Flora and Fauna
An International Research Journal of Biological Sciences
Journal recognised by DST New Delhi (NAAS RATING 4.74)
ISSN 2456-9364(Online) 0971-6920(Print)

STABILITY ANALYSIS FOR GRAIN YIELD AND ITS ATTRIBUTING TRAITS IN COLOURED PERICARP SORGHUM (SORGHUM BICOLOR (L.) MOENCH).

N. Ajay[1], R. R. Dhutmal[2], K. S. Baig[3], H. V. Kalpande[4], A. W. More[5], A. R. Gaikwad[6], S. G. Shinde[*7], D.K. Patil[8], D. K. Zate[9], J. D. Deshmukh[10], S. M. Umate[11], A. B. Bagade[12], A. D. Pandagale[13], V. N. Chinchane[14], M. P. Wankhade[15], V. R. Ghuge[16] , A. K. Choudhari[17]

[3]Director of Research, Vasantrao Naik, Marathwada Krishi Vidhyapeeth, Parbhani, Maharashtra, India.

[1]M.Sc. Student, [6, *7,10,13,14 & 15]Assistant Professor, [2,5,9,11,12&14]Associate Professor 4 Head, Department of Genetics and Plant Breeding, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India.

[8]Associate Dean & Principal, College of Agriculture, Badnapur, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India.

[12]Associate Professor (Agronomy), Cotton Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India.

*Email ID : sandeepshinde@vnmkv.ac.in

Abstract

Understanding the stability of grain yield and yield-attributing traits is critical for sorghum improvement under variable agro-ecological conditions. Twenty-one coloured pericarp sorghum genotypes were evaluated across three rabi environments—Parbhani, Basmathnagar, and Nanded—during 2022–23 using a randomized block design with two replications. Stability parameters were analysed according to the Eberhart and Russell (1966) model. Significant genotypic and environmental differences were observed for all yield traits. GP 40053-1-2 exhibited high grain yield and stable performance across environments, whereas IS 23891 and ISSVT 102 showed high yield potential. Genotypes GP 3138 and ISSVT 102 performed better under poor environments, while ICRISAT 409 and YPT 1007 performed better under favourable environments. The study identifies superior and stable genotypes suitable for rabi sorghum improvement.

KEYWORD: Sorghum; Rabi sorghum; Coloured pericarp; Grain yield; Yield-attributing traits; Stability analysis; Eberhart and Russell model; Genotype × environment interaction; Stable genotypes; High-yielding genotypes; Randomized block design; multi-environment evaluation

1. INTRODUCTION

Sorghum was a drought-tolerant C4 cereal belonging to the grass family *Poaceae*. It ranked as the fifth most important cereal globally and the third most important 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) interactions, 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 had been 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. It was naturally gluten-free, had a relatively low glycaemic index and possessed 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. It was the third major cereal after rice and wheat, with Maharashtra, Karnataka and Madhya Pradesh as the leading producing states. Within Maharashtra, districts in 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.

1.1 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 rural as well as urban populations.

As a result, even in traditional sorghum belts of Marathwada, the crop had often been confined to marginal lands or relegated to a secondary role. This trend threatened on-farm sorghum diversity and the regional food–fodder security that had historically depended on this hardy cereal. The decline in area, combined with increasing climate variability, highlighted 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.

1.2 Role of Coloured Pericarp Types and Grain Quality

Sorghum exhibited wide variation in pericarp colour—red, white, yellow, brown and black— controlled genetically through pigments such as anthocyanins, flavonoids and tannins located primarily in the pericarp and testa. These colours were closely associated with phenolic content, antioxidant capacity and end-use quality. White grains were preferred for porridge and many food products; red grains were used in brewing; yellow grains were valued for higher phenolic and nutritional content; and brown (tannin) sorghums were utilized for specific health-oriented or industrial purposes.

Since grain colour and associated phenolic profiles directly affected both consumer acceptance and industrial suitability, breeding and selecting stable coloured pericarp sorghums suited 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.

1.3 Importance of Stability Analysis for Reversing Area Decline

Weather and environmental conditions strongly influenced sorghum phenology, yield and grain quality, resulting in 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 diverse environments, adjusting its phenotype without substantial performance penalties under stress or fluctuating conditions.

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

1.4 How This Study Could Help Increase Sorghum Area

The proposed investigation, **"Stability Analysis in Coloured Pericarp Sorghum (*Sorghum bicolor* (L.) Moench)"**, aimed **to estimate the stability for grain yield and its attributing traits**.

By identifying coloured pericarp sorghum genotypes that combined high, stable yields with stable grain quality across the diverse environments of Marathwada and wider Maharashtra, the study had the potential to 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 through appropriate extension strategies, value-addition initiatives and price incentives, they could improve the profitability and reduce the risk associated with sorghum cultivation. This, in turn, could help slow, halt or even reverse the ongoing shift of area from sorghum to soybean and other competing crops in the region.

