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Effect of Gamma Radiation on Morpho-Physiological Characters of Soybean

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Abstract

An experiment was carried out at the experimental farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from January, 2011 to April, 2011. The study was conducted to evaluate the effect of gamma radiation on morpho-physiological characters of BARI soybean. Four levels of gamma irradiation viz. 200, 300, 400 and 500 Gy γ-ray from 60C source and control were irradiated on assigned two genotypes viz. BARI soybean 5 and BARI soybean 6. Data for growth analyses were collected at different days after sowing. Results revealed that the soybean varieties and gamma irradiation significantly affected morpho-physiological characters where BARI soybean 5 and 200 Gy γ-ray levels produced the greater results alone or combinations. This combination produced the tallest plant (37.42 cm), maximum leaf and branch plant^{-1} (23.15 and 2.10) at 75 DAS. 200 Gy γ-ray irradiated plants of BARI soybean 5 produced the highest seed yield (2373.70 kg ha-1) followed by control treatment (1887.90 kg ha-1) at the same variety. On the other hand, the plants consequential from 500 Gy γ-ray radiated of BARI soybean 5 had shown the lowest seed yield (1050.70 kg ha-1). This result indicating that irradiation significantly decreased on seed yield with increasing doses of gamma rays. So, the variety BARI soybean 5 and 200 Gy γ-ray alone or combination had outstanding superiority for plant growth over the other gamma ray levels.

Key words: Gamma radiation, Growth, Soybean

Introduction

Soybean (*Glycine max* L. Merill) is an important and well recognized oil seed and grain legume crop of the world. It belongs to the family Leguminosae and sub-family Papilionaceae. It is highly valuable crop in agriculture, which provides high quantity plant protein and vegetable oils. It was introduced in Bangladesh in around 1942, but its cultivation was started in late seventies as coordinated soybean research project, which was functioning from 1975-1980 for its improvement and promotional activities of soybean. The cultivation of soybean in Bangladesh (mainly in Noakhali and Feni) started in 1978. Soybean is called the "Golden bean" or "Miracle bean" or "Protein hope of future" because of its high nutritive value. Soybean (*Glycine max* L.) is a major food and feed source that mainly cultivated for oil and protein (Napoles *et al.*, 2009). Per 100g soybean seed contains about 40-45g protein, 20g oil, 20-25 g carbohydrate, 11.50 mg iron, 208.0 mg calcium and 432 calories energy (Rahman, 2001). About 60% of the world supply of vegetable protein and 30% of the oil are provided by soybean (Fehr, 1989). For these reasons, soybean had been recognized as one of the premier agricultural crops of the world (Kaul and Das, 1986). Mutation breeding in crop plants is an effective tool used in mutation breeding to promote gene recombination and mutation frequency (Khundi *et al.*, 1997; Jamil and Khan, 2002; Majeed *et al.*, 2010) especially in crops having narrow genetic base. Low dose of gamma-ray treatment is recommended for the improvement of several plant species (Chen *et al.*, 2010). Ashraf *et al.* (2003) reported that seedling emergence, panicle fertility and grain yield declined with increasing dose level. Many mutants have been identified as donors of desirable traits in breeding program. Mutation breeding work in soybean crop has yielded in identification of many mutant lines with desirable traits like high germination and survival percent (Rahman *et al.*, 1994). In Bangladesh, gamma radiation techniques has been successfully utilized by BINA, BARI and other some research Institutes. Research reports of gamma radiation effect on growth and yield of soybean genotypes is very limited in Bangladesh. But knowledge of gamma radiation will help to exploit both aerial and edaphic resources of the environment are essential to guide the farmers to maximize the yield of the crop. The objectives of the present study were to select the suitable cultivar that ensures the higher growth and to find out the most advantageous gamma radiation dose in relation to growth characteristics among genotypes of BARI Soybean 5 and BARI Soybean 6.

Materials and Methods

Experimental site

The experiment was carried out in the Research Farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from January, 2011 to April, 2011. The experimental area is located at 24.6^0 N and 90.5^0 E latitude and at an altitude of 18 m from the sea level (Khan, 1997).

