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RESEARCH ARTICLE

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Binasoybean-6: A High Yielding Mutant Soybean Variety Developed through Sustainable Mutation Breeding

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ABSTRACT

Background: Soybean is an important source of food, protein and oil and hence more research is essential to increase its yield under different agro-ecological conditions, including stress. In this regard, four popular soybean varieties *viz.* Shohag, BDS-4, BAU-S/64 and BARI Soybean-5 were irradiated using Co^{60} gamma rays to create genetic variation for earliness, higher seed yield and other desirable agronomic traits.

Methods: The experiments were conducted at Bangladesh Institute of Nuclear Agriculture (BINA) Headquarters farm, Mymensingh during 2006-2009 and 28 elite mutant lines were selected for evaluation. The mutant line, SBM-22 derived from mother variety BARI Soybean-5 irradiated with 300Gy of gamma rays was found to be superior compared to other mutants. Considering the superior performance of mutant SBM-22 including 28 mutants and mother check variety BARI Soybean-5, were evaluated through different trials. The evaluation trials were conducted at different agro-ecological zones of the country during *Rabi* season (January to April) of 2010-2018.

Result: Significant variations were observed both in individual location and over locations for all traits. Reactions to major diseases and insect-pests infestation were also studied. Due to better performance of the mutant SBM-22, Bangladesh Institute of Nuclear Agriculture (BINA) applied to the National Seed Board (NSB) of Bangladesh for registration as an important soybean variety "Binasoybean-6". Consequently, the NSB of Bangladesh registered SBM-22 as an improved soybean variety in 2019 as Binasoybean-6 for commercial cultivation.

Key words: Binasoybean-6, High yielding, Irradiation, Mutant, Soybean.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is a short day, photoperiod-sensitive and self-pollinated leguminous crop that provides superior protein and edible oil (Guo *et al.,* 2020; Çirka *et al*., 2021). Presently, soybean is one of the world's most important economic legume crops. Birt *et al*. (2004) reported that cancer, blood serum cholesterol, osteoporosis and heart disease *etc.* reduces by consumption of soybean-based foods. Due to high protein content, ready availability and relatively low cost, the by-product of soybean processing, soybean meal is widely used as forage (Krishnan and Jez, 2018).

Mutation breeding is important for understanding the phenology of seed crops and for maximizing yield in a given environment. Genetic, environmental factors and the interaction between the two factors control the yield and yield related traits of soybean (Mao *et al.,* 2017). Genetic variation due to induced mutation plays an important role in adaptation to different environments. Generations of new and improved varieties can be enhanced by new sources of genetic variation. Therefore, evaluation of genetic divergence and relatedness among breeding materials has significant implications for the crop improvement (Bisen *et al.,* 2015; Jain *et al*., 2018). Knowledge on mutation breeding in soybean could help breeders and geneticists to understand the structure of genotypes, predict which combinations would produce the best mutant and facilitate to widening the breeding material for selection. The effect of gamma rays in yield and yield attributes in soybeans has been poorly understood. In the present study, gamma rays from Co^{60} sources has been used in soybean genotypes for maturity and yield related traits. The derived mutants were analyzed for identification of the superior breeding material. The objectives of this study are to determine the mutational

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effects of gamma irradiation under different environments and the interaction of environments on soybean yield.

MATERIALS AND METHODS

Four popular soybean varieties *viz.* Shohag, BDS-4, BAU-S/64 and BARI Soybean-5 were irradiated using Co^{60} gamma rays in Mutation Breeding Laboratory at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Seeds were exposed to 150, 200, 250, 300 and 350Gy doses of gamma rays for growing M_1 generation in *Rabi* season 2006. Seeds of each M_1 plants were harvested and kept separately. In M_2 generation plants were grown in plant-progeny rows in *Kharif*-II (July to November) season of 2006. A large numbers of variants were observed and desirable variants were selected to grow M_3 generation. M_3 variants obtained from all the four parents were grown during *Rabi* season 2007 following plant-progeny rows for selecting desirable mutants. The selected desirable mutants were grown as M_4 and then M_5 generations to study in respect of earliness, seed yield and yield contributing characters during *Rabi* and *Kharif*-II seasons 2008. Finally, a total of 28 desirable mutant lines from all the four mother genotypes were selected for evaluation in M_6 generation.