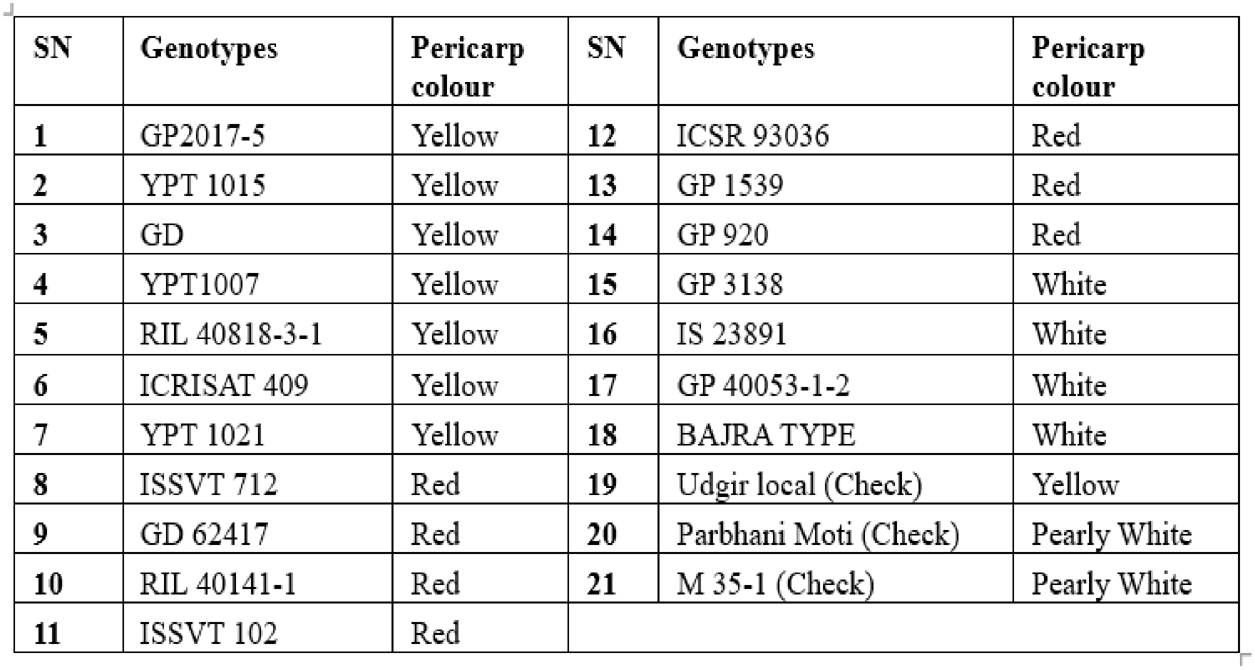
2. Materials and Methods

The field trial was carried out across three experimental sites representing distinct agro-climatic conditions: Parbhani (E1), Basmathnagar (E2), and Nanded (E3). The experiment was laid out in a Randomized Block Design with two replications, using a spacing of 45 × 15 cm and a fertilizer dose of 80:40:40 NPK kg/ha. Data were recorded on several agronomic and yield related traits, including days to 50% flowering, days to physiological maturity, plant height, panicle length and breadth, test weight, grain yield per plant, and fodder yield per plant. Stability analysis was performed following the Eberhart and Russell (1966) model, which estimates the stability parameters—mean performance (μ), regression coefficient (bi), and deviation from regression (S^2di)—to assess genotype behaviour across varying environments.

2.1 Plant Materials

Twenty-one genotypes—including 18 coloured pericarp germplasm lines and 3 checks—were evaluated (Table 2.1).

Table 2.1: List of genotypes studied



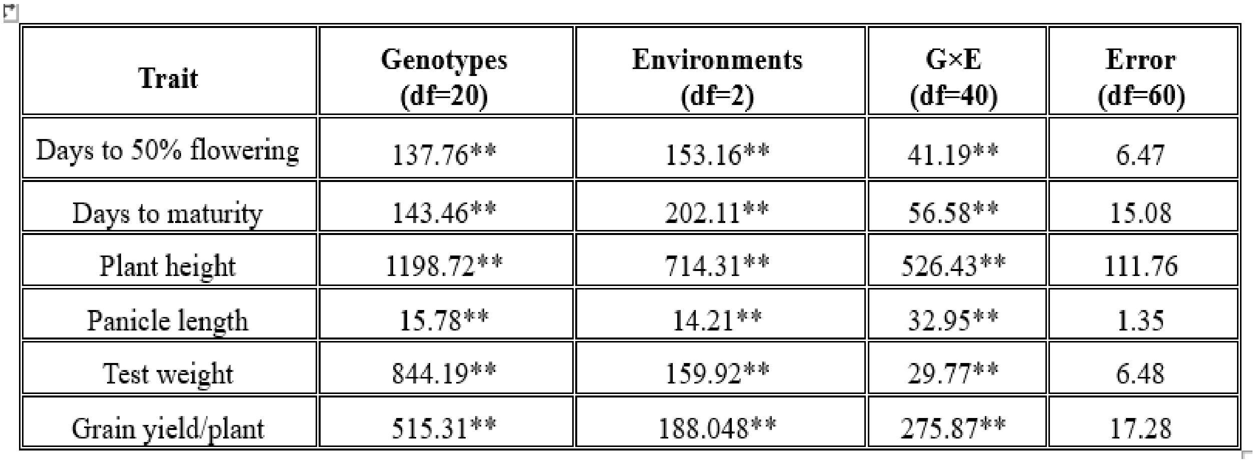
SN	Genotypes	Pericarp colour	SN	Genotypes	Pericarp colour
1	GP2017-5	Yellow	**12**	ICSR 93036	Red
2	YPT 1015	Yellow	**13**	GP 1539	Red
3	GD	Yellow	**14**	GP 920	Red
4	YPT1007	Yellow	**15**	GP 3138	White
5	RIL 40818-3-1	Yellow	**16**	IS 23891	White
6	ICRISAT 409	Yellow	**17**	GP 40053-1-2	White
7	YPT 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			

3. Results & Discussion

3.1 Analysis of Variance

Significant genotypic differences were recorded across all environments for all yield-related traits.

