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Stability of yield and related traits in dual-purpose sorghum (*Sorghum bicolor*) across locations*

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Sorghum [*Sorghum bicolor* (L.) Moench] is the most important dryland cereal crop grown for food, feed and fodder in India. The grain-purpose types are grown during both the rainy (*kharif*, about 3.0 million ha) and the post-rainy seasons (*rabi*, about 4.2 million ha). In addition to these, forage and dual-purpose (grain and fodder) type of sorghum are cultivated mainly in the north-western, central and also other parts of the country. Sorghum is usually grown on marginal lands with low fertility, no or limited irrigation and with high levels of biotic and abiotic yield limiting factors. Under such conditions, farmers rely mostly on in-built resistance and yield stability of the cultivar. Assessment of stability and adaptability of a genotype to varied environments is useful for identifying and recommending varieties for known conditions of cultivation and is a requirement in breeding programmes. Stability of trait expression can be understood by partitioning the genotype × environment (G × E) interaction into linear trends and a departure from linear called residual (Eberhart and Russell 1966). The present study was carried out to evaluate a set of dual-purpose sorghum genotypes for their grain and fodder yield stability across *kharif* sorghum growing regions, and to identify stable and highly adaptable genotypes for wider cultivation.

Nine newly bred varieties and a hybrid contributed by different coordinating centres under All India Coordinated Sorghum Improvement Project (AICSIP) were evaluated along with standard varietal (CSV 15 and HC 308) and hybrid checks (CSH 16) in a randomized block design with three replications at seven locations (Coimbatore, Palem, Deesa, Udaipur, Pantnagar, Mauranipur and Ranchi) during rainy season of 2006. Each plot consisted of six rows of 6.75 m length at spacing of 45 cm between the rows and plants spaced at 15 cm within a row. All the recommended package of practices were followed for raising a good crop. Observations were recorded for days to flower, days to maturity, plant height (cm), biomass (kg/ha), grain yield (kg/ha) and fodder (stover) yield (kg/ha) at each location. Ten randomly selected plants from each replication were used to record days to flower, days to maturity and plant height while grain and fodder yields were recorded on net plot (four rows) basis. The stability parameters, viz mean, regression coefficient (b_i) and deviation from regression (S^2d_i) were calculated as per the model proposed by Eberhart and Russell (1966). The phenotypic index (*Pi*) of each genotype, which greatly facilitates identification of poor (negative *Pi*) and highly potential (positive *Pi*) genotypes, was expressed as deviation of genotypic mean (pooled over locations) from the population mean (Sharma 1998).

Pooled analysis of variance showed highly significant differences among the genotypes and environments for all the characters indicating the presence of variability among the genotypes and environments (Table 1). The G × E interaction was significant for plant height, biomass and fodder yields. Presence of significant G × E interaction for different traits in sorghum was also reported by Burli *et al.* (2004), Khandelwal *et al.* (2005) and Prabhakar *et al*. (2010). The environment-linear component showed highly significant variances for all the traits signifying unit changes in environmental index for each unit change in environmental conditions. The G × E (linear) mean square was significant for plant height, biomass and fodder yields implying thereby differential performance of genotypes under diverse environments but with varying reaction norms or in other words the linear sensitivity of different genotypes is variable. Significant G × E (linear) as well as pooled deviation mean squares for these traits indicate the presence of both predictable and non-predictable components. Similarly, the linear component of variance was higher than the non-linear component for most of the characters. Similar results were

*short note

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reported by Iyanar and Ravikesavan (2005). As linear component is higher for these characters, performance prediction of genotypes based on these traits would be more accurate across the environments.

As per Eberhart and Russell (1966) model, a stable genotype is one that shows high mean, near unity regression coefficient (b_i) and non-significant deviation from regression (S^2d_i). The genotypes SPV 1750 and SPV 1730 were linearly predictable in terms of days to flower because of lower mean compared to population mean and non-significant S^2d_i values (Table 2). These genotypes were suitable to unfavourable environments as the regression coefficient was lower than unity. The genotype SPV 1730, similar to its expression for days to flower, was found stable for days to maturity across the locations as it recorded unit regression and non-significant deviation from regression values.

For plant height, the genotypes SPV 1730 and SPV 1754 recorded high mean, non-significant deviation from regression and regression coefficient near unity similar to the check HC 308 and were thus found to be stable (Table 2). With respect to biomass, the entries SPH 1467 and SPV 1616 were linearly predictable owing to high mean, regression coefficient near unity and non-significant deviation from regression. Genotypes SPV 1716 and SPV 1754 had significantly higher regression coefficient than unity indicating below average stability. High mean, significantly higher regression coefficient and non-significant deviation from regression for SPV 1754 indicate that the genotype is suitable for favourable environments. High mean value coupled with highly significant deviation from regression in case of SPV 1716 indicates that it is highly sensitive to environmental changes.

