Bangladesh J. Nuclear Agric, 37(2): 43-56, 2023 *ISSN 0258-7130*

DOI: https://doi.org/10.3329/bjnag.v37i2.71779

EVALUATION OF CULTIVATED GLADIOLUS VARIETIES OF BANGLADESH AND RADIO SENSITIVITY TEST FOR VARIETAL IMPROVEMENT

N. Akhther[1]*, M.R. Islam[1] and M.K. Hassan[2]

Abstract

The study was conducted at the research field of Nalitabari Sub-station, BINA, Sherpur during the period November 2019 to May 2020 to characterize, evaluate and select promising gladiolus varieties suitable for Bangladesh and to determine the optimum dose of radiation for LD_{50} for varietal improvement. The parameters studies were plant height, days to 1st flowering**,** number of leaves per plant, leaf length, leaf breadth, length of spike, length of rachis, number of flower per spike, flower diameter, number of corms per plant, weight of single corm, vase life, per cent germination, per cent survivability, shoot length and root length. The longest plant (154.2 cm) was observed in White Prosperity, while the shortest plant (101.7 cm) was in Regency. The longest leaf (70.3 cm) was found in Red Cascade and the shortest leaf (48.0 cm) was found in Her Majesty. The highest number of floret per spike was produced by Red Cascade (17.3) followed by White Prosperity (17.0). The Regency produced the lowest number (8.0) of floret per spike. The longest vase life (9.3 days) was observed in American Beauty followed by (8.7 days) Red Cascade, while the shortest vase life (5.7 days) was recorded in Wine and Roses. In radio sensitivity test, 30-40 Gy of gamma irradiation would be the optimal dose for inducing useful mutation in gladiolus.

Key words: Gladiolus, Flower, Morphology, Gamma irradiation, Radio-sensitivity

Introduction

Gladiolus (*Gladiolus grandiflorus* L.) of Iridaceae family is one of the most important cut flowers in the world (Bai *et al.,* 2009) as well as in Bangladesh. Commercial cultivation of flowers in Bangladesh actually started during 80s, and 1991, flowers were listed as exportable products from Bangladesh (Mukul 2020). Gladiolus ranked the 1st in terms of production (9914 tons) with a market share of 31% (Hossen 2018). Today, floriculture has emerged as a lucrative profession in Bangladesh with a much higher potential for returns than most other field and horticultural crops (Sultana, 2003). Bangladesh is well suited for growing cut flowers and other ornamental plants due to favorable climatic and other conditions like cheap land, low labour cost, relatively low capital investment and high value addition (Dadlani, 2004). Now-a-days, farmers are

[1]Horticulture Division, Bangladesh Institution of Nuclear Agriculture, Mymensingh-2202, Bangladesh;
[2]Department of Horticulture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh,
*Corresponding author's email: nakhther@yahoo.com

commercially growing gladiolus in Bangladesh (Islam and Haque, 2011). To enrich the genetic resources of gladiolus, available germplasm (varieties) from home and abroad are to be collected for evaluation with a view to its further improvement. Some progressive farmers, nurserymen and private entrepreneurs, have already collected different gladiolus varieties from abroad and other sources, and growing successfully. The exotic varieties are well-known for their better spike quality and multiplication rate of corms and cornels. However, their suitability under local conditions needs to be properly tested before recommendation as variety. Diverse genetic resources are the key for varietal improvement programme. Selection of ideal variety(ies) based on morphological traits and other postharvest quality attributes from the collected germplasm (varieties) may be of immense value for further improvement of gladiolus in Bangladesh.

