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Stability Analysis for Physical Grain Quality Parameters in Coloured Pericarp Sorghum (*Sorghum bicolar* (L.) Moench)

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ABSTRACT

Physical grain quality traits such as pericarp colour, endosperm texture, grain hardness, lustre, density, and porosity are crucial for food and industrial applications of sorghum. Twenty-one coloured pericarp sorghum genotypes were evaluated across three environments during 2022–23 using the Eberhart and Russell (1966) stability model. Significant genotype, environment, and G×E effects were detected for grain quality traits. GP 40053-1-2 displayed high stability for endosperm texture, hardness, and bulk density. IS 23891 exhibited superior porosity, while GP 920 showed the highest hardness. All genotypes maintained stable pericarp colour. The identified stable genotypes provide valuable inputs for quality-based sorghum breeding.

Introduction

Sorghum was a drought-tolerant C4 cereal of the grass family *Poaceae*, ranked as the fifth most important cereal globally and the third in India after rice and wheat, with major cultivation in semi-arid regions such as Maharashtra and Marathwada.

Its coloured pericarp types and diverse genotypes, combined with strong genotype × environment (G × E) interaction, made stability analysis essential for identifying high-yielding and stable types that could help arrest and reverse the decline in sorghum area in regions where it was being replaced by crops such as soybean.

Sorghum bicolor (L.) Moench was an annual, tall, monoecious C4 grass with a deep and spreading root system. It was adapted to tropical and subtropical drought-prone semi-arid regions where it served as a key cereal for food, feed and fodder. It was nutritionally rich, containing about 74% starch, 11% protein, moderate fat, crude fibre and ash, and it was naturally gluten-free, with a relatively low glycaemic index and high levels of antioxidants, polyphenols, dietary fibre and minerals, making it suitable for people with chronic lifestyle disorders such as diabetes and gluten intolerance.

In India, sorghum was mainly grown in the *kharif* (largely hybrids) and *rabi* (mostly improved varieties) seasons and was the third major cereal after rice and wheat. Maharashtra, Karnataka and Madhya Pradesh were the leading producing states. Within Maharashtra, districts of the Marathwada and adjoining regions such as Solapur, Beed, Parbhani, Osmanabad and Latur contributed a large share of the area and production, although the overall sorghum area had been under pressure from competing crops.

Declining Sorghum Area in Maharashtra and Marathwada

Over the past two to three decades, the sorghum area in Maharashtra, including the Marathwada region, had declined steadily as farmers shifted to more remunerative oilseeds and commercial crops, particularly soybean in *kharif* and, in some tracts, cotton and other cash crops. This shift had been driven by relatively higher market prices, assured demand, better support prices and strong processing industries for soybean, along with changing dietary habits that had reduced direct human consumption of sorghum in both rural and urban populations.

As a result, even in traditional sorghum belts of Marathwada, the crop had often been confined to marginal lands or reduced to a secondary role, which threatened on-farm sorghum diversity and the regional food–fodder security that depended on this hardy cereal. The decline in area, coupled with climate variability, underlined the need for sorghum cultivars that were not only high-yielding but also stable and tailored to specific environments and market uses, so that farmers perceived sorghum as economically competitive with soybean and other alternatives.

Role of Coloured Pericarp Types and Grain Quality

Sorghum exhibited wide variation in pericarp colour—red, white, yellow, brown and black—controlled genetically by pigments such as anthocyanins, flavonoids and tannins located mainly in the pericarp and testa. These colours were closely linked with phenolic content, antioxidant capacity and end-use quality. White grains were often preferred for porridge and many food products, red grains for brewing, yellow grains for their higher phenolic and nutritional value, and brown (tannin) sorghums for specific health-oriented or industrial uses. Because grain colour and the associated phenolic profile directly affected both consumer acceptance and industrial suitability, breeding and selecting stable coloured pericarp sorghums tailored to food, feed, brewing and health-food markets could create new demand segments. Aligning genotype selection with these differentiated value chains improved price realisation for farmers in Maharashtra and Marathwada, making sorghum a more attractive alternative to competing crops.

Importance of Stability Analysis for Reversing Area Decline

Weather and environmental conditions strongly influenced sorghum phenology, yield and grain quality, leading to significant genotype × environment interactions across seasons, locations and years. A genotype was considered stable when it maintained relatively consistent grain yield and desirable grain-quality traits across a wide range of environments, adjusting its phenotype without large performance penalties under stress or fluctuating conditions.

Stability analysis using models such as the Eberhart and Russell (1966) approach allowed breeders to quantify G × E interactions, identify genotypes with high mean yield and low deviations from regression, and classify genotypes as widely adapted or specifically adapted to particular environments. In the context of coloured pericarp sorghum, such analysis helped pinpoint lines that consistently expressed desirable grain colour, phenolic profile and physical quality, along with stable yield, under the variable conditions typical of Marathwada and other parts of Maharashtra.

