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Effect of Gamma Radiation on the Growth, Yield and Quality of Four Onion Accessions

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Abstract: *An experiment was conducted at the Horticulture farm of Hajee Mohammad Danesh Science and Technology University and the Laboratory of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from November, 2017 to May, 2018 to study the effects of gamma radiation on the growth, yield and quality of four onion accessions. The experiment was consisted of two factors such as (i) different accessions viz., accession-1, accession-2, accession-3, accession-4 and (ii) four gamma radiation levels (0 Gy, 50 Gy, 75 Gy and 100 Gy). Seeds from all accessions were irradiated separately with 50 Gy, 75Gy, 100 Gy and also a control at BINA from ^{60}Co gamma radiation sources. The experiment was laid out in RCBD with three replications. The seeds of 16 treatment combinations of the accessions and radiation levels were sown in seed bed on 15th November, 2017 and 45 days old seedlings were transplanted in the main field on 30th December, 2018. Some biochemical compositions were also tested after harvest on 26th March, 2018. Different accessions showed significantly influenced on almost all the mentioned parameters studied concerned with growth, yield contributing characteristics, yield as well as biochemical characteristics. The accession-3 produced the highest germination (67.25%) and bulb yield (16.57 t/ha) with increased plant height (49.00 cm), number of leaves per plant (7.08), fresh weight of leaves, individual bulb weight, diameter of bulb, length of bulb, chlorophyll (7.23 µmol/m^2) content of leaf, TSS (14.83%), calcium (0.16%), phosphorus (0.37%), protein (12.60%), and vitamin C (9.18 mg/100g) content of bulb compare to other accessions. Radiation levels also had significant influence on all the parameter studied. The application of the 75 Gy gamma radiation produced highest germination (79.33%), plant height, number of leaves per plant, bulb diameter, individual bulb weight, length of bulb, chlorophyll content (7.45 µmol/m^2) of leaf, TSS (15.92%), calcium (0.16%), phosphorus (0.40%), vitamin C (9.22 mg/100g), protein (11.20%) and bulb yield (17.47 t/ha) as compared to control. The combined effect of accessions and gamma radiations was statistically significant on the yield, yield contributing characters as well as quality of onion. The highest germination (82.33%) as well as plant height, no. of leaves per plant , individual bulb weight, diameter of bulb, length of bulb, bulb yield (18.59 t/ha), chlorophyll content in leaf, calcium, phosphorus, TSS, vitamin C and protein content in bulb were recorded from accession-3 radiated with 75 Gy. Similarly the lowest bulb yield (14.45 t/ha) as well as in respect of almost all the mentioned parameters were found at accession-1 with control treatment. Therefore, the overall results indicate that accession-3 with 75 Gy might be an efficient and eligible practice for onion production.*
Key word: *Gamma radiation, growth, onion accession, quality and yield*

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I. Introduction

Onion (*Allium cepa* L.) is one of the most important spice crops in Bangladesh as well as in the world. On the other hand onion is the queen of the kitchen (Selvaraj, 1976). It belongs to the family Alliaceae. Among the spice and condiment crops grown in Bangladesh, onion ranked first in both production with 1867 thousand MT (BBS, 2017) and area with 177.42 thousand ha (BBS, 2016). The country was 9th largest onion producer countries in the world (FAOSTAT, 2016). It covers 36% of the total areas under herbaceous bulb and spices. The average yield of onion in Bangladesh is low (10.78 t/ha) as compared to India (17.84 t/ha) and the world average yield (20.72 t/ha) (FAOSTAT, 2016). So, there is huge gap between requirement and production. Due to increase of the population, it is not possible to meet the domestic demand even though the production of onion is increasing over the period of the time in Bangladesh. A large volume of onion enters into the country through smuggling from neighboring country. Moreover, to meet the shortage, Bangladesh has to import a large amount of onion from India and other countries every year at the cost of its hard earned foreign currency (Hossain and Islam, 1994). In Bangladesh, the demand for onion is increasing gradually with the increasing of population. It is difficult to increase the area of the crop due to land constraint. One of the ways to overcome the problem is to increase yield per unit area. Use of high yielding variety is the most important consideration of any crop. But very little attention has so far been given to the improvement of this crop either through selection, hybridization, introduction or induced mutation using gamma rays of suitable variety in the country. Introduction of new high yielding variety by research and development may help to overcome this shortage. In plant improvement the irradiation of seeds may cause genetic variability that enable the plant breeders to select new genotypes with improved characteristics such as salinity tolerance, disease resistance, high yielding and good quality varieties (Abu *et al.,* 2005). Gamma rays are emitted from the nucleus. It has been frequently used to create variation in chromosome of gene of crop plants on their cytological characteristics which vary from species to species and among different genotypes within the same species. The onion bulb and seeds were influenced by different doses of gamma irradiation. Considering the importance of the crop, relatively very little information is available on the chemical constituents of different varieties of onions. The nutritive value, pungency and the quality of lachrymatory factors on onion bulb vary in different genotypes. It is necessary to keep the factors in view in any shades of the chemical constituents of onion varieties. The present communication describes constituents such as carbohydrates, mineral matters, lachrymatory factors and proteins in some important varieties of onion represent pure genetic lines. In the above context, the study entitled, “Effect of gamma radiation on the growth yield and quality of four Onion Accessions” was undertaken with the following objectives-i) to investigate the effects of gamma radiation on the growth and yield of 4 onion accessions; ii) to evaluate the effects of gamma radiation on the quality of four onion accessions and iii) to find out the appropriate combination dose(s) of radiation and suitable accession(s) for maximizing the production of onion.