Table 3.1 Pooled ANOVA for Yield and Attributing Traits

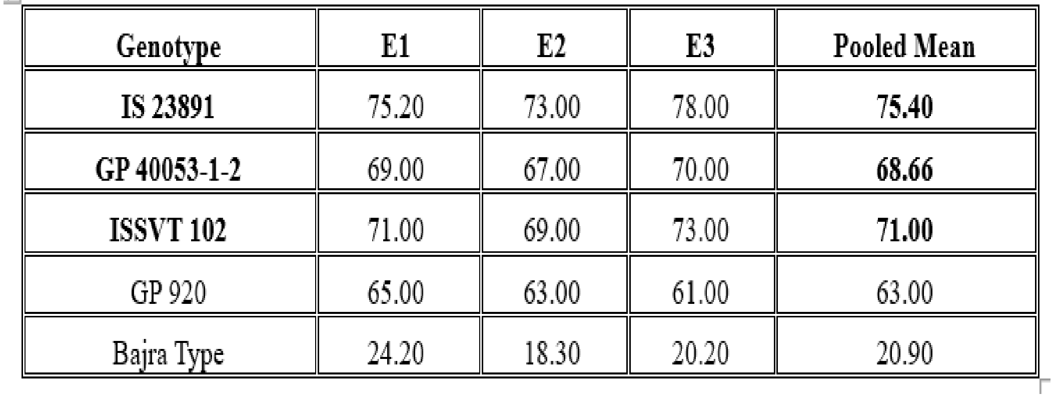


Trait	Genotypes (df=20)	Environments (df=2)	G×E (df=40)	Error (df=60)
Days to 50% flowering	137.76**	153.16**	41.19**	6.47
Days to maturity	143.46**	202.11**	56.58**	15.08
Plant height	1198.72**	714.31**	526.43**	111.76
Panicle length	15.78**	14.21**	32.95**	1.35
Test weight	844.19**	159.92**	29.77**	6.48
Grain yield/plant	515.31**	188.048**	275.87**	17.28

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

3.2 Mean Performance of Grain Yield

Table 3.2. Grain Yield per Plant Across Environments



Genotype	**E1**	**E2**	**E3**	**Pooled Mean**
IS 23891	75.20	73.00	78.00	**75.40**
GP 40053-1-2	69.00	67.00	70.00	**68.66**
ISSVT 102	71.00	69.00	73.00	**71.00**
GP 920	65.00	63.00	61.00	63.00
Bajra Type	24.20	18.30	20.20	20.90

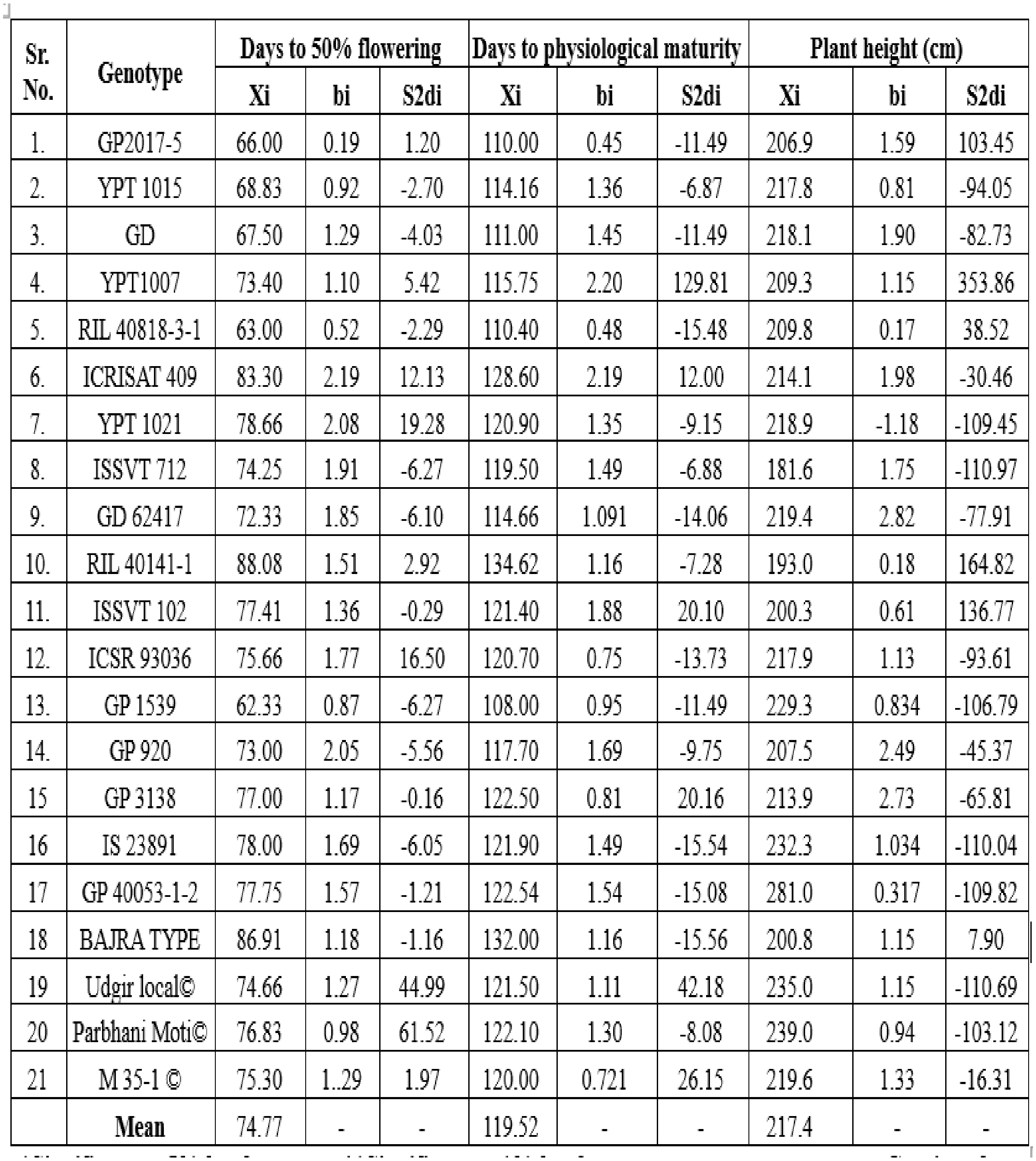
The pooled analysis of variance revealed significant differences among genotypes, environments, and their interactions for all yield and yield-contributing traits, indicating the presence of substantial genetic variability and differential environmental influence (Eberhart & Russell, 1966). Significant G×E (linear) components indicated predictable genotype responses across environments, consistent with earlier findings in sorghum (Kenga et al., 2003; Prabhakar & Patil, 2002).

