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Short Communication

Stability analysis of grain yield and its contributing traits in advanced mutant lines of sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract

In the present study, 23 sorghum genotypes comprising 17 advanced mutant lines (M5) and six check varieties were evaluated for stability parameters over four locations during *rabi* 2017-18. Based on the ten morphological and yield traits, pooled ANOVA showed significant differences for the quantitative traits except for seed yield per plant. Mean sum of squares due to E+ (GxE) was significant for most of the characters except for days to flowering, and 100 seed weight. Environment component showed significant values for all traits. The GxE (linear) showed non-significant interaction for most of the characters in this study except for plant height, panicle length and seed yield. J-12 and J-3 mutants had mean value more than population mean and coefficient of regression near to unity and adapted to all situations.

Key words: Sorghum, stability, induced mutations, grain yield

Sorghum (*Sorghum bicolor* (L) Moench) is one of the major cereal crops of the semi-arid tropics with production coming from Nigeria, Ethiopia, Mexico, the USA and India. It is cultivated over 5.10 mh in India with an annual production of 4.80 mt. It is the source of food, fodder and predominantly cultivated in states of Maharashtra, Karnataka and Tamil Nadu. In Karnataka, *kharif* and *rabi* sorghum are being cultivated over 0.99 mh with an annual production of 0.914 mt of grain (Anonymous 2019). *Rabi* sorghum is mainly cultivated under rainfed conditions and predominantly dominated by varieties and local landraces (Badigannavar et al. 2015).

Genetic improvement of rabi sorghum was hindered by narrow genetic base and lack of phenotypic variability and stability present in the breeding lines (Prabhakar, 2002). In order to create genetic variability for quantitative traits, mutation breeding has been practiced in most of the field crops, including sorghum. Induced mutations using gamma rays (physical) and Ethyl Methane Sulphonate (EMS) have contributed immensely in bringing heritable changes and aid in selection and improvement of a trait (Rawling et al. 1958). The present study explored application of physical and chemical mutagens in sorghum for improving quantitative traits, especially yield traits.

The large variation due to GxE interaction pose a difficulty in associating phenotypic performance to genetic makeup and lead to difficulty in selection. Therefore, there is need to understand the nature of the GXE interaction to test stability of the genotypes adapting to variable climatic/edaphic conditions. Eberhart and Russel (1966) has defined the stability of a genotype in producing highest yield with regression coefficient (b_i) around unity and any deviations from regression (S^2d_i) is near zero. Several studies have revealed the effect of year and locations on yield contributing traits of grain sorghum (Narkhede et al. 1998). These studies have attributed differential yielding ability of sorghum genotypes to climatic conditions across the seasons. Several methods have been proposed to deal with GXE effects, which

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otherwise complicates identification of ideal test environment. The multi-environment trials involve identification of mega-environment, where a stable cultivar can utilize resources for maintaining average yield performance (Yan and Kang 2002). In this context, the present study was conducted to assess the sorghum mutant lines over the locations for stability parameters and to measure adaptability and stability. This would help in identifying mutants suitable for low, marginal, average and high yielding environments may be useful.

Two landraces, *viz.,* Chincholi local and JP-1-5 were initially subjected to physical (gamma rays @ 300Gy) and chemical (Ethyl Methane Sulphonate @ 0.1%) mutagenesis. M_1 and subsequent generations were grown as plant to row progenies at Bhabha Atomic Research Centre (BARC) Trombay, Mumbai and Agricultural Research Station Gulbarga, Karnataka. Nine mutant lines *viz*., C-105, C-109, C-28, C-69, C-95, C-42, C-39, C-18 and C-66 from Chincholi based and eight mutant lines *viz*., J-12, J-35 J-11, J-8-1, J-6-1, J-4-1, J-3 and J-44 from JP-1-5 based mutant population were selected from the M_5 generation in comparison with Chincholi and JP-1-5 (parents); checks, GS-23, DSV-4, SPV-86 and M 35-1. They were evaluated during *rabi* 2017-18 at Agricultural Research Station Gulbarga (E_1), Raichur (E_2), Hagari (E_3) and Malnoor (E_4) in Randomized Block Design (RBD) with two replications. Observations were recorded on randomly chosen five plants in each mutant and mean values were used for statistical analysis. The stable genotype is the one which can perform under no environmental influences as well as GxE interaction. Eberhart and Russell (1966) proposed model of stability analysis and was used for assessing the environmental influence and GxE interaction in each genotype and for each character.