Mutagenesis in ornamental plants represents a powerful tool, not only to clarify physiological mechanisms in plant functioning (Honda *et al*., 2006), but also to obtain new varieties useful for the floriculture industry (Canul-Ku *et al*., 2012). Changes in phenotypic traits, such as the color, shape or size of the flower and chlorophyll variegation in leaves, can easily be detected. Mutation induction has proven to be an efficient method for generating ornamental plant varieties that meet the quality standards as demanded by the international market. Many of the objectives of genetic improvement programs consist of achieving morphological changes and inducing resistance to biotic and abiotic stresses can be achieved through mutation induction. Mutation in the biosynthetic pathway of structural or regulatory genes may also cause a change in the color of the gentian (*Gentiana triflora*) flower (Nakatsuka *et al.*, 2005). Gamma ray is one of the most important mutagenic agents within ionizing radiation because they have been shown to be highly penetrating and potent in inducing variability in plants (Deshpande *et al.*, 2010). Radio sensitivity depends on the type of radiation and the dose used, as well as on the explant's traits; type of tissue and size; degree of development; and moisture content (Datta and Teixeira-da Silva, 2006) as these traits alter the cells' response to radiation. Sensitivity also depends on the genetic constitution of the plant material, such as the number and chromosomal size, the nucleotide, the heterochromatin, centromere number and position, degree of polyploidy, nuclear DNA content and replication time at initial stages, as well as cytoplasmic, biological, chemical and environmental factors (Deshpande *et al*., 2010). Therefore, the present experiments were designed to characterize, evaluate and to select promising variety(ies) suitable for Bangladesh and to determine the optimum dose of gamma irradiation for LD_{50} in gladiolus for varietal improvement through mutation induction.

Materials and Methods

Two experiments were conducted during the period from November 2019 to May 2020 at the research field of the Nalitabari Sub-station, Bangladesh Institute of Nuclear Agriculture (BINA), Sherpur. The experimental location was in high land, and the land was prepared by power tiller followed by laddering. All weeds and other stubbles were removed

prior to planting the corms. The design of the experiment was randomized block design consisting of 8 treatments with 3 replications, with a view to find out the overall performance of different exotic popular cultivars of Gladiolus *viz*. White Prosperity, Red Cascade, Novalux, American Beauty, Regency, Her Majesty, Jester and Wine and Roses. The germplasm were collected from farmers' field of Godkhali, Jashore and Savar, Dhaka, and exotic sources. The unit plot size was 1.5 m × 2 m. Medium sized (3.5-4.5 cm) corms of different gladiolus varieties were planted at about 7-8 cm depth in the plot maintaining a spacing of 30 cm × 25 cm. Manures and fertilizers were applied at the rate of cowdung- 5 t/ha, Urea- 180 kg/ha, TSP- 70 kg/ha, MoP-140kg/ha, Boron- 2.0 kg/ha and Zinc- 4.0 kg/ha and Sulphur 30 kg/ha (FRG, BARC, 2018). All manure and chemical fertilizers except urea were applied as basal dose during final land preparation and urea was applied in three splits at top-dressed at 30, 45 and 60 days after planting. Different intercultural operations like irrigation, weeding, earthing up, stacking, pesticide and fungicide application were performed as needed. The parameters studies were plant height (cm); days to 1st flower initiation; number of leaves per plant (NLPP), leaf length (cm) and leaf breadth (cm) at 1st flowering stage; length of spike (cm), spike diameter (cm), length of rachis (cm), number of flower per spikes, flower diameter (cm), number of corms per plant, weight of single corm (g), diameter of corm (cm), number of cormels per plant, diameter of cormels (cm) and shelf life (days). The spikes were cut when lower one or two florets showed color but still in tight bud stage. The cut spikes were kept into water to study the vase life. Corms and cormels were harvested only when the leaves turned into brown colour (Mukhopadhyay, 1995). For radio sensitivity test, fifty (50) corms were irradiated with gamma rays at the doses of 0, 10, 20, 30, 40, 50, 60, 70 and 80 Gy by ^{60}Co gamma irradiator at Bangladesh Institute of Nuclear Agriculture, Mymensingh, Data were recorded on corm germination (%), corm survival (%), shoot length and root length. Data were analyzed using Analysis of Variance (ANOVA) by Statistix 10 (Version 10.0 Analytical Software USA). The means for all the treatments were calculated and analysis of variance (ANOVA) for all parameters was performed by F-test. Statistically significant differences among the different doses were identified by LSD at the 5% levels of significance as described by Gomez and Gomez (1984).