How This Study Could Help Increase Sorghum Area

The proposed investigation, "Stability Analysis in Coloured Pericarp Sorghum (*Sorghum bicolor* (L.) Moench)", aimed to estimate stability for physical grain quality parameters, particularly those associated with pericarp colour and end-use suitability.

By identifying coloured pericarp sorghum genotypes that combined high, stable yields with stable grain quality under the diverse environments of Marathwada and wider Maharashtra, the study could generate varieties and hybrids that were more reliable for farmers and more attractive to markets and processing industries. When such stable, market-oriented cultivars were supported by appropriate extension measures, value-addition initiatives and price incentives, they could improve the profitability and risk profile of sorghum cultivation, helping to slow, halt or even reverse the ongoing shift of area from sorghum to soybean and other competing crops in the region.

Materials and Methods

The experiment was conducted across three testing environments—Parbhani (E1), Basmathnagar (E2), and Nanded (E3)—to evaluate the physical grain quality traits of coloured pericarp sorghum genotypes. The trial followed a Randomized Block Design with two replications, using a spacing of 45 × 15 cm and applying a fertilizer dose of 80:40:40 NPK kg/ha. Observations were recorded on key grain quality parameters, including pericarp colour, endosperm texture, grain lustre, grain shape, grain hardness, bulk density, and porosity. Stability analysis was carried out using the Eberhart and Russell (1966) model, which estimates mean performance (μ), regression coefficient (bi), and deviation from regression (S^2di) to determine genotype stability across environments.

Plant Materials

Twenty-one genotypes—including 18 coloured pericarp germplasm lines and 3 checks—were evaluated (Table 1).

Result and Discussion

Pooled ANOVA

Highly significant genotypic differences were recorded for all physical grain quality traits, including pericarp colour, endosperm texture, lustre, hardness, grain shape, bulk density, and porosity. Such broad variability aligns with earlier reports on sorghum grain quality diversity (De Alencar Figueiredo *et al.,* 2010; Dykes *et al.,* 2009; Verma *et al.,* 2017).

Pericarp colour variation observed (white to greyed-orange) mirrors the diversity patterns documented in landraces and germplasm collections (Teshome *et al.,* 1997; Mukkun *et al.,* 2018). Endosperm texture differences, with IS 23891, ISSVT 102, and GP 40053-1-2 showing fully farinaceous grains, support previous findings that genotype significantly influences endosperm characteristics (Anglani, 1998; Audilakshmi & Aruna, 2005; Shull *et al.,* 1990).

Grain hardness varied widely, with GP 920 showing maximum hardness, consistent with reports linking specific genotypes to extreme hardness ranges (Rooney *et al.,* 2005; Itagi & Hemalatha, 2017). High lustre in GP 2017-5, YPT 1015, IS 23891, and GP 40053-1-2 matches the physio-chemical variability trends observed previously (Shen *et al.,* 2018; Xiong *et al.,* 2020).

Bulk density and porosity also showed substantial genotype-driven variability. The higher bulk density in GP 40053-1-2 and Parbhani Moti aligns with earlier observations linking these traits with grain composition and milling efficiency (Patil *et al.,* 2019; Ananda *et al.,* 2023; Guindo *et al.,* 2019).

High porosity in GP 40053-1-2 and IS 23891 is consistent with earlier reports associating grain structure with processing qualities (Tesso *et al.,* 2006; Rooney & Johnson, 1970).

Stability analysis revealed that IS 23891, ISSVT 102, and GP 40053-1-2 exhibited stable endosperm texture (bi ≈ 1; $S^2di \approx 0$). GP 920 exhibited stable and superior hardness across environments, supporting reports of predictable grain hardness performance (Shivani & Sreelakshmi, 2014; Rohmani *et al.,* 2006). Grain lustre stability was strongest in GP 40053-1-2 and IS 23891. Bulk density stability among genotypes aligns with findings from Ghazy *et al.,* (2012) and Umakanth *et al.,* (2012b).

Overall, the stability analysis identifies GP 40053-1-2, IS 23891, ISSVT 102, and GP 920 as highly stable and superior for multiple grain quality traits. These results align with long-standing observations that grain physical quality in sorghum is strongly genotype-dependent yet influenced by G×E interactions (Ananda *et al.,* 2023; Guindo *et al.,* 2019).

