Evaluation of sorghum genotypes for the stay-green trait and grain yield

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Introduction

Sorghum (*Sorghum bicolor*) is one of the major cereal crops in the semi-arid tropics where prolonged droughts are frequent. Water deficit is the major constraint to rainfed sorghum production worldwide. In India sorghum is primarily cultivated in two distinct seasons: June to October (rainy/*kharif*) and October to February (postrainy/*rabi*). The postrainy season crop is grown mostly on stored soil moisture on Vertisols over 5 million ha of the Deccan Plateau situated between 16° and 20° N and 74° and 80° E. Sorghum grain yields are increasing during the rainy season but have remained the same in postrainy season (Vidyabhushanam 1986). In postrainy season sorghum, fodder quality may suffer due to senescence as the crop is grown on residual moisture and often experiences severe terminal drought stress. Stay-green or non-senescence is an important trait associated with drought tolerance (Rosenow 1977). It is indicated by maintenance of green stems and upper leaves when water is limiting during grain filling. Sorghum genotypes with the stay-green trait continue to fill their grains normally even under limited water or moisture stress conditions (Duncan et al. 1981, Rosenow and Clark 1981, Borrell et al. 2000). Delaying the onset of leaf senescence and reducing its rate (ie, two components of the stay-green trait) offer an effective strategy for increasing grain production, fodder quality and grain crop residues particularly under water limited conditions. This article describes the effect of the stay-green trait on grain yield of 38 sorghum stay-green genotypes.

Materials and methods

One hundred and forty-six sorghum genotypes including three controls (E 36-1, M 35-1 and R 16) along with one improved variety (SPV 1359), *rabi* hybrid (CSH 13R) and *kharif* maintainer line (296B) were evaluated at four locations in India, Patancheru, Bijapur, Solapur and Rahuri, in unreplicated nurseries in the 2001 postrainy season for the stay-green trait. The data were recorded for agronomic traits including time to 50% flowering, plant height, plant agronomic score (1 = most desirable and 5 = least desirable) and stay-green score (1 = 0 to 10% leaves dried and 5 = >75% leaves dried) at maturity and analyzed using each location as a replication. Overall performance of the sorghum genotypes indicated that stay-green score ranged from 1.0 to 4.5 (mean 3.0; SE$\pm$0.49). Among the controls, E 36-1 showed an average score of 1.8 whereas R 16 and M 35-1 averaged 3.0 and 3.5, respectively. Among the genotypes evaluated, 56 recorded stay-green score less than the mean and 17 of them had score ≤2.0. Thirty-eight promising genotypes [13 varieties, 13 B-lines (maintainer lines) and 12 R-lines (restorer lines)] selected on the basis of their stay-green score and agronomic desirability in this trial were evaluated further at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru during the 2002 and 2003 postrainy seasons, with four controls (296B, a high-yielding rainy season adopted B-line used in the development of many commercial hybrids; M 35-1, a high-yielding landrace popular in postrainy season sorghum areas; E 36-1, stay-green cultivar; and R 16, fully senescent cultivar) in randomized complete block design (RCBD) in two replications under normal fertility conditions (80:40:0 NPK). Irrigation was given at sowing and as necessary during early crop growth stages, but stopped at 45 days after sowing (two weeks prior to flowering) so that moisture stress could develop after flowering. Thus, moisture stress became progressively more severe during plant growth. Data were recorded for time to 50% flowering, plant height, plant agronomic score (1 = most desirable and 5= least desirable), grain yield, 100-grain weight and stay-green score at maturity based on visual ratings (Wanous et al. 1991) using 1 to 5 scale (1 = 0 to 10% leaves dried and 5 = >75% leaves dried) based on the proportion of leaf area of normal sized leaves that had senesced and dried. The rate of senescence determines the maintenance of quality flowers and seed set (Xu et al. 2000).

Table 1. Mean sums of squares of sorghum stay-green lines trial evaluated during the 2002 and 2003 postrainy seasons at ICRISAT, Patancheru, India[1].

Source of variation	df	Grain yield (t ha^{-1})	Stay-green score	Time to 50% flowering (days)	Plant height (m)	Plant agronomic score	100-grain weight (g)
Year (Y)	1	0.132	20.720**	1672.024**	1.150**	26.720*	0.252
Error	2	0.480	0.0298	9.643	0.001	0.744	0.080
Genotype (G)	41	3.608**	1.384**	72.598**	0.302**	0.840**	0.685**
Y × G	41	2.937**	0.903**	18.487**	0.011	0.391**	0.130**
Error	82	0.233	0.213	3.972	0.009	0.098	0.041
Total	167						

1. * = Significant at 5% level; ** = Significant at 1% level.

Table 2. Correlation co-efficiencies of stay-green sorghum lines among agronomic traits over postrainy seasons in 2002 and 2003 at ICRISAT, Patancheru, India[1].

Trait	Time to 50% flowering (days)	Plant height (m)	Plant agronomic score	100-grain weight (g)	Grain yield (t ha^{-1})	Stay-green score
Time to 50% flowering (days)	1.000					
Plant height (m)	–0.130	1.000				
Plant agronomic score	–0.382*	–0.104	1.000			
100-grain weight (g)	–0.097	0.309*	–0.565**	1.000		
Grain yield (t ha^{-1})	–0.505**	0.268	–0.179	0.297	1.000	
Stay-green score	–0.079	0.288	0.045	0.120	0.485	1.000

1. * = Significant at 5% level; ** = Significant at 1% level.

