Jurnal Sains Nuklear Malaysia, 2019, 31(1): 1 – 10
ISSN: 2232-0946

EFFECTS OF CHRONIC GAMMA IRRADIATION ON THREE RICE VARIETIES

Fahmina Yasmine[1], Mohammad Asad Ullah[1], Faiz Ahmad[2], Mohammad Ashiqur Rahman[3] and Abdul Rahim Harun[2]

[1]Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture,
Mymensingh2202, Bangladesh
[2]Agrotechnology and Biosciences Division, Malaysian Nuclear Agency,
Bangi, 43000 Kajang, Selangor, Malaysia
[3]Agricultural Engineering Division, Bangladesh Institute of Nuclear Agriculture,
Mymensingh2202, Bangladesh
Correspondence author: maullah09@gmail.com

ABSTRACT

Rice is the most important staple food for a large part of the world's human population, especially in tropical Latin America, the West Indies, East, South and Southeast Asia. Mutation-based breeding is to develop and improve plant varieties by modifying one or two major traits to increase their productivity or quality in a relatively short time than conventional breeding. This is now widely used in agriculture to get the success rapidly. The present study inspects the effect of chronic gamma irradiation on rice (Binadhan-8, NMR-152 and Pongsuseribu-2) varieties. Rice seedlings at the age of 14 days were exposed to chronic gamma irradiation (low dose rate radiation) in Gamma Green House (GGH) at Malaysian Nuclear Agency for 60 days. The treated seedlings were designated in three replicates. The accumulated doses received by the rice plants were from 29 to 639 Gy for 60 days. Control plants were grown outside the gamma green house. The plant heights were recorded every week after planting in GGH. Effects of radiation were measured in terms of plant height, number of tiller and number of filled grain produced. At cumulative doses of 67 and 162 Gy (0.07and 0.17 Gy/hr, respectively), the rice seedlings showed the highest plant height with maximum tillering and highest number of filled grain. Those rates are stimulating to the growth and development of the plants. This study helps explicate the biological effects of low-dose gamma irradiation in rice plants at various exposure periods.

Keywords: Chronic gamma irradiation, Gamma Green House, mutation breeding, rice

INTRODUCTION

Plants exposed to stress conditions have a wide range of adaptations to avoid or dissipate excess stress, as well as mechanisms that reduce the amount of injury caused by stress. Plants face various environmental stresses during all stages of development. Ionizing radiation such as X-rays, beta-rays, gamma rays, and neutron and proton rays, can impose stress on plants and influence the full genetic potential for growth and reproduction (Ashby et al., 1967). Mutation breeding using nuclear technology has been widely used and proven to improve traits of many crops around the world. There are approximately 800 rice varieties that have been registered under the Mutant Varieties Database from the International Atomic Energy Agency (FAO/IAEA, 2014). Induced mutation can increase genetic variability and is highly effective, economical as well as a recognized method for enhancing natural and genetic resources and developing improved cultivars of cereals, fruits and other crops (Lee et al., 2002).

Gamma radiation is one of the physical mutagens for plant mutagenesis in which alteration at DNA levels can produce new traits towards crops improvement. There are two types of gamma irradiation for crop improvement which are acute and chronic gamma irradiation. Acute gamma radiation is the exposure at high dose in short period of time, whilst chronic gamma irradiation is the exposure that is continued over long period of time (IAEA, 1977). A wide range of characters which have been improved through mutation breeding include plant architecture, yield, flowering and maturity duration, quality and tolerance to biotic and abiotic stresses.

