Plant Archives Vol. 24, No. 1, 2024 pp. 1409-1415 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.1.196

GAMMA RAYS INDUCED MUTATIONS IN SORGHUM: ISOLATING DESIRED GENETIC VARIATIONS FOR ENHANCED CROP DEVELOPMENT

Divya Patel[1]*, B.K. Davda[2], Himani Vadodariya[3], Dhairya Makwana[3] and Mukesh Parmar[4]

[1]Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand-388 110, India.
[2]Main Sorghum Research Station, Navsari Agricultural University, Athwa Farm, Surat - 395 007, Gujarat, India.
[3]Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari-396 450, India.
[4]ICAR HUB, Central Arid Zone Research Institute, Jodhpur - 342 002, Rajasthan, India.
*Corresponding author E-mail : dp0468694@gmail.com

(Date of Receiving-05-01-2024; Date of Acceptance-09-03-2024)

ABSTRACT

Sorghum genotype '*Wani* Local' was used to induce mutation by gamma rays. The experimental material comprised of different doses of gamma rays *viz.*,100 Gy, 200 Gy, 300 Gy, 350 Gy, 400 Gy and 500 Gy along with control treatments. Putative mutations observed in the M_1 generations were noted down and individual plants were selfed and harvested to raise M_2 generation. The M_2 generation comprising of total 120 mutant progenies of six treatments were evaluated in Compact Family Block Design with three replications during *rabi* 2022-23. In M_1 generation, based on the study of germination per cent and plant survival, the frequency of viable fertile plants decreased with increased doses of mutagen. The frequency of mutations in M_2 generation was maximum for 200 Gy and minimum for 500 Gy treatment. Desirable/Dominant mutants possessing higher grain yield, long and compact panicle, short plant height, earliness, bold seed and broad leaf were identified. Thus, the present study revealed successful utilization of gamma rays in inducing beneficial mutants in sorghum.

Key words : Sorghum, Gamma rays, Yield, Viable mutations.

Introduction

Sorghum, scientifically known as *Sorghum bicolor*, is an important cereal grain crop cultivated widely across the world, primarily for its grains used in various culinary and industrial applications. Belonging to the grass family *Poaceae*, it is an annual plant known for its resilience in diverse climates and its versatility in uses.

This versatile crop has a long history, with origins traced back to Africa thousands of years ago. Sorghum is a highly adaptable crop, thriving in both arid and semi-arid regions, making it a valuable option for areas with limited water resources.

A mutation refers to a permanent change in the DNA sequence of an organism, which can arise due to various factors like errors during DNA replication, exposure to mutagenic agents, or environmental influences. Mutations are of two types spontaneous and induced. The frequency of natural mutation is very low and hence induced mutations are used for genetic variability for quantitative and qualitative traits. Among various physical mutagens such as X-rays, fast neutrons, thermal neutrons, ultraviolet and beta radiation, gamma rays in particular are well known for their effect on plant growth and development by inducing cytological, physiological and morphological changes in cells and tissues (Thapa, 2004). Gamma rays fall into the category of ionizing radiation and interact with atoms or molecules to produce free radicals in cells. These radicals can damage or modify important components of plant cells and have been reported to affect the morphology, anatomy, biochemistry and physiology of plants differentially, depending on the irradiation level.

Sorghum mutation breeding is a technique used to induce genetic variations in sorghum plants by exposing them to mutagenic agents like radiation or chemicals. The goal is to create new and improved sorghum varieties with desirable traits such as higher yield, disease resistance, tolerance to environmental stresses like drought or pests, improved nutritional content, or better grain quality.

The *Ponk (hurda)* sorghum is a new and more remunerative segment of sorghum. The *Wani* local is mainly cultivated in Gujarat state for the production of tender grain. This *Wani* local is known as *"Andhali Wani"* due to the characteristic of very small opening of flowers and grains are mostly covered by glume. The present study was undertaken mainly to focus on identification/ validation of favorable mutants in M_2 generation.

Materials and Methods

In this study, dry, uniformly sized and healthy seeds containing approximately 8 to 10 percent moisture were chosen. These seeds were subjected to gamma ray treatment using Cobalt-60 as the gamma ray source, which had an effective dose rate of 23.9 Gy/min. The doses administered ranged from 100 to 500 Gy, with a separate group of untreated seeds used as the control. Any observable changes in the initial generation (M_1) due to potential mutations were recorded and individual plants displaying mutations were cultivated to yield the succeeding generation (M_2). During the *rabi* season of 2022-23, the M_2 generation, comprising a total of 20 lines derived from M_1 mutants for each treatment, underwent evaluation. The assessment took place using a Compact Family Block Design with three replications at the Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat.

