Pvt. Ltd, At-Pakhora, Post Pakhora, Gangapur, Aurangabad, Maharashtra, India

2 Shivaji Art, Commerce and Science College, Kannad, Aurangabad, Maharashtra, India

MATERIALS AND METHODS

The experimental material consisted of 8 restorers (PR1 to PR8), 8 CMS and their maintainers (PB1 to PB8), 64 crosses (PA1 X PR1 to PA8 X PR8) and various 24 checks. Checks includes IS 18551 and IS 3578 as resistant and susceptible checks from germplasm, SPSFPR 94006 A/B and 296 A/B as resistant and susceptible checks for comparison of parents (Lines and testers), three commercial hybrids (CSH 34, HTJH 3206 and CSH 37) for comparison crosses and their female (A/B lines) and male (R lines) parents, four shoot fly resistant QTL introgressed lines (SFR Line 1-4) and four wild relatives of sorghum (IS 18944, IS 18945, IS 18947, IS 14275). These 112 genotypes were screened for shoot fly resistance in randomized block design with three replications in rainy seasons 2019 and 2020 by adopting infester row technique [2] at Hytech Seed India Pvt. Ltd. At /Post Pakhora, Gangapur, Aurangabad, Maharashtra. The 64 hybrids were produced by crossing 8 CMS lines with 8 restorers in line x tester mating design [3] in 2018 and 2019 post rainy seasons. Fresh seed of each genotype tested was used for evaluation. The data was recorded on shoot fly damage parameters viz., number of plants at 7 DAE (Days after emergence), number of plants with eggs at 14 DAE, number of shoot fly eggs per plant (E/P) at 14 DAE), percent egg laying (% EL) at 14 DAE, percent dead hearts (% DH) at 14 DAE, 21 DAE, 28 DAE and morphological character, leaf glossiness (LG) scored on 1 to 5 scale [1 = highly glossy (light green, shining, narrow, and erect leaves), 2= glossy, 3=moderately glossy,4= moderately non glossy and 5 = non glossy (dark green, dull, broad, and drooping leaves)] at 10-12 DAE (fifth leaf stage) in the early morning hours, when the expression of this trait is most apparent [4]. Year-wise data analyzed by using online statistical tool OP STAT to test the significant differences among the genotypes for mean performance and estimate correlations among the characteristics, whereas over year pooled RBD analysis & line x tester analysis was performed by using Windostat Version 9.2 (Indostat services, Hyderabad) to estimate variance components, narrow sense heritability and genetic advance.

REULTS AND DISCUSSION

The statistical analysis of experimental data of rainy seasons of year 2019 and 2020 shown significant treatment mean sum of square differences, indicating the substantial amount of variation among the genotypes for all the characters studied viz., leaf glossiness, number of eggs per plant at 14 DAE, % egg laying at 14 DAE and % dead hearts at 14 DAE. Since the error variance for all the traits studied was found homogeneous with significant interaction effects, the data over year was pooled for randomized block design (RBD) and Line x Tester analysis. Combined analysis of variance for pooled data over year shown highly significant, differences between years, entries (treatments) and year x entry (treatment/ genotype) interaction effects for all the traits (Table 1).

Table 1 Mean sum of squares (ANOVA) for shoot fly damage parameters and leaf glossiness in 2019 & 2020 rainy season shoot fly screening trials

Source of variations	DF	LG	E/P 14 DAE	% EL 14 DAE	% DH 14 DAE	% DH 21 DAE	% DH 28 DAE
Replicates	2	0.609	1.374**	959.991***	46.646	46.587	32.494
Year	1	45.054***	64.066***	2852.729***	35683.973***	2699.452***	1658.266***
Entry	111	4.297***	1.565***	1964.178***	1984.391***	2036.651***	2035.328***
Year*Entry	111	0.606***	0.253***	44.658***	135.341***	33.671***	27.292***
Error (B)	446	0.289	0.225	52.075	95.168	17.793	14.857
Total	671	1.072	0.55	374.037	467.232	358.471	353.651

**Significant at 1% level; ***Significant at 0.5% level

Table 2 Mean performance of genotypes evaluated in shoot fly screening trials in 2019 and 2010 rainy seasons