II. Materials And Methods

The present study was conducted at the farm of Hajee Mohammad Danesh Science and Technology University, Dinajpur and laboratory of Horticulture Division at the Bangladesh Institute of Nuclear Agriculture during the period from November 2017 to May 2018 to study the effects of gamma radiation on the growth, yield and quality of four onion accessions. The experiment was consisted of two factors such as (i) different accessions viz., accession-1, accession-2, accession-3, accession-4 and (ii) four gamma radiation levels (0 Gy, 50 Gy, 75 Gy and 100 Gy).The experiment was laid out in RCBD with three replications. Seeds from all accessions were irradiated separately with 50 Gy, 75Gy, 100 Gy and also a control at BINA from ^{60}Co gamma radiation sources. The seeds of 16 treatment combinations of the accessions and radiation levels were sown in seed bed on 15th November, 2017 and 45 days old seedlings were transplanted in the main field on 30th December, 2017. Some biochemical compositions were also tested after harvest on 26th March, 2018. Accession-1(BARI onion-1) and Accession-2(BARI onion-4) were collected from Spices Research Centre (SRC), Bogura, Bangladesh and Accession-3 (Advance line 10) as well as Accession-4(Advance line 2) `was collected from Horticulture Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. In total 48 (3x16) unit plots were made. The treatment combinations were randomly placed to unit plots in each block. The size of each unit plot was 1.0 m x 1.0 m. The space kept between blocks and plots were 60 cm and 50 cm respectively. Well decomposed cow dung 1000 g/plot, Urea 26g/plot, Triple supper phosphate (TSP) 20g/plot and Muriate of potash (MP) 16g/plot were applied as per recommendation by Kabir, 2008. The entire amount of cow dung, TSP, half of urea and half of MP were applied at the time of general land preparation. The rest of urea and MP were used as side dress with 30 and 50 days after transplanting. Intercultural operations were done as and when necessary. Data were recorded on germination (%), seedling height (cm), number of leaves per seedling, plant height (cm), number of leaves, length of longest leaf (cm), breadth of longest leaf (cm), chlorophyll content (μmol/m^2), fresh weight of leaves (g), dry weight of leaves (g), fresh weight of roots (g), dry weight of roots (g), individual fresh weight of bulb (g), dry weight of bulb (g), length of bulb (cm), diameter of bulb (cm), yield of onion bulb per plot, yield of onion bulb per hectare, total Soluble Solid content, vitamin C (Ascorbic Acid) content in bulb, nitrogen content (%), calcium content and phosphorus content. The collected data on various parameters under study were statistically analyzed using MSTAT computer package program. The means for all the treatments were calculated and analysis of variance for all the characters was performed by F-variance test. The significance of the difference between means was expressed in least significant difference (LSD) taking the probability level (Gomez and Gomez, 1984).

III. Results And Discussions

The present investigation had marked influence on seedling and plants growth characteristics, yield and yield contributing characteristics of bulb and biochemical characteristics of bulb during growth period, final harvest as well as after harvesting. Results of the analyses of variance in respect of all parameters obtained from the present investigation have been presented and discussed in this chapter under heading and subheading.

1. Growth characteristics of onion seedling

Main effect of accessions on germination (%), seedlings height and no. of seedlings leaf on the growth characteristics of onion seedlings

The effect of accessions on the % seed germination, seedlings height and no. of seedlings leaf were highly significant. The highest number of germination (67.25%) (Fig.1), the tallest (28.42 cm) seedling and the maximum number of leaves per seedling (3.43) were found in accession-3 (Table.1). The lowest number of germination (61.06%) (Fig.1) and minimum number (3.26) of seedlings leaves per seedlings were obtained in accession-1 at 15 days after germination (Table.1).

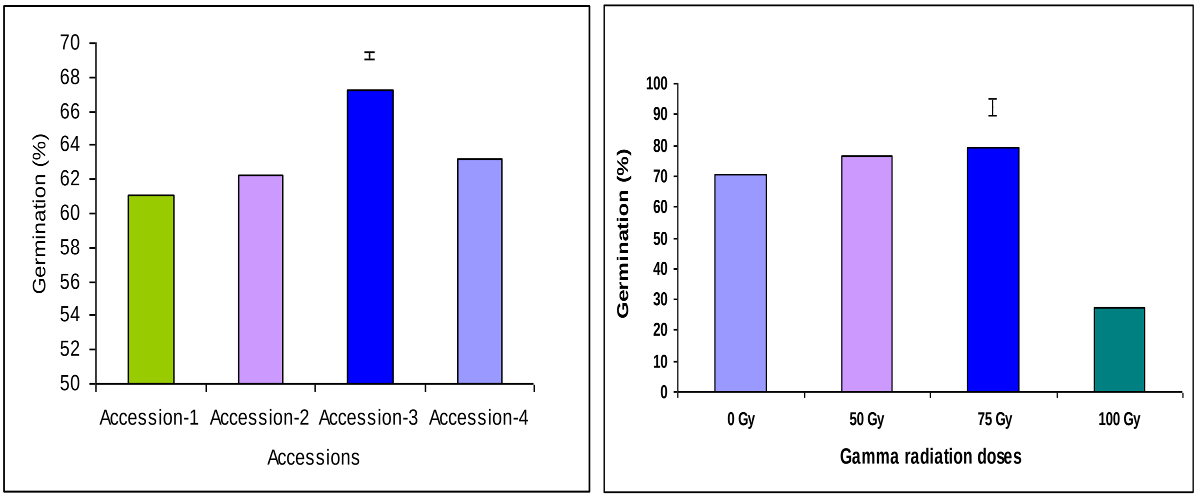


Fig. 1. Main effect of accessions (left) and radiation doses (right) on germination of seeds. Vertical bar represents LSD at 1% level of significance.

Table.1. Main effect of accessions on seedling, chlorophyll content, fresh and dry weight of leaves, roots and bulbs, length, diameter and yield of bulb at final harvest on onion

Accessions	Seedling (after 35 days)		Chloro-phyll content of leaves (µmol/m^2)	Fresh wt. of leaves (g)	Dry wt. of leaves (g)	Fresh wt. of roots (g)	Dry wt. of roots (g)	Indivi-dual fresh wt. of Bulb (g)	Dry wt. of bulb (g)	Length of bulb (cm)	Diameter of bulb (cm)	Yield / plot (kg)
	Height (cm)	No. of leaves										
A_1	26.61	3.26	6.48	4.64	0.78	0.41	0.10	28.38	3.02	3.43	3.92	1.49
A_2	26.27	3.30	6.50	4.91	0.86	0.41	0.10	28.90	3.09	3.50	4.04	1.49
A_3	28.42	3.43	7.24	6.18	0.93	0.68	0.17	31.71	3.43	3.79	4.40	1.65
A_4	27.62	3.32	6.91	5.15	0.91	0.50	0.11	29.33	3.23	3.52	4.18	1.53
LSD at 5%	0.53	0.07	0.30	0.43	0.04	0.03	0.01	0.10	0.15	0.09	0.13	0.06
LSD at 1%	0.71	0.09	0.41	0.58	0.05	0.04	0.02	1.34	0.20	0.12	0.18	0.09
Level of sig.	**	**	**	**	**	**	**	**	**	**	**	**
CV(%)	2.34	2.54	5.35	9.90	4.59	7.08	10.52	4.05	5.57	3.10	3.82	4.86