Table.1 List of genotypes studied

SN	Genotypes	Pericarp colour	SN	Genotypes	Pericarp colour
1	GP2017-5	Yellow	12	ICSR 93036	Red
2	YPT 1015	Yellow	13	GP 1539	Red
3	GD	Yellow	14	GP 920	Red
4	YPT1007	Yellow	15	GP 3138	White
5	RIL 40818-3-1	Yellow	16	IS 23891	White
6	ICRISAT 409	Yellow	17	GP 40053-1-2	White
7	YPT 1021	Yellow	18	BAJRA TYPE	White
8	ISSVT 712	Red	19	Udgir local (Check)	Yellow
9	GD 62417	Red	20	Parbhani Moti (Check)	Pearly White
10	RIL 40141-1	Red	21	M 35-1 (Check)	Pearly White
11	ISSVT 102	Red			

Table.2 Pooled ANOVA for Physical Grain Quality Traits

Trait	Genotypes	Environments	G×E	Error
Endosperm texture	5.01**	0.31	0.91	0.19
Grain hardness	4.35**	1.40**	1.17**	0.15
Bulk density	0.06**	0.04*	0.02*	0.007
Porosity	57.19**	43.48**	24.35**	1.94

*Indicates significant at 5% level, ** indicates significance at 1% level

Table.3 Mean Grain Hardness across Environments

Genotype	E1	E2	E3	Pooled Mean
GP 920	9.10	8.90	9.60	9.20
M 35-1	9.05	8.95	9.72	9.24
GP 40053-1-2	8.54	8.89	8.71	8.71
ISSVT 712	6.19	5.74	5.62	5.85
GD 62417	6.01	5.30	5.56	5.62

Table.4 Bulk Density and Porosity (Pooled)

Genotype	Bulk Density (g/cc)	Porosity (%)
GP 40053-1-2	1.30	32.5
IS 23891	1.295	30.5
YPT 1021	1.295	21.93
Parbhani Moti	1.295	17.37
M 35-1	1.295	19.37

Table.5 Estimate of stability parameters for physical grain quality characters over three environments in sorghum

Sr. No.	Genotype	Endosperm Texture (1-9 score)			Grain hardness (kg/cm2)		
		Xi	bi	S2di	Xi	bi	S2di
1.	GP2017-5	5.31	-2.69	0.55	7.13	-0.96	**-0.14**
2.	YPT 1015	4.77	-1.80	0.87	8.23	-0.84	**-0.14**
3.	GD	4.97	-6.05	-0.12	6.83	2.66	**-0.11**
4.	YPT1007	4.15	-4.70	-0.14	7.40	-0.47	**-0.08**
5.	RIL 40818-3-1	4.27	-7.01	-0.19	9.20	1.38	**0.04**
6.	ICRISAT 409	5.20	7.07	0.14	6.85	0.95	**-0.08**
7.	YPT 1021	4.30	8.23	0.33	8.99	1.13	**-0.16**
8.	ISSVT 712	5.54	0.54	-0.02	5.85	-0.17	**0.02**
9.	GD 62417	5.12	14.01	2.14	5.62	0.59	**0.06**
10.	RIL 40141-1	4.92	11.83	5.53	6.77	1.98	**-0.01**
11.	ISSVT 102	7.96	0.50	-0.16	7.21	-0.60	**-0.15**
12.	ICSR 93036	5.60	3.31	0.12	8.33	0.64	**-0.10**
13.	GP 1539	4.88	4.27	-0.20	6.68	0.83	**-0.15**
14.	GP 920	6.80	1.62	-0.20	9.20	1.23	**-0.13**
15.	GP 3138	7.20	0.92	-0.15	5.80	1.37	**-0.15**
16.	IS 23891	8.16	1.02	-0.16	7.70	0.61	**0.83**
17.	GP 40053-1-2	7.60	1.22	-0.20	8.71	0.98	**-0.11**
18.	BAJRA TYPE	3.37	7.04	-0.10	5.81	1.90	**0.15**
19.	Udgir local©	5.70	1.29	0.37	7.99	1.28	**-0.15**
20.	Parbhani Moti©	5.40	0.92	2.27	6.61	0.98	**-0.12**
21.	M 35-1 ©	5.10	1.45	1.45	9.24	1.25	**-0.09**
	Mean	**5.54**	**-**	**-**	**7.43**	**-**	**-**

*Significant at 5% level; **Significant at 1% level

Continued….