Observation trial was conducted in *Rabi* 2009 at BINA HQ farm, Mymensingh with those 28 (SBM-1 to SBM-28) selected M_6 mutant lines namely SBM-1, SBM-2, SBM-3, SBM-6, SBM-10, SBM-21 and SBM-23 obtained from Shohag; SBM-4, SBM-5, SBM-11, SBM-13, SBM-14, SBM-27 and SBM-28 obtained from BAU-S/64; SBM-7, SBM-8, SBM-16, SBM-17, SBM-19, SBM-20 and SBM-26 obtained from Bangladesh Soybean-4; and SBM-9, SBM-12, SBM-15, SBM-18, SBM-22, SBM-24 and SBM-25 obtained from BARI Soybean-5. From this study, the mutant line, SBM-22 derived from the variety BARI Soybean-5 irradiated with 300Gy of gamma rays was found to be superior regarding earliness, higher seed yield and other desirable agronomic traits. Considering the superior performance of SBM-22, preliminary yield trial (PYT) along with 28 mutant lines including SBM-22 was conducted at BINA sub-station farm Magura during Rabi season 2010. Different trials were conducted in different agro-ecological zones of the country like as Mymensingh, Rangpur, Magura, Cumilla, Chandpur and Noakhali districts during *Rabi* season of 2010-2018.

All of these experiments were laid out in a randomized complete block design (RCBD) with three replications. Spacing maintained among rows was 30 cm and 5-7 cm between plants in rows (Malek *et al*., 2012). Data on various characters such as plant height, number of branches/plant, pods/plant and seeds/pod was taken from 10 randomly selected plants from each plot. Maturity period was counted from seed sowing to the day when the plants and pods of each plot turned into yellowish brown color and almost all the leaves shed. Seed yield of each plot was recorded after proper sun-drying of seeds and then converted into kg/ha. The recorded data were analyzed statistically following Gomez and Gomez (1984) and the mean values were compared by DMRT at 5% level of significance.

RESULTS AND DISCUSSION

Plant growth, development and yield are strongly inhibited by the environmental effect which is an important factor for crop improvement as well as develop a new variety. Mean values for different characters of individual locations and combined over locations of the preliminary and multi-location trials during 2010 to 2014 are not shown, only the latest advanced trials in 2015, 2016 and 2018 are presented in Table 1 to 3.

Preliminary yield trial (PYT) of M_7 soybean mutants during *Rabi* season 2010

Twenty eight M_7 mutant lines along with four mother genotypes were put into PYT at BINA Headquarters farm and BINA sub-station farm at Magura. Seeds were sown within first week of January 2010 (data not shown). BDS-4 produced the highest number of pods/plant (79) and showed non-significant difference with mutants SBM-27, SBM-28, SBM-14, SBM-13, SBM-12 and SBM-11 while SBM-26 produced the lowest number of pods/plant (44). Among the mutants, days to maturity ranged from 118 (SBM-05 and SBM-06) to 140 days (SBM-27). Two mutants SBM-16 andSBM-07 produced highest yield 3164 kg/ha and 2830 kg/ha respectively. Among all, 11 mutants, namely SBM-07, SBM-08, SBM-14, SBM-16, SBM-17, SBM-18, SBM-21, SBM-22, SBM-23, SBM-24 and SBM-25 gave higher seed yield than their mother varieties.

Preliminary yield trial (PYT) of M_8 soybean mutants during *Rabi* 2011

Twelve selected M_8 mutant lines along with three mother genotypes were tested in PYT at BINA Headquarter’s farms and BINA sub-station at Magura (data not shown). Among the mutants, average days to maturity ranged from 100 (SBM-19) to 107 (SBM-12). Bangladesh Soybean-4 produced the highest number of pods/plant (55) having non-significant difference with two mutants, SBM-26 and SBM-12 while SBM-23 produced the lowest number of pods/plant (36). Ten mutants namely SBM-9, SBM-12, SBM-16, SBM-17, SBM-18, SBM-20, SBM-21, SBM-22, SBM-23 and SBM-26 produced higher seed yield than their mothers. SBM-15 (2416 kg/ha) and SBM-19 (2361 kg/ha) produced lowest seed yield when compared with other mutants.

Multi-location yield trial with promising soybean mutants during *Rabi* 2013

Four promising mutants SMB-9, SMB-15, SMB-18 and SMB-22 along with mother BARI Soybean-5 and another check variety Binasoybean-2 were evaluated in this trial at BINA HQ farm and BINA sub-station farm at Rangpur and Magura during January to April 2013 (data not shown). Days to maturity ranged from 103 (Binasoybean-2) to 112 days (SBM-18 and SBM-22). The mutants SBM-18 and SBM-22 produced significantly higher number of pods/plant (41 and 39, respectively) and seed yield (2642 and 2606 kg/ha, respectively).