** significant at 1% level

A_1=Accession-1 A_2=Accession-2 A_3=Accession-3 A_4= Accession-4

This may be due to the genetical behaviour of the individual accession. The smallest (26.27 cm) seedling was found in accession-2 (Table.1). Variation of seedling height may depend on the consisting genetic makeup or characteristics and cell division of the accessions which influence the growth of the seedlings (Dwivedi *et al.*, 2012).

Main effect of different levels of gamma radiation on germination (%), seedlings height and no. of seedlings leaf on the growth characteristics of onion seedlings

The effect of **different irradiation levels** on % seed germination, seedlings height and no. of seedlings leaf were highly significant (Fig.1 and Table.2). The highest % germination of seed (79.33%), tallest seedling (29.74 cm) and maximum numbers of leaves per seedling (3.65) were obtained from 75Gy radiation level. The lowest percent of germination (27.25%) (Fig.1), the smallest seedling (25.05 cm) and minimum number of leaves per plant (3.03) were recorded from 100 Gy radiation level (Table.2). The germination was decreased with increasing of doses. The inhibition of seed germination at high doses could be due to the damage in seed tissue, chromosomes and subsequent mitotic retardation and the severity of the damage depend on the doses used. Hormenesis, the stimulation of different biological processes which increased growth of leaves that accurse when seeds are subjected to pre-irradiation with low doses of a radiation source (Thapa, 1999). Low levels of irradiation may damage only part of the generative nucleus while maintaining its capacity to fertilize the egg cell and lead to hybridization where as higher irradiation dose caused chromatin fragmentation, lack of metaphase orientation and failure of the generative nucleus to divide (Lecuyer, 1991). This might be the main cause of variation.

Table.2. Main effect of different levels of gamma radiation on seedling, chlorophyll content, fresh and dry weight of leaves, roots and bulbs, length, diameter and yield of bulb at final harvest

Accessions	Seedling (after 35 days)		Chloro-phyll content of leaves (μmol/m^2)	Fresh wt. of leaves (g)	Dry wt. of leaves (g)	Fresh wt. of roots (g)	Dry wt. of roots (g)	Indivi-dual fresh wt. of Bulb (g)	Dry wt. of bulb (g)	Length of bulb (cm)	Diam-eter of bulb (cm)	Yield/ plot (kg)
	Height (cm)	No. of leaves										
A_1	26.61	3.26	6.48	4.64	0.78	0.41	0.10	28.38	3.02	3.43	3.92	1.49
A_2	26.27	3.30	6.50	4.91	0.86	0.41	0.10	28.90	3.09	3.50	4.04	1.49
A_3	28.42	3.43	7.24	6.18	0.93	0.68	0.17	31.71	3.43	3.79	4.40	1.65
A_4	27.62	3.32	6.91	5.15	0.91	0.50	0.11	29.33	3.23	3.52	4.18	1.53
LSD at 5%	0.53	0.07	0.30	0.43	0.04	0.03	0.01	0.10	0.15	0.09	0.13	0.06
LSD at 1%	0.71	0.09	0.41	0.58	0.05	0.04	0.02	1.34	0.20	0.12	0.18	0.09
Level of sig.	**	**	**	**	**	**	**	**	**	**	**	**
CV(%)	2.34	2.54	5.35	9.90	4.59	7.08	10.52	4.05	5.57	3.10	3.82	4.86

** Significant at 1% level

A_1=Accession-1, A_2=Accession-2, A_3=Accession-3, A_4= Accession-4

Combined effect of onion accessions and levels of gamma radiation on germination (%), seedlings height and no. of seedlings leaf on the growth characteristics of onion seedlings

The combined effect of onion accessions and levels of gamma radiation on % seed germination (Table. 3), seedlings height and no. of seedlings leaf were significantly influenced. It was observed that the highest % germination (82.33%), seedling height and number of leaves per seedling (3.90) were found in accession-3 with 75 Gy radiation dose. The lowest % germination (25.67%) was obtained from accession-1 with 100 Gy (Table. 3). The smallest (24.54 cm) seedling and the lowest (2.97) number of leaves per seedling were obtained from accession-2 with 100 Gy and accession-4 with 100 Gy radiation dose, respectfully. According to Melki and Marouani (2010), a high dose of gamma irradiations (100, 200, 300, and 400 Gy) decreases the germination process in seeds. In depth, the growth inhibition induced by high-dose irradiation has been attributed to the cell cycle in cell division and (or) varying damage to the entire genome (Preussa and Britta, 2003) generating free radicals in plant that may bring metabolic disorders in the seeds leading to growth retardation (Kumar *et al,* 2013). A similar result also marked by Kebish *et al.* (2015) on garlic.

Table-3. Combined effect of onion accessions and radiation levels on plant growth, yield and yield contributing characteristics

