RESEARCH ARTICLE

Induction of Genetic Variability Through Mutagenesis in *Rabi* Sorghum [*Sorghum bicolor* (L.) Moench]

Borde YS, Deshmukh JD, Lagad SL

Department of Genetics and Plant Breeding, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

ABSTRACT

The 'TSV-32' *rabi* sorghum genotype was used to create a mutation using an electron beam. The experimental material included several electron beam, viz., 100 Gy, 200 Gy, 300 Gy, 400 Gy, and 500 Gy, as well as wet and dry control seeds. Individual plants were selfed, harvested, and recorded for putative mutations that might have been present in the M_1 generations. During Rabi 2022-23, the M2 generation, comprising a total of 36 mutant progenies from seven different treatments, was assessed using a random block design with three replications. Among the M_2 generation, genetic variability was significant for yield and yield contributing traits. In most treatments, a relatively higher mean performance was observed compared to the control for all traits, except days to 50% flowering, days to maturity, number of grains per primary panicle, panicle width, and 100-seed weight. For the majority of the characters in the segregating M_2 generation, the GCV and PCV values revealed significant variability. Moderate GCV, PCV, and GAM values were found for grain yield per plant, and GAM values were also found for grain yield per plant and 100-seed weight.

Received: 11 May 2025

Revised: 27 May 2025

Accepted: 03 Jun 2025

Keywords: *Rabi sorghum, Electron beam, Mutation, Genetic Variability, Heritability.*

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most significant cereal in the world in terms of area and production. It is an often cross-pollinated, diploid (2n = 2x = 20) plant that is a member of the Poaceae family. The primary jowar-producing states in the nation include Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Gujarat, Rajasthan, Uttar Pradesh (Bundelkhand region), and Tamil Nadu.

Mutation breeding has played a beneficial role in sustainable agriculture, it is a complementary strategy for crop development that promotes unselected genetic variability for useful, practical breeding applications. Due to the extremely low frequency of natural mutation, induced mutations are employed to increase genetic variability for both quantitative and qualitative parameters. Among various physical mutagens such as x-rays, fast neutrons, thermal neutrons, ultraviolet radiation, beta radiation, and gamma rays, the electron beam is particularly well known for its effect on plant growth and development, inducing cytological, physiological, and morphological changes in cells (Thapa, 2004). Several reports are available where breeders use gamma radiations as a source for inducing genetic variability in quantitative characters to enhance yield and yield-contributing traits. Recently, high-power linear electron accelerators

*Corresponding author mail: ysborde25@gmail.com

with energies ranging from 500 keV to 10 MeV have gained importance for various applications. The accelerators operate in a switch-on-off mechanism, similar to X-ray facilities. It produces an electron beam that can be used to irradiate materials in a high-throughput manner. Electron beam radiation is essential tool for inducing genetic variability, enhancing yield, and contributing to yield-related traits.

Genetic variability for economic traits is the prerequisite for any successful breeding program, as the degree of response to selection depends on the amount of variability. In any crop, yield is a complex character influenced by many of its contributing characters, which are controlled by polygenes and environmental factors. Therefore, an understanding of the genetics of yield and its component traits is required.

'TSV-32' *rabi* sorghum genotype was chosen as base material. It was a selection from CSV-20 X Phule Anuradha. This is an early-maturing sorghum genotype (47-55 days to 50% flowering). The variability present in this segment is very low. Under these circumstances, creating variability through induced mutation will provide additional scope for improvement in Rabi sorghum. The primary focus of the current research is on inducing genetic variability in sorghum (TSV-32) through Electron beam.

MATERIALS AND METHODS

The present investigation was conducted on sorghum (Sorghum bicolor (L.) Moench) at the Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. During Rabi 2022-23. which is situated at the latitude of 19^o 24' N, longitude of 76^o 78' E, and altitude of 458.38 m above mean sea level (msl), with the soil type of shallow to medium black.

Pure selfed seeds (1200) of *TSV-32* with 10 per cent moisture content were exposed to 100, 200, 300, 400 and 500 Gy dose of electron beam radiation from electron accelerator at Nuclear Agriculture & Biotechnology Division, BARC Trombay, Mumbai and sown as M_1 generation along with the same number of untreated seeds of each variety served as control seeds during *rabi* 2021-22.