Results and Discussion

Plant height

Plant height is one of the most important characters as it contributes towards higher spike length with more number of florets and thereby enhances spike quality. Plant height among the genotypes ranged from 154.3 to 101.7 cm. The longest plant was observed in the White Prosperity (154.3 cm) while the shortest plant (101.7 cm) was observed in Regency (Table 1). The variation observed in plant height among the genotypes might be due to difference in genetically constituents as well as environmental effects. Wide variation in plant height amongst some genotypes of gladiolus was observed by Hossain *et al*. (2011)

and Swaroop (2010). Singh *et al.* (2017) recorded plant height from 80.3-134.7 cm with a mean of 112.0 cm in ten hybrids of gladiolus. In another study the longest plant (90.86 cm) also found in White Prosperity among 11 varieties examined (Solanki *et al.*, 2019).

Days to 1st spike initiation

The minimum days taken for spike initiation (69) was observed in Wine and Roses followed by Jester (70) maximum days in spike initiation (81.0) was observed in Regency (Table 1). Solanki *et al.* (2019) observed a range from 69.04 (White Prosperity) -83.73 (Candy Man) days required for 1st spike initiation of gladiolus. Variation in days to spike initiation and 1st floret opening in gladiolus seem to be genetically controlled as reported by Pragya *et al*. (2010).

Number of leaves, leaf length and leaf breadth

Significant variation was observed as to the number of leaves amongst the genotypes. The maximum number of leaves (9.0) was obtained from the White Prosperity followed by American Beauty (9.0) and the minimum number of leaves (7.7) was found from Regency (Table 1). The longest leaf (70.3 cm) was found in Red cascade and the shortest leaf (48.0 cm) was found in Regency. On the other hand, the largest leaf breadth (4.0 cm) was found American Beauty and the smaller leaf breadth (2.7 cm) was found in Wine and Roses (Table 1). This result was in agreement with the findings of Hossain *et al.* (2011), who found number of leaf ranged from 8.50-12.25. Hoque *et al.* (2019) found that number of leaf was varied significantly ranges from 11.7-8.0. Wide variation in leaf length amongst some genotypes of gladiolus was observed by Singh, and Dadlani (1990). This variation might be due to genotype as well as some known and/or unknown environmental factors. Plant produces food materials through the process of photosynthesis. With the increasing number of leaves, photosynthesis generally increases, and plant can produce more food that influences the growth and development of the plant.

Table 1. Morphological characters of eight gladiolus germplasm

Name of the germplasm	Plant height (cm)	Days of 1st flower initiation	No. of leaves per plant	Leaves length (cm)	Leaves breadth (cm)	Spike length (cm)	Spike diameter (cm)
White Prosperity	154.3a	74.0bc	9.3a	57.4bc	3.3b	103.0a	6.8b
Red cascade	140.3ab	77.0b	8.0ab	70.3a	2.9bc	98.3ab	8.0a
American Beauty	127.3bc	71.0cd	9.0ab	59.0b	4.0a	87.3bc	6.1cd
Nova lux	125.3bc	75.0b	8.7ab	58.2bc	3.0bc	99.3ab	6.5bc
Her Majesty	102.3d	77.0b	8.0ab	58.0bc	3.3ab	64.7d	5.8d
Regency	101.7d	81.0a	7.7b	48.0c	2.9bc	68.3d	6.8b
Jester	122.3b-d	70.0d	8.7ab	53.7bc	3.0bc	78.0cd	6.2cd
Wine and roses	104.3cd	69.0d	8.0ab	53.3bc	2.7c	72.3d	6.9b
CV	11.2	2.5	9.17	10.47	12.11	9.7	4.3
Level of sig.	**	**	NS	*	*	**	**
$LSD_{(.05)}$	23.9	3.2	1.4	10.5	0.67	14.3	0.50

Spike length and diameter, and rachis length

The spike length, spike diameter and rachis length, number of varied significantly among the germplasms. The longest spike (103.0 cm) was produced by White Prosperity and the shortest spike (64.7cm) was found in Her Majesty. On the other hand, the thicker spike diameter (8.0 cm) was found in Red Cascade and thinner spike diameter (5.8 cm) was found in Her Majesty (Table 1). Bhagur (1989) found that spike length ranged from 61.60 to 137.97cm in varietal evaluation of gladiolus. Hossain *et al.* (2011) recorded significant variation in spike length which ranged from 92.05-59.63 cm. The highest rachis length was observed in White Prosperity (77.5cm), and the lowest rachis length (34.0 cm) was observed in Wine and Roses (Table 2). Rachis length differed from 19.0 cm to 53.7 cm with an average of 36.4 cm (Hoque *et al.* 2018). Tirkey *et al.* (2018) recorded a variable rachis length in six gladiolus genotypes that ranged from 37.3 cm to 62.7 cm. The variation in different characters among varieties might be due to variation of genetic traits and the effect of prevailing environmental conditions (Kumar, 2015).