Treatment combi-nation	Germ inatio n (%)	Plant height (cm) at different DAT						No. of leaves per plant at different DAT						Chloro -phyll content (µmol/ m²)	Indivi -dual Fresh wt. of Bulb (g)	Dry wt. of Bulb (g)	Leng -th of bulb (cm)	Diam -eter of bulb (cm)	Yield (t/ha)
		15	30	45	60	75	Final	15	30	45	60	75	Final						
A_1D_0	68.23	10.60	26.97	29.00	33.73	43.76	39.25	2.24	4.10	4.77	6.70	5.52	4.97	6.07	26.24	2.67	3.07	3.57	14.00
A_1D_1	74.21	13.20	28.36	33.37	36.97	45.32	41.17	2.40	4.30	4.85	6.00	5.63	5.13	6.29	27.56	2.90	3.21	3.75	14.39
A_1D_2	76.13	15.60	30.05	38.20	43.13	48.77	45.92	2.88	4.87	5.67	6.40	6.73	5.93	7.18	31.67	3.41	4.14	4.47	16.58
A_1D_3	25.67	11.02	29.41	33.83	37.97	45.33	41.70	2.43	4.33	5.05	5.10	5.73	5.38	6.36	28.06	3.11	3.33	3.91	14.71
A_2D_0	64.89	12.01	25.89	34.00	38.13	43.82	40.48	2.57	4.40	4.90	5.60	6.00	5.13	6.10	27.56	2.78	3.08	3.67	14.42
A_2D_1	77.21	14.63	28.38	34.80	39.00	46.59	42.94	2.70	4.55	5.03	5.80	6.20	5.35	6.34	27.99	2.90	3.16	3.87	14.61
A_2D_2	79.59	15.24	33.27	40.50	45.00	49.94	46.09	2.80	4.75	5.80	6.20	6.75	6.10	7.23	31.90	3.59	4.10	4.66	16.65
A_2D_3	27.30	12.27	27.23	32.40	39.90	43.84	40.00	2.40	4.27	5.10	5.20	6.36	5.52	6.35	28.15	3.09	3.25	3.95	15.03
A_3D_0	77.47	13.21	24.07	39.60	43.93	47.41	45.24	2.68	4.53	5.67	6.60	6.70	5.78	7.33	29.56	3.20	3.57	4.07	15.50
A_3D_1	79.50	15.47	25.97	41.47	43.81	49.84	46.07	2.92	4.58	5.87	6.78	6.84	5.96	7.50	30.58	3.45	3.68	4.25	15.94
A_3D_2	82.33	17.40	31.00	44.42	47.80	51.96	47.52	3.20	5.20	6.38	7.10	7.80	6.87	7.98	35.56	3.85	4.50	4.92	18.59
A_3D_3	29.70	13.33	26.83	40.83	44.33	47.26	45.37	2.63	4.45	5.77	5.80	6.97	6.03	6.14	31.16	3.24	3.81	4.36	16.25
A_4D_0	71.47	12.31	27.03	32.43	39.13	44.75	41.21	2.46	4.30	5.00	5.90	6.04	5.35	6.39	26.56	2.77	3.32	3.90	13.86
A_4D_1	75.67	13.84	29.00	36.63	40.27	47.94	44.01	2.60	4.23	5.10	5.70	6.10	5.42	6.49	27.73	3.01	3.43	4.05	14.51
A_4D_2	79.27	15.33	31.20	40.70	44.93	51.49	49.99	2.75	4.86	5.60	6.30	6.91	6.19	7.44	34.56	3.78	3.84	4.62	18.08
A_4D_3	26.33	13.07	26.20	32.93	40.30	42.31	40.50	2.26	3.97	5.38	4.70	6.29	5.48	7.33	28.49	3.36	3.50	4.14	14.81
LSD at 5%	9.26	1.61	2.51	1.95	2.17	2.39	2.79	0.20	0.45	0.33	0.29	0.22	0.37	0.60	3.54	0.33	0.18	0.26	1.11
LSD at 1%	12.48	2.17	3.40	2.63	2.92	3.21	3.76	0.26	0.60	0.45	0.39	0.30	0.50	0.81	2.69	0.41	0.24	0.35	1.50
Level of sig.	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	8.76	7.08	5.26	3.20	3.16	3.05	3.84	4.57	5.99	3.71	3.01	2.11	3.97	5.35	4.05	5.57	3.10	3.82	14.00

** Significant at 1% level

A_1=Accession-1 A_2=Accession-2 A_3=Accession-3 A_4= Accession-4

D_0= Control D_1= 50 Gy D_2= 75 Gy D_3= 100 Gy

2. Growth characteristics of onion plants

Main effect of accessions on plant height (cm), number of leaves per plant, length and breadth of longest leaf (cm), Chlorophyll content of leaves (µmol/m²), fresh wt. of leaves per plant (g), fresh wt. of roots per plant (g), dry weight of leaves and roots per plant (g) on the growth characteristics of onion plants

Data on Plant height (Fig.2), number of leaves per plant (Fig.2), length and breadth of longest leaf were recorded periodically at 15, 30, 45 60, 75 DAT and at final harvest. The results showed significant variation with the increasing trend gradually with the advancement of time up to 75 DAT from 15 DAT and gradually declined due to senescence. The tallest plant (49.00 cm), maximum number of leaves (7. 08) per plant, length (42.21 cm) and breadth (0.98 cm) of longest leaf, chlorophyll (7.24µmol/m²), fresh weight of leaves (6.18 g) per plant, fresh weight of roots (0.68 g) per plant, dry weight of leaves (0.93 g) per plant and dry weight of roots (0.17 g) per plant all were obtained from accession-3 (Table.1). The results of the present study has a partial agreement with the findings of Qureshi *et al.* (2004), Mohanty *et al.* (2002), Tripathy *et al.* (2014), Soni *et al.* (1991) and Dewangan *et al.* (2012).

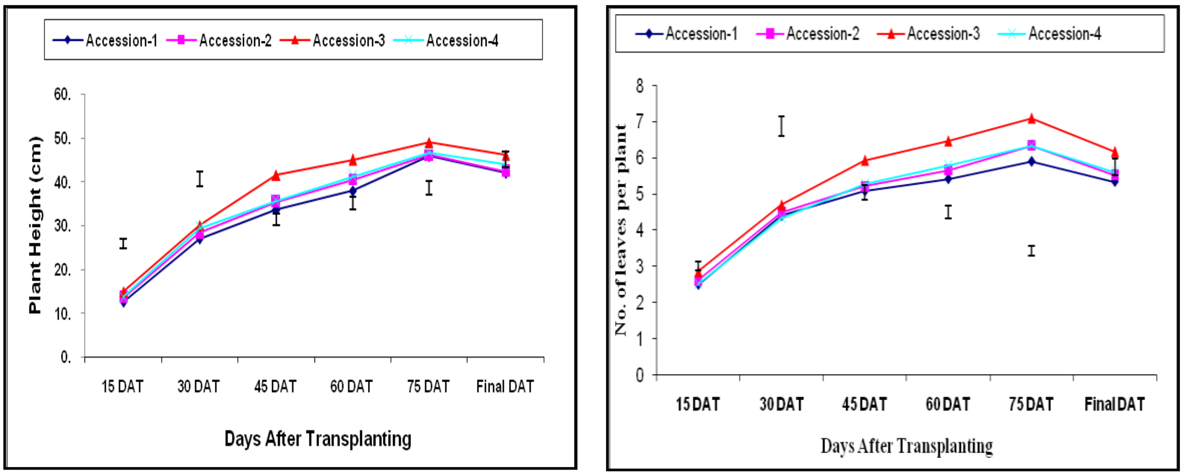


Fig.2. Main effect of accessions on plant height (left) and no. of leaves per plant (right). Vertical bars represents LSD at 1% level of significance