Mean performance indicated wide variability across genotypes for days to 50% flowering, days to maturity, plant height, panicle length, test weight, and grain yield—similar to reports by Girish et al. (2016) and Chavan et al. (2010). Early flowering in GP 1539 and RIL 40818-3-1 supports the presence of selection-ready early-duration material, a trend also noted by Madhusudhana et al. (2003) . GP 40053-1-2 and IS 23891 consistently showed superior grain yield and test weight, corroborating past evidence that high-yielding sorghums often exhibit strong stability and adaptability (Burli et al., 2004; Showemimo, 2007).

Stability analysis using the Eberhart and Russell model indicated that BAJRA TYPE, RIL 40141-1, and ICRISAT 409 were stable for flowering time ($bi \approx 1$; $S^2di \approx 0$). Stability in maturity duration was also exhibited by P. Moti, U-Local, YPT 1021, and GP 40053-1-2, reflecting general adaptability. Earlier studies have emphasized the importance of such parameters in selecting broadly adapted sorghum genotypes (Elangovan & Raut, 2010; Khandelwal et al., 2019). For plant height and grain yield, GP 40053-1-2, IS 23891, and ISSVT 102 combined high mean with desirable stability parameters. Similar stability patterns in grain yield have been reported by Ezzat et al. (2010), Saeed & Francis (1983), and Souza et al. (2013) . GP 40053-1-2 also exhibited stable fodder yield, aligning with findings by Kher et al. (2008) and Meena et al. (2020) on dual-purpose sorghum stability. Overall, the results identify **GP 40053-1-2**, **IS 23891**, and **ISSVT 102** as high-yielding, stable, and widely adaptable genotypes. These findings align with recent stability studies in sorghum highlighting the importance of selecting genotypes with strong linear regression responses and minimal deviation from regression for multi-environment cultivation (Ibrahim et al., 2019; Saikiran et al., 2022).

3.3 Stability Analysis

Table 3.3 Estimate of stability parameters for yield and its attributing traits over three environments in Sorghum



Sr. No.	Genotype	Days to 50% flowering			Days to physiological maturity			Plant height (cm)		
		Xi	bi	S2di	Xi	bi	S2di	Xi	bi	S2di
1.	GP2017-5	66.00	0.19	1.20	110.00	0.45	-11.49	206.9	1.59	103.45
2.	YPT 1015	68.83	0.92	-2.70	114.16	1.36	-6.87	217.8	0.81	-94.05
3.	GD	67.50	1.29	-4.03	111.00	1.45	-11.49	218.1	1.90	-82.73
4.	YPT1007	73.40	1.10	5.42	115.75	2.20	129.81	209.3	1.15	353.86
5.	RIL 40818-3-1	63.00	0.52	-2.29	110.40	0.48	-15.48	209.8	0.17	38.52
6.	ICRISAT 409	83.30	2.19	12.13	128.60	2.19	12.00	214.1	1.98	-30.46
7.	YPT 1021	78.66	2.08	19.28	120.90	1.35	-9.15	218.9	-1.18	-109.45
8.	ISSVT 712	74.25	1.91	-6.27	119.50	1.49	-6.88	181.6	1.75	-110.97
9.	GD 62417	72.33	1.85	-6.10	114.66	1.091	-14.06	219.4	2.82	-77.91
10.	RIL 40141-1	88.08	1.51	2.92	134.62	1.16	-7.28	193.0	0.18	164.82
11.	ISSVT 102	77.41	1.36	-0.29	121.40	1.88	20.10	200.3	0.61	136.77
12.	ICSR 93036	75.66	1.77	16.50	120.70	0.75	-13.73	217.9	1.13	-93.61
13.	GP 1539	62.33	0.87	-6.27	108.00	0.95	-11.49	229.3	0.834	-106.79
14.	GP 920	73.00	2.05	-5.56	117.70	1.69	-9.75	207.5	2.49	-45.37
15	GP 3138	77.00	1.17	-0.16	122.50	0.81	20.16	213.9	2.73	-65.81
16	IS 23891	78.00	1.69	-6.05	121.90	1.49	-15.54	232.3	1.034	-110.04
17	GP 40053-1-2	77.75	1.57	-1.21	122.54	1.54	-15.08	281.0	0.317	-109.82
18	BAJRA TYPE	86.91	1.18	-1.16	132.00	1.16	-15.56	200.8	1.15	7.90
19	Udgir local©	74.66	1.27	44.99	121.50	1.11	42.18	235.0	1.15	-110.69
20	Parbhani Moti©	76.83	0.98	61.52	122.10	1.30	-8.08	239.0	0.94	-103.12
21	M 35-1 ©	75.30	1..29	1.97	120.00	0.721	26.15	219.6	1.33	-16.31
	Mean	74.77	-	-	119.52	-	-	217.4	-	-

