Original Research Article

Study on GxE interaction of Sorghum lines (*sorghum bicolor* L. Moench) for grain yield and its contributing traits in germplasm of Indore, India.

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ABSTRACT

To determine the stability of sorghum germplasm for grain yield as well as the amount and nature of genotype by environment interactions for grain yield in order to find and recommend stable high yielding variants. The trial was arranged in a randomized block design (RBD) in three replications.Germplasm were evaluated in 2 environments in Indore in 2019-2020 and 2020-2021 in main cropping seasons.60 sorghum germplasm was evaluated under Thirteen morphological traits viz., Days to 50% flowering, Days to maturity, plant height (cm), Number of leaves per plant at the time of flowering, Leaf length of 4th leaf (cm), Leaf width of 4th leaf (cm), Panicle length (cm), Panicle width (cm), No. of Primary branches per panicle, No. of grains per primary branch, Grain yield/Plant (g), Leaf Area of 4th leaf (cm^2), 100 seed weight (g) were recorded for 3 randomly selected plants for each germplasm per replication. Linear regression model for stability suggested by Eberhart and Russell (1966) was employed.Genotype x Environment interactions were found significantly in similar trend for the traits namely, days to 50% flowering, number of leaves per plant, leaf length of fourth leaf, leaf width of fourth leaf, panicle length, panicle width, number of primary branches per panicle, number of grains per primary branch, leaf area of the fourth leaf, grain yield per plant and 100 seed weight. It shows consistent results over years.Genotype x Environment interaction also revealed that the genotype SEB12025 found consistent for primary branches per panicle, grain yield. The germplasm E- 246 found suitable for seed weight, panicle width, Width of fourth leaf. Apart from POP-18, POP 27-1, EC-6, ERN-32, Gird-30, Gird 33-1, VKG 34/47, VKG 34/37, ER-15, EC- 16, ER-1, SEB 12025, E-207, ER-21, Gird-36, EGN-1, E-207, ER-3, Gird-41, E- 284,E-246, ER-3,Gird-41,Gird-5,ERN-32,GGUB-20, ELG-25,Sor 86,NCC-1,E-246 and ELG-31 no genotypes found consistent for any of the character.The characters which were found stable for a particular genotype should further be improved to develop stable and high-yielding genotypes for sustainable production. More locations and years could be taken to obtain a database about genotype x environment interaction to draw a more valid conclusion.

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Keywords – Stability analysis, Eberhart and Russell model, G x E interaction.

Introduction-

Sorghum is one of the most significant cereal crops in the world, a tropical plant from the poaceae family. It is called *Sorghum bicolor* (L) Moench (Anglani, 1998). It is thought to have originated and been domesticated in East Africa (4000–3000 BC), most likely along the border of Ethiopia and Sudan (Doggett, 1988). Its estimated genome size is 750 Mb, which is twice as large as the genome of rice and six times as large as the genome of Arabidopsis. It contains 2n = 20 chromosomes (Passardi*et al*., 2004). A dryland cereal crop with an annual production of 60 million tones, sorghum is farmed on over 44 million hectares of land (Prakash *et al.*, 2010) throughout 99 countries (ICRISAT, 2009). (Iqbal *et al.*, 2010). Sorghum is a self-pollinating annual crop with thick culms that can grow to a height of 5 m, are frequently branched, and have numerous tillers. Several authors such as De Wet and Huckabay (1967); Doggett (1988) and Smith and Frederiksen (2000) reported that Ethiopia is the primary center of origin and hence, center of diversity for sorghum. Sorghum is now widely found in the dry areas of Africa, Asia, Americas and Australia (Dickon *et al*., 2006).The area under sorghum cultivation in India during 2017-2018 is 49.6 ha with a total production of 49.5 lakh tones. The productivity is about 996 kg per ha. In Madhya Pradesh, the sorghum cultivation area is 2.7 lakh ha. The state harvested production of 5.7 lakh tones with a productivity of 2112 kg per ha.Although sorghum is cultivated both in tropical and temperate climates, it is best known for its adaptation to the drought- prone semi-arid tropical (SAT) regions of the world (Baummhardt, 2000) and among cereal crops used for food for the poorest people who live in semiarid regions of the world (Jiang *et al.*, 2013). It is adapted to environments with 400-600 mm annual rainfall that are too dry for other cereals (Dickon *et al.*, 2006).). Due to its ability to adapt to unfavorable environmental conditions, it is also one of the most significant tropical cereal crops, grown widely over larger areas at altitudes ranging from 400 to 3000 meters above sea level. Sorghum is becoming a widely grown crop due of this. For millions of people who live in arid and semi-arid regions of the world, it is their primary source of protein and energy.

