Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(6): 2242-2244
Received: 01-09-2018
Accepted: 03-10-2018

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Genetic diversity analysis for shoot fly tolerance traits in *Rabi* sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract
Mahalanobis D^2 statistics was applied to assess the divergence among 121 *Rabi* sorghum genotypes. The analysis of variance revealed significant differences among the genotypes for all the traits studied. Among the 12 quantitative characters studied trichome density on lower leaf surface contributed maximum (34.60 %) to the total divergence. All the genotypes were grouped into seven clusters, cluster I was the largest with 74 genotypes, followed by cluster II (29 genotypes), cluster III (10 genotypes), cluster IV (5 genotypes), remaining clusters, *viz.*, cluster V, VI and VII were solitary in nature. Maximum intra cluster distance was shown by cluster IV (5.06), and the maximum inter cluster distance (10.91) was noticed between the clusters III and VII indicating that the crosses between accessions of these different clusters could manifest heterosis and better recombinants after hybridization.

Keywords: *Rabi* sorghum, shoot fly, D^2 analysis, genetic diversity

Introduction
The major constraints in cultivation of sorghum during *Rabi* (post-rainy) season apart from abiotic stresses and among different major insect pests, the sorghum shoot fly, *Atherigona soccata* Rondani is the most destructive one and it can causes 50 - 90 % yield reduction in *Rabi* sorghum (Jotwani, 1983 [1]; Rao and Gowda, 1967 [2]). Sorghum is primarily grown under subsistence farming. Lower yields of sorghum have been attributed to a number of factors; among them the loss caused by the insect pests has been considered as one of the important factors for lower production. The shoot fly resistance like any other quantitative trait is a complex and polygenically controlled. Hence, the expression of these traits is likely to be affected to a greater extent by environmental factors. Existence of genetic diversity is an essential requirement of successful hybrid breeding programme. Perhaps one of the reasons why the *Rabi* hybrid programmes have not made sufficient head way is lack of systemic assessment of genetic diversity before using in the hybrid combination. To predict the genetic worth of a plant, a thorough understanding of the genetic diversity would help in developing sound plant improvement programmes and also to measure the genetic distance among the breeding lines and to identify characters responsible for such divergence.

Material and methods
The present investigation was carried out during *Rabi* season 2013-14 at Regional Agricultural Research Station, Vijayapur (Karnataka, India). A total of 121 genotypes (IS lines, selected B and R lines) along with checks collected from All India Co-ordinated Sorghum Improvement Project, RARS, Bijapur were used for the study. The design adopted was Randomized Block Design with two replications, with a spacing of 60 x 15 cm. Three competitive plants were selected randomly from each row in each replication for recording seedling height and trichome density but characters *viz.*, leaf glossiness, oviposition (%) and dead hearts (%) were recorded on plot basis. Recommended package of practices were followed but plant protection measures were avoided to build up shoot fly pressure. To attain uniform shoot fly pressure under field condition the "inter land fish meal technique" (Soto, 1974) [3] was followed. The data was subjected to statistical analysis using Mahalanobis, (1936) [4] D^2 statistics and Tocher's method (Rao, 1952) [5] for determining group constellation. Average inter and intra cluster distances were estimated as per the procedure outlined by Singh and Chaudhary (1977) [6].

Results and Discussion
The mean sum of squares of different characters pertaining to shoot fly tolerance and its components were highly significant for all the 12 characters studied indicating greater

distinctness among 121 *Rabi* sorghum genotypes (Table 1). Genetic divergence in the population, especially in respect of the character in which improvement is sought for, is a pre requisite for successful plant breeding work. The 121 genotypes were grouped into 7 clusters (Table 2), among the 7 clusters, cluster I was the largest with 74 genotypes, followed by cluster II (29 genotypes), cluster III (10 genotypes), cluster IV (5 genotypes), remaining clusters, viz., cluster V, VI and VII were solitary in nature. It signifies that cluster may contain the genotypes from different origins or genotypes from different origins may be grouped into single cluster. The genotypes of solitary clusters may be of distinct and unique, therefore these can be useful in further breeding programme.