Variation can be due to gene characteristics of accessions (Jadhav *et al.*, 1990). The shortest plant (12.60 cm), lowest number of leaves (2.49) (Fig.2), the lowest leaf length (10.18 cm) and breadth (0.28 cm), minimum chlorophyll (6.48μmol/m^2), fresh weight of leaves (4.64 g) per plant, fresh weight of roots (0.41 g), dry weight of leaves (0.78 g) and dry weight of roots (0.10 g) were obtained from Accession-1(Table.1). The variation might be due to the arranging pattern of grana and thylakoid present in chloroplast different accessions. The lowest were also found in accession-1. Dry weight depends on dry matter content (Ali, 1999). The more dry matter content the more weight loss.

Main effect of different levels of gamma radiation on plant height (cm), number of leaves per plant, length and breadth of longest leaf (cm), Chlorophyll content of leaves (μmol/m^2), fresh wt. of leaves per plant (g), fresh wt. of roots per plant (g), dry weight of leaves and roots per plant (g) on the growth characteristics of onion plants

Main effect of **different levels of gamma radiation** was found to be a remarkable significant variation in respect of plant growth characteristics of onion (Fig.3 and Table. 2). The tallest plant (50.54 cm), maximum number of leaves (7.05) per plant (Fig.3), length (43.97 cm) and breadth (0.99 cm) of longest leaf, chlorophyll content (7.45 μmol/m^2), fresh weight of leaves (6.55 g) and roots (0.62 g), dry weight of leaves (1.10 g) and roots (0.15 g) per plant were recorded in 75 Gy gamma irradiation level (Table.2). The chlorophyll content was increased with an increase in the radiation until it reached 100 Gy (Alikamanoglu *et al.*, 2007). Irradiation dose 75 Gy might be highly influenced by hormenesis that increase no of leaves and roots that ultimately increase fresh weight (Thapa, 1999).

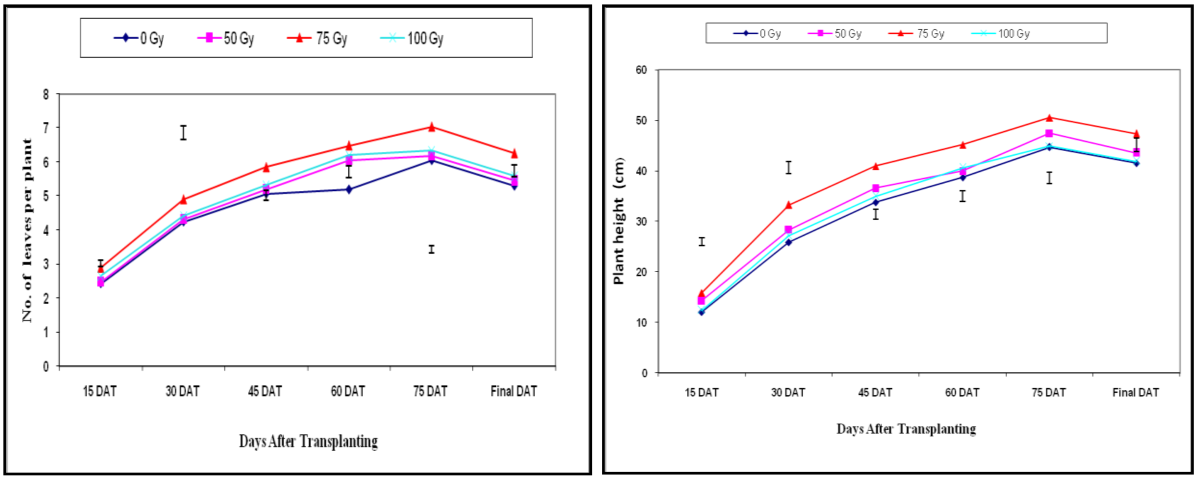


Fig.3. Main effect of irradiation doses on plant height (left) and no. of leaves per plant (right). Vertical bars represents LSD at 1% level of significance

On the contrary, the shortest plant (44.93 cm), minimum no. of leaves (6.06) per plant (Fig. 3), length (39.50cm) and breadth (0.76 cm) of longest leaf, chlorophyll content (6.47 μmol/m^2) of leaves, fresh weight of leaves (4.50 g) and roots (0.36 g) per plant, dry weight of leaves (0.66 g) and roots (0.09 g) per plant were recorded from control treatment (Table.2). Inhibition of auxin synthesis due to low doses apparently causes growth retardation while larger doses can destroy auxin activity directly (Chervin *et al.*, 1992; Liu *et al.*, 2008).

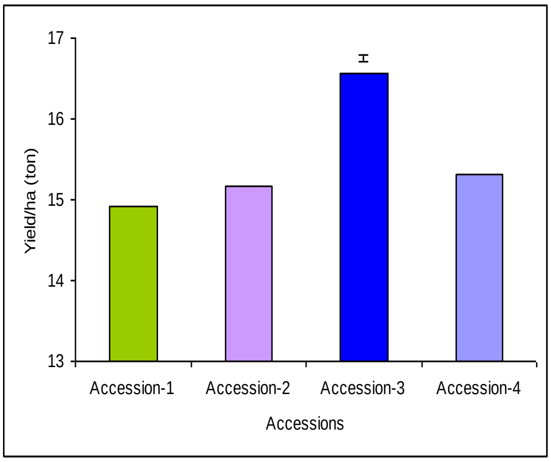
Combined effect of accessions and different levels of gamma radiation on plant height (cm), number of leaves per plant, length and breadth of longest leaf (cm), Chlorophyll content of leaves (μmol/m^2), fresh wt. of leaves per plant (g), fresh wt. of roots per plant (g), dry weight of leaves and roots per plant (g) on the growth characteristics of onion plants