Moreover, it is widely used as a source of nutrition, fodder, biofuel, fiber and confection (Abubakar and Bubuche, 2013). It is able to grow under severe stress conditions.

Sorghum can be cultivated successfully on almost all soils and in the temperature range of 16–400C (Abubakarand Bubuche, 2013). Sorghum is one of the major food and cash crop for the most insecure farmers in the semi-arid areas which experience low and unreliable rainfall

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patterns, and which are not suitable for most other crops, including maize (Bibi *et al.,* 2010). It is also used for animal feed and nowadays, sorghum has emerged as a smart crop for production of ethanol (biofuel). It supports about 500 million people serving as a source of food, feed, fiber and building material (Mesfin, 2016). In developed countries, sorghum is used primarily as animal feed and in the sugar, syrup, and molasses industry. Genotype x environment interaction is the major concern for plant breeders for developing improved cultivars. GEI results from a change in the relative rank of genotype performance or a change in the magnitude of differences between genotype performances from one environment to another. In multi-environment trials, the phenotype of an individual in each test environment is a measure of an environment main effect, a genotype main effect, and the genotype by environment interaction (GEI) (Yan and Tinker, 2005). The GE interaction reduces the correlation between phenotype and genotype and hence selection progress. most of the varieties were not evaluated for their specific and wider adaptability and thus exhibit fluctuating yields when grown in different environments or agro-climatic zones. To this end, multi- environment adaptability and stability test is crucial to identify stable high yielding and adaptable cultivars and discover sites that best represent the target environment (Yan *et al.,* 2000). Adaptability is the result of genotype, environment and genotype by environment interaction and generally falls into two classes: (1) the ability to perform at acceptable level in a range of environments, referred to as general adaptability, and (2) the ability to perform well only in desirable environments, known as specific adaptability (Farshadfar and Sutka, 2008). Nevertheless, information on the effect of GEI on the yield performance of sorghum varieties under different environments in India is limited. Therefore, the objectives of the current study were to determine the magnitude and nature of genotype by environments interaction for grain yield and also to determine the stability of sorghum varieties for grain yield and hence to identify and recommend stable high yielding variety.

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MATERIALS AND METHODS

Description of the Study Area

The Present investigation on “Study on G x E interaction of Sorghum germplasm lines (*Sorghum bicolor* (L.) Moench) for Grain yield and its contributing traits” was carried out in the experimental fields of All India Coordinated Research Station, College of Agriculture, Indore, (M.P) during 2019-2020 and 2020-2021.

Plant Materials

The experimental plant materials comprised of 60 sorghum germplasm including local check and varieties released from different research centers in India. The detailed information about the experimental materials is presented Table 1.

Table 1. List of Sorghum genotypes used for study.

