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Research Article

Stability of yield and related traits in the land races of *rabi* sorghum (*Sorghum bicolor* (L.) Moench)

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Abstract
Forty five *rabi* sorghum land races were evaluated along with three checks M35-1, CSV 22R and Phule Chitra for three years (2011-2013) at ARS, Tandur to identify promising and stable donors for yield and related traits to be used in crossing programmes. Analysis of variance of pooled data over three years indicated significant differences among the genotypes and environments for days to 50% flowering, days to maturity, plant height, test weight, grain yield and fodder yield. Significant GxE interaction was observed for the six traits indicating differential response of the genotypes to different seasons. Environmental indices revealed early expression of flowering and early crop maturity in 2012 and 2013 respectively. The expression of plant height was good in 2013 and test weight, grain and fodder yields in the year 2011. This study identified that the land races Jamkhed local1 and RSV 1460 for breeding early duration types, RSV 1425 for improving the test weight, RS 1449 and Pusegaon local for grain yield improvement, Dharampur local, Nimbodi local, SSRG 170, SSRG 204, SSRG 203 and SSRG 236 for forage sorghum improvement are suitable.

Keywords
G x E interaction, Stability parameters, Regression coefficient, Environmental index

Introduction

Sorghum is the fifth most important cereal crop in the world after rice, wheat, maize and barley and is the staple food of more than 500 million people in the developing countries. Owing to its multiple uses as food, feed, fodder and biodiesel it is extensively cultivated. In India, *rabi* sorghum is being grown in an area of 4.8 million ha with a production of 4.1 millon tons and productivity of 971 kg/ha (Umakanth *et al*., 2012). Indian productivity is far less than the world average productivity (1.4t/ha) because of its cultivation under varied soil types in receding soil moisture conditions by resource poor farmers. Genetic improvement in *rabi* sorghum was hindered because of narrow genetic base and lack of phenotypic variability and stability among the breeding lines (Prabhakar, 2002).

Land races are primitive cultivars selected and cultivated by farmers for generations together for subsistence. They have wide genetic diversity, adaptability and high degree of resistance to biotic and abiotic stresses. Indian *rabi* sorghum landraces are rich repository of genetic variability that responds to selection. Variability in the *rabi* landraces was exploited in the development of popular cultivars like M35-1 (a selection from Maldandi landrace 75 years ago at Mohol in Maharashtra), CSV 216R (a landrace selection from Maharashtra released in 2000), Selection 3 (selection from Bidar local) and Phule maulee. Several landraces were being used as donors in parental line improvement in developing heterotic and quality *rabi* hybrids. (Reddy *et al*., 2006 and Sajjanar *et al*., 2009). The present investigation therefore, was carried out to identify promising and stable landraces for use as donors in the genetic improvement of dual purpose sorghum.

The most popular aid for stability estimation is the model proposed by Eberhart & Russel (1966). According to it a genotype is considered stable if it has a unit regression over the environments (b=1) and minimum deviation from regression (S2d = 0). A genotype with high mean yield over the environments, unit regression coefficient (b = 1) and minimum deviation from regression (S2di = 0) is preferable. High value of regression (bi>1) indicates that the variety is more responsive for input rich environment, while low value of regression (bi<1), is an indication that the variety may be adapted to poor environments.

Materials and methods

The experimental material consisted of 45 landraces of *rabi* sorghum collected from *rabi* sorghum growing areas of Karnataka and Maharashtra. The seed was obtained from the Indian Institute of Millets Research under the All India Coordinated Sorghum Improvement Project (AICSIP). The accessions primarily belong to the biological race *durra*. The varieties M35-1, CSV22R and Phule Chitra were used as checks. The field trial was conducted at

Agricultural Research station, Tandur in a randomized block design with three replications. Each genotype was represented by one row of 5m length with a spacing of 45 cm between rows and 15cm between plants in each replication. The soil type was deep black clayey loam. The crop was evaluated during *Rabi* 2011, 2012 and 2013 by following the standard package of practices. Ten randomly selected plants from each replication were used to record the data on days to 50 % flowering (days), days to maturity (days), plant height (cm), test weight (g), grain yield (kg) and fodder yield (kg).The pooled data of three years was subjected to analysis of variance. The stability parameters were computed after verifying the homogeneity of error variances following the Eberhart and Russell (1966) model. The environmental indices (*ei*) were computed as deviation of the environmental mean pooled over years from the population mean.