Multi-location yield trial of advanced soybean mutants during *Rabi* 2014

Four promising mutants SMB-9, SMB-15, SMB-18 and SMB-22 along with their mother BARI Soybean-5 and another check variety Binasoybean-1were evaluatedat BINA HQ farm and BINA sub-station farms at Magura and Cumilla; farmers' field at Chandpur and Noakhali during January to April 2014 (data not shown). Days to maturity ranged from 112 in Binasoybean-1 to 116 days in SBM-9. Number of seeds/pod ranged from 1.80 in SBM-9 to 1.92 in SBM-22; and hundred seed weight ranged from 12.42 in Binasoybean-1 to 14.58 g in BARI soybean-5. All the mutants produced significantly higher seed yield than checks and particularly, SBM-18 and SBM-22 produced the highest seed yield (2793 and 2730 kg/ha, respectively).

On-station yield trials with advance soybean mutants during *Rabi* 2015

Four promising mutants SMB-9, SMB-15, SMB-18 and SMB-22 along with their mother BARI Soybean-5 and another check Binasoybean-2 were evaluated at BINA HQ farm and BINA sub-station farms at Magura and Cumilla during January to April 2015. On an average, maturity period ranged from 101 (SBM-15 and Binasoybean-2) to 105 days (BARI Soybean-5). Number of pods/plant ranged from 33 in Binasoybean-2 to 66 in SBM-9. Particularly, mutants SBM-18 and SBM-22 produced higher seed yield among the mutants and checks (Table 1).

On-station and on-farm yield trials with advance soybean mutants during *Rabi* 2016

Four promising mutants SMB-9, SMB-15, SMB-18 and SMB-22 along with their mother BARI Soybean-5 and another check Binasoybean-2 were evaluated at BINA HQ farm and farmers' field at Noakhali and Chandpur during January to April 2016. Maturity period ranged from 97 days in Binasoybean-2 to 108 days in SBM-18 and SBM-22. Mutant line SBM-18 produced the highest seed yield of 2584 kg/ha closely followed by SBM-22 (2561 kg/ha) and Binasoybean-2 (2508 kg/ha), whereas, SBM-15 (2281 kg/ha) produced the lowest seed yield (Table 2).

On-station and on-farm yield trials with advance soybean mutants during *Rabi* 2018

Two promising mutants SMB-18 and SMB-22 along with their mother BARI Soybean-5 and another check variety

Table 1: Mean of different quantitative characters during *Rabi* 2015.

Locations	Mutants /varieties	Days to maturity	Plant height (cm)	Branches /plant(no.)	Pods/ plant (no.)	Seeds /plant (no.)	100-seed wt. (g)	Seed yield (kg/ha)
BINA HQ Farm, Mymensingh	SBM-9	107ab	39e	2.9b	46abc	2.1	13.3bc	2444de
	SBM-15	101d	45b	2.9b	44c	2.1	13.7ab	2644cd
	SBM-18	110a	43cd	3.0b	46ab	2.0	13.7a	2911ab
	SBM-22	103cd	48a	3.2a	44bc	2.1	12.9bc	2733bc
	Binasoybean-2	105bc	43d	2.6c	26d	2.1	14.1a	3111a
	BARI soybean-5	106bc	45bc	3.2a	48a	2.1	12.8c	2333e
BINA sub-station Farm, Magura	SBM-9	102ab	43b	3.5a	73b	2.2b	13.3bc	2189c
	SBM-15	96c	61a	2.8d	51c	2.2c	13.7ab	2483abc
	SBM-18	103a	57ab	3.1bc	61c	2.0d	13.7ab	2833a
	SBM-22	97c	58a	3.2ab	84a	2.2bc	12.9c	2786ab
	Binasoybean-2	99bc	25c	2.8cd	36d	2.2bc	14.1a	1967c
	BARI soybean-5	101ab	56ab	2.6d	58c	2.3a	12.8c	2228bc
BINA sub-station Farm, Cumilla	SBM-9	100b	75bc	3.7a	78a	2.1	14.1a	2393ab
	SBM-15	105a	80b	3.1b	69b	2.1	13.3abc	2367b
	SBM-18	100b	73bc	2.7c	67b	2.0	13.8a	2490a
	SBM-22	110a	97a	2.9c	59c	2.1	12.9bc	2407ab
	Binasoybean-2	93c	59c	3.7a	48d	2.1	13.5ab	2230b
	BARI soybean-5	108a	84ab	3.2b	69b	2.1	12.7c	2373b
Combined (means over three locations)	SBM-9	103c	52c	3.4a	66a	2.1	13.6b	2342c
	SBM-15	101d	62ab	2.9b	55c	2.1	13.6b	2498b
	SBM-18	104b	58bc	2.9b	58bc	2.0	13.7b	2744a
	SBM-22	103c	68a	3.1b	62ab	2.1	12.9c	2642a
	Binasoybean-2	101d	31d	2.7c	33d	2.2	14.1a	2348c
	BARI soybean-5	105a	62ab	3.0b	58bc	2.2	12.8c	2311c

Same letter(s) in a column for individual location means/combined means over locations do not differ significantly at 5% level of probability by DMRT.