Treatment / Genotypes	LG	E/P 14 DAE	% EL 14 DAE	% DH 14 DAE	% DH 21 DAE	% DH 28 DAE
CMS lines and maintainers (Female parents)						
PA1	4.2	1.9	87	76	94	95
PB1	4.5	1.8	89	80	100	100
PA2	4.2	1.8	86	73	89	93
PB2	4.0	1.8	83	70	96	97
PA3	3.8	1.8	91	85	99	99
PB3	4.3	1.9	97	91	100	100
PA4	2.0	1.5	82	60	87	94
PB4	2.0	1.7	72	60	85	90
PA5	4.3	2.0	94	80	98	98
PB5	4.2	1.8	96	80	99	99
PA6	4.2	2.3	96	80	99	100
PB6	3.8	2.3	95	80	97	98
PA7	4.7	2.0	97	89	99	99
PB7	4.2	2.0	91	81	99	99
PA8	4.7	2.2	92	80	99	100
PB8	4.7	2.1	95	89	97	99
Testers (Male parents)						
PR1	1.7	1.7	86	54	95	98
PR2	1.0	1.9	82	53	82	86
PR3	4.0	2.1	95	86	97	99
PR4	4.3	2.3	97	91	99	100

PR5	4.2	2.5	98	92	100	100
PR6	4.3	2.4	95	84	99	99
PR7	3.7	1.9	88	74	96	97
PR8	4.5	2.0	90	86	99	99
			Crosses			
PA1 X PR1	3.2	2.1	97	81	94	97
PA1 X PR2	2.5	2.0	85	77	94	96
PA1 X PR3	3.8	2.1	96	86	96	97
PA1 X PR4	4.0	2.3	92	86	97	98
PA1 X PR5	3.7	2.0	93	86	98	99
PA1 X PR6	3.7	2.5	91	81	93	98
PA1 X PR7	3.7	2.1	97	82	97	99
PA1 X PR8	4.2	2.0	94	84	97	98
PA2 X PR1	3.7	2.4	92	83	96	96
PA2 X PR2	3.0	2.4	92	75	95	97
PA2 X PR3	4.0	2.3	98	90	99	99
PA2 X PR4	3.7	2.3	93	89	98	99
PA2 X PR5	4.0	2.6	97	89	99	99
PA2 X PR6	4.2	2.5	96	84	94	95
PA2 X PR7	4.2	2.0	93	83	96	96
PA2 X PR8	4.3	2.2	96	87	98	98
PA3 X PR1	4.3	2.2	96	84	98	99
PA3 X PR2	4.0	2.0	93	81	97	99
PA3 X PR3	4.0	2.6	95	90	99	100
PA3 X PR4	4.5	2.3	94	92	99	99
PA3 X PR5	4.2	2.5	97	93	99	99
PA3 X PR6	4.5	2.4	98	86	99	99
PA3 X PR7	3.8	2.5	93	85	99	99
PA3 X PR8	4.3	2.1	97	92	99	99
PA4 X PR1	1.7	2.0	83	59	89	91
PA4 X PR2	1.7	1.8	88	72	85	91
PA4 X PR3	3.2	2.1	93	83	93	96
PA4 X PR4	2.8	2.1	89	78	96	97
PA4 X PR5	3.2	2.2	93	82	98	99
PA4 X PR6	3.3	2.3	94	84	90	95
PA4 X PR7	2.3	1.8	85	64	91	95
PA4 X PR8	3.3	1.9	89	81	95	97
PA5 X PR1	3.5	2.4	92	80	94	96
PA5 X PR2	3.2	2.0	98	80	97	98
PA5 X PR3	3.8	2.1	92	79	92	94
PA5 X PR4	4.2	2.4	96	88	98	99
PA5 X PR5	4.2	2.4	95	88	99	99
PA5 X PR6	4.0	2.2	96	82	95	96
PA5 X PR7	3.8	2.2	92	84	98	99
PA5 X PR8	4.2	2.1	96	87	98	98
PA6 X PR1	3.5	1.9	93	81	96	97
PA6 X PR2	3.3	2.1	92	80	92	96
PA6 X PR3	4.3	2.1	89	87	96	99
PA6 X PR4	4.0	2.6	95	88	98	99
PA6 X PR5	4.3	2.3	94	88	98	99
PA6 X PR6	3.7	2.7	95	86	96	96
PA6 X PR7	3.5	3.0	98	80	98	99
PA6 X PR8	4.0	2.8	96	86	98	98
PA7 X PR1	2.7	2.5	86	70	96	98
PA7 X PR2	3.2	2.1	91	79	92	94
PA7 X PR3	4.3	2.3	93	83	99	100
PA7 X PR4	4.2	2.4	96	90	100	100
PA7 X PR5	4.0	2.5	98	94	97	97
PA7 X PR6	4.0	2.5	96	89	97	98
PA7 X PR7	3.8	2.5	89	84	96	96
PA7 X PR8	4.7	2.2	93	88	99	100
PA8 X PR1	3.2	2.9	92	83	95	98
PA8 X PR2	3.3	2.4	94	78	97	99
PA8 X PR3	4.3	2.5	96	87	96	97
PA8 X PR4	4.8	2.2	97	88	99	100