The chronic irradiation is tremendous, resulting in changes in physical appearance, molecular structures and metabolism. These changes are random events, inheritable, with the stability depending on cell damages after irradiation at molecular levels. Chronic gamma irradiation produces a wider mutation spectrum and is useful for minimizing radiation damages towards obtaining new improved traits for commercial values (Azhar and Ahsanulkhaliqin, 2014). Continuous exposure at low dose of gamma irradiation results in considerably elevated somaclonal variation frequency without negative effects on natural response. The chronic radiation is a type of a radiation treatment in which the samples receive low dose radiation either continuously or intermittently over a prolonged period of time. This cumulative dose may be high enough for sensitive root system and causing damage to its cell if it is given in a high dose rate in a short time but, if received at a low dose rate over a period of time, a significant portion of the acute cellular damage may be repaired at random event. In physical mutagenesis studies related to chronic gamma radiation, it is important to determine a suitable dose and/or effective dose of mutagen for a crop plant which can be employed for inducing maximum variability at low casualties. Seed germination, seedling growth, pollen sterility and chromosomal aberration are the commonly used criteria for studying radio-sensitivity in plants (Sheikh et al., 2012). Gamma irradiation has significantly affected the number of tiller and number of grain in upland rice studied due to radiation hormesis that are stimulating to the growth and development of the plants (Aziliana et al., 2015). This paper describes the effects of chronic gamma irradiation on three rice varieties. The data obtained from this study will be beneficial for future studies involving low dose gamma irradiation on rice plants.

MATERIALS AND METHODS

Plant Materials

Three rice varieties (Binadhan-8, NMR-152 and Pongsu Seribu-2) were used in this study and seeds were collected from Agrotechnology and Bioscience Division, Malaysian Nuclear Agency.

Chronic Gamma Irradiation

Seedlings of rice at the age of 14 days were exposed to chronic irradiation to observe the response of plants to gamma rays at different cumulative doses. The seedlings were placed in pots at six points (also known as ring) distances from Caesium-137 source in GGH (Figure 1). The growing plants received dose for 16 hours every day. The treated seedlings were designated in three replicates. The total radiation doses received by the rice plants were from 29 to 639 Gy for 60 days.

Jurnal Sains Nuklear Malaysia, 2019, 31(1): 1 – 10
ISSN: 2232-0946

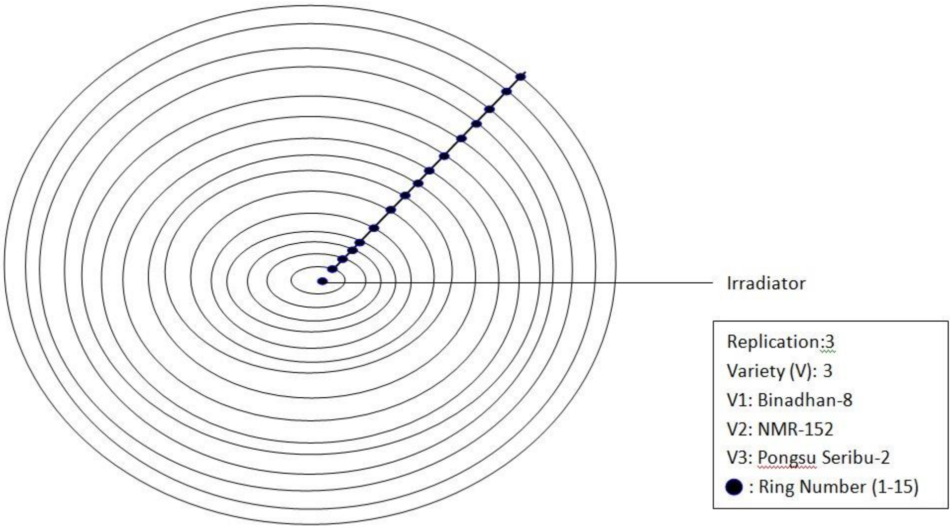

Figure 1: Layout of experiment inside GGH

Data Collection

The plant heights were recorded every week after planting in GGH. After 60 days, the plants were removed from GGH and transferred to glasshouse until maturity. At maturity time the tiller number, the number of filled grains per panicle and weight of 1000 grains were recorded. Control plants were grown outside the gamma green house under conditions very similar to those irradiated plants. In order to determine the effect of gamma irradiation, analysis of variance was then performed using the Statistical Analysis Software (STAR) Version 16.

RESULTS AND DISCUSSION

Gamma irradiation has played a significant role in plant breeding discipline for developing new variety with improvement of selected traits via chronic gamma irradiation.