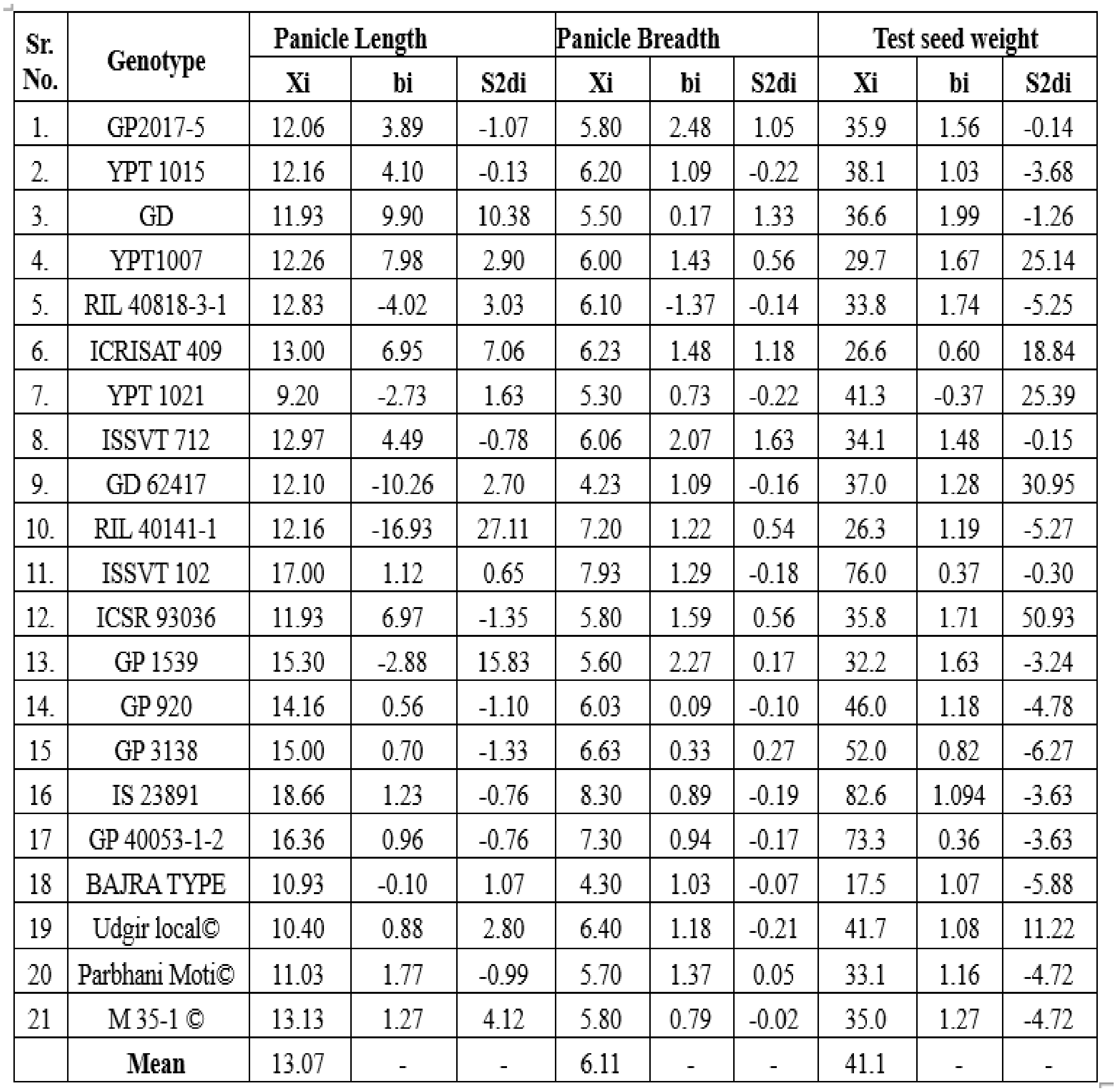
***Significant at 5% level** ****Significant at 1% level** **Continued….**