Pooled ANOVA for stability of various traits showed significant genotypic differences for days to 50% flowering, maturity, plant height, number of leaves, panicle length and seed weight. Variance due to G X E was significant for plant height, panicle length and panicle width. The mean sum of square (MSS) due to E+ (G x E) was also significant for most of characters except days to 50% flowering, maturity and seed weight. This indicated observable differences among the environments as well as the mutants. Environment as linear component was significant for all characters, whereas G x E (linear) interaction was non - significant for most of the characters except plant height, panicle length, panicle width and grain yield per plant. Thus, the variation present in the environments was linear and any change in the environmental index can be attributed to the environmental conditions (Girish et al. 2016). Pooled deviation (nonlinear portion of the variance), an unpredictable portion of G x E interaction was non - significant for plant height, number of leaves and panicle width. Similarly, significant interactions between genotype and environments were also reported by Madhusudhana et al. (2003). They highlighted significant linear component as against non-linear component, which would in turn help in knowing the *per se* performance of sorghum mutants at different environments.

Various stability parameters such as mean performance (μ), regression coefficient (bi) and squared deviation of individual mutants from linear regression (S^2di) for parents/check varieties as well as mutants were calculated for quantitative traits to assess the stability over the environments (Table 1). For days to 50% flowering, superior mutants J-6-1, C-28, C-69 and C-18 showed earliness with mean values less than population mean. Except, J-12, all other mutants showed non-significant values for regression. The deviations from regression values were significant for all the mutants except J-12, J-35, J-8-1, J-6-1, J-3, J-44 and C-95. Similarly, J-6-1 had matured in 108 days with regression coefficient less than unity, while C-69 had less mean values and coefficient was more than unity. For plant height, C-109 (244.16 cm) and C-66 (239.16 cm) showed significant regression values with high mean values as compared to population mean (231.11cm). J-8-1, J-6-1, J-4-1, J-44, C-105, C-69, C-95, C-42 and C-18 mutants had mean value more than population mean and regression coefficient. Compared to other mutants, they were dwarf types and stable over wide range of environments. Number of leaves showed non-significant regression coefficient except for C-39. J-11, J-8-1, J-6-1, J-4-1, C-109, C-28, C-95 and C-18 mutants. While, only J-44 and C-28 showed the significant regression coefficient for stem girth.

With respect yield contributing traits, all the mutants showed non-significant regression coefficient except C-69 and SPV-86 for panicle length. Mutants, J-35, J-6-1, J-3, J-44, C-109 had mean value more than population mean (14.34 cm) and regression coefficient around unity. Mutants possessing long panicles with better stability were observed in J-35, J-6-1, J-3, J-44, C-109. Similar to this study, significant GXE interaction was also reported for panicle length in sorghum genotypes (Yan and Hunt 2001). For panicle width, only C-66 and E-36-1 showed significant

Table 1. Estimates of mean and stability parameters for various mutant lines of sorghum