Effect of Chronic Gamma Irradiation on Plant Height of Three Rice Varieties

From the experiment, chronic gamma irradiation caused inhibitory effects on three rice plant height as shown in Table 1, 2 and Figure 2, 3, 4 and 5. At 7, 14 and 28 days after irradiation, Binadhan-8 produced maximum plant height at 67 Gy while the lowest height was observed at 639 Gy. However after 60 days, plant height of Binadhan-8 was highest at 162 Gy, though it was not significantly different with those irradiated at 67 Gy. For NMR-152 variety, the highest plant height after 7 days of irradiation was observed at 286 Gy but it was not significantly different with 162 Gy while the lowest plant height was found at 639 Gy. After 14, 28 and 60 days of irradiation, the lowest plant height was obtained at 639 Gy) and the highest at 286 Gy. On the other hand, Pongsu Seribu-2 produced lowest plant height in higher dose of gamma ray and produced highest in 286 Gy. But in case of 28 days after irradiation, Pongsu Seribu-2 produced taller plant in all doses of gamma ray than control and highest plant height was found in 67 Gy, which was significantly same with 162 Gy and 38 Gy.

Table 1: Effect of chronic gamma irradiation on plant height at 7 days and 14 days

Cumulative Dose (Gy)	Dose rate (Gy/hr)	Ring	Plant Height (cm) at 7 Days After Irradiation			Plant Height (cm) at 14 Days After Irradiation		
			Binadhan-8	NMR-152	Pongsu Seribu-2	Binadhan-8	NMR-152	Pongsu Seribu-2
Control	0	0	29.42^{bc}	35.75^{b}	40.67^{ab}	36.20^{b}	45.00^{bc}	52.33^{a}
29	0.03	10	28.50^{bc}	32.83^{c}	35.50^{e}	35.67^{b}	42.63^{c}	40.80^{d}
38	0.04	8	29.92^{b}	32.87^{c}	36.17^{de}	36.25^{b}	43.93^{bc}	47.68^{bc}
67	0.07	6	35.58^{a}	32.67^{c}	37.92^{cd}	42.58^{a}	42.63^{c}	51.70^{a}
162	0.17	4	29.00^{bc}	39.00^{a}	39.33^{bc}	36.15^{b}	45.82^{b}	49.38^{ab}
286	0.29	3	27.92^{bc}	39.50^{a}	42.42^{a}	35.00^{bc}	49.33^{a}	51.82^{a}
639	0.67	2	27.50^{c}	32.17^{c}	32.08^{f}	32.52^{c}	36.27^{d}	46.25^{c}
Mean			29.69	34.97	37.73	36.34	43.66	48.57
CV%				2.40			2.72	

a, b, c, d, e: Mean with different letter(s) in column are statistically different among treatment by LSD test ($p \leq 0.05$)

Table 2: Effect of chronic gamma irradiation on plant height at 28 days and 60 days

Cumulative Dose (Gy)	Dose rate (Gy/hr)	Ring	Plant Height (cm) at 28 Days After Irradiation			Plant Height (cm) at 60 days After Irradiation		
			Binadhan-8	NMR-152	Pongsu Seribu-2	Binadhan-8	NMR-152	Pongsu Seribu-2
Control	0	0	48.50^{c}	61.33^{b}	65.92^{c}	73.30^{bc}	81.33^{d}	111.11^{c}
29	0.03	10	49.25^{bc}	56.75^{c}	70.67^{b}	72.51^{c}	81.30^{d}	116.20^{b}
38	0.04	8	50.92^{b}	62.00^{b}	69.75^{a}	75.77^{b}	78.89^{d}	110.67^{cd}
67	0.07	6	61.42^{a}	60.00^{b}	76.67^{a}	86.27^{a}	90.33^{c}	123.47^{a}
162	0.17	4	51.00^{b}	60.92^{b}	76.17^{a}	88.63^{a}	95.65^{b}	110.00^{cd}
286	0.29	3	47.17^{c}	64.50^{a}	66.33^{c}	72.00^{c}	99.17^{a}	120.99^{a}
639	0.67	2	44.50^{d}	49.75^{d}	67.00^{c}	63.01^{d}	78.31^{d}	107.74^{d}
Mean			50.39	59.32	70.36	75.93	86.43	114.31
CV%				1.44			1.29	

a, b, c, d: Mean with different letter(s) in column are statistically different among treatment by LSD test ($p \leq 0.05$)