Table 1: ANOVA for shoot fly resistance and its components in 121 *Rabi* sorghum genotypes (IS lines, selected B and R lines).

Traits	Replication	Genotypes	Error	S.Em.±	CD 5%
Degrees of freedom	1	120	120		
	Mean squares				
Leaf glossiness	0.41	0.96**	0.35	0.41	1.17
Seedling height at 14 DAE (cm)	28.76	30.69**	16.25	2.84	7.98
Seedling height at 21 DAE (cm)	9.17	52.64*	38.46	4.37	12.28
Seedling height at 28 DAE (cm)	41.10	46.83**	14.85	2.71	7.63
Oviposition % at 14 DAE	30.94	472.75**	15.19	2.76	7.72
Oviposition % at 21 DAE	248.28	307.85*	216.30	10.40	29.12
Oviposition % at 28 DAE	511.29	323.89*	224.16	10.59	29.64
Dead heart % at 14 DAE	68.05	200.30**	89.74	6.70	18.76
Dead heart % at 21 DAE	172.83	440.39**	149.62	8.65	24.22
Dead heart % at 28 DAE	297.72	360.82**	222.56	10.55	29.54
Trichome density on upper leaf surface (no./mm^2)	34.39	407.17**	25.59	3.56	10.02
Trichome density on lower leaf surface (no./mm^2)	267.58	1708.91**	68.95	5.85	16.44

* - Significant at 5%, ** - Significant at 1%; Leaf glossiness (1-5 scale): 1-high intensity of glossiness & 5- non-glossiness; Estimates for percentage data are based on angular transformations, DAE – Days after emergence

Table 2: Distribution of 121 *Rabi* sorghum genotypes in 7 clusters for shoot fly resistance and its component traits

Cluster No.	No. of genotypes	Name of the genotypes
I	74	IS 4578, IS 2872, BL–9, DS -5, CSV - 22 (5), BJV-44, IS 33763, RL- 12, LG-34, IS 40820, NIC 12, RL-7, IS 6351, RL-1, IS 30443, M 35-1 (2), IS 40772, EP 117, IS 40180, IS 40251, CSV-29R, RL-11, LG-11, M - 35-1 (7), BL-1, RL-15, RL-8, EP 97, RL-10, IS 5676, RL-21, RL-6, IS 40209, RL–9, IS 40752, LG-1, M 35-1 (4), IS 29914, BL-2, M 35-1 (1), RL-22, Phule Anuradha -3, EP 87, R-5, RL-25, RL-26, M 35-1 (6), RL-4, IS 40798, IS 40180, RL-3, LG 48, IS 33845, IS 40791, BL-12, CSV 22 (2), Phule Anuradha -1, IS 40824, Br -33, PEC 7, 5-4-1, BL-5, BL-6, IS 27912, RL-17, BL-11, RL-13, BL-14, IS 4698, IS 33756, IS 33853, RL-14, BL-4, IS 36377
II	29	IS 29314, IS 29654, BL-19, RL-19, IS 5295, IS 4951, Phule Anuradha -2, RL-24, LG 47, CSV 22 (4), BL-10, IS 16151, RL-20, IS 30508, Phule Maulee -1, RL-17, IS 13549, IS 5919, RL-16, BL-3, Phule Anuradh -4, Phule Maulee-3, IS 25732, IS 7679, IS 40799, IS 30451, BL-8, IS 40805, Phule Maulee -2
III	10	IS 40245, BL-13, CSV 22 (1), EP 94, IS 4576, EP 59, M 35-1 (5), M 35-1 (3), IS 40813, IS 40778
IV	5	IS 3121, IS 26025, EP 61, CSV 22 (3), BL-7
V	1	LG 33
VI	1	IS 2902
VII	1	IS 22720