Results and discussion

The pooled analysis of variance (Table 1) revealed that mean sum of squares due to genotypes and environments were significant for the traits *viz.*, days to 50% flowering, days to maturity plant height, test weight, grain yield and fodder yield indicating the presence of variability among the genotypes as well as production environments. The G x E interaction for various traits was also significant indicating the differential response of the genotypes in different seasons. Significant genotypic environment interaction for various yield related traits was reported in *rabi* sorghum by Shivani *et al* (2014), Raghu rami reddy *et al* (2004), Santos *et al* (1995), Narkhede *et al* (1997), Khandelwal *et al* (2005), Prabhakar *et al* (2010) and Umakant *et al* (2012). Both linear and nonlinear components of G x E interaction were significant showing the importance of both linear (predictable) and non-linear (unpredictable) components in the expression of these traits. The linear component (GE linear) being predominant over the nonlinear component (pooled deviation) for the days to 50% flowering helps in predicting the performance of genotypes across environments. The non linear component was predominant over the linear component (GE linear) for the traits days to maturity, plant height, test weight, grain yield and fodder yield revealing the role of unpredictable factors in explaining the stability.

For trait days to 50% flowering, ten genotypes had non-significant deviation from regression indicating their stability in performance (RSV 1460, 1478, 1479, Jamkhed local 1, Jamkhed local 2, Nimbodi local, Bidar local, Bairadogi, SSRG147 and SSRG 206). Regression coefficients were less than 1 for four genotypes namely RSV 1460, RSV 1479, Nimbodi local and Bairadogi suggesting their suitability under low input or unfavourable environmental conditions. The genotypes RSV 1478, Jamkhed local 1, Bidar local, SSRG 147 and SSRG 206 had regression coefficients above 1 indicating their suitability under favourable or input rich conditions. None of the landraces were early, except Jamkhed local 1 (u=70 days) which is suitable under high input conditions (b=1.64) and RSV 1460 (u=71 days) suitable under low input conditions (b=0.8).

The genotypes recorded an overall mean of 119 days for maturity over the three environments. Six genotypes were found to be early and stable for crop duration. The four landraces Yadigir local, Jamkhed local 1, Bairadogi and Honawad 2 were suitable under low input conditions (b<1) while RSV 1460 and SSRG 170 were suitable to high input conditions (b>1).

The Plant height among the genotypes varied between 144 cm (SSRG 170) to 211.4 cm (SSRG 201) with an average of 183.4 cm. None of the genotypes except CSV 22R recorded unit regression coefficient. Four landraces were found to be stable for tallness. Aurad local and SSRG 201 were suitable under high input conditions (b>1), while SSRG 202 and SSRG 206 were suitable to low input conditions (b<1). The two landraces stable for reduced plant height namely RSV 1426 and SSRG 170 were suitable to low input conditions (b<1). These genotypes may be utilized in breeding semi dwarf non-lodging types.

The test weight among the genotypes varied between 2.68 g (SSRG 164) to 3.53g (RSV 1461) with an overall mean of 3.08 g. RSV 1425 (u=3.46g) recorded unit regression coefficient indicating average response to environmental conditions while RSV 1461(u=3.53g) was found suitable to low input conditions (b<1).

The grain yield among the landraces varied between 1050.2 Kg/ha (Mardi local) to 2173.1 kg/ha (Halyal local) with an average of 1678 kg/ha. Out of twelve landraces stable for grain yield, Halyal local and Mangalwedha local were found suitable to favourable environments (b>1) while RSV 1458 was found suitable to unfavourable environments (b<1). The landraces RSV 1449, Pusegaon local and the variety Phule chitra were suitable under average input conditions (b close to1) and hence can be used as donors in grain yield improvement of *rabi* sorghum. High stability of Phule Chitra for grain and fodder yields under diverse *rabi* situations was earlier

reported by Sanjana Reddy *et al* (2009). It was observed that the promising and stable landraces for various yield traits were more suitable to poor or low input environments as they were cultivated for generations together and hence have become adapted to such conditions. The landraces were known to have high yield stability with intermediate yield level under low input agricultural system (Zeven, 1998).

The fodder yield, landraces Halyal local and Mangalwedha local showed high mean yield and suitable under input rich environments (b>1) while Bidar local showed high mean yield and suitable to low input environments (b<1). The six landraces Dharampur local, Nimbodi local, SSRG 170, SSRG 204, SSRG 203 and SSRG 236 were stable under average input conditions(b=1) and hence can be deployed for breeding forage types.