Number of florets per spike and floret diameter

Variable flower characters were observed in the studied accessions (Table 2). Eight genotypes had different floret colour and marking (Figure 1). Variation in average number of floret per spike amongst the genotypes ranged from 8.0 to 17.3. The highest number of floret per spike was produced by Red Cascade (17.3) followed by White Prosperity (17.0). The Regency produced the lowest number (8.0) of floret per spike. White Prosperity and American Beauty produced the largest floret (10.4 cm) and the smallest floret (7.5 cm) was produced by Wine and Roses. The number of flowers per spike varied from 5.33 to 20.00 as reported by Negi *et al*., (1982), .8.3 to 14.3 by Hossain et al. (2011); 11.2 to 15.0 by Tirkey *et al.* (2018), 7.0 to 15.7 by Hoque *et al*. (2019). Solanki *et al.* (2019) stated that maximum number of floret per spike (18.00) was found in White Prosperity followed by American Beauty (17.73) and minimum number of florets/spike (12.93) was found in Novalux.

Vase life

The vase life of flowers also differed among the cultivars, and the longest vase life (9.3 days) was observed in American Beauty followed by in Red Cascade (8.7 days) and the shortest longevity of flowers (5.7 days) was recorded in Wine and Roses (Table 2). Hoque *et al*. (2019) reported that **v**ase life in the accessions varied and ranged from 8 to 11 days. The present findings are in conformity with the findings of Swaroop (2010) and Pandey *et al*. (2012) who studied morphological traits of various gladiolus genotypes and found wide variation among the studied genotypes. The variation in different characters among varieties may be due to genetic traits and the effect of prevailing environmental conditions.

Table 2. Floral properties and vase life of collected eight gladiolus germplasm

Name of the germplasm	Floret colour	Rachis length (cm)	No. of floret per spike	Flower diameter (cm)	Vase life (days)
White Prosperity	White in colour, ruffled	77.7a	17.0a	10.4a	8.0b-d
Red cascade	Bright red with white blotches.	68.0ab	17.3a	9.8a	8.7ab
American Beauty	Reddish pink in colour with whitish throat	48.3cd	12.3bc	10.4a	9.3a
Nova lux	Yellow with deep yellow throat	60.3bc	13.3b	10.2a	8.3a-c
Her Majesty	Deep violet	43.0d	12.0b-d	8.0bc	7.3cd
Regency	Deep maroon with velvety appearance and highly ruffled	44.3cd	8.0e	8.5b	8.0b-d
Jester	Deep yellow with red throat	50.0cd	9.3c-e	7.6bc	7.0d
Wine and roses	Soft rose-pink flowers with a red wine throat and a ruffled edge	34.0d	9.0de	7.5c	5.7e
CV		18.2	14.2	6.33	9.1
Level of sig.		**	**	**	**
$LSD_{(.05)}$		17.0	1.0	1.0	1.2

Number, size and weight of corm and cormels

Different genotypes exhibited significant variation for corm characters (Tables 3, Figure 2). The number of corms produced per plant was the highest in White Prosperity (2.1) followed by American Beauty (1.9), Nova lux and Jester (1.7). The lowest number of corms (1.3) was produced by the Regency and Her Majesty. Variation in number of corm per plant amongst some genotypes of gladiolus was as 1.0-4.0 (Anuradha and Gowda, 1994) and 1.15-2.55 (Hossain *et al.*, 2011)**.** Weight of individual corm was also found to be varied significantly among the genotypes. The highest corm weight was obtained from in American Beauty (76.1g) and the lowest in Her Majesty (29.0 g). The highest diameter (6.3 cm) of large corm was observed in White Prosperity and the lowest was (4.8 cm) in Jester. Sharma and Sharma (1984) reported that corm weight was the highest in Yellow genotype (67g) and lowest in GL-25(18g) genotype which was more or less in consonance with the present investigation. Hoque *et al.* (2019) also found that the corm size different among the varied from 6.6 to 3.6 cm. The number of cormel per plant differed significantly affected by genotypes (Table 3). The highest number of cormels per plant was obtained from the White Prosperity (34.0) followed by Nova Lux (30.0), and the Jester (13.3) produced the lowest number of cormels per plant.

