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Stability of new varieties for yield components in *rabi* sorghum *(Sorghum bicolor)*

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ABSTRACT

A study was conducted during 2004–07 to evaluate promising *rabi* (winter) sorghum *(Sorghum bicolor* (L.) Moench) to identify suitable genotypes for earliness, high grain and fodder yields. Genotype × environment interactions in 22 *rabi* (winter season) sorghum varieties were studied over 3 environments for flowering, maturity, grain and fodder yields. Significant differences were observed among environments and varieties for the characters. The G × E interactions for the characters was significant and the significant mean squares due to environment (linear) indicated the existence of real varietal differences in characters for regression over the environmental mean. The varieties, namely 'SLV 15', 'SLV 29', 'SLV 45' and 'CRS 1' were found stable for earliness and they can be directly used for breeding earliness. For improvement of grain yield, the varieties 'SLV 40', 'SLV 43', 'SLV 44', 'SLV 50' and 'SLV 51' were the most stable under rainfed situation. For both grain and fodder yields, the stable varieties were 'SLV 40', 'SLV 43', 'SLV 44' and 'SLV 51'.

Key words: Deviation from regression, Genotypes, G × E interaction, *Rabi* sorghum, Regression co-efficient

Genotype × environmental interaction has great significance in evaluating crop varieties over a wide range of environmental conditions. The information on G × E interaction leads to successful evaluation of stable genotypes which could be used either for general cultivation or in future breeding programme. Sorghum *(Sorghum bicolor* (L.) Moench) is one of the major crops for grain and fodder, which is widely grown in India under rainfed conditions. *Rabi* sorghum is grown over a total area of 5.6 million hectares mainly in the states of Maharashtra, Karnataka and Andhra Pradesh with average productivity of 719 kg/ha (NRCS 2008). In spite of such low productivity, *rabi* (winter season) sorghum continues to be an important component of dryland economy in these states with fairly consistent area over many years. One of the major reasons for instability in yield of rabi sorghum is due to the non-availability of stable genotypes. Breeding for earliness in rabi sorghum has also assumed great importance in order to escape the terminal drought. (Prabhakar 2002). Earlier workers (Gite *et al.* 2006, Narkhede *et al*. 1997) have identified few genotypes that are stable over environments. But, the studies were limited to few characters and locations only. The present study, therefore, was undertaken to evaluate promising genotypes over three environments in order to identify stable genotypes for earliness, high grain and fodder yields.

MATERIALS AND METHODS

The experimental material consisting of 22 *rabi* sorghum genotypes (newly developed varieties, viz 'SLV 15', 'SLV 25', 'SLV 27', 'SLV 29', 'SLV 34', 'SLV 35', 'SLV 40', 'SLV 41', 'SLV 42', 'SLV 43', 'SLV 44', 'SLV 45', 'SLV 46', 'SLV 47', 'SLV 50', 'SLV 51' and 'SLV 56' with check varieties 'Mauli', 'CSV 216R', 'CRS 1', 'CSV 14R' and 'M35 1') were grown in a randomized block design with 3 replications at Centre on *Rabi* Sorghum, Solapur during *rabi* seasons of 2004–05 to 2006–07 under rainfed conditions. The pedigrees of the new varieties used in the study are given in Table 1. Each plot consisted of 4 rows of 5 m length with a spacing of 45 cm × 15 cm. All the recommended package of practices for *rabi* sorghum was followed. The observations were made on 4 characters, viz days to flowering, days to maturity and grain and fodder yields in each plot. The data recorded for 3 seasons were analyzed for stability parameters as per the method suggested by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The analysis of variance for stability (Table 2) revealed significant differences among environments and genotypes for all the characters suggesting the presence of variation among genotypes and environments. The genotype × environment (G × E) interactions for all the 4 characters were

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Table 1 Pedigree of varieties