The average D^2 values of intra and inter cluster distances are given in Table 3. The inter cluster distances were higher than the intra cluster distances indicating the presence of wider genetic diversity between the clusters rather than within the clusters. The intra cluster distances varied from 0.00 (cluster V, VI, VII) to 5.06 (cluster IV) revealing the presence of divergent genotypes within different clusters. Maximum intra cluster distance among the genotypes was shown by cluster IV (5.06) followed by cluster II (4.83), cluster III (4.45) and cluster I (3.82). The inter cluster distance varied from 5.83 to10.91. The maximum inter cluster distance (10.91) was noticed between the clusters III and VII. The maximum inter cluster distance suggests that the genotypes belonging to these clusters indicating that these groups were genetically most divergent, if chosen for further breeding programme, they are likely to give higher performances. Similar higher value of inter cluster was recorded between cluster I and VII which indicates that genotypes included in these clusters also possess considerable genetic diversity among themselves.

Table 3: Average D^2 values of intra and inter cluster distances for *Rabi* sorghum genotypes

Cluster	I	II	III	IV	V	VI	VII
I	3.82	7.00	5.85	10.18	5.83	6.70	10.46
II		4.83	7.32	6.53	7.10	6.66	7.03
III			4.45	8.75	7.07	8.78	10.91
IV				5.06	10.10	9.42	7.30
V					0.00	6.75	10.34
VI						0.00	8.43
VII							0.00

Diagonal values indicates intra cluster distances and off diagonal indicates inter cluster distances.

The cluster mean values estimated over genotypes for twelve characters related to shoot fly resistance and its components; overall character wise score across the 7 clusters are presented in Table 4. The cluster I with 74 genotypes and cluster V (1 genotype) ranked first and second respectively, these genotypes appears to be most potential one because these genotypes recorded high intensity of leaf glossiness, lower oviposition and dead heart infestation and higher number of trichome per mm^2 on both upper and lower leaf surface and could be selected for further breeding programme. Glossy cultivars were more resistant to *Atherigona soccata* than non-glossy cultivars (Halalli, 1985) [7]. Expression of glossiness in seedlings is an important component trait of shoot fly resistance in sorghum (Agarwal and House, 1982) [8] and it can be used as simple and reliable selection criteria for shoot fly resistance (Maiti and Gibson, 1983) [9]. Resistant cultivars possess trichomes on the abaxial surface, which act as physical barriers to penetration of young maggots (Mote, 1986) [10].

Among the 12 quantitative characters studied trichome density on lower leaf surface contributed maximum (34.60 %) to the total divergence (Table 5). This was followed by trichome density on upper leaf surface (28.57 %) and oviposition percentage at 14 DAE (24.67 %) remaining characters did not contribute significantly to the total divergence. The clusters contributing maximum to the divergence were given greater emphasis for deciding the type of cluster for the purpose of further selection and the choice of parents for hybridization. Similar findings for Contribution of characters towards the divergence were recorded by (Omori, 1988) [11].

Table 4: Mean values of 7 clusters in 121 *Rabi* sorghum genotypes for shoot fly resistance and its components