Binasoybean-1 were evaluated at BINA HQ farm and BINA sub-station farm at Magura and farmers' field at Chandpur and Noakhali during January to April 2018. Maturity period ranged from 116 days in Binasoybean-1 and BARI Soybean-5 to 118 days in SBM-22. The mutant SBM-18 produced the highest seed yield of 2197 kg/ha followed by SBM-22 (2109 kg/ha). Compared with the mother variety, these two mutants (SBM-18 and SBM-22) were late (117 and 118 days) but both the mutants recorded higher number of pod/plant (56 and 52), seeds/pod (2.2 and 2.09) and 100-seed weight (13.9 and 13.5) respectively. Due to the higher yield attributing characters these mutants recorded higher yields than the mother variety (Table 3).

Overall performance of the new variety Binasoybean-6

Pooled data of yield and yield related attributes of the newly registered variety Binasoybean-6 has been analyzed considering the mean seed yield of all trials conducted during 2010 to 2018 (Table 4). The new variety Binasoybean-6 produced the higher mean seed yield of 2612 kg/ha compared to mother variety BARI Soybean-5 (2327 kg/ha). The mutant line SBM-22 was found to be tolerant to yellow mosaic disease and also showed the lowest incidence of insect-pests (hairy caterpillar and pod borer) infestation.

Mutation breeding can improve yield and yield attributes by the genetic improvement in soybean compared to conventional breeding (Manjaya, 2009; FAO/IAEA, 2018). From the present study it was observed that, most of the mutants performed comparatively superior over their respective mother varieties for seed yield and other yield contributing characters. These results were in agreements with other researchers (Ahire *et al.,* 2005; Malek *et al.,* 2014) who reported improved yield attributes in soybean mutants following mutagenesis. Malek *et al.* (2014) developed 27 soybean mutants by irradiating four soybean genotypes using gamma rays from the Co^{60} gamma source and 18 superior mutants were selected for better seed yield. In Bangladesh, average yield of soybean presently is 1.64 tons/ha as compared with world average. To overcome this bottleneck, viable alternative would be cultivation of a high yielding varieties (Malek *et al.,* 2014). The average yield of the mutant SBM-22 is 2.6 tons/ha which can play a major role for bridge the yield gap of this crop in Bangladesh. Development of mutant variety Binasoybean-6 is a milestone in soybean breeding through induced mutagenesis.

Table 2: Mean of different quantitative characters during *Rabi* 2016.

Locations	Mutants /varieties	Days to maturity	Plant height (cm)	Branches /plant (no.)	Pods /plant (no.)	Seeds /pod (no.)	Pod length (cm)	Seed yield (kg/ha)
Mymensingh	SBM-9	110a	44b	3.0a	45a	1.8ab	3.1ab	2425a
	SBM-15	102d	48ab	3.2a	47a	1.7ab	2.9b	2125bc
	SBM-18	108ab	43b	2.9a	41a	1.7ab	3.0b	2242b
	SBM-22	105c	53a	2.5ab	43a	1.6b	3.3ab	2200bc
	Binasoybean-2	98e	31c	1.7b	24b	1.9a	3.6a	2192bc
	BARI soybean-5	106bc	50ab	2.9a	49a	1.7ab	3.0ab	1975c
Noakhali	SBM-9	103c	39a	2.8a	39a	1.9a	3.1b	2217bc
	SBM-15	105bc	42a	2.9a	36ab	1.9a	3.1b	2100c
	SBM-18	107ab	41a	3.2a	38ab	2.1a	3.4ab	2292a
	SBM-22	110a	40a	2.3a	41a	2.0a	3.4ab	2333ab
	Binasoybean-2	99d	28b	2.8a	30b	2.1a	3.6a	2308abc
	BARI soybean-5	104bc	45a	3.1a	39a	2.1a	3.1b	2233bc
Chandpur	SBM-9	105bc	40b	3.4ab	56ab	1.9c	3.4ab	2750cd
	SBM-15	101c	52a	3.5ab	59a	2.0b	3.2b	2617d
	SBM-18	109a	46a	3.8a	58ab	2.2ab	3.3ab	3217a
	SBM-22	108ab	48a	3.1ab	49bc	2.1b	3.4ab	3150ab
	Binasoybean-2	95d	37b	3.0b	36c	2.3a	3.6a	3025ab
	BARI soybean-5	107ab	50a	3.0b	46bc	2.1b	3.1b	2950bc
Combined means over location	SBM-9	106ab	41b	3.1a	47a	1.9b	3.2ab	2464ab
	SBM-15	103b	47a	3.2a	48a	1.9b	3.1b	2281b
	SBM-18	108a	43ab	3.3a	45a	2.0ab	3.2ab	2584a
	SBM-22	108a	47a	2.7a	43a	1.9b	3.3ab	2561a
	Binasoybean-2	97c	32c	2.5a	30b	2.1a	3.6a	2508a
	BARI soybean-5	106ab	48a	3.0a	44a	2.0ab	3.1b	2386ab