PA8 X PR5	4.5	2.3	93	85	99	99
PA8 X PR6	4.3	2.2	98	87	96	98
PA8 X PR7	4.2	2.6	95	86	96	96
PA8 X PR8	4.7	2.6	96	91	99	100
Checks / Control						
IS 18551	1.0	1.3	60	42	72	82
SPSFPR 94006A	2.0	1.5	75	46	80	86
SPSFPR 94006B	2.0	1.5	78	49	88	94
IS 3578	5.0	2.5	96	96	100	100
296A	4.5	2.3	94	81	100	100
296B	4.8	2.1	95	79	100	100
CSH 34 A	4.7	2.2	93	90	98	99
CSH 34 B	4.7	2.1	91	83	99	100
CSH 37 A	4.3	1.8	93	83	98	99
CSH 37 B	4.0	2.2	91	77	99	99
CSH 34 R	3.5	2.3	94	77	96	98
HTJH 3206 R	5.0	2.0	98	92	100	100
CSH 37 R	4.5	2.4	96	86	96	98
CSH 34	4.0	2.2	94	85	97	98
HTJH 3206	4.5	2.5	97	93	100	100
CSH 37	3.8	2.7	96	86	93	96
SFR line 1	4.8	1.9	92	85	99	99
SFR line 2	2.7	1.6	85	69	95	99
SFR line 3	2.5	1.4	84	57	91	94
SFR line 4	3.8	1.9	90	80	95	99
Wild 1	5.0	0.0	0	0	0	0
Wild 2	4.3	0.0	0	0	0	0
Wild 3	3.8	0.0	0	0	0	0
Wild 4	4.5	0.0	0	0	0	0
Mean	3.8	2.1	89	78	93	94
C.V.%	14.1	22.6	8	12	5	4
C.D 5%	0.6	0.5	8	11	5	4

Mean performance of genotypes over two years (Table 2) shown that parents PA3, PA4, PA5, PR1, PR2 and PR7 were significantly glossy compared to susceptible checks 296A, IS 3578 and CSH34 A, HTJH 3206 R and CSH 37 R. Only PR2 was at par glossy with resistant check, IS 18551. Parents PR1 and PR2 were significantly glossy over CSH 34 R. SFR Line 2 and 3 also exhibited glossiness. Out of 64 crosses, 13 and 17 were significantly superior over CSH 37 and CSH 34 respectively for glossiness. They were mostly combinations of either glossy female and/or male parents. Glossiness seems to be a partial dominant trait with more maternal effect as the crosses with glossy parent PA4 were all glossy though PR3, PR4. PR5, PR6 and PR8 are moderately non glossy. PA4 was glossy while crosses on it were moderately glossy. If both the parents are glossy the intensity of glossiness in crosses is more viz., PA4 x PR1 and PA4 X PR2.

In general, it was observed that there were less number of eggs per plant and so the percent egg laying/ oviposition on glossy genotypes. This was reflected in less dead heart percentage at 14, 21 and 28 DAE. But in case of wild relatives, there were no egg laying, so no dead hearts even though they were moderately non glossy. This suggests glossiness is not the sole reason for less egg laying and dead hearts. Oviposition non-preference and tolerance mechanisms of resistance are the major components of shoot fly resistance [5].

Significantly less dead heart percentage over CSH 34 were observed in crosses where both the parents were glossy viz., PA4 X PR1, PA4 X PR2, PA4 X PR7, while in case of PA7 X PR1, though it is glossy more number of eggs were laid but dead hearts percentage remain low. This may be due to heavy shoot fly pressure. More egg load and less dead hearts on SP Nos. 15140, 15230 and 15229 glossy genotypes also observed by [6]. These crosses remain significantly superior over the CSH 34 for dead heart percentage at 21 and 28 DAE. PA5 X PR3 was exception to this [7-8].

