SEED SETTING ABILITY AND STIGMA RECEPTIVITY IN POSTRAINY SORGHUM VARIETIES UNDER COLD STRESS

P SANJANA REDDY, JV PATIL, SUNIL GOMASHE, T PHANI KRISHNA

Abstract: Postrainy season grown sorghum is an important crop for food and fodder security in semi-arid tracts of India where other crops are not available for this specific environmental niche. However, an yield plateau is reached for postrainy sorghum as it is dominated by land races or purelines from land race based crosses. Hybrids developed for the postrainy sorghums were not successful with poor set when crop experiences low night temperatures being one of the reasons among several others. With an objective to evaluate the existing genotypes for tolerance to cold stress, 186 crosses made among 20 genotypes were studied for seed set% and 17 of the 20 genotypes evaluated for agronomic and yield traits during 2011 postrainy season. The seed set% was good in CSV 8R, Phule Anuradha, Phule Chitra, Phule Vasudha, PKV Kranti, SPV 1595 when used as both male (good pollen viability) and female parents (good stigma receptivity) indicating their tolerance to cold stress. The pollen germinability and stigma receptive traits of a genotype were not associated with grain yield and were independently inherited in this study. The taller plants had greater receptive stigmas while the plants with more leaf width had good germinable pollen.

Introduction: Sorghum is the fifth important cereal crop in the world grown for food, feed, fodder, fuel and fiber. Due to its hardiness and adaptation to wide range of climatic conditions, it is considered as a crop of future. India has largest area under sorghum cultivation (6.32 mha) which is about 16.7% of the world's area. However, it ranks fourth in production (6.01 mtons) with the leading countries in production being Mexico (6.97 mtons), Nigeria (6.9 mtons) and USA (6.27 mtons). The productivity of India (951 kg/ha) is way behind the world's average of 1535 kg/ha [1]. In India, sorghum is grown in both rainy and postrainy seasons. The rainy sorghum crop is usually caught in rains during maturity disposing the grain to attack by various grain mold fungi affecting grain yield and quality. In contrast, the postrainy sorghum is grown under residual moisture conditions and the crop is highly valued for both grain and fodder. The cultivar requirements are diverse for these to crops [2]. About 90% of the rainy sorghum area is dominated with hybrids and this has led to rapid increases in productivity gains as against postrainy season sorghum area which is dominated with varieties that are mostly pureline selections from landraces or landrace based crosses.

The reasons for the failure of hybrids in postrainy season are many. Several studies in the past have indicated only modest levels of heterosis for economic traits in post rainy season sorghum as most of the parents utilized in post-rainy hybrid programs were related by descent. The hybrids developed and released did not attract the farmers as these hybrids lacked matching grain quality, and shoot fly resistance comparable to the most popular landrace variety, M 35-1 [3]. Also poor seed setting mainly caused due to low temperatures prevailing during anthesis is observed in hybrids. Tolerance to early and midseason cold temperature is needed for increasing production in temperate and tropical sorghum production areas around the world, where the plants experience cold stress during emergence and/or anthesis [4]. When minimum temperatures goes below 12ºC to 15 ºC during flowering, hybrids that are otherwise male fertile show male sterility as evidenced by partial to complete absence of seed set under bagging [5]. Therefore, greater attention is required to ascertain the differences among the landraces for their ability to restore fertility in hybrids, especially under low temperatures, normally observed in post-rainy season. By eliminating temperature sensitivity (in relation to development) in both male and female parents, greater success could be achieved in breeding hybrids for post-rainy season. Thus, there is a need to study the existing postrainy sorghum varieties for their pollen viability and stigma receptivity and ultimately seed setting capability for their further exploitation in breeding. Hence the current study was taken up to study the tolerance of pollen and stigma to cold stress in a series of crosses involving postrainy sorghum varieties, R-lines and comparing with a rainy season adapted restorer.

Material and methods: A total of 186 crosses were made between 20 genotypes that include 16 postrainy varieties, 2 postrainy restorers (AKR 354, RS 585), 1 rainy season adapted restorer (C 43) and 1 stay green source (E 36-1). Pollination was carried out for three consecutive days to ensure all the emasculated florets are pollinated. The seed set data was recorded as % seed set. The temperature during the entire crossing period recorded below 15^{o}C.

About 17 of the above 20 genotypes were included in the augmented design wherein a large set of genotypes were evaluated for grain yield and agronomic traits during 2011 postrainy season at Rajendranagar, Hyderabad. Days to flowering was recorded as the time taken in days when 50% of the plants in a plot showed anthesis. Plant height was recorded as the height from the base of the plant to the tip of the panicle in cm. Leaf length, leaf width, panicle length, panicle width were recorded in cm on 3 plants and average taken. The primaries were counted on three panicles and average taken. Stay-green score was taken on a 1 to 5 scale where 1= <10% of the leaf area showing senescence and 5=>90% of the leaf area showing senescence. Lodging score taken on a 1 to 5 scale where 1= none of the plants showing lodging and 5= >90% of the plants lodged. Aphid tolerance score taken on a 1 to 5 scale where 1= plants free from aphids and 5=>90% of the plant area blackened due to formation of molds on aphid secretions. All the panicles in a plot were harvested and weight recorded. The weight was divided by number of panicles to obtain panicle weight per plant in grams. Similarly grain yield per plant & fodder yield per plant were recorded in grams. The data was analysed for augmented design using Genstat 12th ed.