Same letter(s) in a column for individual location means/combined means over locations do not differ significantly at 5% level of probability by DMRT.

Table 3: Mean of different quantitative characters during *Rabi* 2018.

Mutants/varieties	Days to maturity	Plant height (cm)	Branches /plant (no.)	Pods /plant (no.)	Seeds /pod (no.)	100-seed weight (g)	Seed yield (kg/ha)
BINA HQ farm, Mymensingh							
SBM-18	114a	80a	2.34ab	52a	2.20b	13.41b	2163a
SBM-22	113b	75b	2.40a	50b	2.30a	13.89a	2158a
Binasoybean-1	110c	80a	2.07b	46bc	2.10c	12.23c	1798b
BARI Soybean-5	113b	74bc	2.31ab	46c	2.22ab	13.62ab	1789b
BINA sub-station farm, Magura							
SBM-18	113b	78a	2.5a	72a	2.45a	14.46a	2920a
SBM-22	117ab	74b	2.3b	69ab	2.30b	13.67b	2796b
Binasoybean-1	118a	78a	2.1c	65b	2.20c	12.61c	2323c
BARI Soybean-5	117ab	75ab	2.1c	67ab	2.25bc	14.38ab	2382bc
Farmers' field, Chandpur							
SBM-18	120b	78b	2.13a	52a	2.10a	13.91a	1850a
SBM-22	123a	79ab	1.8b	47b	1.9b	12.41b	1720b
Binasoybean-1	119bc	81a	1.6c	44c	1.83c	12.54ab	1625c
BARI Soybean-5	117c	75c	1.7bc	47b	1.87bc	13.87ab	1723bc
Farmers' field, Noakhali							
SBM-18	119a	81ab	1.9a	48a	2.10a	13.86ab	1856a
SBM-22	118ab	79b	1.7ab	43ab	1.85b	13.91a	1763b
Binasoybean-1	117b	83a	1.65b	40b	1.73c	12.39ab	1687bc
BARI Soybean-5	118ab	72c	1.68ab	42ab	1.79bc	12.34b	1625c
Combined (means over four locations)							
SBM-18	117ab	79ab	2.22a	56a	2.23a	13.9a	2197a
SBM-22	118a	77b	2.05b	52b	2.09b	13.5ab	2109b
Binasoybean-1	116b	81a	1.86c	49c	1.97c	12.4c	1858c
BARI Soybean-5	116ab	74c	1.96bc	51bc	2.03bc	13.6b	1880bc

Same letter(s) in a column for individual location means/combined means over locations do not differ significantly at 5% level of probability by DMRT.

Table 4: Year-wise and mean seed yield (kg/ha) of the newly released variety Binasoybean-6.

Name of proposed variety and check	2010	2011	2013	2014	2015	2016	2018	Mean seed yield of seven years
Released new mutant variety Binasybean-6	2664	2969	2606	2730	2642	2561	2109	2612
BARI Soybean-5 (check)	2428	2408	2395	2480	2311	2386	1880	2327

CONCLUSION

The registered new mutant variety "Binasoybean-6" has been developed from BARI Soybean-5. The mutant line SBM-22 was found to be higher yielding as well as tolerant to yellow mosaic (YM) disease and also showed lower incidence of insect-pests infestation. Higher seed yield and improved yield attributes in the mutants revealed that induced mutations can successfully be employed to create genetic variations in soybean. This can be considered as a milestone achievement in mutation breeding. This variety may partially fulfill the challenges of increasing demand of edible oils and also has an opportunity for increase cultivable land under soybean in Bangladesh.

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