The tallest plant, no. of leaves per plant, longest leaf length and breadth at all DAT along with all the plant characteristics were found to be highly significant by the combined effect of accessions and irradiation levels. All combination treatment was the highest at 75 DAT. The tallest (51.96 cm) plant, highest (7.80) number of leaves, maximum (7.97 μmol/m^2) chlorophyll content (Table.3), longest leaf length (45.00 cm), longest leaf breadth (1.10 cm), fresh weights of leaves (7.90 g), fresh weight of root (0.74 g) per plant, dry weight of leaves (1.29 g) and roots (0.19g) per plant were measured at accession-3 irradiated with 75 Gy gamma radiation. Free radicals produced from irradiation doses have been damaged or modified important components of plant cells and reported to affect differentially the morphology and anatomy (Maxie *et al.*, 1966). The increase in the size of the leaves was due to cell expansion rather than to cell division (Korableva and Metlitskii, 1963). The shortest (42.31 cm) plant was obtained from accession-4 irradiated with 100 Gy gamma radiation dose (Table. 3) and the lowest breadth of longest leaf was found in the accession-1 with 100 Gy. There was a strongly agreement with the result studied by Kebish *et al.*, 2015 that maximum decreased in plant height was observed when garlic cloves were exposed to 120 and 150 Gy. On the other hand, the lowest number of leaves (5.52), chlorophyll (6.07 µmol/m^2) content of leaves (Table.3), length (38.87 cm) of longest leaf, fresh weight of leaves (4.06g), fresh weight of roots (0.21g), dry weight of leaves (0.50g) and roots (0.05g) per plant was found from accession-1 with 0 Gy. High doses of radiation were decreased the capabilities of the photosynthetic apparatus by damaging the photo system in organized pattern of grana and stroma thylakoid (Alikamanoglu *et al.*, 2010). Radiation ranging from 0.1, 0.2, 0.3 kGy lessens the content of photosynthetic pigment (Alikamanoglu *et al.*, 2010). The result of dry weight showed dissimilarity with Curzion and Croci (1988). This was due to the fresh weight of leaves and variation in dry matter content which might be affected through irradiation doses.

3. Yield and yield contributing traits of onion

Main effect of accessions on individual fresh weight of bulb (g), dry weight of onion bulb (g), length (cm) and diameter of bulb (cm) and yield of bulb (kg/plot and t/ha) on yield and yield contributing traits of onion

The effect of different accessions on **yield and yield contributing traits** was significant (Fig.4 and Table.1). The maximum individual fresh weight (31.71 g) of bulb, dry weight of bulb (3.43 g), length of bulb (3.79 cm), diameter of bulb (4.40 cm), yield per plot (1.65 kg) (Table.1) as well as the bulb yield per hectare (16.57 t/ha) (Fig.4) was obtained from accession-3. The result of yield was matched with Haque *et al.* (1994). Tripathy *et al.* (2014) also found significantly better bulb weight (70.44 g) in NRCWO-3. At the same time, the minimum fresh weight of bulb (28.38 g), dry weight of bulb (3.02 g), length (3.43 cm) and diameter (3.92 cm) of bulb, yield (1.49 kg) per plot and yield (14.92 t/ha) per hectare were found in accession-1 (Table.1). The result of length and diameter were partially similar with findings of Jadhav *et al.* (1990), Sarkar and Jain (2002), Tarai *et al.* (2015).



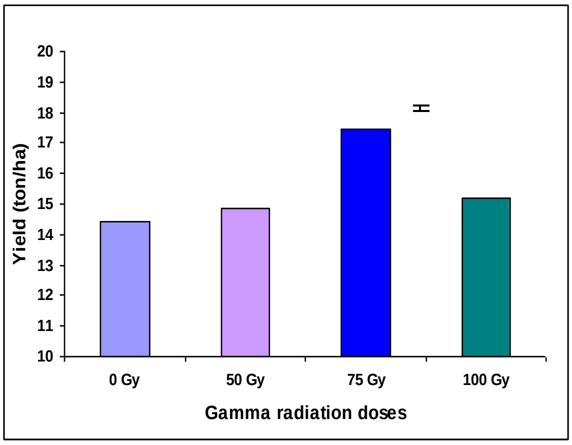


Fig. 4. Main effect of accessions (left) and radiation levels (right) on the yield (ton/ha) of onion. Vertical bar represents LSD at 1% level of significance

Main effect of different levels of gamma radiation on individual fresh weight of bulb (g), dry weight of onion bulb (g), length (cm) and diameter of bulb (cm) and yield of bulb (kg/plot and t/ha) on yield and yield contributing traits of onion

The **yield and yield contributing traits** were significantly influenced by the effect of different levels of irradiation (Table.2 and Fig.4). The highest fresh weight of bulb (33.42 g), dry weight of bulb (3.66 g), length (4.15 cm) and diameter (4.67 cm) of bulb, yield (1.73 kg) of onion per plot (Table.2) and yield (17.47 t/ha) per hectare (fig.4) were found by the application of 75 Gy radiation dose. Conversely, the lowest fresh weight of bulb (27.48 g), dry weight of bulb (2.85 g), length (3.26 cm) and diameter (3.80 cm) of bulb, yield (1.44 kg) of onion per plot (Table.2) and yield (14.45 t/ha) per hectare (fig.4) were obtained in the plants which were grown without use of irradiation. The cell division and fragmentation by gamma doses change in plant characteristics to enhance the bulb quality and compare to control. The result showed dissimilarity with the findings of Curzio and Croci (1988) that the radio inhibition process does not seems to affect adversely the levels of dry matter content in onion bulb. Irradiation dose 50 Gy may only causes morphological variation and less significant variation with control. Higher production of leaves causes increased photosynthetic activities leading to more accumulation of carbohydrate and there after production of the largest bulb. At higher dose 75 Gy the genetical variation started which was improved a genetical behaviour as well as yield characteristics (Islam *et al.,* 2015).