Variety	Pedigree
'SLV 15'	Selection from cross ('SPV 1537' × 'RS 585')
'SLV 25'	Selection from cross ('SPV 1375' × 'SPV 1155')
'SLV 27'	Selection from cross ('SPV 1155' × 'NIC 21275')
'SLV 29'	Selection from cross ('SPV 1376' × 'NIC 21240')
'SLV 34'	Selection from cross ('CSV 14R' × 'SPV 1537')
'SLV 35'	Selection from cross ('CSV 14R' × 'M35 1')
'SLV 40'	Selection from 'PEC 23'
'SLV 41'	Selection from 'IS 5256'
'SLV 42'	Selection from 'IS 3961'
'SLV 43'	Selection from 'PEC 11'
'SLV 44'	Selection from 'IS 33714'
'SLV 45'	Selection from 'EC 8'
'SLV 46'	Selection from 'PU 25'
'SLV 47'	Selection from 'PU 15'
'SLV 50'	Selection from 'EP 95'
'SLV 51'	Selection from 'IS 33844'
'SLV 56'	Selection from 'IS 3420'
'CRS 1' ('SPV 1537')	Selection from Hegari Landrace from hegari, Bijapur Tq, Bijapur district, Karanataka
'M35 1'	Selection from Maldandi Bulk
'CSV 14R'	'M35-1' ('CS 2947' × 'CS 2644') × 'M35-1'
'CSV 261R'	Selection from Dhulia germplasm
'Mauli'	Landrace selection from Ahmednagar district, Maharashtra

significant. The significant mean squares due to environment (linear) indicated the existence of real varietal differences in the characters for regression over environmental mean. A significant pooled deviation for grain and fodder yields indicated that the varieties differed considerably with respect to their yield stability. The results obtained in the present study are in agreement with the findings of Narkhede *et al*. (1997), Gite *et al*. (2006), Borole *et al.* (2007) and Patil *et al*. (2007) in *rabi* sorghum. The means (x) for the characters, namely days to flowering, maturity, grain and fodder yields along with 2 stability parameters, viz regression co-efficient (bi) and deviation from regression (s^2di) are presented in Table 4.

Days to flowering

Among 3 environments, the environment 2 (*rabi* 2005–06) with positive values of environment index (0.8052) appeared to be suitable for better indication of days taken for flowering of varieties. The crop experienced rainfall immediately after sowing during *rabi* 2005–06, hence, there was no stress during flowering (Table 3). The varieties which flowered early were 'SLV 15' (64), 'SLV 29' (64), 'SLV 45' (61), 'SLV 47' (63), 'CRS 1' (61) and 'Mauli' (66). However, the stable varieties for this character were 'SLV 15', 'SLV 29', 'SLV 45' and 'CRS 1', since they showed regression co-efficient values (1.09, 1.03, 0.97 and 0.99, respectively) near to unity with least non-significant deviation from regression (Table 4). The highly unstable varieties were 'SLV 34', 'SLV 47', 'SLV 51' and 'CSV 14R', since they showed significant deviation from regression. The varieties which showed bi value greater than unity with non-significant deviation from regression were 'SLV 25', ''SLV 35', 'SLV 40', 'SLV 46' and 'CSV 216R'. The performance of these varieties can be predicted and they could respond to favourable environments only. The varieties which could perform better under poor environments were 'SLV 42' and 'SLV 43'.

Days to maturity

The environment 3 (*rabi* 2006–07) was the favourable for knowing the clear indication of days taken for maturity of genotypes, since it showed positive value (0.8354) of environmental index. As the rains (93.4 mm) were received after flowering in *rabi* 2006–07, the genotypes did not receive any stress during maturity (Table 3).While considering the genotypes suitable for breeding earliness, the genotypes which matured early were 'SLV 15' (109), 'SLV 29' (110), 'SLV 34' (111), 'SLV 45' (108), 'SLV 47' (108) and 'CRS 1' (105). However, from stability point of view, the stable varieties for days to maturity were 'SLV 15', 'SLV 45' and 'CRS 1', since they showed bi values (1.04, 1.05 and 1.03, respectively) near to unity with least non-significant deviation from regression (Table 4). The highly unstable varieties were 'SLV 29', 'SLV 41', 'SLV 50', 'SLV 51' and 'CSV 14R', since they showed significant deviation from regression. The

Table 2 Anova for stability in *rabi* sorghum varieties over 3 environments

Source	DF	Days to flowering MSS	Days to maturity MSS	Grain yield (kg/ha) MSS	Fodder yield (kg/ha) MSS
Varieties	21	123.29**	87.98**	328 347.1**	492 520.5**
Environments	2	14.78**	13.63**	132 023.4**	211 236.8**
Varieties × environment	42	3.46**	4.28**	28 477.2*	48 410.9*
Environment (linear)	1	23.48**	26.48**	267 488.7**	414 606.4**
V × E (linear)	21	2.21*	2.78	938 533.8**	1126 239.6**
Pooled deviation (non-linear)	22	1.98*	3.01*	42 347.5*	59 285.8*
Pooled error	126	0.62	1.22	18 935.6	24 615.5

*P= 0.05, **P=0.01

Table 3 Rainfall received and its distribution during crop period in 3 different environments

Environment	Rainfall		Distribution		
	Actual	Normal	Aug.–Sept.	Oct.–Nov.	Dec.–Jan.
1	603.9	721.4	247.4	0.0	0.0
2	706.4	721.4	396.5	80.0	0.0
3	684.2	721.4	223.8	241.2	93.4

varieties which showed bi value greater than unity with non-significant deviation from regression were 'SLV 35', 'SLV 40', 'SLV 43', 'SLV 46' and 'M35 1'. The performance of these varieties can be predicted and they could respond to favourable environments only. The varieties which could perform better under poor environments were 'SLV 42', 'SLR 56' and 'Mauli'.