Sr. No.	Genotype	Bulk density (g/cc)			Porosity (%)		
		Xi	Bi	S2di	Xi	bi	S2di
1.	GP2017-5	1.20	0.11	0.00	19.50	2.11	**-0.93**
2.	YPT 1015	0.92	2.97	0.01	21.93	3.25	**-1.79**
3.	GD	1.21	0.64	0.02	21.75	2.12	**-0.67**
4.	YPT1007	1.28	-2.04	0.00	17.37	1.65	**9.96**
5.	RIL 40818-3-1	1.30	-0.53	0.00	19.37	1.61	**10.70**
6.	ICRISAT 409	0.92	1.45	0.00	19.62	2.10	**-1.59**
7.	YPT 1021	1.29	0.88	0.21	24.06	-1.37	**-1.81**
8.	ISSVT 712	1.28	0.35	-0.01	21.96	0.46	**10.90**
9.	GD 62417	0.89	3.58	0.04	18.62	0.46	**6.04**
10.	RIL 40141-1	0.99	5.45	0.02	28.50	0.88	**8.03**
11.	ISSVT 102	1.14	2.14	-0.01	19.31	0.61	**8.51**
12.	ICSR 93036	1.21	0.49	0.01	23.62	1.33	**6.26**
13.	GP 1539	1.34	-4.21	0.02	18.25	1.63	**-1.53**
14.	GP 920	1.16	0.10	-0.01	20.08	1.89	**-1.18**
15.	GP 3138	1.10	-2.69	0.06	18.75	1.81	**-1.88**
16.	IS 23891	0.91	3.62	0.01	30.50	0.28	**4.26**
17.	GP 40053-1-2	1.29	1.22	0.00	32.50	1..56	**12.12**
18.	BAJRA TYPE	1.25	0.72	0.03	18.50	0.62	**15.03**
19.	Udgir local©	1.16	1.07	0.05	28.30	0.98	**16.02**
20.	Parbhani Moti©	1.29	1.75	0.02	24.50	1.34	**-1.22**
21.	M 35-1 ©	1.29	1.10	0.06	25.00	0.94	**11.27**
	Mean	**1.16**	**-**	**-**	**22.47**	**-**	**-**

*Significant at 5% level; **Significant at 1% level

Stability Patterns

The genotype GP 40053-1-2 exhibited stability across multiple physical grain quality traits, demonstrating its suitability as a consistent performer. For grain hardness, GP 920 and M 35-1 recorded the highest values, indicating their potential for hardness-based processing and food applications. In terms of porosity, GP 40053-1-2 along with IS 23891 showed superior performance, making them ideal for industrial uses where porosity is a key requirement. Notably, pericarp colour was highly stable across environments, with all 21 genotypes exhibiting S^2di values close to zero, reflecting complete stability for this trait.

Physical grain quality traits are strongly influenced by environment, as evidenced by significant G×E interactions. Hardness and porosity traits indicate suitability for malting and industrial processing. GP 40053-1-2 is the best stable performer across traits. The consistent pericarp colour across environments suggests strong genetic control.

In conclusion, the investigation titled "Stability Analysis in Coloured Pericarp Sorghum - *Sorghum bicolar* (L.) Moench" evaluated 21 rabi season coloured pericarp sorghum lines across three locations: Parbhani, Basmath, and Nanded, focusing on estimating stability for physical grain quality parameters. Experimental material included 18 germplasm lines and 3 checks, assessed in a randomized block design with two replications. Observations for different morphological and grain quality traits were recorded at various crop growth stages, following Eberhart and Russell (1966) stability analysis model.

Analysis of variance showed significant genotypic variation for days to 50% flowering, physiological maturity, plant height, fodder yield/plant, grain yield/plant, grain shape, pericarp colour, grain lustre, grain hardness, endosperm texture, test weight, bulk density, and porosity. Significant genotype × environment (G × E) interactions were observed, indicating variability in genotypes' linear response across environments for most traits.

Specific genotypes demonstrated stability for key grain quality traits:

GP 40053-1-2 showed stable and high performance for panicle breadth, grain yield/plant, fodder yield/plant, endosperm texture, grain hardness, and bulk density across all locations.

Other genotypes showed stability in individual traits but no genotype was stable for all traits.

Grain shape, lustre, and pericarp colour were stable across all genotypes and environments.

Some genotypes exhibited early flowering (GP 1539, RIL 40818-3-1) and early maturity (GP 1539, GP 2017-5), while others were late flowering/maturing (ICRISAT 409, RIL 40141-1).

In Conclusion, Significant variability existed among genotypes for most grain quality traits.

Genotype × environment interaction significantly influenced trait expression.

Certain genotypes, notably GP 40053-1-2, showed stable performance for multiple grain quality and yield traits.

Stability for grain shape, lustre, and pericarp colour was consistent across environments.

The study validates the use of Eberhart and Russell (1966) model in identifying genotypes with desirable stability for grain quality, aiding in breeding resilient, high-quality sorghum lines suitable for diverse environmental conditions.

This study supports the development of improved coloured pericarp sorghum genotypes that maintain quality traits across environments, thereby meeting industry and consumer needs while contributing to crop stability in drought-prone regions like Marathwada and Maharashtra.

Author Contributions

N. Ajay: Investigation, formal analysis, writing—original draft. R. R. Dhutmal: Validation, methodology, writing—reviewing. K. S. Baig:—Formal analysis, writing—review and editing. H. V. Kalpande: Investigation, writing—reviewing. A. W. More: Resources, investigation writing—reviewing. A. R. Gaikwad: Validation, formal analysis, writing—reviewing. S. G. Shinde: Conceptualization, methodology, data curation, supervision, writing—

reviewing the final version of the manuscript. D. K. Patil: Validation, methodology, writing—reviewing. D. K. Zate:—Formal analysis, writing—review and editing. J. D. Deshmukh: Investigation, writing—reviewing. S. M. Umate: Resources, investigation writing—reviewing. A. D. Pandagale: Validation, formal analysis, writing—reviewing. M. P. Wankhade: Conceptualization, methodology, data curation, supervision, writing—reviewing the final version of the manuscript. V. R. Ghuge: Validation, methodology, writing—reviewing. A. K. Choudhari:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Abdulai, A. L.; Parzies, H.; Kouressy, M; Vaksmann, M; Asch, F; Brueck, H. (2012) stability studies in sorghum in Coimbatore district of Tamil Nadu. International Journal of Agricultural Research. 7: (1) 17-32. https://doi.org/10.3923/ijar.2012.17.32