Dominant mutations observed in the M_1 generation were recorded, and individual plants were self-pollinated, harvested, and used to raise the M2 generation during the Rabi 2022-23 season. A total of thirty-six (36) selfed progeny selected from each treatment were grown in a head-to-row progeny design in the M2 generation in a randomized block design with seven treatments, including 2 controls and three replications. The observations were recorded on days to 50% flowering, days to maturity, plant height (cm), number of primaries per panicle, number of grains per primary, panicle length (cm), panicle width (g), 100 grain weight (g), grain yield per plant (g) and *fodder yield per plant (g), Relative water content (%), Chlorophyll content (SPAD values), Leaf area (cm^2), Flag leaf area (cm^2).* The standard statistical approach for the Random Block Design (RBD), described by Panse and Sukhatme (1954), was used to analyze the variance for differences between and within families. According to the method recommended by Burton (1952) the variability parameters genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability, and genetic advance — were estimated.

RESULTS AND DISCUSSION

The results of the analysis of variance for the M_2 generation of *rabi* sorghum are furnished in Table 1. Highly significant differences among the genotypes were observed for fourteen characters, indicating the presence of sufficient variability among genotypes for these fourteen characters.

For all fourteen of the traits under consideration, the mean sums of squares due to progenies within families were found to be highly significant, demonstrating that progenies within the family differ from one another. Anand and Kajjidoni (2014), Htun et al. (2015), Kham et al. (2015), Suthakar and Mullainathan (2015), and Takele et al. (2021) have all observed such variation yield and yield-attributing traits. The outcome of the variability parameters is shown in Table 2. For each of the fourteen characters in the M_2 generation of sorghum, the genetic components; genotypic variance, phenotypic variance, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (in broad sense), genetic advance (GA) and genetic advance as the percent of mean (GAM) were calculated using the proper statistical formulas. The results are presented in Table 2.

(PCV) was found to be higher than the genotypic coefficient of variation (GCV) for all the characters with extremely minor differences, indicating a substantial genetic influence. Anand and

Table 1: Analysis of variance for yield and yield contributing characters in rabi sorghum

Source of Variation	df	DFF	PH (cm)	DM	NPPP	NGPP	PL (cm)	PW (cm)
Treatments	6	3.05*	114.07**	2.19*	5.33*	15.56**	0.62*	0.16*
Replication	2	0.90	9.22	0.14	3.57	8.19	0.24	0.17
Error	12	0.90	13.95	1.31	1.57	2.41	0.21	0.05

Source of Variation	df	100 SW (g)	FYPP (g)	RWC (%)	CC (spad values)	LA (cm^2)	FLA (cm^2)	GYPP (g)
Treatments	6	0.16*	33.99*	8.38*	49.50**	1668.02**	1501.3**	249.54**
Replication	2	0.14	30.46	2.27	24.99	668.9	286.2	27.98
Error	12	0.05	9.84	4.08	7.25	412.3	585.3	22.54

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

DFF= Days to 50% Flowering, PH= Plant Hight, DM= Days to Maturity, NPPP= Number of Primaries Per Panicle, NGPP= Number of Grains Per Primary, PL= Panicle Length PW= Panicle Width, 100 SW= 100 Seed Weight, FYPP= Fodder Yield Per Plant, RWC= Relative Water Content, CC= Chlorophyll Content, LA= Leaf Area, FLA= Flag Leaf Area, and GYPP= Grain Yield Per Plant.