Fig. 1. Variation in colour and forms of spikes of the collected eight gladiolus varieties.

Table 3. Properties of corms and cormels of eight gladiolus varieties

Name of the germplasm	No. of corm per plant	Size of single corm (cm)	Wt. of single corm (gm)	No. of cormels per plant	Size of cormels (cm)
White Prosperity	2.1	6.3a	61.6ab	34.0a	1.4ab
Red cascade	1.4	5.6ab	63.7ab	29.7ab	1.1ab
American Beauty	1.9	6.2a	76.1a	22.5a-c	1.6ab
Nova lux	1.7	6.0a	58.7ab	30.0a-b	1.2ab
Her Majesty	1.3	5.1bc	29.0c	19.7b-c	0.9b
Regency	1.3	4.9bc	42.7bc	19.3b-c	2.4a
Jester	1.7	4.8c	40.0bc	13.3c	1.3ab
Wine and Roses	1.6	5.9a	63.0ab	21.0bc	1.1ab
CV	-	7.98	28.4	31.1	59.5
Level of sign.	NS	**	*	NS	NS
$LSD_{(.05)}$	-	0.8	27.1	12.9	1.4

Radio sensitivity test

The maximum corm germination (98%) was found control (non irradiated) corms in Wine and Roses (Table 4). On the other hand, 10 Gy irradiated corms in American Beauty had maximum germination (95%), followed by 20 Gy irradiated corms White Prosperity (94%). The minimum corm germination (1%) was found in 80 Gy irradiated corms. Non irradiated control plants showed maximum survivability (95%) in Wine and Rose (Table 5). In case of irradiation, 10 Gy irradiated White Prosperity and American Beauty and 20 Gy irradiated Red Cascade showed 90% survivability. No plant was found to survive in the 80 Gy irradiated corms (Table 5). Among the doses of irradiation, 80 Gy showed lethal. The decrease in seed germination induced by mutagenic treatments may be the result of damage of cell constituents at molecular level or altered enzyme activity (Khan and Goyal, 2009). Seed germination with abnormalities in mitotic cycles and in metabolic pathways of the cells have correlated reported by Micco *et al*. (2011). The reduction in germination and survival may be due to absorption of ionizing radiation in biological materials, acting directly on critical targets in the cell (Kovacs and Keresztes, 2002). Bashir *et al*. (2013) also reported that the seed germination percentage and percent survival decreased with an increase in dose of the gamma irradiation. The present findings are in agreement with the above mentioned reports. Similar findings were also reported where in, higher doses of gamma radiation reduced germination percentage and survival in fennel (Verma *et al*., 2017).

In case of shoot and root growth highly differences were observed among the lower and higher doses of irradiation. The longest shoot length (34 cm) was found 10 and 30 Gy

irradiated Nova Lux and shortest shoot length (10 cm) was found 70 Gy irradiated in Jester. In respect of root growth, longest root (16 cm) was found in 10 and 20 Gy irradiated in Nova Lux and White Prosperity and the minimum root length (3 cm) in 70 Gy irradiated in Regency (Table 6, Figure 2). Growth inhibition demonstrated in the case of high radiation dose could be due to cell cycle arrest at G2/M phase during somatic cell division and/or various damages in the entire genome (Preussa and Britta, 2003). The results of the experiment indicated that high dose of gamma radiation reduced germination percentage, seedling survival, shoot length and root length. It was found that more than 30 Gy of gamma irradiation to cause near about 50% reduction in root length and shoot length (Tables 6 and 7). It is expected that 30 Gy of gamma ray would be the optimal dose for inducing useful mutation gladiolus which will help to develop desirable mutants.