Results and Discussion:Stigma receptivity and pollen germinability: Assuming that seed development is an efficient way to measure stigma receptivity [6] and pollination success [7], seedset% was measured. Seedset% in the postrainy varieties when used as seed parents ranged from 45% (CSV 14R) to 94% (CSV 216R) and when used as pollen parent ranged from 53% (CSV 216R) to 90% (CSV 1829) (Table 1). The seed set % in the postrainy restorers when used as seed parent was 48 to 50% and when used as pollen parent was 36 to 80%. The seed set% in the rainy season adapted restorer C 43 and stay green source E 36-1 was low (21 to 50%) when used as either seed or pollen parent indicating susceptibility to cold stress. Overall, seed set was low in E 36-1, C 43, AKR 354 when used as both male and female parents indicating their susceptibility to cool temperatures (Table 1). The seed set was good in CSV 8R, Phule Anuradha, Phule Chitra, Phule Vasudha, PKV Kranti, SPV 1595 when used as both male and female parents indicating their tolerance to cold stress. Seed set was moderate in DSV 4, DSV 5, M 35-1, SPV 1411, Phule Maulee, Phule Revati when used as both male and female parents. Seed set was good in CSV 14R and RS 585 when used only as pollen parent indicating poorly receptive stigmas may be one of the factor while it was good in CSV 18R, CSV 216R was good when used only as seed parent indicating poor pollen viability in these genotypes.

Table 1. Seed set in crosses made involving 20 genotypes of sorghum during 2011 postrainy season

Variety	As seed parent	As pollen parent
CSV 8R	89 (7)	87 (6)
CSV 14R	45 (4)	83 (8)
CSV 18R	80 (13)	66 (13)
CSV 1829	90 (3)	90 (2)
CSV 216R	94 (8)	53 (11)
DSV 4	76 (15)	62 (10)
DSV 5	67 (9)	69 (8)
M 35-1	66 (8)	70 (10)
SPV 1411	74 (10)	78 (14)
Phule Anuradha	93 (12)	84 (9)
Phule Chitra	81 (12)	78 (10)
Phule Vasudha	82 (11)	78 (11)
Phule Maulee	72 (10)	73 (14)
Phule Revati	60 (7)	77 (10)
PKV Kranti	87 (10)	81 (12)
SPV 1595	88 (7)	78 (9)
E 36-1	21 (8)	50 (6)
C 43	48 (13)	33 (3)
RS 585	50 (7)	80 (11)
AKR 354	46 (12)	36 (10)

Figures in parenthesis indicate the number of crosses involving the parent

Mean performance: From the 20 genotypes, 17 genotypes including 14 postrainy varieties, 2 postrainy restorers (RS 585, AKR 354) and a rainy season adapted restorer (C 43) were evaluated for grain yield and agronomic traits in augmented design and their adjusted means are presented in Table 2. The genotypes showed wide variability for all the traits. The days to flowering ranged from 67 to 84, plant height from 110 to 300 cm, leaf length from 8 to 80 cm, leaf width from 6.5 to 9.7 cm, stay-green score from 1.0 to 5.0, lodging score from 1.0 to 3.5, aphids score from 1.5 to 4.5, panicle weight/ plant from 26 to 119g, panicle length from 16.3 to 27.8 cm, panicle width from 4.5 to 8.0 cm, number of primaries from 37 to 100, grain yield/ plant from 3.7 to 98g and dry fodder per plant from 60 to 248g (Table 2). The postrainy variety CSV 216R had the best stigma receptivity of 94% and also had good grain yield of 95.5g/ plant which was the second best. In contrast, AKR 354 which had poor stigma receptivity of 46% had highest grain yield of 98g/plant. Similarly RS 585 with stigma receptivity of 50% had a grain yield of 73.6g/ plant. However the poor stigma receptivity and pollen germinability of C 43 reflected in a poor grain yield of 13.7g/ plant. Thus the pollen germinability and stigma receptive traits of a genotype were not associated with grain yield and were independently inherited in this study. However, their associations in the F_1 hybrid population and the combining ability in the parents need to be studied as the seedset problem persists in the hybrids.

