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Stability Analysis for Yield and Component Traits in Sorghum [*Sorghum bicolor* (l.) Moench.]

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Stability analysis were carried out for grain yield and component traits using one hundred fifty accessions of sorghum during *Kharif*, 2013, 2014 and 2015 under rainfed condition at ICAR-CAZRI, Regional Research Station, Pali. Mean squares for genotype, environments and genotype x environment interaction were significant for almost all the studied characters. Genotype GPU-4 for grain yield/ plant, earliness, maturity and leaf area and GPU- 8 for grain yield/ plant, fodder weight/ plant and dry weight/ plant exhibited high *per se* performance, non-significant S^2di and regression coefficient around unity. They were considered stable for these characters. EJ-34 showed good performance for grain yield, maturity and peduncle width under unfavorable environment and IS-6953 and GPU-14 was suitable for grain yield, earliness and peduncle width under favorable environment.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is the most important dry land cereal crop grown for food, feed and fodder in India. It is genetically suited to hot and dry agro-ecologies with frequent drought, where it is difficult to grow other crops (Jain *et al.*, 2010). Sorghum is preferred over maize in *kharif* season because of its high tolerance to various stresses and its superiority to pearl millet in having lower oxalate and fiber content. Sorghum stover is valued over all other sources of fodder (paddy straw, pearl millet straw and wheat straw). 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. Increasing the productivity of dry land cereals is one of several strategies that will improve global food security (Stewart and Lal, 2018). Assessment of stability and adaptability of a genotype to varied environments is useful for identifying and recommending genotypes 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 and to use in future breeding programmes.

Materials and Methods

One hundred fifty sorghum accessions collected from Directorate of sorghum, Hyderabad, Sorghum Research Station, Dessa, SDAU, and NAU, Surat, Gujarat, Rajasthan College of Agriculture, Udaipur and farmer field of Rajasthan were used for present study. These accessions were evaluated under rainfed condition at ICAR-CAZRI, Regional Research Station, Pali, Marwar (25°46′N, 73°50′E; 225 masl) Rajasthan during *Kharif*-2013, 2014 and 2015 in a Randomized Block Design (RBD) with three replications. The experimental soil was fine sandy clay loam in texture, mixed hyper thermic belonging to the family Lithic calciorthids having shallow depth of 25-45 cm and underlying dense layer of murrum (highly calcareous weathered granite fragments coated with lime) up to 10-15 m depth. The soil of the experimental farm was moderately saline with pH 8.2 and contains low organic carbon 0.37%. Nutrient profile of soil contains 215 kg ha^{-1} available N, 11.3 kg ha^{-1}Olesn's extractable P and 225 kg ha^{-1} available K at the time of sowing. The experiment unit was a single row plot of 3.5 m long, spaced 0.5 m apart. The standard agronomic practices were followed throughout the period of crop growth. The observations were based on the five randomly selected plants from each genotype and replication for different agro-morphological traits *i.e.* plant height, number of leaves, leaf area, peduncle length, peduncle width, fodder weight/ plant, dry weight/ plant, 1000 seed weight and grain yield /plant. The observation for days to 50% flowering and days to maturity was recorded on the plot basis. Statistical analysis for stability was performed according to Eberhart and Russell (1966) method.

Results and Discussion

The Analysis of Variance for stability revealed that mean squares due to genotypes were significant for all the characters which showed the presence of variability among all the genotypes under investigation. The mean squares due to environments (Linear) were significant for all the characters except 1000 seed weight. The mean squares due to genotype x environment were significant for all the characters except days to 50% flowering, leaf area and 1000 seed weight. Pooled deviation differs significantly for all the above characters except number of leaves, peduncle length, peduncle width and 1000 seed weight (Table 1). These results corroborated with the findings of Kenga *et al.* (2003), Das and Prabhakar (2003), Khandelwal *et al.* (2005), Kale (2012) and Jadhav and Deshmukh (2017). A perusal of stability parameters for grain yield per plant indicated that out of one hundred fifty accessions, thirty four accessions exhibited higher mean value for grain yield per plant than population mean. All these accessions also exhibited non-significant S^2di, indicating their predictable performance. Out of the thirty four accessions, seven accessions *viz.*, EJ-34, ES-7, IS-20582, IS-11497, EJ-18, Gundari and GPP-8 were good performer for unfavorable environment *i.e.* bi less than 1 (bi<1). EJ-34 also exhibited stable performance for maturity and peduncle width for unfavorable or unpredictable environmental conditions. Out of the thirty four accessions, four accessions *viz.*, E-4, EB-22, GPU-4 and GPU-8 were average performer *i.e.* bi around unity (bi=1). These accessions therefore can be considered as suitable and will provide stable performance under different environmental conditions for higher grain yield per plant. With respect to component traits, two accessions out of above four accessions, exhibited higher *per se* performance, non-significant S^2di and regression coefficient around unity for grain yield as well as earliness, maturity and leaf area (GPU-4) while GPU-8 also showed stable performance for fodder weight/ plant and dry weight/ plant. Among the thirty four accessions, twenty three accessions *viz.*, EJ-38, IS-14008, IS-6953, CSV-22, E-47, ES-5, IS-15664, SMU-1, IS-13974, SPV-1822, GPU-1, GPU-2, GPU-3, GPU-14, GPU-17, EJ-17, EJ-55, EG-48, EG-1, GJ 40, GPP6, GPP19 and GPP-22 were good performer for predictable or favorable environment *i.e.* bi more than 1 (bi>1). IS-6953 and GPU-14 also expressed stable performance for earliness and peduncle width for favorable environment (Table 2).