Mutation frequency

The mutation frequency was estimated using the formula suggested by Gaul (1958):

$$\text{Mutation frequency (\%)} = \frac{\text{Number of mutated plants}}{\text{Total number of plants scored}} \times 100$$

The viable mutation deviating from the control plants was recorded up to harvest day. The viable mutations such as abnormal leaves, highly branched types, dwarf plants, sterile plants and changes in seed size were recorded.

Plant height : The plant height was measured from ground level to the tip of the matured panicle and plants were categorized as very short, short, medium, long and very long.

Stem diameter : Stem diameter (at lower one third height of plant) was categorized as small, medium and large.

Time of panicle emergence : Plants were classified as very early, early, medium, late and very late.

Leaf width : The observation for leaf width was sorted as narrow, medium, broad and very broad.

Panicle density at maturity (ear head compactness) : Plants were classified based on ear head compactness as very loose, loose, semi loose, semi compact and compact.

Panicle length (without peduncle) : The observation for panicle length was categorized as very short, short, medium, long and very long.

Internode length : Variations in internode length were recorded as long, medium and short.

Peduncle length : The observation for peduncle length was recorded as short, medium and long.

Grain size : The observations for grain mutations were recorded as bold and small grain size.

Results and Discussion

The M_1 generation was evaluated for different growth parameters presented in Table 1.

Out of the total 2260 seeds, treatments 100 Gy (1808) and 200 Gy (1685) recorded the highest initial plant count followed by treatments 300 Gy (1252) and 400 Gy (1142). While the lowest initial plant count was found in the 500 Gy (1050) treatments. The highest seed germination was observed at 80 per cent in the case of 100 Gy while the lowest germination rate found in 500 Gy at 46.46 per cent showed that germination percentage reduced with the increased dose of gamma rays.

In the case of mortality, the highest mortality was recorded at 500 Gy (39.43) followed by 350 Gy (32.42),

Table 1 : Effect of Gamma rays on Initial plant count, Germination (%) and Mortality (%).

Treatment	Initial plant count	Final plant stand	Germination (%)	Mortality (%)
T_1 (100 Gy)	1808	1612	80.00	10.84
T_2 (200 Gy)	1685	1368	74.56	18.81
T_3 (300 Gy)	1252	992	55.40	20.77
T_4 (350 Gy)	1240	838	54.87	32.42
T_5 (400 Gy)	1142	815	50.53	28.63
T_6 (500 Gy)	1050	636	46.46	39.43
Control	2100	2000	92.92	4.76

Table 2 : Desirable higher yielding mutants in M_2 generation.

Dose	100 Gy	200 Gy	300 Gy	350 Gy	400 Gy	500 Gy	Total
(I) Mutations for stature and growth							
Tall	11	6	0	4	7	0	28
Semi dwarf	4	4	6	2	3	2	21
Dwarf	2	1	0	1	1	2	7
Multiple tiller	3	0	0	1	2	0	6
Thick stem	6	5	3	1	4	2	21
Thin stem	4	2	1	1	3	1	12
Very thin stem	2	1	0	0	2	0	5
Long internode	6	3	0	1	3	0	13
Medium internode	4	2	0	1	2	1	10
Short internode	2	1	5	0	0	2	10
Long peduncle	6	5	1	1	0	2	15
Medium peduncle	3	4	2	3	2	0	14
Short peduncle	2	2	1	4	0	3	12
Early	3	2	1	0	0	0	6
Late	0	0	0	1	3	2	6
(II) Mutation affecting leaf characteristics							
Broad leaf	1	0	0	0	1	0	2
Narrow leaf	0	1	2	0	0	1	4
(III) Panicle mutants							
Compact panicle	6	4	2	1	0	0	13
Loose panicle	2	2	0	0	2	2	8
Broad panicle	3	3	2	1	2	1	12
Small panicle	0	0	2	1	1	1	5
Long panicle	4	3	1	0	3	2	13
(IV) Grain mutants							
Small	0	2	0	0	1	1	4
Bold	2	1	2	1	0	0	6
Total	76	54	31	25	43	25	254
Frequency (%)	4.20	3.21	2.47	2.02	3.76	2.38	

400 Gy (28.63), 300 Gy (20.77) and 200 Gy (18.81), while the lowest mortality of plants was observed at 100 Gy (10.84).

Viable mutations in M_2 generation

Frequency of viable mutations

Data on the spectrum and frequency of viable mutations affecting various morphological characters are presented in Table 2. The majority of mutants identified represented changes in plant habit, panicle morphology and maturity characteristics. Mutant plants may have mutations for one or more traits.