Table 3.3 Continued…

Sr. No.	Genotype	Panicle Length			Panicle Breadth			Test seed weight		
		Xi	bi	S2di	Xi	bi	S2di	Xi	bi	S2di
1.	GP2017-5	12.06	3.89	-1.07	5.80	2.48	1.05	35.9	1.56	-0.14
2.	YPT 1015	12.16	4.10	-0.13	6.20	1.09	-0.22	38.1	1.03	-3.68
3.	GD	11.93	9.90	10.38	5.50	0.17	1.33	36.6	1.99	-1.26
4.	YPT1007	12.26	7.98	2.90	6.00	1.43	0.56	29.7	1.67	25.14
5.	RIL 40818-3-1	12.83	-4.02	3.03	6.10	-1.37	-0.14	33.8	1.74	-5.25
6.	ICRISAT 409	13.00	6.95	7.06	6.23	1.48	1.18	26.6	0.60	18.84
7.	YPT 1021	9.20	-2.73	1.63	5.30	0.73	-0.22	41.3	-0.37	25.39
8.	ISSVT 712	12.97	4.49	-0.78	6.06	2.07	1.63	34.1	1.48	-0.15
9.	GD 62417	12.10	-10.26	2.70	4.23	1.09	-0.16	37.0	1.28	30.95
10.	RIL 40141-1	12.16	-16.93	27.11	7.20	1.22	0.54	26.3	1.19	-5.27
11.	ISSVT 102	17.00	1.12	0.65	7.93	1.29	-0.18	76.0	0.37	-0.30
12.	ICSR 93036	11.93	6.97	-1.35	5.80	1.59	0.56	35.8	1.71	50.93
13.	GP 1539	15.30	-2.88	15.83	5.60	2.27	0.17	32.2	1.63	-3.24
14.	GP 920	14.16	0.56	-1.10	6.03	0.09	-0.10	46.0	1.18	-4.78
15	GP 3138	15.00	0.70	-1.33	6.63	0.33	0.27	52.0	0.82	-6.27
16	IS 23891	18.66	1.23	-0.76	8.30	0.89	-0.19	82.6	1.094	-3.63
17	GP 40053-1-2	16.36	0.96	-0.76	7.30	0.94	-0.17	73.3	0.36	-3.63
18	BAJRA TYPE	10.93	-0.10	1.07	4.30	1.03	-0.07	17.5	1.07	-5.88
19	Udgir local©	10.40	0.88	2.80	6.40	1.18	-0.21	41.7	1.08	11.22
20	Parbhani Moti©	11.03	1.77	-0.99	5.70	1.37	0.05	33.1	1.16	-4.72
21	M 35-1 ©	13.13	1.27	4.12	5.80	0.79	-0.02	35.0	1.27	-4.72
	Mean	13.07	-	-	6.11	-	-	41.1	-	-

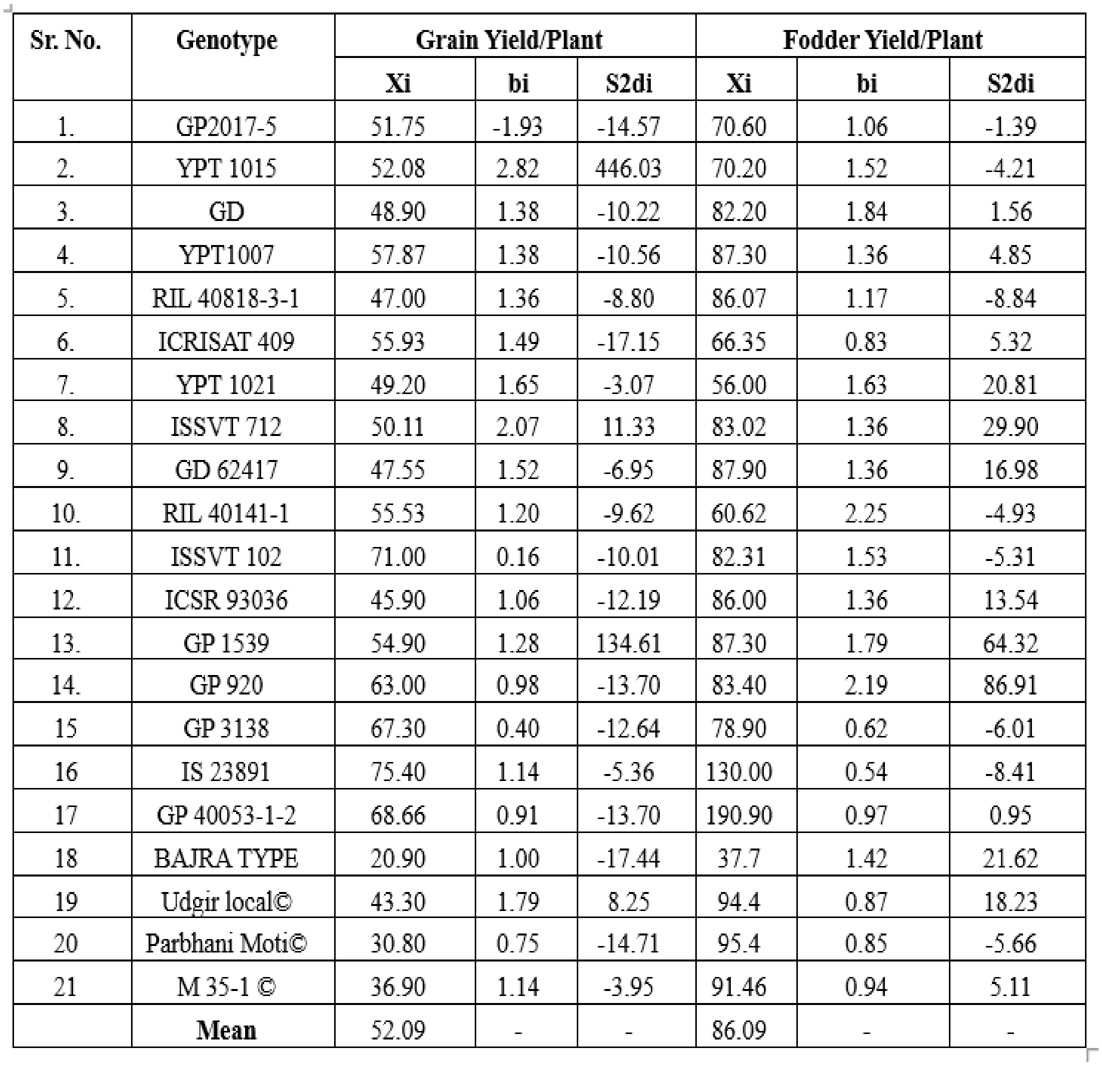
***Significant at 5% level **Significant at 1% level Continued….**