Percent dead hearts at 14 DAE and 21 DAE in PA2, PA4, PR1 and PR2 were significantly superior over shoot fly QTL introgressed lines viz., SFR Line 1, SFR Line 4, whereas it was at par with SFR Line 2, SFR Line 3. PA4 and PR2 maintained significant superiority at 28 DAE also. Lower values for all the traits are beneficial for shoot fly resistance. The association of leaf glossiness, percent egg laying and shoot fly dead hearts is diagrammatically shown in Chart 1.

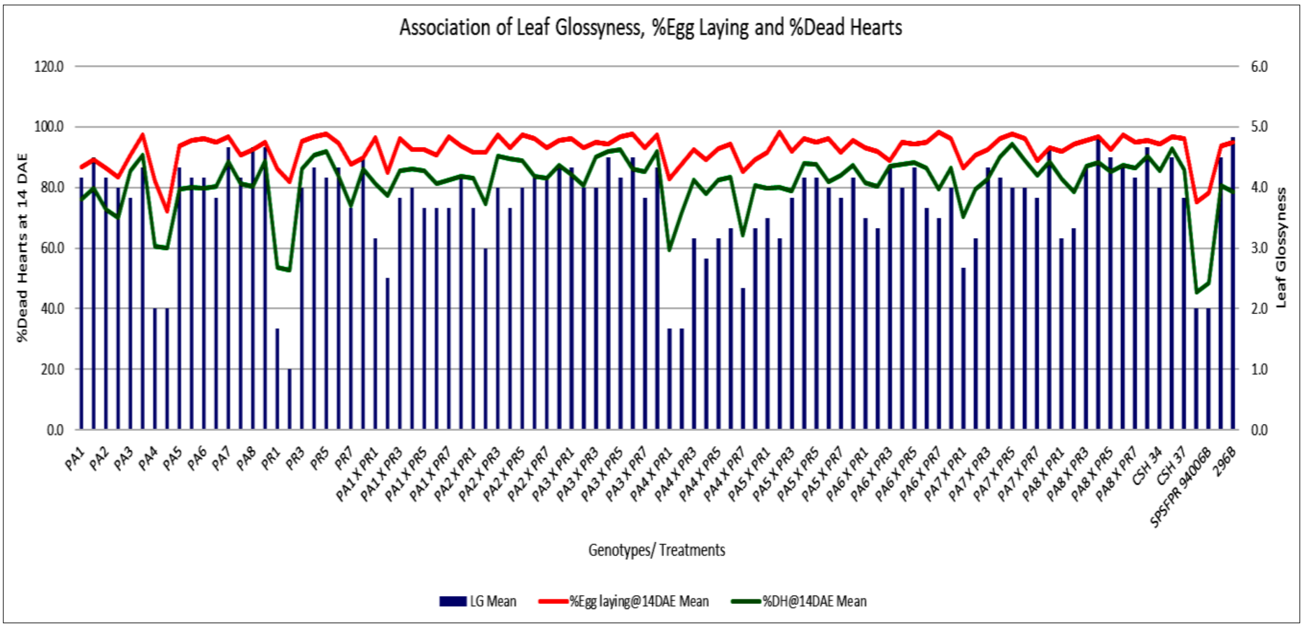
Association of characters

There was a strong, positive and highly significant correlation (Table 3) between leaf glossiness and percent egg laying (r = 0.837**), percent dead hearts at 14 DAE (r = 0.945**), percent dead hearts at 21 DAE (r = 0.880**) and percent dead hearts at 28 DAE (r = 0.886**). Under heavy shoot fly pressure even glossy genotypes were found with more eggs per plant but the dead hearts are significantly less and that could be the reason for moderate positive significant correlation between glossiness and eggs per plant (r = 0.516*). Negative associations between leaf glossiness, oviposition and dead hearts also observed by [9-10] whereas [11] reported significant positive correlation between leaf glossiness and dead heart percentage at 28 DAE at both the genotypic and phenotypic levels.