Several viable mutations have been isolated *viz*., narrow leaf, dwarf, early maturing, thick/thin stem, short/ long internode, compact/loose/long panicles and small/ bold grains.

The frequency of viable mutations was maximum in 100 Gy (4.20%) and 400 Gy (3.76 %) treatments followed by 200 Gy (3.21%) and 300 Gy (2.47%). The lowest frequency of viable mutations was observed in the case of 500 (2.38%) Gy and 350 Gy (2.02%).

Similar results were observed by Reddy and Smith (1976), Viraktamath and Goud (1977), Reddy and Cheralu (1984), Xin *et al*. (2008), Ambli and Mullainathan (2015), Htun *et al*. (2015), Jiao *et al*. (2016), Nikiema *et al*. (2020), Takele *et al*. (2021) and Kalpande *et al*. (2022).

Mutation affecting stature and growth

Tall mutants : These mutant plants are taller with long internodes and have a height of more than 220 cm. None of the tall mutants exhibited lodging. However, they were 6-7 days late in 50% flowering compared to the control. These mutants were observed in 100 Gy, 200 Gy, 350 Gy and 400 Gy treatments.

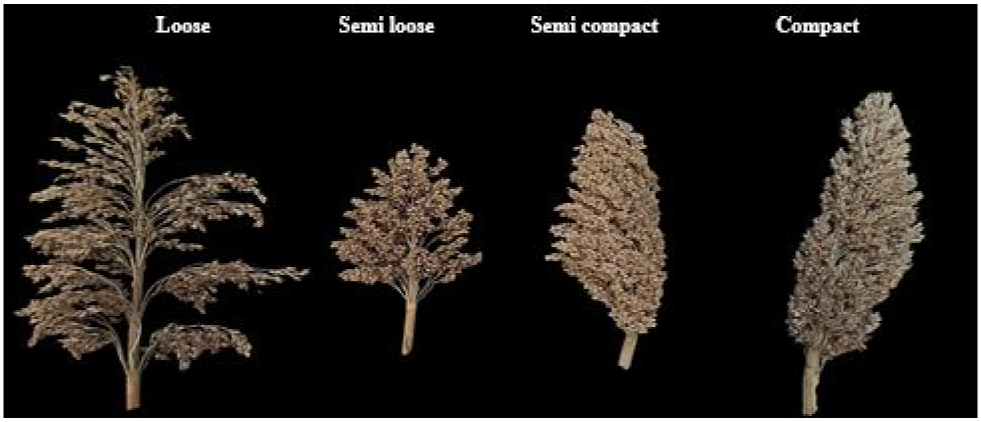

Fig. 1 : Different panicle shape and panicle density at maturity in M_2 generation of sorghum.

Semi dwarf mutants : These mutant plants were similar to the parental type except reduction in height (in the range of 180-210 cm).These mutants were observed in all the treatments.

Dwarf mutants : These mutants were dwarf (less than 200 cm). The dwarf mutants possessed reduced number of nodes and internodal length. These mutants were observed in all the treatments except in 300 Gy.

Multiple tillering mutants : These mutants possessed 4-5 tillers and were as tall as control or lesser than control but had soft, glabrous leaves and weak culms. These mutants remained green even after the maturity of grains. These mutants were observed in 100 Gy, 350 Gy and 400 Gy treatments.

Early mutant : These mutant plants flowered 7-8 days earlier than the control. Some of these mutants had the same height as that of the control. However, some have reduced height with a reduced number of nodes. These mutants were observed in 100 Gy, 200 Gy and 300 Gy treatments.

Late mutants : These mutants showed delayed flowering and maturity by 6-7 days than control. These mutants were found in the case of 350 Gy, 400 Gy and 500 Gy treatments.

Thick stem mutants : The stalk had nearly double the diameter of the normal but had reduced height. These plants were 6-7 days later than the control and had broad leaves and broad panicles. These mutants were observed in all treatments.

Thin stem mutants : These mutants were characterized by lesser stem girth as compared to controls. These were similar in plant height to controls.

Very thin stem mutants : These mutants had stem girth of less than 1.5 cm with smaller panicles as compared to the control. These mutants were observed in 100 Gy, 200 Gy and 400 Gy treatments.

Long internodes mutants : Plants with long internodes (>25 cm) were observed in all treatments except in 300 Gy.