The Environmental index helps in identification of favourable and unfavourable environments for the expression of a trait of interest. Estimates of environmental index (Table 3) revealed negative ei values for days to 50% flowering indicating early flowering by 5.2 days in 2012, while the genotypes flowered late by 3.6 days in 2011. Irrespective of the flowering the genotypes attained maturity 4.4 days early in 2013 but late by 4.3 days in 2012. The average plant height was reduced by 7.6 cm in 2012 while it increased by 4.7 cm in 2013. The mean test weight was lessened by 0.05g in 2012 but increased by 0.04g in 2011. The mean grain yield increased by 197 kg/ha in 2011 but decreased by 175 kg/ha in 2012. The mean fodder yield increased by 1253 kg/ha in 2011 but reduced by 1555 kg/ha in 2013.

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Table 1. Analysis of variance for yield related traits in *rabi* sorghum

Source of variance	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Test wt (g)	Grain yield (Kg/ha)	Fodder yield (Kg/ha)
Replications within environments	6	22.877*	20.306*	1162.241**	0.17*	18086.88*	106358.7*
Varieties	47	12.08*	18.586*	494.224*	0.159*	194848.7*	1316873*
ENV+(Var.*Env)	96	34.721***	52.681*	305.738*	0.106*	182276.6*	3031806.000**
Environments	2	1026.549***	920.573***	2121.698**	0.114*	1689103.000***	97942870.000**
Var.*Env	94	13.619*	34.216*	267.101*	0.106*	150216.4*	1012421*
Environments (Lin.)	1	2053.099***	1841.145***	4243.396***	0.228*	3378206.000***	195885700.000**
Var.*Env (Lin)	47	19.138**	16.831*	235.95*	0.102*	124642.3*	797919.5*
Pooled deviation	48	7.931***	50.525***	292.039***	0.108***	172128.3*	1201362.000***
Pooled error	282	1.36	9.178	97.591	0.023	18411.22	136219.4
Total	143	27.28	41.475	367.688	0.124	186408.6	2468156