Experimental materials

Two genotypes of soybean viz. BARI Soybean- 5 and BARI Soybean- 6 were used as experimental materials for the study. All the genotypes were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur- 1701.

Soil

The soil of the experimental area was to the Sonatola soil series of grey flood plain soil under the Agro-ecological Zone (AEZ- 9) and belonged to the Old Brahmaputra Flood Plains Alluvial Tract (UNDP; FAO, 1988). The selected plot was high land, fertile, well drained and having pH 6.7.

Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The whole experimental area was divided into three equal blocks. Each block was then further divided into 10 plots where two soybean varieties were allotted at random according to 5 treatments. Thus there were 30 (2×5×3) unit plots altogether in the experiment. The size of unit plot was 3m × 1m. Row to row and plant to plant distances were 30 and 6 cm, respectively, in each plot.

Land preparation

The experimental land was first open on 1st January, 2011 with a power tiller. The field was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. The plots were spaded one day before planting and the whole amount of fertilizers were incorporated thoroughly before sowing according to fertilizer recommendation guide (BARC, 2012). The soil was treated with insecticides at the time of final ploughing. Insecticides Furadan 5G was used @ 8 kg ha^{-1} to protect young plants from the attack of mole cricket, ants, and cutworms.

Manures and fertilizers

All manures and fertilizers were applied during final plot preparation. The cow dung was applied 15 days ahead of final land preparations. The whole amount of TSP, MP, Gypsum and half of Urea were applied as basal dose at the time of final land preparation. The remaining half of the urea was top dressed in splits at 30 days after sowing (Source: Fertilizer Recommended Guide of BARC 2012).

Table1. Doses of manure and fertilizers in plots

Manure and fertilizers	Dose (ha^{-1})	Quantity per plot
Cow dung	6 ton	3.6 kg
Urea	40 kg	24 gm
TSP	120 kg	72 gm
MP	60 kg	36 gm
Gypsum	120 kg	72 gm

Seed sowing

Seeds of soybean irradiated with five different doses of gamma rays were sown by hand at 3-4 cm depth. Seeds were sown on 19th January, 2011. Few seedlings were grown in the border of the plots as stock seedling for gap filling subsequently.

Intercultural operations

a) Thinning out

Emergence of seedling was completed within 10 days after sowing. Over crowded seedlings were thinned out two times. First thinning was done after 15 days of sowing which is done to remove unhealthy and lineless seedlings. The second thinning was done 10 days after first thinning.

b) Gap filling

Seedlings were transferred to fill in the gaps where seeds failed to germinate. The gaps were filled in within two weeks after germination of seeds.

c) Weeding

First weeding was done at 30 DAS and then once a week to keep the plots free from weeds and to keep the soil loose and aerated.

d) Irrigation

The first irrigation was done after the first weeding after that the irrigation was applied by observing the soil moisture condition. However, each top-dressing was followed by irrigation.

e) Disease and pest management

Soon after emergence the soybean seedling were infested by cutworms and hairy caterpillars (*Diasrisia obliqua*). Hand picking of cutworm larvae and spraying of Sevin 85WP @4.2 kg ha^{-1} were done as control measures. The attack of sclerotia was controlled by using ash at the base of the plants about 1-2cm below the soil followed by light irrigation with the help of water can.

Harvesting, threshing and drying

The crop was harvested with sickle on 22nd March, 2011 at full maturity of the crop when the color of leaf turned yellow and dropped off and dried in the sun for 3-4 days. The seeds were dried in sun for 2-3 days and the plot wise weights were recorded.

Data collection and statistical analysis

Ten random selected plants of a plot were tagged carefully for recording necessary morphological parameters. This process was followed for all the plots individually. Seed yield was taken on individual plot basis at moisture content of 12% and converted into kg ha^{-1}. The data obtained from experiment on various parameters were statistically analyzed in MSTAT-C computer program (Russel, 1986). The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished by Duncan's Multiple

Range Test (DMRT) and the significance of difference between pair of means was tested by the Least Significant Differences (LSD) test at 5 % levels of probability (Gomez and Gomez, 1984).