Table 2. Mean performance of the sorghum genotypes for agronomic and yield traits, 2011-12 postrainy season

S. No.	Genotype	Days to 50% flowering	Plant height (cm)	Leaf length	Leaf width	Stay green score	Lodging score	Aphid tolerance score	Panicle weight/ plant	Panicle length	Panicle width	No. of primaries	Grain yield/ plant	Dry fodder per plant
1	CSV 8R	74	230	73	8.3	3	1.5	4.5	74	18.8	5.3	58	55.6	120
2	CSV 14R	72	250	72	9.2	1.5	2	4.5	90	22.5	7.3	71	74.5	159
3	CSV 18R	77	300	72	9.7	2	2	3	119	21.7	6.5	68	94.6	225
5	CSV 216R	80	300	73	7.7	3	3	3	116	21.0	6.7	77	95.5	130
6	DSV 4	81	280	80	8.8	2.5	1	3.5	81	27.8	6.2	72	64.0	248
7	DSV 5	82	300	75	9.0	3	1	4	79	23.0	7.2	68	65.9	210
8	M 35-1	72	260	58	8.7	2.5	2	3.5	100	17.5	7.2	64	85.6	178
9	SPV 1411	80	260	73	7.7	4	2	3.5	81	17.8	5.8	66	65.3	118
10	Phule Anuradha	67	230	59	8.8	1	1.5	2.5	84	18.7	6.2	56	66.9	147
11	Phule Chitra	74	270	65	8.8	1.5	1	2.5	110	21.0	8.0	79	91.3	200
12	Phule Vasudha	77	290	77	8.8	1	1.5	1.5	110	20.7	6.3	74	87.7	195
13	Phule Maulee	71	260	63	8.2	1	2	2	75	20.0	6.3	66	61.7	155
14	Phule Revati	75	280	75	8.2	3	3.5	4	104	22.7	6.0	86	90.9	145
15	PKV Kranti	84	270	70	7.0	5	3.5	3	107	19.0	6.5	100	80.5	110
18	C 43	74	110	60	6.5	3	1	2	26	23.0	4.5	37	13.7	60
19	RS 585	70	190	64	7.3	2	1	2	87	18.3	7.0	59	73.6	160
20	AKR 354	72	220	63	7.0	2.1	1	1.5	117	16.3	7.7	68	98.0	202

Correlations: The taller plants had greater receptive stigmas while the plants with more leaf width had good germinable pollen. Pollen germinability did not correlate with stigma receptivity. Similar results were obtained while studying pollen characters of B and R-lines on crossing with A-lines in sorghum [8]. Though such studies were not made earlier and results reported, these results are needed to be further confirmed. Apart from pollen and stigma traits, other traits were also studied. Both grain and fodder yields assume equal importance in postrainy sorghums. Grain yield was positively and significantly associated with plant height, panicle weight, panicle width, number of primaries and dry fodder yield/ plant (Table 3). The dry fodder yield/ plant was positively and significantly associated with plant height, leaf width, panicle weight/ plant, panicle width and grain yield.

Conclusions: Significant differences ($P < 0.05$) were found among the tested genotypes for pollen germinability, stigma receptivity and other agronomic and yield traits. Pollen germinability did not correlate with stigma receptivity and both of them did not correlate with grain yield and other yield contributing traits. However the taller plants had better receptive stigmas. As compared to postrainy varieties, postrainy restorers and rainy restorer performed poor as seed parent or had poor stigma receptivity. Hence future focus may be for the development of crosses among the extreme performing genotypes for pollen and stigma traits and studying their combining ability.

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Table 3. Correlations among the sorghum genotypes for pollen germinability, stigma receptivity with agronomic and yield traits

	Days to 50% floweri	Plant height	Leaf length	Leaf width (cm)	Stay green score	Lodging	Aphid tolera	Panicle weig	Panicle len	Panicle wid	No. of pri	Grain yield/ plant	Dry fodder per	Stigma rece
Plant height (cm)	0.51*	1.00												
Leaf length (cm)	0.70**	0.60*	1.00											
Leaf width (cm)	-0.04	0.62**	0.33	1.00										
Stay green score	0.70**	0.02	0.26	-0.50*	1.00									
Lodging score	0.32	0.39	0.21	-0.11	0.46	1.00								
Aphid tolerance score	0.29	0.33	0.45	0.40	0.39	0.31	1.00							
Panicle weight/plant (g)	0.15	0.71**	0.23	0.31	-0.09	0.39	-0.05	1.00						
Panicle length (cm)	0.39	0.16	0.55*	0.34	-0.04	-0.08	0.30	-0.25	1.00					
Panicle width (cm)	-0.09	0.44	-0.09	0.31	-0.30	-0.10	-0.07	0.67**	-0.21	1.00				
No. of primaries	0.53*	0.72**	0.47	0.12	0.31	0.65**	0.19	0.71**	0.07	0.44	1.00			
Grain yield/ plant (g)	0.09	0.73**	0.22	0.35	-0.14	0.36	0.00	0.98**	-0.26	0.73**	0.69**	1.00		
Dry fodder per plant (g)	0.08	0.58*	0.31	0.66**	-0.44	-0.35	-0.02	0.51*	0.29	0.61**	0.25	0.55*	1.00	
Stigma receptivity	0.32	0.52*	0.24	0.30	0.09	0.28	0.09	0.28	-0.02	-0.14	0.31	0.22	0.03	1.00
Pollen germinability	-0.08	0.38	0.22	0.48*	-0.09	0.24	0.42	0.19	-0.13	0.12	0.34	0.23	0.04	0.38

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Senior Scientist, Director Scientist, PhD Scholar,
Directorate of Sorghum Research, Rajendranagar, Hyderabad
e-mail: sanjana@sorghum.res.in , jvp@sorghum.res.in
sunil@sorghum.res.in , phanikrishna.tp@gmail.com