*, ** significant at 5 and 1 per cent level

Table 2. Stability parameters for yield related traits in *rabi* sorghum

Genotypes	Days to 50% flowering			Days to maturity			Plant height (cm)			Test wt (g)			Grain yield (Kg/ha)			Fodder yield (Kg/ha)		
	Mean	bi	v^2di	Mean	bi	v^2di	Mean	bi	v^2di	Mean	bi	v^2di	Mean	bi	v^2di	Mean	bi	v^2di
RSV-1425	75.33	1.31	5.25*	119.89	0.66	34.28*	189.22	-0.06	-112.48	3.46	1.04	-0.03	1414.67	0.55	-7140	3970	0.31	-108203
RSV-1426	77.44	0.71	35.64**	111.11	0.61	1208.17**	159.67	-0.72	51.89	3.42	5.81*	-0.03	1742.47	0.68	457098**	4637.66	1.79	1040404**
RSV-1449	72.89	2.24	17.67**	120.11	1.05	67.21**	170.44	1.55	18.22	3.31	3.09	0.07	1771.07	0.97	10471	4382.74	1.52	77539
RSV-1458	75.33	1.73	30.16**	119.78	0.82	67.57**	184.89	1.16	452.36*	3.20	-3.20	-0.01	2100.63	-0.13	-3302	5287.13	1.05	842359**
RSV-1460	70.67	0.80	5.17	116.78	1.28	13.04	180.89	5.06	-55.16	2.73	-2.59	0.19**	1966.63	-0.06	42800	4656.66	1.15	757038*
RSV-1461	74.67	0.19*	-1.81	119.33	1.63	14.04	196.89	1.14	60.39	3.53	-4.98	0.00	1700.51	-0.88	115616**	4419.4	1.21	3389717**
RSV-1462	77.33	1.02	28.39**	121.33	1.34	9.69	177.33	2.02	49.36	2.81	-6.27	0.28**	1886.37	2.87	270161**	5137.1	1.86	464344*
RSV-1468	72.67	0.89	12.19**	118.45	1.02	16.84	182.22	3.12	49.14	3.09	-6.17*	-0.03	1491.43	0.44	-4913	3808.9	0.73	-82702
RSV-1478	72.44	1.61	2.79	118.67	0.80	-7.74	117.67	2.05	108.49	3.14	-3.10	0.40**	1781.17	-0.22	520837**	4956.48	1.48	2598581**
RSV-1479	73.22	0.27	-1.03	119.45	1.93	26.82	176.56	2.17*	-119.66	2.92	5.13*	-0.03	1522.49	0.28	290219**	3604.68	0.45*	-135488
Tansoli halli local	73.11	-0.17	1.87	119.67	2.04	35.61	194.67	0.78	210.57	2.96	8.91	0.88**	1713.4	2.95	493774**	3837.51	1.05	3403232**
Yadgir local	72.11	0.72	13.88**	115.78	0.52	12.42	167.22	1.00	919.68**	3.28	-6.23	0.04	1783.16	-0.6	5300	4757.28	1.86	1623886**
Dharampur local	73.67	1.91	2.62	118.67	-0.29	33.60	186.45	1.47	175.55	3.33	-3.06	0.09*	1968.59	1.22	134624**	4827.11	0.97	-28574
Tillehal local	73.78	0.55	-1.65	119.22	1.56	-3.43	175.33	0.48	89.05	2.93	-6.23	-0.02	1538.82	2.84	241039**	4593.13	1.23	1388815**
Halyal local	74.33	1.42	15.62**	120.11	1.42	5.18	173.56	1.46	340.83	3.00	5.93	-0.02	2173.14	1.54	37870	5265.03	1.44	-100321
Jamkhed local 1	70.44	1.64	-0.31	115.89	0.39	-0.65	176.44	-0.94	-115.44	2.98	-5.64	0.01	1548.22	2.22	436811**	3882.07	0.36	2908577**
Mundewadi local	77.89	0.85	-0.47	122.45	0.77	8.96	174.22	2.23	464.35	2.86	3.50	0.04	1821.98	1.32	35934	4804.36	1.35	-129680
Khadkat local	70.89	1.58	12.50**	117.56	0.31	-4.79	183.22	0.25	187.28	3.24	2.55	-0.01	1461.61	0.76	120834**	3582.64	0.59	-76129
Patoda local	70.44	0.18	19.52**	116.33	1.43	59.31**	178.67	3.62	1408.51**	3.21	-2.56	0.21**	1568.15	0.26	61694*	3911.71	0.62	-72265
Nimbodi local	73.00	0.07	0.62	118.67	1.74	25.01	181.11	2.22	-60.21	2.93	2.04	-0.03	1814.93	0.79	25448	4492.53	1	-123016
Jamkhed local 2	72.33	1.04	-0.11	119.00	1.40	-4.74	190.00	-0.26	178.49	3.14	-6.32	0.01	1740.79	0.11	214555**	4876.49	1.14	938542**
Bidar local	73.22	1.22	-1.43	119.56	1.30	-9.24	177.00	5.07	122.09	3.36	2.07	0.08*	1812.21	0.44	128826**	5323.68	0.79	93132
Pathari local	75.67	0.85	-1.61	121.56	1.33*	-9.43	190.67	1.25	-15.09	3.11	5.40	-0.02	1738.98	3.9	-13207	4422.83	1.5	4445619**
Katarkhatav local	77.00	0.10	5.80*	123.22	2.43	4.63	171.89	-0.51	-54.92	3.39	-7.23*	-0.02	1341.91	-0.44	384521**	3009.5	0.28	70720
Aurad local	75.33	-0.06	10.71**	122.56	2.07	72.07**	201.67	1.91	-102.05	3.07	3.55	0.16**	1262.59	0.13	-5781	3385.83	0.38	-85650
Mardi local	75.44	1.40	7.17*	121.45	1.27	5.28	193.33	3.31	60.92	3.19	5.78	0.05	1050.21	2.46	9519	3688.77	0.28	2694799**
Gondavle local	74.56	2.09	1.75	121.67	0.35	10.48	193.22	2.55	502.02*	3.17	2.04	-0.03	1877.51	0.74	46635	4737.77	0.87	-133221
Mangalwedha local	74.22	1.13	1.14	121.33	1.38	6.26	180.56	0.50	698.82**	3.32	0.25	0.50**	2050.64	2.09	-14076	5283.19	1.49	140013
Honsal local	74.56	2.30	3.93	121.89	0.56	96.56**	191.78	-2.12	0.83	3.12	5.36	0.24**	1888.7	3.95	7855	5001.38	1.68	3670068**
Pusegaon local	73.78	0.52	-1.54	119.45	1.52	0.35	193.45	2.04	204.26	3.12	4.25	0.13*	2013.1	1.21	1324663	4913.42	0.29	993518**
Kavalagudda mungaru	77.00	0.71	30.87**	121.11	1.64	-0.52	168.22	1.04	-111.86	3.17	2.78	0.10*	1600.11	1.83	-16005	4278.62	0.88	534043*
Tikota	73.56	1.94	-0.28	117.11	-0.28	76.70**	184.78	-0.20	930.10**	2.86	5.16	0.06	1957.78	-1.48*	-16372	5459.1	0.25	2388259**
Bairodagi	72.22	0.92	-0.12	114.11	0.46	-8.32	188.67	0.11	237.41	3.03	-0.35	0.08*	1534.51	2.01	-11304	3950.83	1.24	319468
Honawad-2	71.00	1.57	18.46**	114.11	-0.38*	-9.14	174.00	-1.13	-80.51	3.22	-1.66	0.04	1944.69	2.17	6555	4896.25	1.71	36882
Honawad	76.56	0.44	15.64**	119.00	1.18	-5.67	170.00	0.34	-75.68	2.99	-2.81	0.12*	1096.44	0.12	-12294	2908.3	0.6	63909