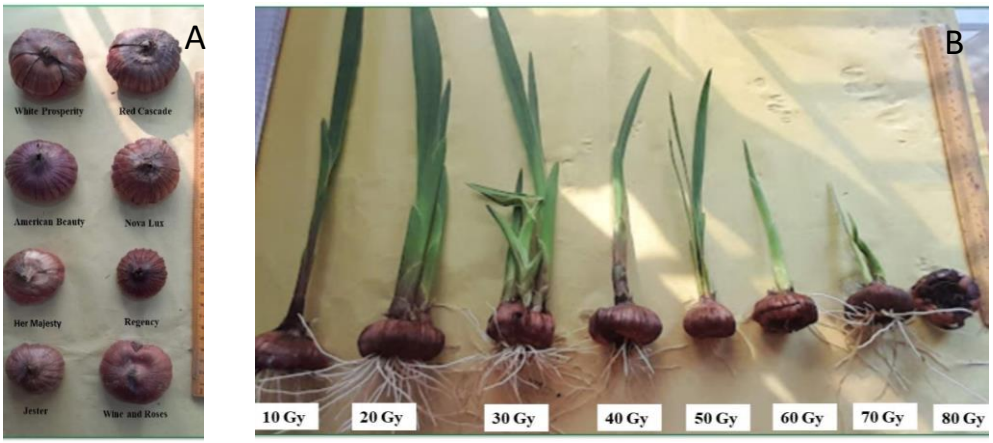

Fig. 2. Corms of eight gladiolus varieties (A), and radio-sensitivity test of the selected gladiolus of variety, namely American Beauty (B).

Table 4. Effect of acute exposure of different doses of gamma rays on germination of gladiolus corms

Dose (Gy)	% Germination							
	White Pros-perity	Red cascade	American Beauty	Nova Lux	Her Majesty	Regency	Jester	Wine and Roses
10	93	93	95	90	89	89	93	93
20	94	92	94	90	90	90	92	93
30	91	90	92	90	87	87	90	90
40	84	82	82	80	80	80	82	82
50	76	74	75	75	70	69	74	74
60	41	40	40	35	25	20	40	45
70	15	20	20	14	10	11	18	22
80	02	01	04	02	00	00	01	03
0	96	95	96	94	92	93	95	98

Table 5**.** Effect of acute exposure of different doses of gamma rays on survivability of gladiolus corms

Dose (Gy)	% Survivability							
	White Pros-perity	Red Cascade	American Beauty	Nova Lux	Her Majesty	Regency	Jester	Wine and Roses
10	90	88	90	88	84	85	87	90
20	89	90	88	90	88	86	89	90
30	86	85	88	86	84	82	80	82
40	80	74	75	75	72	70	72	75
50	68	62	70	60	50	48	50	65
60	35	34	32	33	25	26	25	32
70	12	12	15	10	05	04	08	14
80	00	00	00	00	00	00	00	00
0	93	92	92	90	88	87	90	95

Table 6. Effect of acute exposure of different doses of gamma rays on shoot length of gladiolus seedlings

Dose (Gy)	Shoot length (cm) at 20 Days after planting								
	White Pros-perity	Red Cascade	American Beauty	Nova Lux	Her Majesty	Regency	Jester	Wine and Roses	White Pros-perity
10	39	39	37	40	35	36	37	38	14
20	38	36	36	38	36	33	32	38	16
30	38	39	36	40	34	35	36	36	15
40	27	26	25	26	20	21	23	25	08
50	24	23	23	22	20	20	21	24	06
60	16	14	16	14	15	14	13	12	05
70	15	12	14	12	12	13	10	13	05
80	00	00	00	00	00	00	00	00	00
0	40	37	37	41	35	35	35	35	14

Table 7. Effect of acute exposure of different doses of gamma rays on shoot and root length of gladiolus seedlings

Dose (Gy)	Root length (cm) at 20 Days after planting							
	White Prosperity	Red Cascade	American Beauty	Nova Lux	Her Majesty	Regency	Jester	Wine and Roses
10	14	12	13	16	12	13	13	14
20	16	11	16	14	12	12	14	15
30	15	14	14	15	13	14	12	14
40	08	09	07	08	09	09	08	10
50	06	06	07	06	05	05	06	08
60	05	04	05	06	05	04	06	05
70	05	04	07	04	04	03	04	06
80	00	00	00	00	00	00	00	00
0 (Control)	14	15	14	1	13	14	15	16

Conclusion

The study was undertaken to evaluate and select promising gladiolus lines and to determine the optimum dose of gamma irradiation for effective mutation. Considering overall performance, especially number of florets per spike and spike length, the American Beauty was the best followed by White Prosperity and Red Cascade. American Beauty was also the best in terms of longer vase life and attractive colour. Irradiation doses of 30-40 Gy were found to effectively induce mutation since the values for most the parameters were reduced by approximately 50% or more at the following doses from 40- 80 Gy.