Grain yield

Among the 3 environments, enviorment 2 (*rabi* 2005–06) and enviorment 3 (*rabi* 2006–07) with high positive values of environmental indices (67.5802 and 3.9234, respectively) appeared suitable for better exploitation of grain yield of *rabi* sorghum. Good rains received during (*rabi* 2005–06) and after flowering (*rabi* 2006–07) helped the genotypes to perform better (Table 3). The environment 1 (*rabi* 2004–05) with high negative value of environmental index (–58.1356) was not suitable as there was severe moisture stress experienced during the crop period (Table 3). The varieties which gave higher mean grain yields over 3 years were 'SLV 40' (2 421 kg/ha), 'SLV 42' (1 956 kg/ha), 'SLV 43' (2 502 kg/ha), 'SLV 44' (2 335 kg/ha), 'SLV 50' (2 247 kg/ha), 'SLV 51' (2 188 kg/ha) and 'CSV 216R' (1 992 kg/ha). However, the results indicated that the varieties 'SLV 40', 'SLV 43', 'SLV 44', 'SLV 50' and 'SLV 51' were found most stable, since they showed regression co-efficient values (bi=0.98, 1.05, 0.99, 1.02 and 1.04, respectively) near to unity, least non-significant deviation from regression (s^2di values) and higher mean grain yield (Table 4). The highly unstable varieties were 'SLV 25', 'SLV 27', 'SLV 34', 'SLV 41' and 'SLV 56', since they indicated significant deviation from regression. The genotypes which showed bi values greater than unity and non-significant deviation from regression were 'SLV 35', 'SLV 42', 'SLV 45', 'SLV 46', 'CRS 1', 'M35 1', 'CSV 14R' and 'CSV 216R'. It means these varieties could perform better under favourable environment only. The

Table 4 Stability parameters for different characters in *rabi* sorghum varieties

Variety	Day to flowering			Days to maturity			Grain yield (kg/ha)			Fodder yield (kg/ha)		
	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di
'SLV 15'	64	1.09	1.18	109	1.04	– 1.13	1 404	–2.47	12 050	4 327	2.03	26 341
'SLV 25'	68	1.39	–0.94	115	0.42	0.48	1 699	0.48	65 320**	5 038	1.22	22 350
'SLV 27'	70	0.42	–0.35	117	0.84	2.32	1 803	1.53	58760**	6 250	2.04	45 320*
'SLV 29'	64	1.03	1.12	110	1.08	4.32**	1 398	–4.35	13 672	5 316	1.33	27 850
'SLV 34'	69	1.12	–3.8**	111	0.85	0.51	1 575	–5.62	65 359**	4 891	0.42	32 045
'SLV 35'	71	1.16	2.55	118	1.73	0.83	1 704	1.90	24 320	5 603	0.37	17 354
'SLV 40'	69	2.07	1.62	113	1.17	–1.24	2 421	0.98	12 745	5 437	1.03	18 702
'SLV 41'	73	1.43	–0.06	114	0.94	3.76**	1 822	–3.43	37 951*	5 943	1.23	86 723**
'SLV 42'	72	–1.87	–0.41	115	–0.49	2.31	1 956	1.43	10 063	5 478	0.54	56 730**
'SLV 43'	69	–1.52	0.51	117	2.53	–0.73	2 502	1.05	–27 083	5 697	0.97	17 340
'SLV 44'	76	1.52	–0.02	119	0.75	0.10	2 335	0.99	27 342	5 734	1.08	13 584
'SLV 45'	61	0.97	1.08	108	1.05	0.45	1 448	1.27	20 398	4 632	0.68	15 954
'SLV 46'	77	2.43	1.72	120	2.71	1.68	1 678	1.51	18 352	5 033	1.29	19 734
'SLV 47'	63	1.51	4.54**	108	0.77	1.29	1 420	–3.04	33 413	4 416	2.11	37 891*
'SLV 50'	78	0.93	2.33	122	3.54	–4.0**	2 247	1.02	23 750	5 456	1.19	14 342
'SLV 51'	76	1.58	4.38**	120	2.15	3.88**	2 188	1.04	–28 394	5 278	1.02	7 532
'SLV 56'	71	0.31	0.32	119	–1.28	4.01**	1 731	2.07	55 452**	5 849	4.23	23 798
'CRS 1'	61	0.99	–0.50	105	1.03	2.65	1 352	1.31	11 429	4 398	–5.34	12 031
'M35 1'	75	0.52	2.53	116	1.46	2.23	1 502	1.53	–21 579	5 523	3.73	12 853
'CSV 14R'	76	2.14	5.52**	117	2.53	3.98**	1 627	1.18	12 345	5 708	4.32	32 450
'CSV 216R'	83	1.43	–0.89	124	0.78	0.08	1 992	2.18	30 288	6 730	1.28	23 789
'Mauli'	66	1.49	–0.93	113	–2.11	0.41	1 387	1.67	12 389	4 821	1.23	11 920
Population mean	70.5			115			1 781			5 343		
Mean of B		0.997			1.041			1.002			1.015	