Leaf area plant^{-1}

The leaf area was worked out by disc method on dry weight basis at different growth stages as per the procedure suggested by Vivekananda *et al.* (1972). Twenty five discs of known size were taken through a cork borer from randomly selected leaves of five plants sampled for dry matter distribution. Both the discs and remaining leaf blades was oven dried and the leaf area was calculated by the following formulas and the mean of five plants was expressed in cm^2 per plant.

$$\text{Leaf area} = \frac{Wa \times A}{Wd}$$

Where,

LA= Leaf area (cm^2)

Wd= Weight of 25 discs in g

A= Area of 25 discs in cm^2.

Wa= Weight of all the leaves with discs in gram

Crop growth rate (CGR)

The crop growth rate values at different growth stages were calculated using the following formula-

$$CGR = \frac{1}{A} . \frac{W_2 - W1}{T_2 - T1} \text{ g m}^{-2}\text{d}^{-1}$$

Where,

W_1= Total dry matter production at time initial stage of data recording T_1 (g)

W_2= Total dry matter production at final stage of data recording T_2 (g)

A= Ground area (m^2)

Relative growth rate (RGR)

The relative growth rate (RGR) values at different growth stages were calculated using the following formula-

$$RGR = \frac{Log_e W_2 - Log_e W1}{T_2 - T1} \text{ g.g}^{-1}\text{d}^{-1}$$

Where,

W_1= Total dry matter production at time initial stage of data recording T_1 (g)

W_2= Total dry matter production at final stage of data recording T_2 (g)

Results and Discussion

Plant height

Effect of varieties showed significant difference on plant height at all sampling dates but a non significant effect was observed at final harvest time. The combined effect of two varieties and different doses of gamma ray, the tallest plant (37.42cm) was found in 200 Gy γ-ray irradiated plant of BARI soybean 5 at 75 DAS followed (36.32cm) by the control treatment at harvest time which was statistically identical. The shortest plant (27.15cm) was observed in 500 Gy γ-ray irradiated plant of BARI soybean 5 (Table 2). Alikamanoglu *et al.* (2011) also studied that the toxicity of iron, copper, and zinc in soybean seeds of the NE 3297 variety irradiated at different dosages of gamma rays. After cultivating in plastic boxes for 14 days, the average plant heights, fresh weight, and chlorophyll content decreased in inverse proportion to radiation dose.

Number of leaves plant^{-1}

A significant variation was observed for number of leaves plant^{-1} at all DAS due to the main effect of variety and treatments, and also combined effect of both factors. 200 Gy γ-ray irradiated plants produced the maximum number of leaves plant^{-1} over their all growth periods viz. 30, 45, 60 and 75 days after sowing. But the effect of increasing gamma ray doses on both varieties decreased their morpho-physiological traits as well as leaf number whereas, the BARI soybean 5 showed the superior performance in overall explanation. At the variety BARI soybean 5 produced significantly the maximum (23.15) number of leaves plant^{-1} at 200 Gy γ-ray irradiated plants at 75 DAS. In contrast, 500 Gy γ-ray gamma ray irradiated plants of BARI soybean 6 produced the lowest number of leaves plant^{-1} (11.08) compared to BARI soybean 5 (11.23) where they were statistically same (Table 2). Similar trend was also observed at 30, 45 and 60 days after sowing (Table 2).