Contd.,

Table 2. Contd.,

Genotypes	Days to 50% flowering			Days to maturity			Plant height (cm)			Test wt (g)			Grain yield (Kg/ha)			Fodder yield (Kg/ha)		
	Mean	bi	v^2di	Mean	bi	v^2di		Mean	bi	v^2di	Mean	bi	v^2di		Mean	bi	v^2di	Mean
SSRG164	77.78	1.15	-0.37	120.11	0.35	-4.20	195.67	0.82	-96.10	2.68	-1.60	0.02	1439.43	-1.48	91009*	3697.71	0.98	4696440**
SSRG200	73.89	1.58*	-1.80	117.78	-0.17	55.31**	189.33	2.79	42.95	2.97	8.30	0.04	1559.16	1.38	493027**	4505.65	1.45	-76736
SSRG147	72.33	1.81	0.34	115.11	-0.48	32.05*	198.00	-0.59	-64.30	2.86	3.89	0.02	1637.91	-0.79	150638**	4665.11	1.78	2149853**
SSRG170	73.00	0.04	-1.20	116.11	1.32	26.19	144.00	-0.40	-109.04	2.87	1.78	0.04	1401.91	1.66	61968*	3311.48	0.95	383298
SSRG201	76.89	0.89	-0.06	122.22	1.02	-6.91	211.44	3.07	-103.09	3.14	0.71	-0.03	1345.71	-0.3	-13921	3506.39	0.7	655955*
SSRG204	75.11	1.62	1.14	120.56	0.99	-5.06	198.44	0.41	176.52	2.90	7.92	0.06	1623.66	1.47	246803**	4876.52	0.99	-84154
SSRG202	73.22	1.99	5.03	120.22	0.93	39.51*	207.89	0.18	-117.74	3.23	-4.18	-0.02	1798.87	1.48	295417**	4792.1	1.76	-17378
SSRG206	73.00	1.13	-1.31	119.11	0.70	9.02	203.45	-2.01	11.82	2.79	5.67	0.19**	1977.56	0.52	341119**	4592.17	0.87	-118946
SSRG203	74.44	0.67	-1.76	117.67	0.84	-8.63	193.44	0.77	-56.87	2.74	5.40	-0.02	1542.01	0.83	83762*	3503.68	1.04	-133115
SSRG236	72.00	0.72	8.69*	117.33	1.02	11.56	173.45	0.34	-58.53	2.96	3.33	0.14*	1408.88	-0.84	41378	3527.94	1.05	2664846**
M35-1	72.11	0.32	-1.58	118.33	1.59	-6.29	167.22	-2.21	1132.23*	3.40	4.77	-0.03	1523.71	3.63	174471**	3933.55	0.76	6508869**
CSV 22R	75.89	0.21	-0.51	121.11	1.34	-4.61	202.45	0.97	74.74	3.20	6.05	-0.01	1781.5	2.27	3529	4943.49	1.03	854915**
Phule Chitra	72.89	0.18*	-1.76	117.56	1.33	-8.79	178.89	-0.12	818.72**	3.10	-2.31	0.03	1733.75	1.13	1280	4167.92	1.24*	-135354
Population mean		73.9			118.9			183.4			3.08			1678			4354.7	

*, ** significant at 5 and 1 per cent level

Table 3. Environmental indices for yield related traits in *rabi* sorghum

Trait	Year		
	2011	2012	2013
Days to 50 % flowering	3.625	-5.208	1.583
Days to maturity	0.072	4.343	-4.414
Plant height (cm)	2.870	-7.602	4.731
Test wt (g)	0.047	-0.051	0.004
Grain yield (Kg/ha)	197.521	-175.757	-21.764
Fodder yield (Kg/ha)	1253.128	302.269	-1555.396