Kajiidoni (2014), Kham et al. (2015), Shivaprashad et al. (2019), Htun et al. (2015), and Thange et al. (2021) agreed with these findings. GCV and PCV values for grain yield per plant were moderate (15.97% and 18.19%, respectively), indicating moderate variability across progenies for this character and a greater possibility for improving this character by selection in the appropriate direction. Additionally, the progeny exhibited moderate GCV and PCV values for 100-seed weight (8.36% and 13.25%) and flag leaf area (6.08% and 10.38%). The other variables such as days to 50% flowering (1.32% and 1.99%), plant height (3.24% and 3.86%), days to maturity (0.47% and 1.11%), number of primaries per panicle (2.15% and 3.23%), number of grains per primary (2.00% and 2.49%), panicle length (cm) (1.66% and 2.63%), panicle width (g) (2.62% and 3.96%), *fodder yield per plant (g)* (6.15% and 9.17%)*, Relative water content (%)* (2.53% and 4.96%)*, Chlorophyll content (SPAD values)* (7.40% and 9.11%) *and Leaf area (cm^2)* (3.60% and 5.13%). These characters had low GCV and PCV levels. Low PCV values, accompanied by marginally low GCV values in these traits, suggested a limited level of variability in the materials and a low likelihood of genetic improvement. This suggests that the level of variability and the odds of genetic improvement are moderate. Similar results were found for grain yield per plant by Patel et al., (1980b), Kumar and Singh (1986), Cheralu and Rao (1989) for days to flowering and days to maturity by Nimbalkar et al. (1988), Narkhede et al, (2001); for plant height by Patel et al. (1980a), Patel et al., (1980b), Singh et al., (1980), Amrithadevarathinam et al. (1994) for panicle length and chlorophyll content (spad values) by Narkhede et al, (2001); for 100 grain weight by Negash et al., (2005); for relative water content by Pawar (2007).

High heritability was observed for grain yield per plant (77.05%), plant height (70.53%), number of grains per primary (64.49%), and *chlorophyll content (SPAD values)* (66.00%). Additionally, the progeny showed moderate heritability for days to 50% flowering (44.12%), number of primaries per panicle (44.38%), panicle length (39.67%), panicle weight (43.62%), 100 grain weight (39.84%), fodder yield per plant (44.98%), leaf area (49.15%) and flag leaf area (34.28%). This suggests that the genotypic effect of phenotypes may be well measured and that selection may be effectively used to enhance these traits. These results are consistent with the results reported by Khaing Wah Htum et al., (2015). Anand and Kajidoni (2014).

The characters viz., plant height (9.99%), leaf area (28.83%), flag leaf area (21.08%), and grain yield per plant (15.73%), all showed moderate genetic advance. Supporting results were observed by Khaing Wah Htum et al., (2015). Anand and Kajidoni (2014). The traits with low estimates of genetic advance were days to 50% flowering (1.16%), days to maturity (0.48%), number of primaries per panicle (1.54%), number of grains per primary (3.47%), panicle length (cm) (0.48%), panicle width (g) (0.26%), 100 grain weight (g) (0.25%), *fodder yield per plant (g)* (3.92%)*, Relative*

Table 2: Genetic variability parameters for yield and yield contributing characters in M_2 generation of rabi sorghum.

S. No.	Characters	Mean	G V (%)	P V (%)	GCV (%)	PCV (%)	H^2_{bs} (%)	GA (%)	GAM (%)
1	Days to 50% Flowering	64	0.71	1.62	1.32	1.99	44.12	1.16	1.81
2	plant height (cm)	178.3	33.37	47.32	3.24	3.86	70.53	9.99	5.61
3	Days to maturity	114	0.29	1.60	0.47	1.11	18.32	0.48	0.42
4	Number of primaries per panicle	52	1.25	2.83	2.15	3.23	44.38	1.54	2.96
5	Number of grains per primary	105	4.38	6.79	2.00	2.49	64.49	3.47	3.31
6	Panicle length [cm]	22.3	0.14	0.34	1.66	2.63	39.67	0.48	2.15
7	Panicle width [cm]	7.3	0.04	0.08	2.62	3.96	43.62	0.26	3.56
8	100 seed wight[g]	2.3	0.04	0.09	8.36	13.25	39.84	0.25	10.87
9	Fodder yield per plant[g]	46.1	8.05	17.89	6.15	9.17	44.98	3.92	8.50
10	Relative water content [%]	47.4	1.43	5.51	2.53	4.96	26.02	1.26	2.66
11	Chlorophyll content [spad values]	50.7	14.08	21.34	7.40	9.11	66.00	6.28	12.39
12	Leaf area [cm2]	555.3	398.61	810.93	3.60	5.13	49.15	28.83	5.19
13	Flag leaf area[cm2]	287.6	305.34	890.64	6.08	10.38	34.28	21.08	7.33
14	Grain yield per plant[g]	54.5	75.67	98.21	15.97	18.19	77.05	15.73	28.87