Table 3 Pearson correlation coefficient (r) between leaf glossiness and shoot fly damage parameters in shoot fly resistance screening trials in rainy season 2019 and 2020

Traits	LG	E/P 14DAE	% EL 14 DAE	%DH 14 DAE	%DH 21 DAE	%DH 28 DAE
LG	1					
E/P 14 DAE	0.516*	1				
% EL 14 DAE	0.837**	0.660**	1			
% DH 14 DAE	0.945**	0.619**	0.924**	1		
% DH 21 DAE	0.880**	0.563**	0.919**	0.956**	1	
% DH 28 DAE	0.866**	0.563**	0.913**	0.937**	0.978**	1

*Significance at 5% level, **Significant at 1% level



Association of leaf glossiness, Percent egg laying and percent dead hearts

General combining ability (GCA)

Line PA1, PA4 and tester PR1, PR2 had significant negative GCA effects, while line PA3, PA8 and tester PR3, PR4, PR5, PR6, PR8 had significant positive GCA effects for leaf glossiness. Line PA4 and PA1 had highly significant and significant negative GCA effects respectively for eggs per plant while tester PR2 had significant negative GCA effects. Significant positive GCA effects were observed in PA8. Highly significant negative GCA effects were observed for percent egg laying in line PA4 and tester PR1, PR2, while line PA3 and tester PR6 shown significant positive GCA effects. Negative but non-significant GCA effects were observed in line PA1, PA7 and tester PR7. Parents PA4, PR1, PR2 and PR7 had highly significant negative GCA effects for percent dead hearts at 14DAE, while GCA effects of PA1 and PA6 were negative and non-significant. Positive and highly significant GCA effects were exhibited by parents PA3, PA8, PR4, PR5 and PR8.

Highly significant negative GCA effects for percent dead hearts at 21 DAE were observed in PA4, PR1, PR2 and PA6, whereas non-significant negative GCA effects seen in PA1, PA5 and PR7. Highly significant positive GCA effects were observed in PA3, PR4, PR5 and PR8. Line PA4 and testers PR1, PR2 exhibited highly significant and significant negative GCA effects for percent dead hearts at 28DAE respectively, while the GCA effects of line PA3 and testers PR4, PR5, PR8 were significantly positive. Negative non-significant GCA effects were observed in PA2, PA5, PR6, and PR7. Negative GCA effects for leaf glossiness, eggs per plant, percent oviposition and percent dead hearts are required for shoot fly resistance and genotypes with negative GCA effects show hopes for further improvement [12]. Line PA4 was good general combiner for leaf glossiness, eggs per plant, percent egg laying and percent dead hearts whereas line PA1 found good general combiner for leaf glossiness, eggs per plant. Tester PR1 was good general combiner for leaf glossiness, percent egg laying percent dead hearts whereas PR2 proved good general combiner for leaf glossiness, eggs per plant, percent egg laying and percent dead hearts.

Specific combining ability (SCA)

Three crosses, PA7 X PR1, PA2 X PR4, PA4 X PR1 shown significant negative SCA effects while two crosses, PA3 X PR1, PA3 X PR2 had significant positive SCA effects for leaf glossiness. Cross PA6 X PR1 had highly significant negative while PA6 X PR7, PA6 X PR8, PA8 X PR1 had significant positive SCA effects for number of eggs per plant. Two crosses (PA1 X PR2, PA6 X PR3) had significant negative, while another two crosses (PA1 X PR1, PA6 X PR7) had significant positive SCA effects for percent egg laying. Cross PA4 X PR1 AND PA4 X PR7, PA7 X PR1 exhibited highly significant and significant negative SCA effects for percent dead hearts at 14 DAE. SCA effects of PA4 X PR2 and PA5 X PR3 were highly significant and significant negative respectively, while PA4 X PR5 & PA5 X PR2 it was significant positive for percent dead hearts at 21DAE. Highly significant & significant negative SCA effects were observed in PA2 X PR7 and PA4 X PR1, PA5 X PR3, respectively for percent dead hearts at 28DAE. Specific combining ability effects were significantly negative for leaf glossiness in crosses PA7 X PR1**, PA4 X

PR1*, PA2 X PR4*; for eggs per plant, PA6 X PR1**; for percent egg laying, PA1 X PR2*, PA6 X PR3*; for percent dead hearts at 14 DAE, PA4 X PR1**, PA4 X PR7*, PA7 X PR1*; for percent dead hearts at 21 DAE, PA4 X PR2**, PA5 X PR3*; and for percent dead hearts at 28 DAE, PA2 X PR7**, PA4 X PR1*, PA5 X PR3* [12].