Results and discussion

The data collected in the two seasons were subjected to ANOVA using GENSTAT 9.1 for assessment of the stay-green genotypes. Genotypic differences were highly significant for all the traits observed (Table 1). Years differed significantly for stay-green score, time to 50% flowering, plant height and plant agronomic score. Genotype × year interactions also differed significantly for all observed traits except plant height. Correlations revealed that the genotypes with early flowering produced more grain yield (significantly negative correlation) and tall genotypes produced bold grains (significantly positive correlation) (Table 2). The stay-green trait did not correlate with any other observed agronomic trait. The overall stay-green score of the genotypes ranged from 1.3 to 3.5 (SE±0.32). The stay-green control E 36-1 (Van Oosterom et al. 1996, Haussmann et al. 2002) recorded an average stay-green score of 2.0 with grain yield 4.55 t ha^{-1} (SE±0.34). Grain yield of the genotypes ranged from 1.91 t ha^{-1} to 5.75 t ha^{-1}, 100-grain weight from 2.04 g to 3.73 g, time to 50% flowering from 66 to 87 days and plant height from 0.9 to 2.2 m. The other controls, 296B and M 35-1 scored 2.5 and 3.0 for stay-green and 2.56 t ha^{-1} and 4.94 t ha^{-1} for grain yield, respectively. The highly senescent control R 16 had stay-green score 3.5 with grain yield of 4.47 t ha^{-1}. Three B-lines (ICSB 371, ICSB 405 and ICSB 677) were significantly superior to 296B and one variety (ICSV 21011) and one R-line (ICSR 21002) were significantly superior to M 35-1 for both stay-green and grain yield (Table 3). Among the selected B-lines, ICSB 371 was similar to E 36-1 for grain yield and stay-green whereas the other two B-lines were comparable with E 36-1 for stay-green only. The variety ICSV 21011 and R-line ICSR 21002 were significantly superior to E 36-1 for

Table 3. Performance of sorghum stay-green lines at ICRISAT, Patancheru, India during the 2002 and 2003 postrainy seasons.

Genotype	Grain yield (t ha^{-1})	Stay-green score[1]	Time to 50% flowering (days)	Plant height (m)	Plant agronomic score[2]	100-grain weight (g)
ICSV 21001	2.48	1.3	83	1.4	1.0	3.37
ICSV 21002	3.37	1.3	81	1.4	1.5	3.32
ICSB 351	2.51	1.3	81	1.4	2.0	2.29
ICSV 21013	3.47	1.5	75	1.5	1.5	3.21
ICSR 21009	2.80	1.5	76	1.5	1.8	3.43
ICSR 21011	2.61	1.5	77	1.0	1.8	3.00
ICSV 21003	3.40	1.8	76	1.0	2.0	2.99
ICSB 371	4.54	1.8	70	1.5	2.5	2.71
ICSB 405	3.79	1.8	72	1.1	1.5	3.21
ICSB 676	2.51	1.8	78	0.9	1.5	3.08
ICSR 21010	2.96	1.8	76	1.4	2.0	3.26
ICSB 702	2.54	1.8	77	0.9	1.8	3.11
ICSV 21010	3.53	2.0	69	1.1	2.0	2.33
ICSB 373	2.35	2.0	80	1.5	1.8	2.70
ICSB 375	2.21	2.0	79	1.6	1.5	3.14
ICSB 376	2.62	2.0	78	1.5	1.8	2.79
ICSB 677	3.58	2.0	74	1.0	1.8	3.33
ICSR 21012	3.78	2.0	74	1.1	2.0	2.75
ICSV 21008	2.80	2.3	71	1.5	2.0	3.69
ICSV 21012	4.45	2.3	74	1.6	1.5	3.47
ICSB 675	3.10	2.3	76	1.0	2.0	3.24
ICSB 678	4.11	2.3	77	1.0	1.5	2.97
ICSR 21004	4.10	2.3	78	1.4	1.0	3.68
ICSR 21007	1.91	2.3	77	1.3	2.5	3.04
ICSV 21005	2.57	2.5	83	1.3	1.8	3.40
ICSV 21011	5.29	2.5	73	1.6	1.5	3.29
ICSR 21005	4.04	2.5	78	1.3	1.0	3.64
ICSV 21004	3.47	2.8	80	1.2	1.0	3.71
ICSV 21006	3.39	2.8	74	1.4	1.8	2.83
ICSV 21007	4.00	2.8	79	1.4	1.3	3.38
ICSV 21009	3.25	2.8	76	2.2	1.8	3.73
ICSR 21003	3.81	2.8	79	1.2	1.0	3.46
ICSR 21006	4.61	2.8	78	1.4	1.0	3.51
ICSB 307	3.43	3.0	87	1.3	1.3	2.90
ICSB 589	2.21	3.0	83	1.5	2.3	2.04
ICSR 21002	5.75	3.0	76	1.7	1.3	3.71
ICSR 21001	4.91	3.3	74	1.5	1.8	3.12
ICSR 21008	4.87	3.3	73	1.1	2.8	2.37
Controls						
E 36-1	4.55	2.0	66	1.4	2.0	3.50
296B	2.56	2.5	78	1.0	2.5	3.06
M 35-1	4.94	3.0	70	2.1	1.5	3.61
R 16	4.47	3.5	69	1.6	2.5	3.30
Mean	3.52	2.26	76	1.35	1.71	3.16
SE±	0.34	0.32	1.40	0.07	0.22	0.14
CD (5%)	1.02	1.24	2.49	0.15	0.64	0.48
CV (%)	13.65	20.32	2.60	7.11	18.19	6.41

1. Scored on a 1 to 5 scale at maturity, where 1 = 0 to 10% leaves dried and 5 = >75% leaves dried.
2. Scored on a 1 to 5 scale, where 1= most desirable and 5 = least desirable.

grain yield, despite having numerically inferior (ie, highest) stay-green scores. Seed of these genotypes are available in small quantities from the ICRISAT Sorghum Improvement Program.

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