Admas, S and Tesfaye, K. 2017. Genotype-by-environment interaction and yield stability analysis in sorghum (*Sorghum bicolor* (L.) Moench) genotypes in North Shewa, Ethiopia. Agriculture and Environment. 9: 82−94 https://doi.org/10.1515/ausae-2017-0008

Ali, M.A., 2000. Stability studies in grain sorghum. Ph.D. Thesis, Faculty of Agriculture, Assiut University, Egypt.

Almeida Filho, J. E. de; Tardin, F. D.; Souza, S. A. de; Godinho, V. de P. C.; Cardoso, M. J., 2010. Yield performance and phenotypic stability of grain sorghum hybrids. Revista Brasileira de Milho e Sorgo Vol. 9 No. 1 pp. 51-64. https://doi.org/10.4238/gmr.15027914

Alvels, J.A.G., Cabral, P.D.S., Teodoro, P.E., Candido, L.S., Silva, F.H.D.L.E., Neto, J.H and Reis, E.F.D. 2021. Adaptability and Genotypic Stability of Sorghum in the Brazilian Cerrado. Sugar Tech. 23:38–44

Amare, S., Amare, N., Kedanemaryam, W., Taye, T., Diriba, T., Alemu, T.,... & Meron, B. (2020). Multi environment and spatial analysis of early maturing sorghum [*Sorghum bicolor* (L.) Moench] genotypes in dry lowland areas of Ethiopia. *African Journal of Agricultural Research*, *15*(2), 278-290.

Ananda, G.K.S., Norton, S.L., Barnes, E. *et al.,* Variant analysis of grain shape related genes in the genus *Sorghum*. *Genet Resour Crop Evol* 70, 1377–1394 (2023).

Anglani, C. (1998). Sorghum endosperm texture–A review. *Plant foods for human nutrition*, *52*, 67-76.

Annonymous (2021). Director of Agriculture, Govt. of India, Annual statistical report, 2021-22.

Audilakshmi, S., & Aruna, C. (2005). Genetic analysis of physical grain quality characters in sorghum. *The Journal of Agricultural Science*, *143*(4), 267-273.

Burli, A. V., M. G. Jadhav and S. M. More, 2004. Stability for grain and fodder yield in *kharif* sorghum genotypes. J. Maharashtra agric. Univ., 29(3): 339-340.

Chavan, S. K., Mahajan, R. C., & Fatak, S. U. (2010). Stability studies in sorghum. *Karnataka Journal of Agricultural Sciences*, *23*(2), 322-323.

Chhina, B.S. and Phul, P.S. 1987. Stability analysis for yield influencing traits in grain sorghum. Crop Improv. 14(1): 36-4

De Alencar Figueiredo, L. F., Sine, B., Chantereau, J., Mestres, C., Fliedel, G., Rami, J. F.,... & Courtois, B. (2010). Variability of grain quality in sorghum: association with polymorphism in Sh2, Bt2, SssI, Ae1, Wx and O2. *Theoretical and applied genetics*, *121*, 1171-1185.

Dykes, L., Seitz, L.M., Rooney, W.L. & Rooney, L.W. (2009). Flavonoid composition of red sorghum genotypes. Food Chemistry, 116(1), 313– 317.

Eberhart, S.A. & Russell, W.A. (1966). Stability parameters for comparing varieties. Crop science, 6, 36-40.

EI-Menshawi, M. M. 2005. Stability and combining ability analysis for grain sorghum hybrids and their parental lines. Bulletin of Faculty of Agriculture, Cairo University; 2005. 56: 2, 271-293.

Elangovan, M., & Raut, M. S. (2010). Stability of new varieties for yield components in *rabi* sorghum (*Sorghum bicolor*). *Indian Journal of Agricultural Sciences*, *80*(2), 106-109.

Ezzat, E. M., Ali, M.A and Mahmoud, A.M. 2010. Genotype x Environment interactions and Stability analysis of Grain Sorghum (*Sorghum bicolor* L. Moench). Asian Journal of Crop Science. 2(4): 250-260.

Fasahat, P., Rajabi, A., Mahmoudi, S.B., Noghabi, M.A and Rad, J.M. 2015. An Overview on the Use of Stability Parameters in Plant Breeding. Biometrics & Biostatistics International Journal. 2(5): 00043.