Table 2. Combined effect of varieties and different gamma rays on plant height at different days after sowing

Varieties	Gamma ray (Gy γ-ray)	Plant height (cm)				Number of leaves plant^{-1}			
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
BARI soybean 5	Control	13.53a	23.43	29.41b	36.32	3.28b	8.87b	9.97bc	19.58b
	200	11.20c	27.09	35.63a	37.42	4.10a	10.76a	12.35a	23.15a
	300	7.73d	19.24	25.35cd	28.27	3.02bc	8.00b	11.45ab	15.18d
	400	4.63e	11.43	24.27cde	29.54	2.96bc	5.33cd	9.00cde	11.79e
	500	4.30e	6.76	22.81de	27.15	2.02d	3.77e	6.87f	11.23e
BARI soybean 6	Control	12.17ab	23.97	26.09bcd	29.97	4.43a	6.53c	7.67def	16.93cd
	200	14.43a	24.77	26.95bc	34.03	4.57a	9.20b	9.33cd	19.56b
	300	10.63c	19.97	22.90cde	33.68	3.22b	4.83de	7.39ef	18.49bc
	400	5.57de	13.2	21.24e	32.04	2.70b	4.78de	6.50f	11.30e
	500	4.31e	6.24	14.98f	28.98	2.07d	4.43de	7.10f	11.08e
LSD		**2.29**	**2.85**	**3.56**	**6.82**	**0.46**	**1.3**	**1.74**	**2.04**
CV (%)		**15.1**	**9.19**	**8.32**	**12.95**	**8.21**	**11.36**	**11.56**	**7.5**
Level of sig.		*	**NS**	*	**NS**	**	**	*	**

In a column, figures having similar letter (s) do not differ significantly at P < 0.05 as per DMRT

LSD = Least significant difference; CV = Coefficient of variance

** = 1% level of significance, * = 5% level of significance and NS= non significant

Number of branches plant $^{-1}$

Genotypic and gamma irradiation effect showed significant difference at all data recording periods but a non significant effect was found at 30 and 45 days after sowing due to the combined effect of varieties and gamma irradiation where they differed significantly at 60 and 75 DAS. Among the combined effect, 200 Gy γ-ray irradiated plants of BARI soybean 5 gave the maximum number of branches plant^{-1} (2.10) followed by the second highest (1.90) which was found from the untreated plants of BARI soybean 5 at 75 DAS. Similarly, the minimum number of branches plant^{-1} (1.25) was recorded from the 500 Gy γ-ray irradiated plants of BARI soybean 6 (Table 2).

Leaf dry weight plant $^{-1}$

Leaf dry weight was significantly affected among the varieties and gamma rays, their combined effect also showed significant at all DAS. Combined effect of varieties and gamma rays, 200 Gy γ-ray irradiated plants of BARI soybean 5 produced significantly the highest leaf dry weight plant^{-1} (5.83g) when 500 Gy γ-ray irradiated plants of BARI soybean 6 observed the lowest (3.11g) at 75 DAS (Table 3). Similar results were also found at 30, 45 and 60 DAS (Table 3).

Table 3. Effect of varieties and different doses of gamma radiation on leaf dry weight (g) at different days after sowing

Varieties	**Gamma ray (Gy γ-ray)**	**Number of branches plant^{-1}**				**Leaf dry weight (g)**			
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
BARI soybean 5	Control	1.14	1.3	1.56a	1.90b	0.42b	3.08a	3.41b	4.30b
	200	1.21	1.35	1.66a	2.10a	0.57a	3.31a	3.98a	5.83a
	300	1.08	1.13	1.55a	1.62c	0.30c	2.30bcd	3.51b	3.17d
	400	1.04	1.04	1.32b	1.86b	0.29c	2.02d	3.43b	4.05b
	500	0.57	1.00	1.25b	1.41d	0.27c	2.05d	3.38b	3.19d
BARI soybean 6	Control	1.14	1.05	1.08b	1.43cd	0.31c	2.61b	3.17c	4.14b
	200	1.07	1.15	1.21b	1.45cd	0.14d	2.43bc	2.63d	4.00bc
	300	1.08	1.1	1.29b	1.43cd	0.14d	2.11cd	2.45d	3.49cd
	400	0.91	0.92	1.26b	1.30d	0.27c	2.10d	2.51cd	3.49cd
	500	0.68	0.78	1.08b	1.25d	0.13d	2.01d	2.43d	3.11d
LSD		**0.16**	**0.15**	**0.21**	**0.2**	**0.052**	**0.284**	**0.156**	**0.487**
CV (%)		**9.72**	**8.11**	**9.23**	**7.31**	**4.56**	**8.25**	**4.25**	**7.45**
Level of sig.		**NS**	**NS**	*****	******	******	******	******	******