GV = Genotypic variance (σ^2 g) (%), GCV = Genotypic coefficient of variation (%) PV = phenotypic variance (σ^2 p) (%), PCV = Phenotypic coefficient of variation (%) h^2_{bs} = Heritability (Broad sense) (%), GAM = Genetic Advance as per cent of mean (%)

water content (%) (1.26%) *and Chlorophyll content (SPAD values)* (6.28%). Shivaprashad et al. (2019) discovered similar results for these traits.

In predicting selection response, heritability combined with genetic advance is more valuable than heritability alone. Plant height, grain yield per plant, number of grains per primary and *leaf area all these traits showed high heritability and moderate genetic advance, which indicates the role of additive gene effects and least the* effects of environmental factors on the expression of the traits. Thus, simple phenotypic selection offers a greater potential for improving these traits. Muduli and Misra (2008), Anand and Kajjidoni (2014), Shivaprashad et al. (2019), all found comparable results for these traits.

High heritability coupled with low genetic advance was observed for the number of grains per primary and chlorophyll content (SPAD values), indicating non-additive gene action. So, these traits cannot be improved through simple selection. Similar results were also observed by Shivaprashad et al. (2019).

CONCLUSION

The present investigation clearly demonstrated that electron beam irradiation is an effective physical mutagen for inducing genetic variability in rabi sorghum genotype TSV-32. Significant differences among M_2 progenies for key agronomic traits such as grain yield per plant, plant height, chlorophyll content, and leaf area indicate successful generation of useful variability. Moderate to high estimates of GCV, PCV, heritability, and genetic advance in these traits suggest that additive gene effects are at play, and phenotypic selection can be effectively applied to enhance these traits. Particularly, grain yield per plant showed promising improvement potential due to its high heritability (77.05%) and moderate genetic advance (15.73%). In contrast, traits like days to maturity and 100 seed weight showed low genetic variability, indicating limited scope for improvement through selection alone. Overall, the use of electron beam mutagenesis has opened new avenues for enriching the genetic base of sorghum, and further selection in subsequent generations could lead to the development of superior genotypes suited for rabi season cultivation.

ACKNOWLEDGMENTS

The authors are grateful to the Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre (BARC), Mumbai, India, for Providing Electron beam irradiation of Rabi sorghum seeds. The author is also thankful to Dr. J. D. Deshmukh and other advisory committee members of the Department of Genetics and Plant Breeding, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, for their guidance and valuable suggestions. The authors also acknowledge all technical staff who assisted them in the successful completion of this work.

REFERANCES

Amrithadevarathinam, A., Sankarapandian, R. (1994). Variability pattern and relationship of yield components in grain sorghum. *Madras. Agri. J.* 81(6): 332-334. https://www.cabidigitallibrary.org/doi/full/10.5555/19961605927

Anand Y, Kajidoni ST. Genetic enhancement of grain size and other productivity related traits through induced variability in kharif sorghum. *Karnataka Journal of Agricultural Science*. 2014;27(2):121-124. DOI: https://doi.org/10.33545/26174693.2024.v8.i9g.2196

Biradar, B.D., Parameshwarappa, R., Patil, S.S. and Parameshwar goud, P. (1996). Inheritance of seed size in sorghum (*Sorghum bicolor* L. Moench). *Crop Res.,* 11 (3): 331-337. https://www.cabidigitallibrary.org/doi/full/10.5555/1997160552

Burton G.W. and Devane E.M. (1953) Estimating heritability in tall fescue (Festuca arundinacea) from replicated clonal material. *Agronomy Journal,* 45, 478-481. https://www.cabidigitallibrary.org/doi/full/10.5555/19541601156

Cheralu. C. and Rao, P.J. (1989). Genetic variability and character association for yield and yield components in winter sorghum. *J. Rex. APAU,* 17 (1):4-7. https://www.cabidigitallibrary.org/doi/full/10.5555/19911623365

Htun KW, Min M, Win NC. Evolution of genetic variability for agronomic trait in M_2 generation of sorghum through induced mutation. *International Journal of Technical Research and Applications.* 2015;3(6):145 149.