Filho, J.E.A., Tardin, F.D., Daher, R.F., Barbé, T.C., Paula, C.M., Cardoso, M.J and Godinho, V.P.C. 2014. Stability and adaptability of grain sorghum hybrids in the off-season. Genetics and Molecular Research. 13 (3): 7626-7635

Ghazy, M.F.G., Shahwan, S. M and Rajab, M. N.2012. Stability analysis and genotype x environment interactions for forage sorghum hybrids (*Sorghum bicolor*, L. Moench). Journal of Agricultural Research. 38(1): 142-153.

Girish, G., Badigannavar, A., Muniswamy, S., Yogeesh, L. N., Jayalaxmi, S. K., Talwar, A. M.,... & Ganapathi, T. R. (2020). Stability analysis of grain yield and its contributing traits.

Girish, G., Kiran, S. B., Lokesh, R., Vikas, V., Kulkarni, V., Rachappa, V., Yogesh, L. N and Talwar, A. M. 2016. Stability analysis for yield and its attributing traits in advanced breeding lines of *rabi* sorghum (*Sorghum bicolor* (L.) Moench). Journal of Applied and Natural Science. 8(1): 10-15

Guindo, D., Teme, N., Vaksmann, M., Doumbia, M., Vilmus, I., Guitton, B.,... & Rami, J. F. (2019). Quantitative trait loci for sorghum grain morphology and quality traits: Toward breeding for a traditional food preparation of West-Africa. *Journal of cereal Science*, *85*, 256-272.

Gwanama, C., Mgonja, M., Chisi, M., Folkertsma, R., & Mutegi, R. (2009). Genetic variability characterisation of Tanzania sorghum landraces based on simple sequence repeats (SSRs) molecular and morphological markers. *African Crop Science Journal*, *17*(2).

Ibrahim, K. A., M El-Sagheer, M. E., & Y Abd Elraheem, O. A. (2019). Stability Analysis for Yield and some other traits in grain sorghum using Tai's stability method. *Journal of Plant Production*, *10*(12), 1111-1116.

Itagi, C., & Hemalatha, S. (2017). Variability in grain physio-chemical composition in different sorghum (*Sorghum bicolor* (L.) Moench) genotypes. *International Journal of Current Microbiology and Applied Sciences*, *6*(7), 2610-2618.

Iyanar K and Ravikesavan R. 2005. G × E interaction in multi-cut forage sorghum [*Sorghum bicolor* (L.) Moench]. Advances in Plant Sciences. 18: 537–42.

Kenga R., S. 0. Alabi and Gupta., 2003. Yield Stability Of Sorghum Hybrids And Parental Lines. African Crop Science Journal, Vol. 11. No. 2, 2003, pp. 65-73.

Khandelwal, V., Keerthika, A., & Dhoot, M. (2019). Stability Analysis for Yield and Component Traits in Sorghum [*Sorghum bicolor* (l.) Moench.]. *Int. J. Curr. Microbiol. App. Sci*, *8*(9), 1910-1918.

Khandelwal, V.; Sharma, V.; and Singh, V. (2005). Stability for grain yield in sorghum. Indian J. Genet, 65 (I):53-54.

Khanure, S.K. (1999). Stability analysis for grain yield in *rabi* sorghum. Madras Agric. J., 86 (1-3):49-50.

Khazaei. A., To*rabi*., Mokhtararpour, H and Beheshti, A. R. 2019. Evaluation of yield stability of forage sorghum [*Sorghum bicolor* (L.) Moench] genotypes. Iranian Journal of Crop Sciences. 21 (3): 225-236.

Kher, H. R., H. P. Parmar, M. K. Gangani and D. J. Parmar, 2008. Stability analysis for fodder yield in forage sorghum [*Sorghum bicolor* (L.) Moench]. Crop Research (Hisar); 36: 1/3, 244-245.

Kishore, N. and Singh, L. N. (2004). Stability for forage yield influencing traits in sorghum. Indian J. Genet., 64(1):71- 72.

Lestari, Endang, E., Dewi, I. S., Nur, A., & Yunita, R. (2019). Genetic x environment interaction on agronomic characters and yield components of sorghum (*Sorghum bicolor*) mutant strain. *Biodiversitas Journal of Biological Diversity*, *20*(12).

Madhusudhana, R., Umakanth, A. V., Kaul, S and Rana, B. S. 2003. Stability analysis for grain yield in *rabi* sorghum [*Sorghum bicolor* (L.) Moench]. Indian Journal of Genetics. 63(3): 255-256.

Meena, B. L., Ranwah, B. R., Meena, H. S., Meena, M. D., Meena, K. N., & Rai, P. K. (2020). Stability Analysis in Dual Purpose Sorghum [*Sorghum bicolor* (L.) Moench]. *Int. J. Curr. Microbiol. App. Sci*, *9*(3), 2521-2530

Mukkun, L., Lalel, H. J. D., Richana, N., Pabendon, M. B., & Kleden, S. R. (2018, April). The diversity of local sorghum (*Sorghum bicolor* L. Moench) in Nusa Tenggara Timur province. In *IOP Conference Series: Earth and Environmental Science* (Vol. 144, No. 1, p. 012065). IOP Publishing.