Medium internodes mutants : These mutants were characterized by having an internodal length between 15-23 cm and were shorter in height as compared to the control. These mutants were observed in 100 Gy, 200 Gy, 350 Gy, 400 Gy and 500 Gy treatments

Thick stem mutants : The stalk had nearly double the diameter of the normal but had reduced height. These plants were 6-7 days later than the control and had broad leaves and broad panicles. These mutants were observed in all treatments.

Thin stem mutants : These mutants were characterized by lesser stem girth as compared to controls. These were similar in plant height to controls.

I

Fig. 2 : Gamma ray induced different mutants. **A.** Mutant for enhanced leaf area **B.** Mutants with peduncle length and size variation **C.** Early mutant **D.** Sorghum mutants showing variation in plant height **E.** Multiple tiller mutant **F.** Mutations observed for variation in grain size **G.** Variation in internodal length and stem girth (thickness) **H.** Sterile mutant **I.** Gamma ray induced genetic variation for panicle density and size among different families.

Very thin stem mutants : These mutants had stem girth of less than 1.5 cm with smaller panicles as compared to the control. These mutants were observed in 100 Gy, 200 Gy and 400 Gy treatments.

Long internodes mutants : Plants with long internodes (>25 cm) were observed in all treatments except in 300 Gy.

Medium internodes mutants : These mutants were characterized by having an internodal length between 15-23 cm and were shorter in height as compared to the control. These mutants were observed in 100 Gy, 200 Gy, 350 Gy, 400 Gy and 500 Gy treatments.

Short internodes mutants : These mutants were characterized by having intermodal length of less than 15 cm and were shorter in height as compared to the control. These mutants were observed in all treatments.

Long peduncle mutants : Plants having more peduncle length than their control were observed in all treatments except for the 400 Gy treatment.

Medium peduncle mutants : Plants having the same peduncle length as in control were observed in all treatments except in 500 Gy.

Short peduncle length : These mutants had shorter peduncle length as compared to the control. These were observed in all treatments except in 400 Gy.

Mutation affecting leaf characteristics

Broad leaf mutant : These mutants were characterized by leaves having more width (> 9 cm) as compared to control.

Narrow leaf mutant : These mutants were characterized by leaves having narrow leaves (<5 cm) leaf width.

Panicle mutants

Sterile panicle : Only one mutant was depicted with a sterile panicle in 400 Gy treatments.

Compact panicle : Thirteen mutants were depicted with compact panicles and dense panicle branches; these were with reduced panicle length. None of the mutants among high grain yield with compact panicle was observed in 400 Gy and 500 Gy treatments. These types of panicles are desirable for the *rabi* season.

Loose panicle : Loose panicles are desirable for the *Kharif* season. A total of eight mutants were recorded in this group and also in all the treatments.

Long panicle : These mutants had longer panicles as compared to control. These mutants had less panicle breadth with less grain.

Broad panicle : Twelve mutants were depicted with broad panicles as compared to control. These mutants were found in all gamma-ray treatments.

Small panicle : Tall plants with small panicles and some dwarf plants with small panicles were observed in all gamma ray treatments.

Mutation affecting grain characters

Grain size : Bold grains having lustrous and pale-yellow colors are highly preferred by the consumer's preference. Six mutants recorded bold grain size as compared to control, while four mutants showed small grain size.

Desirable high yielding mutants

Desirable mutations for various economically important traits in sorghum would help in improving the yield potential of the crop. Although, the frequency of desirable mutations affecting quantitative traits is rare, by growing large populations, one can identify such beneficial mutants.

In the present study, ranges of gamma ray treatments were used to induce desirable and viable mutations in the traditional *rabi* sorghum variety. Some of the M_2 progenies with higher grain yield per plant, broad and compact panicle, dwarf, early, bold seed, higher 100 grain weight, and broad leaf mutants were identified. Among the higher grain yielder mutant, six mutants showed earliness in maturity and they can be further evaluated to obtain stable mutants. Improved grain yield and early maturity in a mutant would help in developing varieties, which can tolerate terminal drought stress. Twenty-eight mutants showed dwarf and semi dwarf plant stature, which can be utilized for the development of high grain yielding dwarf genotypes suitable for mechanical harvesting, bird resistance and the component of intercropping system. The narrow leaf mutant isolated for the leaf size was reduced up to one third of control. Mutants with long, broad or compact panicles would be used to increase grain yield. Bold seed mutants may have more consumer preferences. A total of six bold seeded mutants was observed. These results are in accordance with the reports of Bretaudeau (1997), who identified mutants for several characters such as plant height, panicle length, panicle compactness, flowering date (early and late maturity) and tillering capacity. Soeranto *et al*. (2001) noticed some desirable mutants such as high yielding, white coloured grain, and broad and condensed panicle. Singh and Balyan (2009) observed morphological mutants with reduced height, amber grain color and bold grain. Odeje *et al*. (2016), Anand and Kajjidoni (2014) and Kalpande *et al*. (2021) also observed desirable mutants for grain yield. Such desirable mutants identified in this study required validation in the subsequent generations and stable mutants can be used as mutant varieties or parents in the hybridization program. Thus, the present study has revealed and validated the use of gamma rays in inducing beneficial mutants in sorghum.