Gird 1	Gird 35	EG 31	ER 21
Gird 3	Gird 36	NCC 1	EC 16
Gird 5	Gird 41	SEB 12025	ELG 25
Gird 8	Gird 45	GGUB 20	ELG 31
Gird 10	Gird 47	GGUB 33	EGN 1
Gird 11	Gird 48	GGUB 59	EGN 9
Gird 12	Gird 49	SOR 86	EG 31
Gird 20	E 207	VKG 34/47	NCC 1
Gird 21	E 246	V 60-1	SEB 12025
Gird 23	E 248	POP 8	GGUB 20
Gird 29	3774	POP 13	GGUB 33
Gird 30	E 184	POP 37-1	POP 14
Gird 32	EC 6	POP 51-1	POP 17
Gird 31-1	EGN 9	ER 1	POP 18
Gird 33-2	EG 31	ER 3	POP 27-1
Gird 34	NCC 1	ER 15	POP 37-1
POP 51-1	ER 1	ER 3	ER 15

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Experimental Procedures

The experiment was conducted in a Randomized Block Design with three replications. The row to row distance is 45 cm and the plant to plant distance is 12-15 cm. All recommended packages and practices were followed to raise the well-flourished during the conduct of the experiment.

Stability analysis

Eberhart and Russell's model

Eberhart and Russell's model Yield stability was determined following the Eberhart and Russell (1966) model by regressing of the mean grain yield of individual genotypes on environmental index and calculating the deviation from the regression.

Where: Yij = the mean of the ith genotype in the jth environment
μi = the grand mean,
βi = the regression coefficient of the ith genotype on environmental index,
Ij = the environmental index obtained by the difference between the mean of each environment and the grand mean,
δij = the regression deviation of the ith cultivar in the jth environment,

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance showed significant variability among the genotypes for all the characters in both years. The traits number of primary branches per panicle, plant height, panicle width, grain yield, and leaf area of the fourth leaf showed high GCV and PCV estimates. Seed yield per plant ranged from 17.27 g (POP 17) to 130.2 g (SEB 12025) and the mean was 51.80 g in the first year while in the second year it ranges from 23.2 g (POP 17) to 125.6 g (SEB 12025) and its average yield was 53.96 g. In E1 germplasm Gird 1 (44.3), Gird 8 (50.4), Gird 11 (42.9), Gird 12 (44.8), Gird 21 (44.3), Gird 34 (50.5), E-184 (43.6), EG-31 (44.0), GGUB-59 (50.4) were *at par* and significantly superior to other genotypes (Table 1 and Table 2).

Stability Analysis using Eberhart and Russell Regression Model

According to Eberhart and Russell (1966), a stable genotype should have high yield, unit regression coefficient (bi) and deviation from regression (Sdi^2) close to zero. Based on these three parameters germplasm Gird-29, E-184, EGN-1, POP-14, POP-17, POP 51-1, ER-3 had regression coefficient closer to unity, deviation from regression is zero with and mean grain yield greater than the average and hence could be considered as stable genotypes. Whereas, Gird-34, POP-14 and ERN-32 second and third high yielder with regression coefficient of greater than one, deviation from regression (Sdi^2) close to zero, respectively, and thus best fit for specific adaptation in favorable environments. Genotyes such as Gird-3,Gird-5, Gird-8, Gird-11, Gird-12, Gird-20, Gird-21, Gird-21, Gird-23, Gird-30, Gird 31-1, Gird 33-2, Gird-35, Gird-45,Gird-47, Gird-48, E-248, E-102, EC-6, ELG-25, EG-31, SEB 12025, GGUB-20, POP 27-1, ER-1 had regression coefficients less than one, implying their specific adaptability to marginal environments.

DICUSSION

The investigation concluding that estimates of PCV are higher than 66 the corresponding GCV for almost all the characters. In the present study the characters days to 50% flowering, plant height, panicle length, panicle width, test weight, grain yield showed high PCV than

GCV showing the wide range of variation in these characters. These results are in agreement with finding B. Arunkumar, 2013, Gebremedhn, 2019. High PCV values were obtained for grain yield and the same result was obtained by Fantaye belay, 2016. Bello *et al.*, 2007, Godbharle*et al.* 2010, Swamy 2018 reported high value of PCV and GCV for panicle length per plant, 1000 seed weight, days to flowering, and days to maturity Kassahun et al., 2015, Tesfamichael *et al.* (2015) found that phenotypic and genotypic coefficients of variation for plant height were both large. Birader*et al.,*1996, Reddy *et al*,1996). High PCV was obtained for panicle length and grain yield, the similar result of the present study conformed with the findings of Rekha 2015. Large effect of GXE on grain yield was reported in sorghum genotypes. The most stable and high yielding varieties could be commercialized for replacement of the existing varieties (Gasura *et al*. 2015). High stability of variety Phule Chitra for grain yield under diverse rabi grown regions was earlier reported by Sanjana Reddy *et al*. (2009).