Cluster	Leaf glossiness	Seedling height at 14 DAE	Seedling height at 21 DAE	Seedling height at 28 DAE	Oviposition % at 14 DAE	Oviposition % at 21 DAE	Oviposition % at 28 DAE	Dead heart % at 14 DAE	Dead heart % at 21 DAE	Dead heart % at 28 DAE	Trichome density on upper leaf surface	Trichome density on lower leaf surface	Overall score	Rank
I	3.55 (2)	26.23 (1)	37.40 (3)	48.71 (3)	4.29 (2)	20.48 (2)	13.91 (3)	2.63 (2)	5.54 (1)	20.64 (2)	33.79 (2)	91.50 (2)	25	1
II	4.02 (4)	22.68 (4)	33.29 (6)	46.32 (5)	18.73 (5)	38.56 (5)	27.72 (6)	11.17 (7)	20.28 (2)	37.18 (5)	12.31 (5)	42.64 (5)	59	6
III	3.55 (2)	24.26 (3)	35.33 (4)	48.32 (4)	34.58 (6)	35.08 (3)	26.00 (4)	4.50 (3)	29.20 (4)	31.11 (3)	34.92 (1)	95.61 (1)	38	3
IV	4.60 (5)	21.40 (5)	32.01 (7)	42.12 (7)	47.33 (7)	40.26 (6)	27.69 (5)	10.83 (6)	44.77 (5)	43.98 (6)	11.60 (6)	21.51 (6)	71	7
V	3.00 (1)	19.60 (6)	44.10 (1)	64.10 (2)	14.59 (3)	3.85 (1)	7.69 (2)	7.69 (4)	57.69 (7)	7.69 (1)	17.22 (4)	76.08 (3)	35	2
VI	4.00 (3)	17.00 (7)	33.50 (5)	44.00 (6)	0.00 (1)	41.67 (7)	0.00 (1)	0.00 (1)	50.00 (6)	100.00 (7)	20.14 (3)	52.80 (4)	51	4
VII	5.00 (6)	25.85 (2)	41.50 (2)	69.20 (1)	16.67 (4)	35.72 (4)	28.58 (7)	8.34 (5)	21.43 (3)	35.72 (4)	2.49 (7)	6.88 (7)	52	5

Figures in the parenthesis indicate the ranks based on cluster mean. For Leaf glossiness, Oviposition & Dead heart grade given smallest to largest, while for the rest largest to smallest. Overall score is the summation of rank numbers for 12 characters. Leaf glossiness (1-5 scale): 1-high intensity of glossiness & 5-non-glossiness

Table 5: Per cent contribution of shoot fly resistance and its component traits towards divergence in 121 *Rabi* sorghum genotypes.

S. No.	Traits	Times ranked	% contribution
1.	Leaf glossiness	182	2.51 %
2.	Seedling height at 14 DAE	104	1.43 %
3.	Seedling height at 21 DAE	35	0.48 %
4.	Seedling height at 28 DAE	285	3.93 %
5.	Oviposition % at 14 DAE	1791	24.67 %
6.	Oviposition % at 21 DAE	62	0.85 %
7.	Oviposition % at 28 DAE	34	0.47 %
8.	Dead heart % at 14 DAE	114	1.57 %
9.	Dead heart % at 21 DAE	17	0.23 %
10.	Dead heart % at 28 DAE	50	0.69 %
11.	Trichome density on upper leaf surface	2074	28.57 %
12.	Trichome density on lower leaf surface	2512	34.60 %
Total		7260	100.00

The genotypes which have shown high intensity of leaf glossiness (LG 33), high trichome density (IS 40245, BL – 13, EP 94, IS 4576, EP 59, IS 40813, IS 40778) and low oviposition percentage (IS 3121, IS 26025, EP 61, BL – 7) can be used in development of shoot fly tolerant cultivars. The most divergent genotypes B lines *viz.*, BL 1, 2, 4, 5, 6, 9, 12, 17, 11, 14 (cluster I) R lines *viz.*, RL 16, 17,19, 20, 24 (cluster II) can be used to develop new hybrids with enhance levels of shoot fly tolerance after conversion of B lines in to male sterile lines. The solitary clusters in both the shoot fly tolerance (clusters V, VI and VII) and yield component traits (clusters V, VII, VIII and IX) are very distinct from rest of the genotypes, hence can be used extensively in future breeding programme. The greater divergence in the present materials due to leaf glossiness, high trichome density and lower oviposition will offer a good scope for improvement of resistant against shoot fly through rational selection of parents for producing heterotic sorghum hybrids.

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