Table 3.3 continued…



Sr. No.	Genotype	Panicle Length			Panicle Breadth			Test seed weight		
		Xi	bi	S2di	Xi	bi	S2di	Xi	bi	S2di
1.	GP2017-5	12.06	3.89	-1.07	5.80	2.48	1.05	35.9	1.56	-0.14
2.	YPT 1015	12.16	4.10	-0.13	6.20	1.09	-0.22	38.1	1.03	-3.68
3.	GD	11.93	9.90	10.38	5.50	0.17	1.33	36.6	1.99	-1.26
4.	YPT1007	12.26	7.98	2.90	6.00	1.43	0.56	29.7	1.67	25.14
5.	RIL 40818-3-1	12.83	-4.02	3.03	6.10	-1.37	-0.14	33.8	1.74	-5.25
6.	ICRISAT 409	13.00	6.95	7.06	6.23	1.48	1.18	26.6	0.60	18.84
7.	YPT 1021	9.20	-2.73	1.63	5.30	0.73	-0.22	41.3	-0.37	25.39
8.	ISSVT 712	12.97	4.49	-0.78	6.06	2.07	1.63	34.1	1.48	-0.15
9.	GD 62417	12.10	-10.26	2.70	4.23	1.09	-0.16	37.0	1.28	30.95
10.	RIL 40141-1	12.16	-16.93	27.11	7.20	1.22	0.54	26.3	1.19	-5.27
11.	ISSVT 102	17.00	1.12	0.65	7.93	1.29	-0.18	76.0	0.37	-0.30
12.	ICSR 93036	11.93	6.97	-1.35	5.80	1.59	0.56	35.8	1.71	50.93
13.	GP 1539	15.30	-2.88	15.83	5.60	2.27	0.17	32.2	1.63	-3.24
14.	GP 920	14.16	0.56	-1.10	6.03	0.09	-0.10	46.0	1.18	-4.78
15	GP 3138	15.00	0.70	-1.33	6.63	0.33	0.27	52.0	0.82	-6.27
16	IS 23891	18.66	1.23	-0.76	8.30	0.89	-0.19	82.6	1.094	-3.63
17	GP 40053-1-2	16.36	0.96	-0.76	7.30	0.94	-0.17	73.3	0.36	-3.63
18	BAJRA TYPE	10.93	-0.10	1.07	4.30	1.03	-0.07	17.5	1.07	-5.88
19	Udgir local©	10.40	0.88	2.80	6.40	1.18	-0.21	41.7	1.08	11.22
20	Parbhani Moti©	11.03	1.77	-0.99	5.70	1.37	0.05	33.1	1.16	-4.72
21	M 35-1 ©	13.13	1.27	4.12	5.80	0.79	-0.02	35.0	1.27	-4.72
	Mean	13.07	-	-	6.11	-	-	41.1	-	-

***Significant at 5% level **Significant at 1% level Continued**



Sr. No.	Genotype	Grain Yield/Plant			Fodder Yield/Plant		
		Xi	bi	S2di	Xi	bi	S2di
1.	GP2017-5	51.75	-1.93	-14.57	70.60	1.06	-1.39
2.	YPT 1015	52.08	2.82	446.03	70.20	1.52	-4.21
3.	GD	48.90	1.38	-10.22	82.20	1.84	1.56
4.	YPT1007	57.87	1.38	-10.56	87.30	1.36	4.85
5.	RIL 40818-3-1	47.00	1.36	-8.80	86.07	1.17	-8.84
6.	ICRISAT 409	55.93	1.49	-17.15	66.35	0.83	5.32
7.	YPT 1021	49.20	1.65	-3.07	56.00	1.63	20.81
8.	ISSVT 712	50.11	2.07	11.33	83.02	1.36	29.90
9.	GD 62417	47.55	1.52	-6.95	87.90	1.36	16.98
10.	RIL 40141-1	55.53	1.20	-9.62	60.62	2.25	-4.93
11.	ISSVT 102	71.00	0.16	-10.01	82.31	1.53	-5.31
12.	ICSR 93036	45.90	1.06	-12.19	86.00	1.36	13.54
13.	GP 1539	54.90	1.28	134.61	87.30	1.79	64.32
14.	GP 920	63.00	0.98	-13.70	83.40	2.19	86.91
15	GP 3138	67.30	0.40	-12.64	78.90	0.62	-6.01
16	IS 23891	75.40	1.14	-5.36	130.00	0.54	-8.41
17	GP 40053-1-2	68.66	0.91	-13.70	190.90	0.97	0.95
18	BAJRA TYPE	20.90	1.00	-17.44	37.7	1.42	21.62
19	Udgir local©	43.30	1.79	8.25	94.4	0.87	18.23
20	Parbhani Moti©	30.80	0.75	-14.71	95.4	0.85	-5.66
21	M 35-1 ©	36.90	1.14	-3.95	91.46	0.94	5.11
	Mean	52.09	-	-	86.09	-	-