For fodder yield, four genotypes (SPV 1715, SPV 1754, SPV 1716 and SPV 1750) exhibited below average stability while three had above average stability. The entries SPV 1616 and SPH 1467 were found to be stable with relatively higher fodder yields, regression coefficient around unity and non-significant deviation from regression. In contrast, the genotype SPV 1754 possessed higher mean, regression

Table 1 Pooled analysis of variance for different traits in dual-purpose sorghum

Source	df	Days to flower	Days to maturity	Plant height (cm)	Biomass (kg/ha)	Fodder yield (kg/ha)	Grain yield (kg/ha)
Genotypes (G)	12	106.41 **	85.56 **	2685.25 **	14948000 **	15053430 **	1703829 **
Environment (E)	6	961.58 **	928.04 **	46623.46 **	787905900 **	777287700 **	15806830 **
G × E	72	15.00	14.00	281.00 **	11983630 **	11184060 **	362185
Environment (linear)	1	5769.48 **	5568.24 **	279740.80 **	4727435000 **	4663727000 **	94840980 **
G × E (linear)	12	22.00	11.00	915.53 **	46086660 **	48705710 **	168405
Pooled deviation	65	12.49 **	13.30 **	142.24 **	4765868 **	3396669 **	370100 **
Pooled error	168	2.00	2.00	70.00	2253824	1804828	96090

Table 2 Mean performance of genotypes, and stability parameters for plant height, biomass and fodder yield

Genotype	Days to flower	Days to maturity	Grain yield (kg/ha)	Plant height (cm)			Biomass (kg/ha)			Fodder yield (kg/ha)		
				Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
SPV 1715	78	114	2012	242	1.36	431.91**	16839	1.34*	6186726**	14828	1.40*	3196956*
SPV 1714	78	113	2550	201	0.86	–60.06	17472	0.84	–1219424	14922	0.86	–886330
SPH 1467	69	106	3638	238	1.17	113.2*	18595	1.05	–2035192	14957	1.02	–1541745
SPV 1730	73	109	2520	223	1.11	–46.65	15638	0.81	2581943	13118	0.77	1794812
SPV 1754	76	112	2583	223	1.14	7.27	19190	1.51*	3182062	16607	1.49*	1254926
SPV 1716	79	114	2303	213	1.06	8.29	19714	1.71*	16166820**	17411	1.78*	12227380***
SPV 1753	72	108	2935	201	0.87	–20.83	17544	0.82	1925488	14609	0.80	1160583
SPV 1616	73	108	2851	209	1.01	1.97	18470	0.97	–2222841	15618	0.97	–1741801
SPV 1750	69	106	2996	205	0.94	–47.43	17654	1.19*	–1660603	14657	1.15*	–1251340
SPV 1751	75	110	2339	185	0.82	318.39**	15424	0.71*	5402441*	13085	0.70*	2791585*
CSH 16	69	105	3244	185	0.54	91.19	15027	0.44*	2154395	11783	0.44*	1221040
CSV 15	73	108	2937	201	0.94	27.86	18070	0.94	–772996	15134	0.88	–593729
HC 308	80	116	1863	242	1.17	2.05	16398	0.68	–1339805	14535	0.74*	–793154
Mean	74	109	2674	212			17387			14712		
SE (mean/b_i)	1.4	1.5	248.4	4.9	0.1		891.2	0.1		752.4	0.1	

exceeding unity with non-significant deviation from regression indicating suitability to favourable environments with predictable performances.

Though the G × E interaction was not significant for grain yield, the genotypes SPV 1750 and SPV 1616, which had higher mean values were found stable across the environments with non-significant deviations from linear performance. On the contrary, SPH 1467 and SPV 1753, and checks CSH 16 and CSV 15 manifested high mean values and highly significant deviations from regression indicating highly sensitive nature. Phenotypic index calculated for grain yield showed that only six genotypes had positive values, thus indicating good performance of these in general (Table 3). SPH 1467 had the highest phenotypic index while among the varieties SPV 1750 had highest positive value. For fodder and biomass yields the trend in phenotypic index was nearly similar with very high correction in the ranking of genotypes. High positive values were exhibited by SPV 1716 and SPV 1754 for both the traits while SPV 1616 had the third and fourth position for fodder yield and biomass respectively. These genotypes can be utilized in various breeding programmes for enhancing the dual-purpose sorghum productivity.

Table 3 Phenotypic index for grain yield, fodder yield and biomass

Genotype	Grain yield (kg/ha)	Fodder yield (kg/ha)	Biomass (kg/ha)
SPV 1715	–663.20	115.45	–547.91
SPV 1714	–124.91	209.49	84.57
SPH 1467	963.18	243.92	1207.14
SPV 1730	–154.39	–1594.55	–1749.00
SPV 1754	–91.63	1894.30	1802.66
SPV 1716	–371.58	2698.54	2327.00
SPV 1753	260.52	–103.74	156.62
SPV 1616	176.66	905.59	1082.38
SPV 1750	321.56	–55.32	266.19
SPV 1751	–335.63	–1627.32	–1963.05
CSH 16	569.47	–2930.08	–2360.39
CSV 15	261.95	420.97	683.04
HC 308	–812.01	–177.27	–989.24

SUMMARY

The present study detected differential response in 10 dual-purpose sorghum genotypes over locations for fodder and biomass yields, which are very important agronomic traits. The G × E (linear) as well as pooled deviation mean squares were found significant for these traits indicating that the linear sensitivity of different genotypes is variable and performance of genotypes fluctuated significantly from their respective linear path of response to environments. The test hybrid 'SPH 1467' had the highest phenotypic index and was found stable for fodder and biomass yields. Among the varieties, 'SPV 1750' recorded the highest grain yield while 'SPV 1716' had the highest fodder and biomass yield, but were not stable across locations for these traits. The genotype 'SPV 1616' showed high adaptability for grain and fodder yields and biomass, and hence better suited as a dual purpose sorghum variety.

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