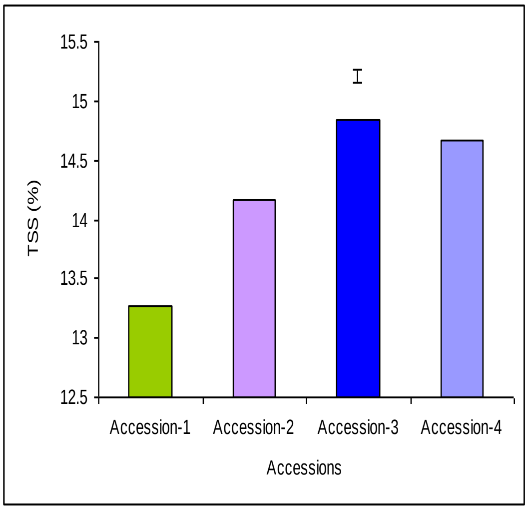
Combined effect of accessions and different levels of gamma radiation on individual fresh weight of bulb (g), dry weight of onion bulb (g), length (cm) and diameter of bulb (cm) and yield of bulb (kg/plot and t/ha) on yield and yield contributing traits of onion

A significant variation was created in respect of **yield and yield contributing traits** due the effect of combined treatment (Table.3). The maximum bulb weight (35.56 g), dry weight of bulb (3.85 g), length (4.50 cm) and diameter (4.92 cm) of bulb, bulb yield per plot (1.85 kg) and bulb yield per hectare (18.59 t/ha) were obtained in accession-3 with 75 Gy radiation dose (Table.3). The growth of plant through improved cell division (Korableva and Metlitskii, 1963) and the highest number of leaves increased photosynthetic activities leading to accumulation stimulated by the optimum irradiation dose (75 Gy) which produced heaviest bulb as well as a quality bulb structure. The lowest bulb weight (26.24 g), minimum dry weight of bulb (2.67 g), length (3.07 cm) and diameter (3.57 cm) of bulb, bulb yield per plot (1.40 kg) and bulb yield per hectare (14.00 t/ha) were recorded from accession-1 with 0 Gy (Table.3). The combinations after exposure were deeply influenced by the several factors related to plant characteristics e.g., species, tissue architecture and genome organization and radiation doses where accession-3 and 75 Gy separately have already showed better performance than other. This result matched with Jan *et al.,* 2012.

4. Biochemical characteristics

Main effect of accessions on TSS (%), vitamin C (mg/100g), nitrogen (%), protein (%), calcium (%) and phosphorus (%) content of bulb on biochemical characteristics on onion

The significant difference was observed in **biochemical contents** of bulbs after harvest (Fig. 5 and Table.4). The highest TSS (14.83%) (Fig.5), maximum Vitamin C (9.18 mg/100g), nitrogen (2.01%), protein (12.60%), calcium (0.16%) and phosphorus (0.37%) content in bulb were found in accession-3 (Table. 4). It was partially agrees with the findings of Dewangan *et al.,* 2012, Sarkar *et al.,* 2015. According to Jadhav *et al.* (1990), the highest TSS content (14.8%) obtained in N 257-9-1 during rabi season. The lowest TSS (13.27%) (Fig.5), and vitamin C (7.76 mg/100g) were content in accession-1(Table.4). The result of vitamin C supported the findings of Saimbhi *et al.* (1970) that ascorbic acid content of 40 Indian varieties of onion varied from 6.07 to 9.47 mg per 100 g.



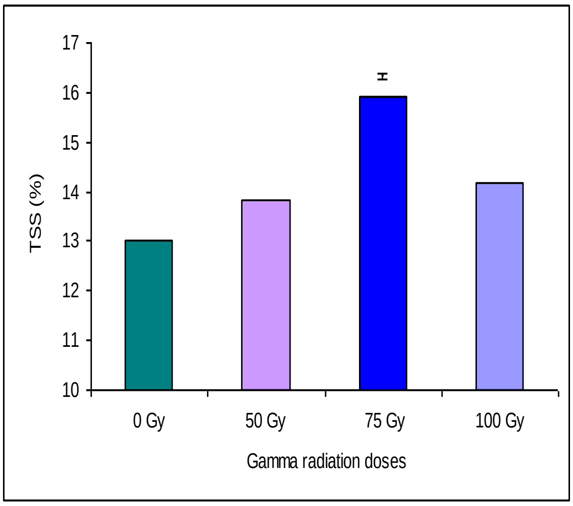


Fig.5. Main effect of accessions (left) and radiation levels (right) on the TSS content of bulb. Vertical bar represents LSD at 1% level of significance

The lowest nitrogen (1.18%) and protein (7.40%) were obtained in the accession-2 (Table.4). Accession-4 was recorded to be inferior in case of calcium (0.14%) and phosphorus (0.30%) content (Table.4). It was similar with the findings of Azoom *et al.,* (2015) where calcium content was 0.06% and phosphorus content was 0.10% in bulbs of `Morada de Amposta'. This might be due to the mineral elements may vary from species to species.

Table-4. Main effect of accessions on biochemical content of onion bulb after harvest

Accessions	Vitamin C (mg/100g)	Nitrogen content (%)	Protein (%)	Calcium (%)	Phosphorus (%)
A_1	7.76	1.50	9.28	0.15	0.35
A_2	8.66	1.18	7.40	0.15	0.29
A_3	9.18	2.01	12.60	0.16	0.38
A_4	9.08	1.39	8.70	0.14	0.31
LSD at 5%	0.60	0.11	0.68	0.009	0.02
LSD at 1%	0.81	0.15	0.92	0.012	0.03
Level of sig.	**	**	**	**	**
CV(%)	8.31	8.93	8.59	7.49	7.69

** significant at 1% level

A_1=Accession-1 A_2=Accession-2 A_3=Accession-3 A_4= Accession-4

Main effect of different levels of gamma radiation on TSS (%), vitamin C (mg/100g), nitrogen, protein (%), calcium (%) and phosphorus (%) content of bulb on biochemical characteristics on onion