**P*= 0.05, ***P*=0.01

X Mean; bi, Regression co-efficient; S^2di, Deviation from regression

entries which can perform better under poor environments are 'SLV 15', 'SLV 29', 'SLV 34', 'SLV 41' and 'SLV 47'. The varieties 'SLV 43', 'SLV 40' and 'SLV 44' gave 25.6%, 21.5% and 17.2% more grain yield, respectively than the check variety 'CSV 216R'. The superiority of these varieties over 'M 35 1' ranged from 55.4 to 66.5%.

Fodder yield

Among the 3 environments, enviorment 2 (*rabi* 2005–06) and enviorment 3 (*rabi* 2006–07) with high positive values of environmental indices (56.3402 and 2.7865, respectively) appeared suitable for better exploitation of grain yield of *rabi* sorghum. Good rains received during (*rabi* 2005–06) and after flowering (*rabi* 2006–07) helped the genotypes to perform better (Table 4). The environment 1 (*rabi* 2004–05) with high negative value of environmental index (–47.9832) was not suitable due to severe moisture stress experienced during the crop period. The varieties which gave higher mean fodder yields over 3 years were 'SLV 27' (6 250 kg/ha), 'SLV 40' (5 437 kg/ha), 'SLV 41' (5 943 kg/ha), 'SLV 43' (5 697 kg/ha), 'SLV 44' (5 734 kg/ha), 'SLV 50' (5 456 kg/ha), 'SLV 51' (5 278 kg/ha), 'SLV 56' (5 849 kg/ha), 'CSV 14R' (5 708 kg/ha) and 'CSV 216R' (6 730 kg/ha). However the results indicated that the varieties 'SLV 40', 'SLV 43', 'SLV 44' and 'SLV 51' were found most stable, since they showed regression co-efficient values (bi=1.03, 0.97, 1.08 and 1.02, respectively) near to unity, least non-significant deviation from regression (s^2di values) and higher mean fodder yield. The highly unstable varieties were 'SLV 27', 'SLV 41', 'SLV 42' and 'SLV 47', since they indicated significant deviation from regression. The varieties which showed bi values greater than unity and non-significant deviation from regression were 'SLV 15', 'SLV 25', 'SLV 29', 'SLV 34', 'SLV 35', 'SLV 40', 'SLV 44', 'SLV 45', 'SLV 46', 'SLV 50', 'SLV 56' and 'M35 1', 'CSV 14R', 'Mauli' and 'CSV 216R'. It means these varieties could perform better under favourable environment only. The variety which performed better under poor environments was 'CRS 1'. The varieties 'SLV 43' and 'SLV 44' were superior by 3.1 and 3.8% over the check 'M 35 1', respectively. But they were statistically on with another check 'CSV 216R'.

Thus it can be concluded that the stable varieties that can be used directly for breeding earliness were 'SLV 15', 'SLV 29', 'SLV 45' and 'CRS 1'. For improvement of grain yield, the varieties 'SLV 40', 'SLV 43', 'SLV 44', 'SLV 50' and 'SLV 51' were the most stable under rainfed situation. The stable varieties for fodder yield were 'SLV 40', 'SLV 43', 'SLV 44' and 'SLV 51'. It is, thus, obvious, that we have to have different varieties for breeding for earliness, high grain yield and fodder yields. These varieties can be directly used in various breeding programmes for enhancing the *rabi* sorghum productivity.

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