	Days to 50% flowering			Days to maturity			Plant height (cm)			No. of leaves			Stem girth(cm)		
Mutants	Gen.μ	bi	S^2di	Gen.μ	bi	S^2di	Gen.μ	bi	S^2di	Gen.μ	bi	S^2di	Gen.μ	bi	S^2di
J-12	76	4.09*	-0.46	117	1.05	-0.56	214.58	1.23	-97.60	10.62	0.81	-0.06	2.15	1.19	-0.01
J-35	74	4.24	1.46	116	1.80	0.10	225.62	1.21	-104.58	10.49	0.86	0.48	1.95	0.69	-0.01
J-11	74	2.45	34.14**	114	3.83	1.98	229.37	1.12	-92.72	11.33	0.90	0.38	2.18	1.01	-0.01
J-8-1	73	0.50	1.82	113	0.32	9.77**	239.58	0.88	-86.77	11.12	1.01	-0.03	2.19	1.29	0.05*
J-6-1	71	1.92	0.84	110	0.98	4.49*	249.79	0.82	-22.34	11.28	1.06	-0.13	2.10	1.46	0.06**
J-4-1	74	-2.39	4.00**	113	-3.64	1.42	243.74	0.99	-131.75	10.70	1.10	-0.22	1.94	1.09	0.00
J-3	72	0.53	1.69	113	0.34	-0.86	249.78	0.73	-93.77	10.62	0.85	-0.32	1.99	0.76	-0.01
J-44	71	-0.20	0.36	111	-0.96	1.42	237.08	1.10	-76.96	10.62	0.82	-0.01	1.88	0.62*	-0.01
C-105	73	4.04	3.50*	115	2.58	1.89	236.24	0.93	-116.42	10.62	0.96	-0.31	1.99	0.69	0.00
C-109	71	-0.92	4.62**	113	0.37	0.99	244.16	0.82*	-129.97	10.99	1.03	0.68	1.92	0.98	-0.01
C-28	71	2.01	4.89**	113	0.19	-0.94	213.12	1.18	-97.45	10.87	1.04	-0.02	2.08	1.40*	-0.01
C-69	71	2.14	4.15**	112	2.36	1.49	240.83	1.13	-78.16	10.49	0.96	-0.17	1.88	1.41	0.01
C-95	72	0.05	-0.72	114	-0.07	1.25	240.62	0.90	-125.17	11.28	1.28	-0.18	2.01	1.10	0.00
C-42	75	2.84	5.86**	116	3.46	0.52	239.66	0.89	-87.76	10.66	1.20	-0.08	1.93	0.75	0.00
C-39	73	1.08	15.70**	113	-0.30	14.4**	225.87	1.09	-25.37	10.58	0.76*	-0.31	1.91	0.66	0.02
C-18	72	1.54	5.95**	115	-0.37	-0.76	239.58	0.82	-89.84	10.91	1.10	-0.31	2.10	1.02	-0.01
C-66	75	2.82	19.84**	116	0.12	0.58	239.16	0.79*	-121.58	10.58	0.97	-0.33	2.06	1.03	0.00
GS-23(C)	69	-1.43	0.11	109	1.43	-1.03	225.83	1.03	240.30	10.58	0.87	0.61	1.87	0.93	-0.01
Chincholi(C)	77	0.98	1.69	116	-1.26*	-0.81	232.91	0.92	162.78	11.45	1.12	-0.16	2.05	1.09	-0.01
JP-1-5(C)	78	1.23	6.51**	117	1.17	-0.57	225.62	0.90	-13.93	10.66	1.06	-0.31	2.01	1.30	0.03
M 35-1(C)	75	-0.39	10.10**	115	1.73	3.20	234.37	0.99	-118.73	10.03	0.98	-0.18	1.81	0.97	-0.01
SPV-86(C)	76	1.80	10.15**	115	3.16	3.93	242.91	1.14	-110.27	10.66	1.30	-0.12	1.77	0.81	0.02
DSV-4(C)	74	-1.45	2.71*	113	2.44	3.88	223.95	1.07	-25.28	10.53	1.20	-0.04	1.91	1.06	-0.01
Population mean	**73**			**113**			**233.11**			**10.69**			**1.960**		