Mungra K.D., B. D. Jadhav and Khandelwal Vikas., 2011. Genetic analysis for yield and quality traits in forage sorghum [*Sorghum bicolor* (L.) Moench]. Indian Society of Genetics & Plant Breeding, F2, First Floor, NASC Complex, PB#11312, IARI, New Delhi 110 012 Online management by indianjoumals.com.

Muppidathi, N.; Subbaraman, N. and Muthuvel, P. (1995 b). Genotypic stability for panicle characters in grain sorghum (*Sorghum bicolor* (L.) Moench). Madras Agric. J., 82 (I): 21-24.

Naggar, A. M. M. A., Salam, R. M. A. E., Asran, M.R and Yaseen, W. Y. S. 2018. Yield Adaptability and Stability of Grain Sorghum Genotypes across Different Environments in Egypt using AMMI and GGE-biplot Models. Annual Research & Review in Biology. 23(3): 1-16.

Nayeem, K.A. and Bapat, D.R. 1989. Phenotypic stability of characters related to productivity of grain sorghum [*Sorghum bicolor* (L.) Moench] Indian J. Genet. 49(2): 195-201.

Patil, H. S., Narakhede, B. N. and Bapat, D. R., 1991b, Phenotypic stability of various characters in sorghum. Journal of Maharashtra Agricultural Universities, 16: 158-160

Patil, N. Y., Pugh, N. A., Klein, R. R., Martinez, H. S., Martinez, R. S., Rodriguez-Herrera, R.,... & Klein, P. E. (2019). Heritability and quantitative trait loci of composition and structural characteristics in sorghum grain. *Journal of crop improvement*, *33*(1), 1-24.

Patil, S.P., Manjare, M.R., Kamdi, S.R., Dethe, A.M. and Ingle, M.B. 1966. Stability analysis in sorghum [*Sorghum bicolor* (L.) Moench]. International Journal of Plant Sciences. 2(2): 70-75.

Pitombeira, J. B. Castro, A. B. de Pompeu, R. C. F. F. Neiva, J. N. M., 2002. Adaptability and stability of sorghum genotypes in five environments of the state of Ceara. [Portuguese]. Revista Ciencia Agronomica; 2002. 33: 1, 20-24.

Prabhakar and K. D. Patil, 2002. Phenotypic stability for grain yield in *rabi* sorghum varieties for the medium soils of scarcity zone. Journal of Maharashtra Agricultural Universities, 27(1): 104-106.

Prabhakar, M., Elangovan, M and Raut, M.S. 2010. Stability of new varieties for yield components in *rabi* sorghum (*Sorghum bicolor*). Indian Journal of Agricultural Sciences. 80 (2): 106–109.

Rao, P.S., Reddy, P.S., Rathore, A., Reddy, B.V.S and Panwa, S. 2011. Application GGE biplot and AMMI model to evaluate sweet sorghum (*Sorghum bicolor*) hybrids for genotype × environment interaction and seasonal adaptation. Indian Journal of Agricultural Sciences. 81 (5): 438–44.

Reddy. R.R.P.; Sankar, M. G. R. and Das, N. D. (2004). Genotype x Environment interactions in *rabi* sorghum. J. Maharashtra Agric. Univ; 21(1):21-24.

Rohmani, M.M., Miah, M. A., Kadir, M. M., Shahjahanandm, M and Uddin, S. 2006. Stability analysis in Sorghum. Bangladesh Journal of Agricultural Research. 31(4): 645-651.

Rooney, L. W., Johnson, J. W., & Rosenow, D. T. (1970). Sorghum quality improvement: types of food. *Cereal Science Today*, *15*, 240-43.

Rooney, W. L., Aydin, S., & Kuhlman, L. C. (2005). Assessing the relationship between endosperm type and grain yield potential in sorghum (*Sorghum bicolor* L. Moench). *Field crops research*, *91*(2-3), 199-205.

Saeed, M., & Francis, C. A. (1983). Yield Stability in Relation to Maturity in Grain Sorghum 1. *Crop science*, *23*(4), 683-687.

Saikiran, V., Shivani, D., Maheswaramma, S., Ramesh, S., Sujatha, K., Sravanthi, K.,... & Kumar, C. S. (2022). Identification of stable genotypes based on grain yield response over different environments in sorghum (*Sorghum bicolor* L. Moench). *Electronic Journal of Plant Breeding*, *13*(2), 705-711.

Sanjari, A. G., & Redai, M. (1994). Study of the genotype environment interaction and the adaptability of Sorghum hybrids in Zanjan region. *Seed and Plant Journal of Agricultural Research (Iran Islamic Republic)*.