Table 2. Pooledanalysisof variancefor60 sorghum germplasm overtwoyears

Source ofVariation	D.f	Plantheight	Daysto 50%flowering	Days tomaturity	No. ofleaves/plant atthe timeofflowering	No. ofprimarybranches/panicle	No. ofgrains/ primarybranch	Seedweight	Leaflength of4thleaf	Leaf width of 4thleaf	Paniclelength	Paniclewidth	Grain yield	Leaf area of4thleaf
Environment	1	165596.60**	154.05**	78.96**	0.50	1097.60**	0.33	16.87**	219.42**	0.44	21.42**	0.74	822.31	22720.94**
Interactions	2	24.86	5.42	0.19	1.05	15.72	6.70	0.06	0.03	0.54	0.23	2.19	48.79	3093.25
Treatment	59	20939.90**	611.98**	626.65**	6.24**	2560.13**	463.42**	1.30**	1122.0**	11.42**	57.57**	24.32**	1566.75	155154.97**

Table 3. Mean yield, regression coefficients and deviation from regression

	Variety	Env. 1	Env. 2	Gen.μ	S^2Di	Rank	βi	Rank
1	1 Variety	44.307	46.467	45.387	0	1	1.000	1
2	2 Variety	37.517	38.467	37.992	0	2	0.440	26
3	3 Variety	56.347	55.967	56.157	0	3	-0.176	45
4	4 Variety	50.400	50.533	50.467	0	4	0.062	42
5	5 Variety	29.553	35.800	32.677	0	5	2.893	51
6	6 Variety	42.910	44.333	43.622	0	6	0.659	20
7	7 Variety	44.890	44.967	44.928	0	7	0.036	43
8	8 Variety	41.190	42.767	41.978	0	8	0.730	15
9	9 Variety	44.303	45.667	44.985	0	9	0.631	22
10	10 Variety	58.680	60.133	59.407	0	10	0.673	19
11	11 Variety	33.673	36.200	34.937	0	11	1.170	8
12	12 Variety	64.823	65.667	65.245	0	12	0.391	27
13	13 Variety	32.960	37.900	35.430	0	13	2.288	47
14	14 Variety	81.357	81.667	81.512	0	14	0.144	39
15	15 Variety	36.687	37.400	37.043	0	15	0.330	31
16	16 Variety	50.513	53.733	52.123	0	16	1.491	25
17	17 Variety	67.323	67.667	67.495	0	17	0.159	38
18	18 Variety	53.000	51.000	52.000	0	18	-0.926	52
19	19 Variety	70.633	101.300	85.967	0	19	14.204	59
20	20 Variety	79.977	80.333	80.155	0	20	0.165	36
21	21 Variety	35.777	37.273	36.525	0	21	0.693	18
22	22 Variety	57.610	59.333	58.472	0	22	0.798	9
23	23 Variety	87.080	89.900	88.490	0	23	1.306	17
24	24 Variety	91.367	71.467	81.417	0	24	-9.217	58
25	25 Variety	61.090	60.667	60.878	0	25	-0.196	46
26	26 Variety	64.767	65.000	64.883	0	26	0.108	41
27	27 Variety	74.037	75.667	74.852	0	27	0.755	12
28	28 Variety	32.670	35.567	34.118	0	28	1.342	21
29	29 Variety	35.293	38.867	37.080	0	29	1.655	28
30	30 Variety	43.617	46.267	44.942	0	30	1.227	11
31	31 Variety	71.043	68.133	69.588	0	31	-1.348	54
32	32 Variety	63.633	63.900	63.767	0	32	0.124	40
33	33 Variety	78.023	76.977	77.500	0	33	-0.485	50
34	34 Variety	41.127	42.733	41.930	0	34	0.744	14
35	35 Variety	81.400	116.533	98.967	0	35	16.273	60
36	36 Variety	32.577	34.933	33.755	0	36	1.092	6