Similar results have been reported in the past by other workers, Madhusudhana *et al.* (2003), Khandelwal *et al.* (2005), Ezzat *et al.* (2010), Glazy *et al.* (2012), Anarase *et al.* (2016) and Patel *et al.* (2019). In case of fodder yield per plant, out of the twenty seven accessions, three accessions *viz.*, EJ-34, E-4 and GPU-2 were good performer for unfavorable environment *i.e.* bi less than 1 (bi<1). Four accessions *viz.*, SMU-1, IS-11497, SPV-1822 and GPU-1 were average performer *i.e.* bi around unity (bi=1). These accessions therefore can be considered as suitable for varying environments. Among the twenty seven accessions, six accessions *viz.*, IS-6953, IS-15664, IS-13974, GPU-4, GPU-17 and GJ 40 were good performer for predictable or favorable environment *i.e.* bi more than 1 (bi>1) (Table 3). Similar results have been reported by other workers, Prabhakar *et al.* (2010), Umakanth *et al*. (2012), Vange *et al.* (2014), Girish *et al.* (2016) and Sissoko *et al.* (2018). A perusal of stability parameters for dry fodder yield per plant indicated that out of twenty six accessions, ten accessions exhibited higher mean value for dry fodder yield per plant than population mean.

All these accessions also exhibited non-significant S^2di, indicating their predictable performance. Out of the ten accessions, only one genotype namely, IS-14008 was good performer for unfavorable environment *i.e.* bi less than 1 (bi<1). Out of the ten accessions, two accessions *viz.*, IS-11497 and GPU-2 were average performer *i.e.* bi around unity (bi=1). These accessions therefore can be considered as suitable and will provide stable performance under different environmental conditions for higher grain yield per plant. Among the ten accessions, seven accessions *viz.*, IS-6953, IS-20582, SMU-1, GPU-1, GPU-4, GPU-8 and Gundari were good performer for predictable or favorable environment *i.e.* bi more than 1 (bi>1) (Table 4).

Similar results have been reported in the past by other workers Glazy *et al.* (2012), Anarase *et al.* (2016) and Patel *et al.* (2019). Nevertheless, experiment has resulted into identification of certain accessions yielding higher than checks and having stable performance over environments.

Table.1 Pooled ANOVA for grain yield and its components in sorghum.

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height	Number of leaves	Leaf area	Peduncle length	Peduncle width	Fodder weight/ plant	Dry weight / plant	1000 Seed Weight	Grain yield /plant
Replication	6	0.566	5.057	535.443**	4.926**	1563.884	5.308**	1.512**	642.325	44.857	2.933*	40.608
Genotypes (G)	149	190.577**	130.386**	3265.757**	6.188**	14671.38**	101.769**	10.531**	7420.370**	938.737**	46.119**	130.540**
Env. + (G x E)	300	19.054	48.828**	595.100**	3.395*	2074.521	5.092**	1.655**	3828.859**	680.990**	0.806	12.535
Environments (E)	2	1254.710**	5233.076**	47730.210**	397.244**	82758.72**	191.485**	68.850**	395789.6	63547.900**	2.382	54.2
Genotypes x Env.	298	10.761	14.034**	278.757**	0.751**	1533.016	3.841**	1.204**	1198.250**	259.065**	0.795	12.255*
Environments (Linear)	1	2509.420**	10466.150**	95460.430**	794.488**	165517.4**	382.969**	134.699**	791579.3**	127095.8**	4.763	108.401*
Genotypes x Env. (Linear)	149	4.629	20.793**	463.432**	1.291**	1205.168	7.592**	2.373**	2053.102**	438.276**	0.269	3.496
Pooled deviation	150	16.780**	7.266**	93.455**	0.21	1848.458**	0.089	0.036	341.109**	79.321**	1.313	20.874**
Pooled error	894	0.841	0.976	55.084	0.313	258.503	0.438	0.187	97.543	26.647	1.079	3.808
Total	449	75.974	75.893	1481.354	4.322	6254.77	37.174	4.6	5020.797	766.523	15.843	51.695

*, ** Significant at 5% and 1% level of significance, respectively.