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

The genotype **GP 40053-1-2** demonstrated stable and high-yielding performance across environments, supported by a regression coefficient close to unity and a low deviation from regression. Genotypes **IS 23891** and **ISSVT 102** also recorded high yields coupled with wide adaptability, making them suitable for diverse growing conditions. In contrast, **ICRISAT 409** and **YPT 1007** showed better performance under favourable environments, while **GP 3138** and **ISSVT 102** exhibited superior adaptability to poor environments, indicating their potential for stress-prone regions.

Significant G×E effects demonstrated strong environmental influence on sorghum yield traits. GP 40053-1-2 showed excellent broad adaptation and stability for yield and panicle traits. IS 23891 demonstrated high yielding ability but slightly specific adaptation. Early flowering genotypes (GP 1539, RIL 40818-3-1) are suitable for drought escape in rabi conditions. Stability analysis confirmed no genotype was stable for all traits, but several exhibited useful specific stability patterns.

4. . Conclusion

The present investigation on “Stability Analysis in Coloured Pericarp Sorghum (Sorghum bicolor (L.) Moench)” aimed to estimate the stability for grain yield and its attributing traits across three locations—Parbhani, Basmath, and Nanded. The study evaluated 21 rabi season coloured pericarp sorghum lines, including 18 germplasm lines and 3 checks, using a randomized block design with two replications. Observations were recorded on five randomly selected plants per treatment for morphological traits and on plot basis for phenological and some grain quality parameters. Stability analysis followed the Eberhart and Russell (1966) model.

Analysis of variance revealed significant genotypic differences for traits including days to 50% flowering, days to physiological maturity, plant height, fodder yield per plant, grain yield per plant, panicle length and breadth, test weight, bulk density, porosity, grain shape, pericarp colour, grain lustre, grain hardness, and endosperm texture. Significant genotype × environment (G × E) interactions for most traits indicated that genotypes varied in their response to environmental changes, underlining the importance of stability analysis.

Results identified genotypes with specific stable trait expressions; for instance, GP 40053-1-2 demonstrated stability in panicle breadth, grain yield per plant, fodder yield per plant, endosperm texture, grain hardness, and bulk density across all locations. Other genotypes showed stability for individual traits or performed better under specific environmental conditions—GP 920, IS 23891, and ISSVT 102 were stable for grain yield over multiple environments, while GP 3138 and ISSVT 102 performed better under poorer environments and ICRISAT 409 and YPT 1007 were stable in favourable environments. Stability was also observed for grain shape, lustre, and pericarp colour across all genotypes regardless of environment.

In conclusion, the study confirmed significant variability among sorghum genotypes for grain yield and key yield-contributing traits, with substantial G × E interaction affecting yield stability. Identification of genotypes with stable and high-yielding performance provides valuable candidates for breeding programs targeting drought-prone semi-arid regions like Marathwada and Maharashtra. These stable genotypes can help ensure consistent sorghum productivity, offering farmers resilient options adapted to diverse environments and helping to mitigate the decline in sorghum cultivation by improving yield reliability under changing climatic and production pressures. This investigation highlights the critical role of stability analysis in developing superior coloured pericarp sorghum varieties for sustainable production and market competitiveness.

References

1) 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.

2) 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

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

4) 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.

5) 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

6) 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.

7) 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).

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

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

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

11) 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.

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

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

14) 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.

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

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

17) 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.

18) 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.

19) 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.

20) 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.

21) Filho, J.E.A., Tardin, F.D., Daher, R.F., Barbé, T.C., Paula, C.M., Cardoso, M.J and Godinho,

22) V.P.C. 2014. Stability and adaptability of grain sorghum hybrids in the off-season. Genetics and Molecular Research. 13 (3): 7626-7635

23) 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).

24) Journal of Agricultural Research. 38(1): 142-153.

25) 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

26) 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.

27) 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.

28) 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).

29) 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.

30) 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.

31) 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.

32) 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.

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

34) 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.

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

36) Khazaei. A., Torabi., 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.

37) 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:

38) 1/3, 244-245.

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

40) 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).

41) 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.

42) 63(3): 255-256.

43) 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

44) 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.

45) 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.

46) 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.

47) Naggar, A. M. M. A., Salam, R. M. A. E., Asran, M.R and Yaseen, W. Y. S. 2018. Yield

48) Adaptability and Stability of Grain Sorghum Genotypes across Different Environments

49) in Egypt using AMMI and GGE-biplot Models. Annual Research & Review in Biology. 23(3): 1-16.

50) 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.

51) 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.

52) 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

53) 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.

54) 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.

55) 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.

56) 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.

57) 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.

58) 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.

59) 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.

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

61) 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.

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

63) 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.

64) 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).

65) 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.

66) 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.

67) 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.

68) 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.

69) 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.

70) 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.

71) 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.

72) 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.

73) 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.

74) 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.

75) 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.

76) 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.

77) 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.

78) 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.

79) 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.

80) 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.

81) 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.

82) 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..