Shen, S., Huang, R., Li, C., Wu, W., Chen, H., Shi, J. & Ye, X. (2018). Phenolic compositions and antioxidant activities differ significantly among sorghum grains with different applications. Molecules. 23(5), 1203.

Shivani, D and Sreelakshmi, C.H. 2014. Genotype X Environment interaction and Stability analysis in *rabi* Sorghum. Journal of Global Biosciences. 3(2): 626- 632.

Showemimo, F. A. (2007). Grain yield response and stability indices in sorghum (*Sorghum bicolor* (L.) Moench). *Communications in Biometry and Crop Science*, *2*(2), 68-73.

Shull, J. M.; Chandrashekar, A.; Kirleis, A. W.; and Ejeta, G. (1990) "Development of Sorghum (*Sorghum bicolor* (L.) Moench) Endosperm in Varieties of Varying Hardness," *Food Structure*: Vol. 9: No. 3, Article 8.

Singh, A. R., & Nayeem, K. A. (1978). Stability of hybrids and their parents in *Sorghum bicolor* Moench. *Indian Journal of Heredity*, *10*(4), 67-79.

Souza, V.F.D., Parrella, R.A.D.C., Tardin, F.D., Costa, M.R., Júnior, G.A.D.C and Schaffert, R.E. 2013. Adaptability and stability of sorghum cultivars. Crop Breeding and Applied Biotechnology.13: 144-151.

Sujatha, K., Pushpavalli, S. N. C. V. L., & Shivani, D. (2016). Stability of yield and related traits in the land races of *rabi* sorghum (*Sorghum bicolor* (L.) Moench). *Electronic Journal of Plant Breeding*, *7*(3), 620-625.

Suresh, M. Ganesan, N. M. Manonmani, S., 2001. Genotype x environment interaction for grain yield in sorghum (*Sorghum bicolor* (L.) Moench). Madras Agricultural Journal; 87: 7/9, 509-510.

Teshome, A., Baum, B. R., Fahrig, L., Torrance, J. K., Arnason, T. J., & Lambert, J. D. (1997). Sorghum [*Sorghum bicolor* (L.) Moench] landrace variation and classification in north Shewa and south Welo, Ethiopia. *Euphytica*, *97*, 255-263.

Tesso, T., Ejeta, G., Chandrashekar, A., Huang, C. P., Tandjung, A., Lewamy, M.,... & Hamaker, B. R. (2006). A novel modified endosperm texture in a mutant high-protein digestibility/high-lysine grain sorghum (*Sorghum bicolor* (L.) Moench). *Cereal chemistry*, *83*(2), 194-201.

Udoh, D. A. A., Rasmussen, S. K., Jacobsen, S.E., Iwo, G. A., and Miliano, W.D. 2018. Yield stability of sorghum genotypes for bioenergy production under contrasting temperate and tropical environments. Journal of Agricultural Science. 10(12): 42-53.

Umakanth, A.V., Patil, J.V., Rani, C.H., Gadakh, S.R., Kumar, S.S., Rao, S.S., Kotasthane, T.V. 2012a. Combining Ability over Environments for yield Related Traits in Sorghum (*Sorghum bicolor* (L.) Moench). Sugar Tech. 14(3): 237-246.

Umakanth, A.V., Venkateshbhat, B., Hariprasanna, K and Ramana, O.V. 2012b. Stability of yield and related traits in dual-purpose sorghum (*Sorghum bicolor*) across locations. Indian Journal of Agricultural Sciences. 82 (6): 532–534.

Vange, T., Ango., Nache. I and Adedzwa, D. K. 2014. Stability Analysis of Six Improved Sorghum Genotypes across Four Environments in the Southern Guinea Savanna Agro ecological Zone of Nigeria. International Journal of Advances in Agricultural Science and Technology. 2 (2): 01-14.

Verma, R., Ranwah, B. R., Bharti, B., Kumar, R., Kunwar, R., Diwaker, A., & Meena, M. (2017). Characterization of sorghum germplasm for various qualitative traits. *Journal of Applied and Natural Science*, *9*(2), 1002-1007.

Worede, F., Mamo, M., Assefa, S., Gebremariam, T., & Beze, Y. (2020). Yield stability and adaptability of lowland sorghum (*Sorghum bicolor* (L.) Moench) in moisture-deficit areas of Northeast Ethiopia. *Cogent Food & Agriculture*, *6*(1), 1736865.

Xiong, Y., Zhang, P., Warner, R.D., Shen, S. & Fang, Z. (2020). Cereal grain-based functional beverages, from cereal grain bioactive phytochemicals to beverage processing technologies, health benefits and product features. Critical Reviews in Food Science and Nutrition, (18), 1-25.

Youngquist, J. B., Carter, D. C., & Clegg, M. D. (1990). Grain and forage yield and stover quality of sorghum and millet in low rainfall environments. *Experimental Agriculture*, *26*(3), 279-286.

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