References

Anuradha, S. and Gowdha, J.V. 1994. Correlation studies in Gladiolus. [In: Floriculture-Technology, Trades and Trends. (Eds.) Prakash, J. and K. R. Bhandry.] Oxford and IBH Publishing Co. Pvt. Ltd. Calcutta. pp.285-287.

Bai, J. G. Xu, P. L. Zong, C. S. and Wang, C. Y. 2009. Effects of exogenous calcium on some postharvest characteristics of cut gladiolus. Agric. Sci. China, 8, 293-303.

(https ://doi.org/10.1016/S1671-2927(08)60212-6)

Bashir, S., Wani, A.A. and Nawchoo, I.A. 2013. Mutagenic sensitivity of gamma rays, EMS and sodium azide in Trigonella foenum-graecum L. Sci. Res. Reporter 3(1): 20-26.

Canul-Ku, J., García-Pérez, F., Campos-Bravo, E., Barrios- Gómez, E. J., de la Cruz-Torres, E., García-Andrade, J. M., Osuna-Canizalez, F. J., and Ramírez-Rojas, S. 2012. Efecto de la irradiación sobre nochebuena silvestre (*Euphorbia pulcherrima* Willd. ex Klotzsch) en Morelos. *Revista Mexicana de Ciencias Agrícolas*, *3*(8):1495-1507.

Chopra, V. L. 2005. Mutagenesis: Investigating the process and processing the outcome for crop improvement. Current Science 89(2), 353-359. (Retrieved from http:// www.jstor.org/stable/24110583)

Dadlani, N. K. 2004. Prospects of floriculture in Bangladesh. A Consultancy Report. FAO/ UNDP (IHNDP/BGD/97/04).

Deshpande, K. N., Mehetre, S. S., and Pingle, S. D. 2010. Effect of different mutagens for induction of mutations in mulberry. Asian J. of Experimental Biological Sci. 1(2): 104-108. Retrieved from https://www.ajebs.com/ special/SP-21.pdf

Fertilizer Recommendation Guide-2018. Bangladesh Agricultural Research Council. Farmgate, Dhaka.p.143

Food and Agriculture Organization of the United Nations/International Atomic Energy Agency (FAO/IAEA). 2017. (https://mvd.iaea. org)

Gomez K.A. and Gomez A. A. 1984. Statistical procedures for Agricultural Research. John Wiley and Sons, New York.

Hernández-Muñoz1, S.; Pedraza-Santos, M. E.; Pedro Antonio López, P. A. and Gómez-Sanabria, J. M. and Morales-García1, J. L . 2019 Mutagenesis in the improvement of ornamental plants. Revista Chapingo Serie Horticultura. 25(3):151-167

Honda, I., Kikuchi, K., Matsuo, S., Fukuda, M., Saito, H., Ryuto, H., Fukunishi, N., and Abe, T. (2006). Heavy-ion-induced mutants in sweet pepper isolated by M1 plant selection. Euphytica. 52(1): 61-66 (doi: 10.1007/s10681- 006-9177-5).

Hoque, M. A. and Mahmud, S. 2019. Morphological characterization and evaluation of nineteen gladiolus germplasm. Ann. Bangladesh Agric. 23(2): 37-48

Hossen, M. 2018. Flower Industry of Bangladesh: Problems and Prospects. (www.ais.gov.bd/krishi_kotha_ detailes/1424/Falgun)

Islam, M. S. and Haque, A. F. M. E. 2011. Performance of gladiolus under protected cultivation in the rainy season. Bangladesh J. Agril. Res. 36(2): 285-290.

Khan, S. and Goyal, S. 2009. Improvement of mungbean varieties through induced mutations. African J. Plant Sci. 3: 174-180.