Acknowledgement

The authors are thankful to the Bhabha Atomic Research Centre, Trombay, Mumbai for providing mutagenic treatment to the seeds used in this study, enabling the investigation.

References

Thapa, C.B. (2004). Effect of acute exposure of gamma rays on seed germination and seedling growth of *Pinus kesiya* Gord and *P. wallichiana* AB Jacks. *Our Nature*, **2(1)**, 13-17.

Gaul (1958). Present aspects of induced mutation in plant breeding. *Euphytica*, **7**, 275-279.

Viraktamath, B.C. and Goud J.V. (1977). Mutagenic effectiveness and efficiency of gamma rays and EMS (ethyl methanesulfonate) for inducing chlorophyll and viable mutations in sorghum [*Sorghum bicolor* (L.) Moench]. In: *Plant Breeding Papers, Third International Congress of the Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO)*, 21-25 p.

Reddy, C.S. and Smith J.D. (1976). Viable mutations in grain sorghum induced by gamma rays, chemical mutagens and their combinations with cysteine. *Genetics*, **83(3)**, 61.

Reddy, C.S. and Cheralu C. (1984). Induced morphological mutations in Indian, African and American sorghums. *Sorghum Newsletter*, **27**, 104.

Xin, Z., Li Wang M., Barkley N.A., Burow G., Franks C., Pederson G. and Burke J. (2008). Applying genotyping (TILLING) and phenotyping analyses to elucidate gene function in a chemically induced sorghum mutant population. *BMC Plant Biol.*, **8(1)**, 1-14.

Htun, K.W., Min M. and Win N.C. (2015). Evolution of genetic variability for agronomic trait in M_2 generation of sorghum through induced mutation. *Int. J. Technical Res. Applic.*, **3(6)**, 145-149.

Jiao, Y., Burke J., Chopra R., Burow G., Chen J., Wang B. and Xin Z. (2016). A sorghum mutant resource as an efficient platform for gene discovery in grasses. *The Plant Cell*, **28(7)**, 1551-1562.

Nikiema, M.P. (2023). Induced Mutagenesis for Enhancing Genetic Variability and Agronomic performance in Sorghum varieties for Burkina Faso., available at *Research Square*. Retrieved from: https://doi.org/10.21203/rs.3.rs-2948288/v1 [Accessed 18th May, 2023].

Ambli, K. and Mullainathan L. (2015). Chlorophyll and morphological mutants of Pearl millet (*Pennisetum typhoides* (Burn.) stapf. Var. CO(cu)9. *Europ. J. Exp. Biol.*, **5(3)**, 72-77.

Kalpande, H.V., Surashe S.M., Badigannavar A., More A. and Ganapathi T.R. (2022). Induced variability and assessment of mutagenic effectiveness and efficiency in sorghum genotypes [*Sorghum bicolor* (L.) Moench]. *Int. J. Radiation Biol.*, **98(2)**, 230-243.

Takele, A., Feyisa T. and Disasa T. (2021). Development of sorghum mutant genotypes and analysis of their agro-morphological diversity, available at *Research Square*. Retrieved from: https://doi.org/10.21203/rs.3.rs-457881/v1 [Accessed 18th May, 2022].

Bretaudeau, A. (1997). Radiation induced mutations for breeding of sorghum. In: *Improvement of basic food crops in Africa through plant breeding, including the use of induced mutations*, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Austria,pp. 25-29.

Anand, Y. and Kajidoni S.T. (2014). Genetic enhancement of grain size and other productivity related traits through induced variability in *kharif* sorghum. *Karnataka J. Agricult. Sci.*, **27(2)**, 121-124.

Soeranto, H., Nakanishi T.M. and Razzak M.T. (2001). Mutation breeding in sorghum in Indonesia. *Radioisotopes*, **50**, 169-175.

Odeje, S.C., Adamu A.K. and Muhammad H. (2016). Combined effects of gamma rays and sodium azide on yield components of selected varieties of Guinea corn (*Sorghum bicolor* L.). *J. Agricult. Vet. Sci.*, **9(5)**, 15-20.