A significant variation was also observed due to irradiation effect on **biochemical characteristics** (Fig. 5 and Table.5). The highest TSS (15.92%) (Fig.5), maximum vitamin C (9.22 mg/100g), nitrogen (1.79%), protein (11.20%), calcium (0.16%) and phosphorus (0.40%) were noted from 75 Gy irradiation dose (Table.5). After 75 Gy at high radiation dose Vitamin C reduced due to effect of higher level of gamma radiation because of there is no significant difference among 0 Gy, 50 Gy and 75 Gy but difference with 100 Gy. Low dose increases protein content by inhibiting protein synthesis assembly (Reuther, 1969). The lowest TSS (13.27%) was measured from the control (Fig. 5), minimum vitamin C (7.34 mg/100g), nitrogen content (1.29%) and protein (8.05%) were observed in 100 Gy radiation level (Table.5). At the same time, lowest calcium (0.14%) and phosphorus (0.30%) were obtained from the 50 Gy dose (Table.5). In amino acids, amino group ($–NH_2$) is radiation sensitive (Siddhuraju *et al.,* 2002). Calcium and phosphorus are related with the finding of Kebish *et al.* (2015). At 50 Gy irradiation dose for onion may only morphological variation start but at higher dose 75 Gy the genetical variation started which was improved in a genetical behaviour. After 75 Gy dose, decreasing trend of protein was observed with increasing rate of gamma rays.

Table-5. Main effect of irradiation levels on biochemical content of onion bulb after harvest

Dose	Vitamin C (mg/100g)	Nitrogen content (%)	Protein (%)	Calcium (%)	Phosphorus (%)
D_0	9.08	1.56	9.75	0.14	0.31
D_1	9.18	1.45	8.97	0.14	0.30
D_2	9.22	1.79	11.20	0.16	0.40
D_3	7.34	1.29	8.05	0.15	0.33
LSD at 5%	0.60	0.11	0.68	0.009	0.02
LSD at 1%	0.81	0.15	0.92	0.012	0.03
Level of sig.	**	**	**	**	**
CV (%)	8.31	8.93	8.59	7.49	7.69

** significant at 1% level

D_0= Control D_1= 50 Gy D_2= 75 Gy D_3= 100 Gy

Combined effect of accession and different levels of gamma radiation on TSS (%), vitamin C (mg/100g), nitrogen, protein (%), calcium (%) and phosphorus (%) content of bulb on biochemical characteristics on onion

There was a significant variation in contest of **biochemical content** by the treatment combination (Table.6). The highest TSS (16.33%), vitamin C (10.40 mg/100g), nitrogen (2.24%), protein (14%), calcium (0.17%), phosphorus (0.47%) were found in accession-3 with 75 Gy (Table.6). Vitamin C might be affected by the bio-molecular change in the cells of plant. But this result disagreed with the finding of Curzio and Croci (1988) that the radio inhibition process does not adversely affect the levels of ascorbic acid content in onion bulb. The lowest TSS (12.00%) was measured from the accession-1 with 0 Gy, the lowest (5.12 mg/100g) vitamin C was measured at several combination, lowest nitrogen (1.04%) and protein (6.50%) recorded in accession-2 with 100 Gy gamma radiation dose (Table.6).

Table.6. Combined effect of onion accessions and radiation levels on Biochemical characteristics

Treatment combination	TSS %	Vitamin C (mg/100g)	Nitrogen (%)	Protein (%)	Calcium (%)	Phosphorus (%)
A_1D_0	12.00	5.12	1.57	9.81	0.13	0.30
A_1D_1	12.67	10.40	1.31	7.70	0.14	0.33
A_1D_2	15.33	10.40	2.02	12.60	0.17	0.44
A_1D_3	13.07	5.12	1.12	7.00	0.17	0.35

A_2D_0	13.00	10.40	1.20	7.50	0.14	0.32
A_2D_1	13.67	5.12	1.15	7.20	0.13	0.25
A_2D_2	15.67	10.40	1.34	8.40	0.16	0.34
A_2D_3	14.33	8.73	1.04	6.50	0.15	0.31
A_3D_0	13.67	10.40	2.13	13.30	0.16	0.34
A_3D_1	14.67	10.40	1.90	11.90	0.15	0.34
A_3D_2	16.33	5.12	2.24	14.00	0.17	0.47
A_3D_3	14.67	10.40	1.79	11.20	0.14	0.35
A_4D_0	13.33	10.40	1.34	8.40	0.13	0.29
A_4D_1	14.33	10.40	1.46	9.10	0.13	0.28
A_4D_2	16.33	10.40	1.57	9.80	0.14	0.34
A_4D_3	14.67	5.12	1.20	7.50	0.14	0.32
LSD at 5%	1.34	0.07	0.23	1.36	0.02	0.04
LSD at 1%	1.81	0.11	0.31	1.83	0.03	0.06
Level of sig.	**	**	**	**	**	**
CV (%)	5.66	8.31	8.93	8.59	7.49	7.69

** Significant at 1% level

A_1=Accession-1 A_2=Accession-2 A_3=Accession-3 A_4= Accession-4

D_0= Control D_1= 50 Gy D_2= 75 Gy D_3= 100 Gy

The lowest calcium (0.13%) producing onions were found in both accession-1 with 0 Gy and accession 2 with 50 Gy (Table.6). The lowest phosphorus (0.25%) was obtained in accession-2 with 50 Gy irradiation dose (Table.6). Exposure of seeds to variable levels of gamma rays which were assessed their effect on the biochemical and molecular traits (Kebish *et al.*, 2015).

IV. Summary

The effects of gamma radiation on the growth, yield and quality of four onion accessions was studied at the Horticulture Farm of Hajee Mohammad Danesh Science and Technology University, Dinajpur and laboratory of Horticulture division of BINA during the period from November, 2017 to May, 2018. The highest bulb yield and quality was noted in accession-3. The growth yield, yield contributing characteristics and quality increased progressively by the applying up to 75 Gy irradiation dose but irradiation dose 100 Gy was found to be unsuitable in germination of seeds. The treatment combination accession-3 with the irradiation dose 75 Gy was recorded to be the highest for most of all growth, quality contributing characters, and yield of onion.

V. Conclusions

From the above results it was revealed that accession-3 irradiated with 75 Gy can be used for maximizing onion production in this country. This study needs to be repeated in different AEZs of the country to strengthen the benefits and recommendation on the use of best accession radiated by beneficial dose for higher production of onion.

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