Kovacs, E. and Keresztes, A. 2002. Effect of gamma and UV-B/C radiation on plant cells. Micron 33: 199- 210.

Krishna, H. and Ahmed, N. 2010. Performance of gladiolus genotypes for cut flower and corm production under high altitude of Uttarakhand. Indian J. Hort. 67: 389-90.

Kumar, M. 2015. Morphological characterization of gladiolus (*Gladiolus hybridus* Hort.) germplasm. J. Plant Dev. Sci. 7(4) : 359-362.

Mac, K. J. 1954. Mutation breeding in polyploid cereals. Acta Agriculturae Scandinavica, 4(1), 549-557 (doi: 10.1080/00015125409439961).

Mba, C., Afza, R., Lagoda, P. J., and Darwig, J. 2005. Strategies of the joint FAO/IAEA programme for the use of induced mutations for achieving sustainable crop

production in member states. (In: Proceedings of the Second International Seminar on Production, Commercialisation and Industrialization of Plantain pp. 289-291).

Micco, V.D., Arena, C., D and, P. and Durante, M. 2011. Effects of sparsely and densely ionizing radiation on plants. Radiation and Environmental Biophysics 50: 1-19.

Mukhopadhyay, A.1995. Gladiolus. Publications and Information division, ICAR New Delhi.p.35

Mukul S. A, 2020. Commercial cultivation of flowers is a new economic prospect. (http//www.sonalinews.com/opinion/news)

Nakatsuka, T., Nishihara, M., Mishiba, K., and Yamamura, S. 2005. Two different mutations are involved in the formation of white-flowered gentian plants. Plant Sci. 169(5): 949-958 (doi: 10.1016/j. plantsci.2005.06.013)

Negi, S.S., Raghava, S.P.S. and Sharma, T.V.R.S. 1982. New cultivars of Gladiolus. *Indian* Hort. 26(4): 19-20.

Pandey, R.K., Bhat, D.J.I., Dogra, S., Singh, A., Laishram, N. and Jamwal, S. 2012. Evaluation of gladiolus cultivars under subtropical conditions of Jammu. Int. J. Agric. Sci. 8: 518-22.

Preussa, S.B. and Britta, A.B. 2003. DNA-damage induced cell cycles check point in Arabidopsis. Genetics 164: 323-334.

Sharma, A.N. and Sharma, S.C. 1984. Some promising gladiolus hybrids. NAGC Bull., No. 157. pp.51-52.

Singh, and Dadlani. 1990. Research Highlights (1971-1985). All Indian Coordinated Floriculture Improvement Project, ICAR, New Delhi.

Singh, N. Tamta, S., Pal, A. K., Rana, T. S., Roy, R. K. and Tewari. S. K. 2017. Characterization of gladiolus germplasm using morphological, physiological and molecular markers. Biochem. Genet. Springer Sci. [https://doi.org/10.1007/s 10528017-9835-4].

Solanki, N. S., Kumar, M. and Singh, D. 2019. Studies on morphological characters of gladiolus. Cultivars under Allahabad agro climatic Condition (Special Issue- 5). International Conference on "Food Security through Agriculture & Allied Sciences" J. of Pharmacognosy and Phytochemistry 2019; SP5: 115-119.

Sultana, N. 2003. Floriculture exports from Bangladesh. A paper presented in International Floriculture Conference on 6th November, 2003, BARC, Farmgate, Dhaka

Swaroop, K. 2010. Morphological variation and evaluation of gladiolus germplasm. Indian J. Agric. Sci. 80: 742-45.

Tirkey, T., S. Tamrakar, G. Sharma and Sahu, M. 2018. Effect of planting dates and cultivars on floral characters of gladiolus under Chhattisgarh Plains. Int. J. Curr. Microbiol. App. Sci. 7(06): 1964-1976 [doi: https://doi.org/10.20546/ ijcmas.2018.706.233].

Verma, A.K., Sharma, S., Kakani, R.K., Meena, R.D. and Choudhary, S. 2017. Gamma radiation effects seed germination, plant growth and yield attributing characters of fennel (*Foeniculum vulgare* Mill.). International J. of Current Microbiology and Applied 6: 2448-2458.