Estimates of genetic variance components

The general combining ability variance was greater than specific combining ability variance for leaf glossiness, eggs per plant, % egg laying, and % dead hearts at 14 DAE, 21 DAE, and 28 DAE, which indicates the additive gene action in controlling these traits. Predominance of additive gene action for shoot fly resistance was reported by [5]. In contrast, predominance of non-additive gene action was reported by [13-14]. Also, the greater additive variance than the dominance variance and the average degree of dominance less than unity (<1) for all these traits (Table 4) was observed which signify the presence of additive gene action for the traits. Greater estimates of additive variances than their dominance variances for % egg laying and dead hearts formation [5]. Additive effects of leaf glossiness in reducing shoot fly incidence [15]. The shift in predominance of gene action and heritability with shoot fly pressure [16].

Table 4 Estimates of components of genetic variance, degree of dominance, heritability and genetic advance in shoot fly screening trials in rainy season 2019 and 2020

	LG	E/P 14	% EL 14	% DH 14	% DH 21	% DH 28
σ2 GCA	0.197	0.010	2.488	14.024	2.971	0.989
σ2 SCA	0.035	0.005	1.852	-0.985	0.404	0.345
σ2a (F=1)	0.394	0.021	4.976	28.048	5.942	1.978
σ2d (F=1)	0.035	0.005	1.852	-0.985	0.404	0.345
σ2a/σ2d	11.268	4.152	2.686	-28.477	14.705	5.737
Degree of dominance	0.298	0.491	0.610	0.187	0.261	0.418
Heritability (NS)%	67.121	33.685	37.812	66.342	68.224	30.199
Genetic advance 5%	1.060	0.172	2.820	8.886	4.148	1.592
Genetic advance as percentage of mean	28.251	7.691	3.031	10.773	4.312	1.632
General mean	3.752	2.237	93.029	82.487	96.203	97.539
Predictability ratio	0.918	0.806	0.729	1.036	0.936	0.852

Percent narrow sense heritability (NS) for leaf glossiness (67.12), eggs per plant (33.69), percent egg laying (37.81), percent dead hearts at 14 days after emergence (66.34), percent dead hearts at 21 after emergence (68.22) percent dead hearts at 28 days after emergence (30.20) was very high which suggest that the direct selection will be effective to improve these traits. There was high & moderate genetic advance as percentage of mean for leaf glossiness (28.25) and percent dead hearts at 14 DAE (days after emergence) (10.77), while its low for eggs per plant, percent egg laying, percent dead hearts at 21 and 28 DAE (days after emergence). High (60.5%) narrow sense heritability for leaf glossiness [5].

Predictability ratio for leaf glossiness, percent dead hearts at 14, 21, and 28 DAE (days after emergence), eggs per plant and percent egg laying is near to one. This high narrow sense heritability, high genetic advance as percent of mean, higher GCA variance than SCA variance, greater additive variance than dominance variance, average degree of dominance less than unity and predictability ratio near to one for leaf glossiness and percent dead hearts at 14 DAE indicates additive gene action. The additive nature of genetic variance is transmitted from parents to offspring and can be fixed in genotypes by selection in early generation. Though we tried to conduct the experiment over two years, it was beyond the scope of this study to thoroughly test the genotypes at different locations/environment to study the stability of performance due to time, space and infrastructure limitations, so advised to test the genotypes at multi locations.

CONCLUSION

Leaf glossiness being a highly heritable character under additive genetic control, with less environmental influence can be used as a selection criterion for development of shoot fly resistant genotypes which acts through non-preference to oviposition. Recombination breeding with simple techniques of pedigree method of selection can be employed for improvement in glossy trait and there by shoot fly resistance. Parents PA4, PR1 and PR2 found good general combiners for shoot fly resistance contributing traits. These parents may be used in breeding crosses for shoot fly resistance development and directly as parents in hybrid development program. The crosses PA4 X PR1, PA4 X PR7, PA7 X PR1, PA5 X PR3, PA4 X PR2 may be tested further at more number of locations and tried for commercial cultivation.

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LITERATURE CITED

1. Satish K, Srinivas G, Madhusudhana R, Padmaja PG, Reddy RN, Mohan SM, Seetharama N. 2009. Identification of quantitative trait loci for resistance to shoot fly in sorghum [*Sorghum bicolor* (L.) Moench]. *Theor. Appl. Genetics* 119(8): 1425-1439.