Khaing Wah Htun, Myat Min. and Nay Chi Win (2015). Evaluation of genetic variability for agronomic traits in M_2 generation of sorghum through induced mutation. *International Journal of Technical Research and Applications.* e-ISSN: 2320 8163, www.ijtra.com 3(6):145-149.

Kham NH, Win NC, Minn M. Study on the variability of induced mutation for improvement of local cultivar sorghum (Shweni-15). *International Journal of Technical Research and Applications*. 2015;3(6):139-144.

Kumar, R. and Singh, K.P. (1986). Genetic variability, heritability and genetic advance in grain sorghum (*Sorghum bicolor* L. Moench). *Form Sci.J.* 1: 1-2. https://www.cabidigitallibrary.org/doi/full/10.5555/19881669872

Muduli KC, Misra RC. Induced polygenic variability in M_2 generation and its relationship with production of high-yielding mutants in finger millet. *Indian Journal of Genetics and Plant Breeding.* 2008;68(4):419-425. https://doi.org/.

Narkhede, B.N., Akade, J.H, Awari, V.R. (2001). Variability studies of rabi sorghum local types (*Sorghum bicolor* L. Moench). *J. Maha. Agric. Univ.* 25(3): 300-302. https://www.cabidigitallibrary.org/doi/full/10.5555/20013161394

Negash, G., Hussein, M., Habtamu, Z. (2005). Genetic variability. heritability and genetic advance in sorghum (*Sorghum bicolor* L. Moench). germplasm. *Crop Res. Hisar*, 30 (3): 439-

445. https://www.cabidigitallibrary.org/doi/full/10.5555/20053225251

Nimbalkar, V.S., Bapat, D.R. and Patil, R.C. (1988). Genetic variability inter relationship and path coefficients of grain yield and its attributes in sorghum. J*. Maharastra. Agric. Univ,* 13 (2): 207-208. https://www.cabidigitallibrary.org/doi/full/10.5555/19901611134

Panse, V.G. and P.V. Sukhatme (1954). Statistical methods for Agricultural Workers, ICAR, New Delhi, pp. 152-165. https://www.cabidigitallibrary.org/doi/full/10.5555/19561604178

Patel, R.H., Desai, K.B., Kukadia, M.U. and Desai, N.M. (1980 a) Components of variability in sorghum, Sorghum Newslett. https://www.cabidigitallibrary.org/doi/full/10.5555/19811603421

Patel, R.H., Desai, K.B., Raja, K.R.V. and Parikh, R.K. (1980 b) Estimation of heritability and other genetic parameters in an F2 population of sorghum. *Sorghum Newslett*., 23: 22-23., 23:19-20. https://www.cabidigitallibrary.org/doi/full/10.5555/19811603487

Shivaprasad T, Girish G, Ashok B, Muniswamy S, Yogesh LN, Ganapathi TR. Genetic variability, correlation and path coefficient studies in sorghum [*Sorghum bicolor* (L.) Moench] mutants. *Electronic Journal of Plant Breeding*. 2019;10(4):1383-1389. DOI: 10.5958/0975-928X.2019.00177.7

Singh, A. R., and Makne, V. G. (1980). Estimates of variability parameters in sorghum (*Sorghum bicolor* L. Moench) *J. Maharastra, Agric. Univ*, 5(1): 80-81. https://www.cabidigitallibrary.org/doi/full/10.5555/19811600268

Takele A, Feyisa T, Disasa T. Development of sorghum mutant genotypes and analysis of their agro morphological diversity; c2021. Retrieved from: https://doi.org/10.21203/rs.3.rs-457881/v1.

Thapa CB. Effect of acute exposure of gamma rays on seed germination and seedling growth of *Pinus kesiya* Gord and *P. wallichiana* AB Jacks. Our Nature. 2004;2(1):13-17. DOI: https://doi.org/10.3126/on.v2i1.318