In a column, figures having similar letter (s) do not differ significantly at $P < 0.05$ as per DMRT
LSD = Least significant difference; CV = Coefficient of variance
** = 1% level of significance, * = 5% level of significance and NS= non significant

Table 3. Effect of varieties and different doses of gamma radiation on total dry matter at different days after sowing

Varieties	**Gamma ray (Gy γ-ray)**	**Stem dry weight (g)**				**Total dry matter (g)**			
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
BARI soybean 5	Control	0.47b	4.33b	5.64b	7.17b	0.89b	7.41b	9.05b	11.47b
	200	0.65a	5.28a	6.39a	8.29a	1.23a	8.59a	10.37a	14.12a
	300	0.40c	3.53cd	4.76d	5.97d	0.70c	5.83d	8.27bc	9.14de
	400	0.23d	3.11d	4.37d	5.70de	0.53d	5.13e	7.80c	9.75cd
	500	0.21d	3.08d	4.31d	5.65de	0.48d	5.13e	7.69c	8.84e
BARI soybean 6	Control	0.34c	3.39cd	5.13c	6.24c	0.65d	6.00d	8.31bc	10.38c
	200	0.21d	4.21b	4.59d	5.53e	0.35d	6.64c	7.21cd	9.53cde
	300	0.24d	3.14d	3.77e	5.51e	0.38d	5.25e	6.22de	9.00de
	400	0.24d	3.05d	3.46e	5.30e	0.51d	5.15e	5.97e	8.79e
	500	0.19d	3.03d	3.41e	5.27e	0.32d	5.04e	5.84e	8.38 e
LSD		**0.073**	**0.344**	**1.185**	**0.467**	**0.116**	**0.415**	**1.175**	**0.784**
CV (%)		**7.24**	**4.56**	**6.25**	**4.51**	**5.33**	**8.69**	**7.24**	**6.35**
Level of sig.		******	******	******	******	******	******	*****	******

In a column, figures having similar letter (s) do not differ significantly at $P < 0.05$ as per DMRT
LSD = Least significant difference; CV = Coefficient of variance
** = 1% level of significance, * = 5% level of significance and NS= non significant

Stem dry weight plant^{-1}

Combined effect of variety, gamma rays on stem dry weight showed significant differences at 30, 45, 60 and 75 DAS. Stem dry weight had higher (8.29g) in 200 Gy γ-ray irradiated plants of BARI soybean 5 followed by the second highest (7.17g) which was observed by untreated plants of the same variety. In contrast, significantly the lowest stem dry weight (5.27g) was recorded by 500 Gy γ-ray irradiated plants of BARI soybean 6 (Table 3).

Total dry matter (TDM)

Total dry matter was significantly affected due to the effect of variety, gamma rays and their combinations at different days after sowing. Among the treatment combinations, 200 Gy γ-ray irradiated plants of BARI soybean 5 produced significantly the highest TDM (14.12g) when 500 Gy γ-ray irradiated plants of BARI soybean 6 observed the lowest TDM (8.38g) at 75 DAS (Table 3). Similarly, 200 Gy γ-ray irradiated plants of BARI soybean 5 produced the higher TDM at 30, 45 and 60 DAS (Table 3).

Crop growth rate (CGR)

Main effect of variety and gamma rays were significantly affected in respect of CGR whereas their combinations were also significant at 45 and 60 DAS but 75 DAS was insignificant. CGR also had higher ($0.49g^{-1}day^{-1}$) in 200 Gy γ-ray irradiated plants of BARI soybean 5 followed by the untreated plants of BARI soybean 5 ($43g^{-1}day^{-1}$) and 200 Gy γ-ray gamma ray irradiated plants of at BARI soybean 6 ($0.42g^{-1}day^{-1}$) which was observed the second and third highest, respectively. In contrast, significantly the lowest CGR ($0.29g^{-1}day^{-1}$) was recorded by 500 Gy γ-ray irradiated plants of BARI soybean 5 (Table 4).