Table.2 Abstract table of promising and stable accessions for grain yield per plant in sorghum

Genotypes	Mean	bi	S^2di
EJ-38	17.06	1.35	3.7
EJ-34	23.38	0.56	4.69
E-4	17.17	1.17	-224
ES-7	19.7	0.64	1.49
IS-14008	19.7	3.46	3.52
EB-22	16.3	0.99	-1.92
IS-6953	24.5	2.51	-3.9
CSV-22	13.32	2.79	2.75
E-47	22.03	3.94	-0.71
ES-5	22.37	4.19	-0.87
IS-20582	14.32	0.7	2.15
IS-15664	15.97	3.16	3.87
SMU-1	13.43	2.88	7.52
IS-11497	16.6	0.7	1.8
IS-13974	14.71	1.53	-2.59
SPV-1822	13.5	1.97	1.48
GPU-1	14.6	1.74	-2.41
GPU-2	15.11	1.32**	-4.05
GPU-3	16.5	1.3	-3.58
GPU-4	23.44	1.11	-3.32
GPU-8	22.78	1.09	-2.53
GPU-14	24.3	2.74	-3.77
GPU-17	24.23	2.81	-3.95
EJ-17	17.79	2.97	5.13
EJ-18	12.77	0.71	-0.81
EJ-55	19.68	2.23	-2.6
EG-48	20.08	2	-3.14
EG-1	18.39	3.1	3.57
Gundari	14.27	0.52	-3.25
GJ-40	24.51	2.37	-0.98
GPP-6	15.98	2.52	7.09
GPP-8	20.91	0.03	4.89
GPP-19	17.39	1.42	-3.86
GPP-22	15.8	2.54	7.43

*, ** Significant at 5% and 1% level of significance, respectively.

Table.3 Abstract table of promising and stable accessions for fodder yield per plant in sorghum

Genotypes	Mean	bi	S^2di
EJ-38	165.2	0.73	24.29
EJ-34	108.8	0.14	-26.51
E-4	166.9	0.36	248.44
ES-7	148	0.87	-100.22
EB-22	130.4	1.13	118.55
IS-6953	255.9	1.45	-57.32
IS-20582	152.4	1.26	-93.75
IS-15664	173.5	1.7	103.48
SMU-1	184.5	0.85	84.96
IS-11497	271.2	0.91	-99.16
IS-13974	188.5	2.13	-17.52
SPV-1822	167.1	0.97	10.93
GPU-1	194.5	0.94	-86.34
GPU-2	201.7	0.7	485.81
GPU-4	177.3	1.29	-26.47
GPU-17	172.3	1.81	206.72
EJ-17	146.4	1.07	-83.24
EJ-18	138.1	1.79	103.59
EJ-55	101.9	0.8	-90.61
EG-48	141	1.04	-8.44
EG-1	123.9	0.91*	-101.12
Gundari	158.7	1.04	-98.68
GJ-40	220.5	1.56	-46.77
GPP-6	133.7	0.93*	-101
GPP-8	86.07	0.61	-96.06
GPP-19	108.3	0.88	-45.59
GPP-22	106	0.66	-74.71

*, ** Significant at 5% and 1% level of significance, respectively.

Table.4 Abstract table of promising and stable accessions for dry fodder yield per plant in sorghum

Genotypes	Mean	bi	S^2di
EJ-34	37.378	0.13	21.77
E-4	56.156	0.44	-22.47
ES-7	47.444	0.6*	-26.66
IS-14008	81.022	0.81	61.94
EB-22	43.5	0.84	-13.78
IS-6953	95.256	2.17*	-21.9
ES-5	50.8	0.93	-10.38
IS-20582	59.8	1.41	2.6
IS-15664	50.689	0.68	-3.94
SMU-1	71.567	1.75	60.31
IS-11497	99.511	1.15	16.83
SPV-1822	42.189	0.34	26.83
GPU-1	69.522	1.58	-16.44
GPU-2	65.589	0.94	-2439
GPU-4	67.378	1.76	14.74
GPU-8	113.989	1.31*	-26.41
GPU-14	51.944	0.72	54.18
EJ-18	52.544	1.85	66.18
EJ-55	32.833	0.76	-16.4
EG-48	50.922	0.98	-13.8
EG-1	42.922	0.98	-24.66
Gundari	67.889	1.26*	-26.6
GPP-6	41.811	0.31	-3.34
GPP-8	33.944	0.57*	-26.01
GPP-19	39.889	0.77	-22.34
GPP-22	36.011	0.38	-18.25

*, ** Significant at 5% and 1% level of significance, respectively.

The stable genotypes across the environment may be used in future breeding programme further development of stable varieties. While the genotypes which performed well under unfavorable and favorable environment may play a role in the development of variety for the respective environments.

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