37	37 Variety	44.017	47.000	45.508	0	37	1.382	23
38	38 Variety	80.943	81.333	81.138	0	38	0.181	35
39	39 Variety	130.000	122.167	126.083	0	39	-3.628	55
40	40 Variety	64.977	65.333	65.155	0	40	0.165	37
41	41 Variety	50.410	41.733	46.072	0	41	-4.019	56
42	42 Variety	56.063	58.133	57.098	0	42	0.959	4
43	43 Variety	38.677	39.233	38.955	0	43	0.258	32
44	44 Variety	55.143	56.333	55.738	0	44	0.551	24
45	45 Variety	66.277	66.333	66.305	0	45	0.026	44
46	46 Variety	37.237	37.667	37.452	0	46	0.199	34
47	47 Variety	27.180	48.433	37.807	0	47	9.844	57
48	48 Variety	32.357	36.167	34.262	0	48	1.765	33
49	49 Variety	22.733	24.900	23.817	0	49	1.004	2
50	50 Variety	20.957	23.567	22.262	0	50	1.209	10
51	51 Variety	30.833	33.600	32.217	0	51	1.281	16
52	52 Variety	32.010	34.133	33.072	0	52	0.984	3
53	53 Variety	36.057	38.767	37.412	0	53	1.255	13
54	54 Variety	20.800	23.200	22.000	0	54	1.112	7
55	55 Variety	86.323	87.067	86.695	0	55	0.344	29
56	56 Variety	26.000	28.300	27.150	0	56	1.065	5
57	57 Variety	20.510	25.867	23.188	0	57	2.481	49
58	58 Variety	60.323	59.467	59.895	0	58	-0.397	48
59	59 Variety	37.163	40.763	38.963	0	59	1.667	30
60	60 Variety	59.220	57.220	58.220	0	60	-0.926	53
	Environmental Index	-1.079	1.079					
	Mean	51.806	53.965					
	C. V.	12.650	7.484					

Comment [a14]: Name of genotype should be mentioned

F Prob.	**0.000**	**0.000**
SE of Difference	**5.351**	**3.298**
CSummary and ConclusionD 95%	**10.596**	**6.530**

Conclusion

Multi-Environment trials are very important for selecting the best genotype for wide or specific environments before any recommendation of genotypes for commercial production. Genotype x Environment interactions were found significantly in similar trend forthetraitsnamely,daysto50%flowering,numberofleavesperplant,leaflengthof fourth leaf,leafwidthoffourthleaf,paniclelength,paniclewidth,numberofprimary branchesperpanicle, numberofgrainsperprimarybranch,leafareaofthefourth leaf, grain yield per plant and 100 seed weight. It showsconsistentresultsover years. Genotype x Environment interaction also revealed that the genotype SEB12025found consistent for primary branches per panicle, grain yield. The germplasm E-246 found suitable for seed weight, panicle width, Width of fourth leaf. Apart fromPOP-18, POP 27-1, EC-6, ERN-32, Gird-30, Gird 33-1, VKG 34/47, VKG 34/37,ER-15, EC- 16, ER-1, SEB 12025, E-207, ER-21, Gird-36, EGN-1, E-207, ER-3,Gird-41,E-284,E-246,ER-3,Gird-41,Gird-5,ERN-32,GGUB-20,ELG-25,Sor 86,NCC-1,E-246andELG-31nogenotypesfoundconsistentforanyofthe characters.

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