Relative growth rate (RGR)

Combined effect of variety and gamma rays showed insignificant at 60 and 75 DAS but at 45 DAS was significant. Among the combined effect, RGR had higher ($0.058g^{-1}day^{-1}$) in 200 Gy γ-ray irradiated plants of BARI soybean 5 followed by the untreated plants of BARI soybean 5 ($0.054g^{-1}day^{-1}$) and 200 Gy γ-ray gamma ray irradiated plants of at BARI soybean 6 ($0.053g^{-1}day^{-1}$) at 45 DAS. In contrast, the lowest RGR ($0.039g^{-1}day^{-1}$) was recorded by 500 Gy γ-ray irradiated plants of BARI soybean 5 (Table 4). All the treatment combinations between varieties and gamma rays were statistically same at 60 and 75 DAS due to its insignificant effect (Table 4).

Seed yield

Combined effect of varieties and gamma rays on seed yield showed significant. The result of seed yield decrease with the increasing doses of gamma ray with BARI soybean 6 but BARI soybean 5 decreases up to 400 Gy γ-ray as shown in table 4. Two hundred Gy γ-ray irradiated plants of BARI soybean 5 produced the highest seed yield (2373.70kg ha^{-1}) followed by control treatment (1887.90kg ha^{-1}) at the same variety. On the other hand, the plants consequential from 500 Gy γ-ray radiated of BARI soybean 5 had shown the lowest seed yield (1050.70kg ha^{-1}). This result indicating that irradiation significantly decreased on seed yield with increasing doses of gamma rays. Yamashita *et al.* (1986) also reported that the selected mutants from gamma irradiated soybean. The mutant lines proved early maturity and dwarf stature till M_9. The grain sizes of mutants were comparable to the parent and were selected for high yield.

Table 4. Effect of varieties and different doses of gamma radiation on crop growth rate and relative growth rate at different days after sowing

Variety	Gamma ray (Gy γ-ray)	Crop growth rate (CGR)			Relative growth rate (RGR)			Seed yield (kg ha-1)
		45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS	
BARI soybean 5	Control	0.43b	0.11ab	0.16	0.054b	0.009	0.024	1887.90b
	200	0.49a	0.12ab	0.25	0.058a	0.009	0.037	2373.70a
	300	0.34c	0.16a	0.06	0.047cd	0.025	0.017	1544.90cd
	400	0.31c	0.18a	0.13	0.044e	0.028	0.015	1404.90de
	500	0.30c	0.18a	0.15	0.041	0.028	0.021	1050.70g
BARI soybean 6	Control	0.36c	0.15a	0.14	0.049c	0.022	0.019	1106.70fg
	200	0.42b	0.04b	0.15	0.053b	0.017	0.024	1725.50bc
	300	0.32c	0.06b	0.19	0.046de	0.002	0.029	1369.20de
	400	0.31c	0.05b	0.19	0.044e	0.006	0.030	1298.50ef
	500	0.29c	0.05b	0.17	0.039e	0.006	0.027	1256.50ef
LSD		**0.016**	**0.073**	**0.104**	**0.016**	**0.016**	**0.023**	**185.92**
CV (%)		**6.25**	**5.43**	**5.57**	**6.00**	**12.23**	**10.95**	**8.80**
Level of significance		**	*	NS	**	NS	NS	**

In a column, figures having similar letter (s) do not differ significantly at P < 0.05 as per DMRT

LSD = Least significant difference; CV = Coefficient of variance

** = 1% level of significance, * = 5% level of significance and NS= non significant

Conclusions

From the above results, it was observed that the variety BARI soybean 5 and 200 Gy γ-ray irradiated plants had outstanding dominance on growth and yield over other variety and gamma rays. In contrast, 500 Gy γ-ray had the adverse effect on growth in BARI soybean 6.

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