2. Sharma HC, Taneja SL, Kameswara Rao N, Prasada Rao KE. 2003. Evaluation of sorghum germplasm for resistance to insect pests. Information Bulletin No. 63. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi–Arid Tropics. ISBN 92-9066-458-4. Order code IBE 063. pp 184.
3. Kempthorne O. 1957. *An Introduction to Genetic Statistics*. John Wiley and Sons, Inc., New York.
4. Sharma HC, Dhillon MK, Reddy BVS. 2006. Expression of resistance to *Atherigona soccata* in F_1 hybrids involving shoot fly-resistant and susceptible cytoplasmic male-sterile and restorer lines of sorghum. *Plant Breeding* 125: 473-477.
5. Dhillon MK, Sharma HC, Reddy BVS, Singh R, Naresh JS. 2006. Inheritance of resistance to sorghum shoot fly, *Atherigona soccata*. *Crop Science*, ISSN: 0011-183X. https;//www.thefreelibrary.com/-/print/PrintArticle.aspx?id=1461125276.
6. Deshpande VP, Kamatar MY, Kathnalli DS, Malleshappa SM, Nayakar NY. 2003. Screening of sorghum genotypes against shoot fly. *Indian Jr. Plant Protection* 31(1): 91-93.
7. Jayanthi PDK, Reddy BVS, Reddy DDR, Gour TB, Nwanze KF. 1996. Genetics of shoot fly resistance in sorghum hybrids of cytoplasmic male sterile lines. Page 152 *in* Abstracts of poster sessions: 2nd International Crop Science Congress: Crop Productivity and Sustainability – Shaping the Future, New Delhi, India, 17–24 Nov 1996. New Delhi, India: National Academy of Agricultural Sciences, Indian Council of Agricultural Research.
8. Reddy BVS, Rattunde HFW, Stenhouse JW. 1997. Breeding sorghums for insect resistance. Pages 115–126 *in* Plant resistance to insects in sorghum (Eds) Sharma HC, Faujdar Singh and Nwanze KF. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.
9. Sajjanar GM. 2002. Genetic analysis and molecular mapping of components of resistance to shoot fly (*Atherigina soccata* Rond.) in sorghum [Sorghum bicolour (L.) Moench]. *Ph. D. Thesis*, submitted to the University of Agricultural Sciences, Dharwad in partial fulfilment of the requirements for the Degree of Ph. D. in Genetics and Plant Breeding.
10. Sivakumar C, Sharma HC, Lakshmi Narasu M, Pampapathy G. 2008. Mechanisms and diversity of resistance to shoot fly, *Atherigona soccata* in *Sorghum bicolor*. *Indian Jr. Plant Protection* 36: 249-256.
11. Syed AJ, More AW, Kalpande HV. 2017. Character association studies in sorghum [*Sorghum bicolor* (L.) Moench] germplasm lines for shoot fly resistance parameters. *Int. Jr. Curr. Microbiol. App. Science* 6(12): 298-302.
12. Dhillon MK, Sharma HC, Singh R, Naresh JS. 2006. Influence of cytoplasmic male-sterility on expression of physico-chemical traits associated with resistance to sorghum shoot fly, *Atherigona soccata* (Rondani). *SABRAO Jr. Breeding and Genetics* 38: 105-122.
13. Agrawal BL, Abraham CV. 1985. Breeding sorghum for resistance to shoot fly and midge. Proceedings of the international sorghum entomology workshop, 15-21 July 1984, Texas A & M University, College Station, Texas, USA. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics, 371-383.
14. Aruna C, Padmaja PG. 2009. Evaluation of genetic potential of shoot fly resistant sources in sorghum (*Sorghum bicolor* (L.) Moench). *Journal of Agricultural Science* 147: 71-80.
15. Maiti RK, Prasada Rao KE, Raju PS, House LR. 1984. The glossy trait in sorghum: its characteristics and significance in crop improvement. *Field Crops Research* 9: 279-289.
16. Rana BS, Jotwani MG, Rao NGP. 1981. Inheritance of host plant resistance to sorghum shoot fly. *Insect Sci. Appl*. 2: 105-100.
17. Kumar S, Singh R, Kumar S. 1996. Combining ability for shoot fly resistance in sorghum. *Crop Improvement* 23(2): 217-220.