	Panicle length (cm)			Panicle neck length (cm)			Panicle width(cm)			100 seed weight(g)			Seed yield per plant (g)		
J-12	13.00	0.89	-0.32	24.47	1.23	-1.18	4.89	1.08	-0.15	3.90	2.30	0.00	50.29	0.98	22.15*
J-35	15.97	1.55	1.72*	27.80	1.39	-2.47	4.87	1.24	0.44*	3.91	1.58	0.03	49.31	0.90	14.70
J-11	13.50	0.45	0.27	23.05	-0.10	5.05	5.26	1.13	-0.03	3.50	1.97	0.18**	48.91	0.84	12.82
J-8-1	17.87	1.57	-0.43	25.10	1.78*	-2.74	5.27	1.30	0.27	3.37	0.03	0.15**	49.87	1.21	31.39**
J-6-1	17.76	1.70	0.27	26.08	0.79	20.27**	5.47	1.24	0.34	3.31	1.12	0.08*	50.21	1.18	33.40**
J-4-1	16.95	1.40	-0.42	28.01	1.85*	-2.31	4.91	0.86	-0.08	3.49	1.01	-0.02	47.54	1.09	22.21*
J-3	17.93	1.51	-0.38	26.51	0.75	9.27*	5.14	1.84	0.23	3.33	1.42	0.06	49.06	0.97	132.21**
J-44	14.70	0.79	-0.40	30.07	0.84	0.41	5.01	0.90	-0.13	3.55	0.45	0.05	45.80	0.91	57.43**
C-105	12.20	0.41	0.49	24.37	0.80	2.92	4.99	1.70	-0.04	4.02	1.16	-0.04	47.57	0.97	97.60**
C-109	15.54	1.36	-0.44	28.70	0.79	-0.39	4.89	1.30	-0.06	3.66	3.02	0.02	48.21	1.05	6.02
C-28	12.58	0.91	1.72*	29.20	0.44	-1.55	4.83	1.35	-0.09	3.73	0.20*	-0.04	49.07	0.92	18.16*
C-69	13.62	2.06*	0.05	27.74	1.22	-1.09	4.84	1.39	-0.12	3.53	-0.17	0.02	47.76	1.12	19.95*
C-95	12.76	1.14	-0.49	24.64	0.99	-2.38	4.98	1.35	-0.16	3.25	1.64	0.23**	54.18	1.12	40.09**
C-42	12.16	0.14	2.13*	24.87	0.27	-0.10	5.12	0.63	-0.05	3.56	0.05	0.05	50.88	0.84	232.59**
C-39	12.74	1.04	-0.58	27.10	0.50	-2.07	4.87	0.78	-0.10	3.67	-0.31*	-0.03	46.01	0.89	0.10
C-18	11.24	0.48	-0.06	25.99	0.38	-0.67	4.95	0.68	-0.14	3.38	0.60	0.21**	46.32	0.93	10.08
C-66	12.21	0.28	3.35**	25.91	0.72	-0.06	4.78	0.52*	-0.16	3.54	0.59	0.41**	46.66	1.06	33.24**
GS-23(C)	15.63	1.01	-0.63	30.49	2.12	3.04	5.08	0.75	0.02	3.92	0.85	0.01	51.29	1.01	46.19**
Chincholi(C)	14.28	1.48	-0.19	26.32	0.71	6.64*	4.97	1.64	-0.09	3.81	1.94	0.09*	49.39	0.91	30.37*
JP-1-5(C)	12.64	1.07	0.67	26.66	1.08	-2.39	5.35	1.57	0.70*	3.95	2.23	0.06	50.71	1.06	3.63
M 35-1(C)	14.49	1.08	-0.56	28.18	1.04	1.81	5.08	0.79	-0.15	3.63	1.11	0.07	45.85	0.92	201.67**
SPV-86(C)	16.28	1.41**	-0.74	29.68	1.15	-2.27	5.33	0.28	0.14	3.55	1.23	0.01	52.85	1.20	42.44**
DSV-4(C)	15.05	0.76	0.44	30.45	0.54	0.56	4.99	0.76	0.05	3.57	1.37	0.00	51.48	1.16	18.98*
Population mean	**14.34**			**27.28**			**5.021**			**3.54**			**48.34**		

regression coefficient, while J-35 and JP-1-5 showed significant deviation from regression coefficient. Similarly for seed weight, all the mutants showed non-significant regression coefficient except C-28 and C-39, whereas, mutants, J-11, J-8-1, J-6-1, C-95, C-18 and C-66 showed the significant deviation from regression coefficient. Among all the mutant lines studied, C-105 produced bold seeds and adapted to wide range of environments.

For grain yield per plant, all the mutants possessed significant deviation from regression coefficient except J-35, J-11, C-109, C-39, C-18, JP-1-5 and IS-2312. Mutants such as J-12, J-8-1, J-6-1, J-3, C-28, C-95 and C-42 had shown mean value greater than population mean with regression value near to unity. Two advanced mutant lines J-35, J-11 and parent JP-1-5 showed mean value greater than population mean, 'bi' value near to unity and non significant deviation from coefficient of regression. 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). The present study involved mutation breeding of landraces, Chincholi and JP 1-5, which showed stable performance for yield traits over diverse locations. These landraces were known to possess high yield under intensive farming and optimum yield levels under low input conditions. Mutant lines, C-109, C-39 and C-18 possessed less population mean and least deviation from coefficient of regression indicating poor adaption to environments. J-35 and J-11 showed high seed yield per plant and stable performance across environments. The stability analysis of sorghum genotypes has been carried out earlier by several researchers. Elite genotypes either show increased yield levels in a specific environment or stable yield levels across series of environments. Such a yield is the relative performance of a genotype across range of environments. Thus, a stable mutant/genotype can utilize resources efficiently in a high yielding environment and also maintain optimum yield levels in other environment as well.

Authors' contribution

Conceptualization of research (ANJ, GG, AB); Designing of the experiments (GG, AB); Contribution of experimental materials (GG, AB); Execution of field/lab experiments and data collection (ANJ, GG, AB, SM, LNY, SKJ, AMT, VK); Analysis of data and interpretation (GG, AB); Preparation of the manuscript (GG, AB, TRG).

Declaration

The authors declare no conflict of interest.

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