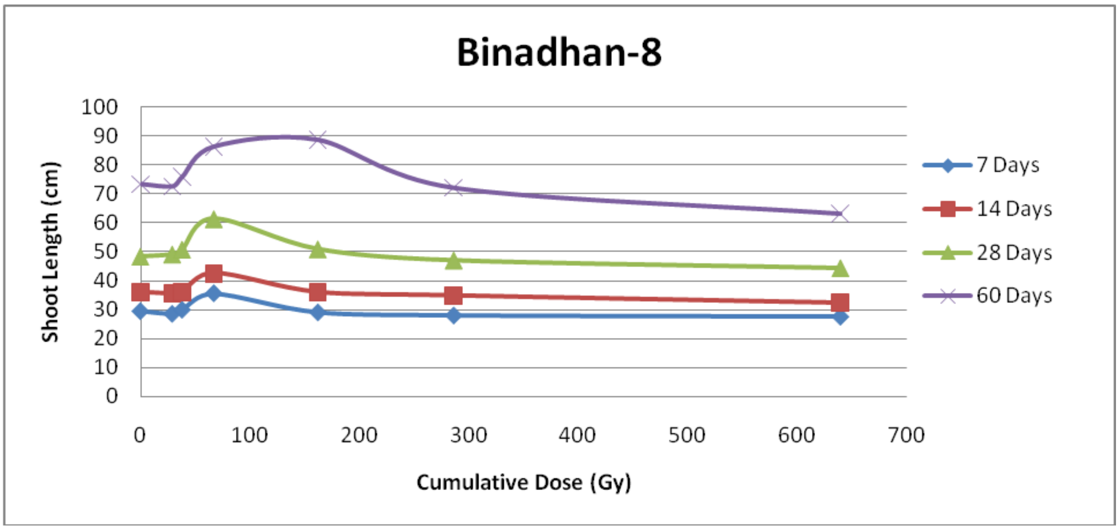

Figure 2: Plant height (cm) of Binadhan-8 at different days after irradiation

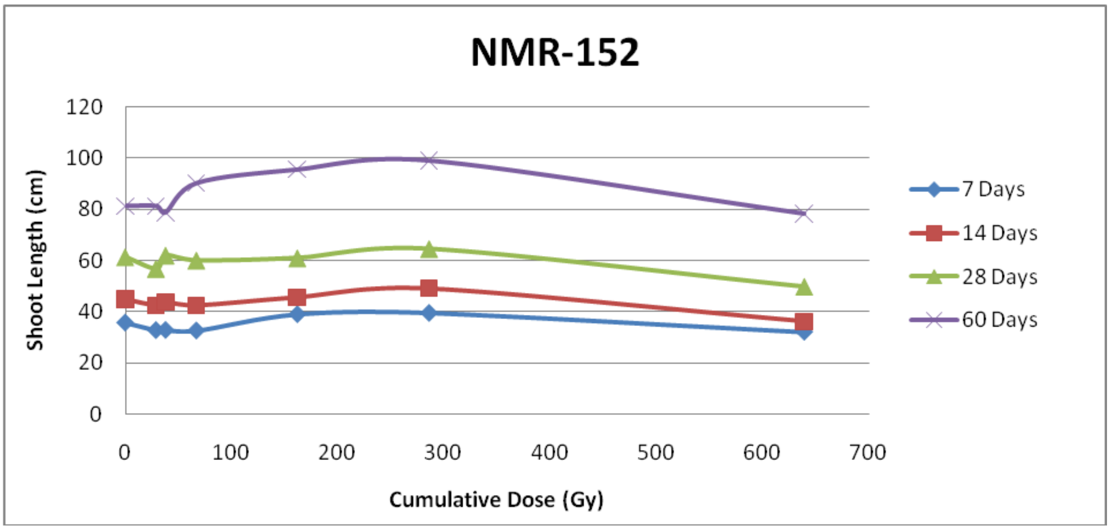

Figure 3: Plant height (cm) of NMR-152 at different days after irradiation

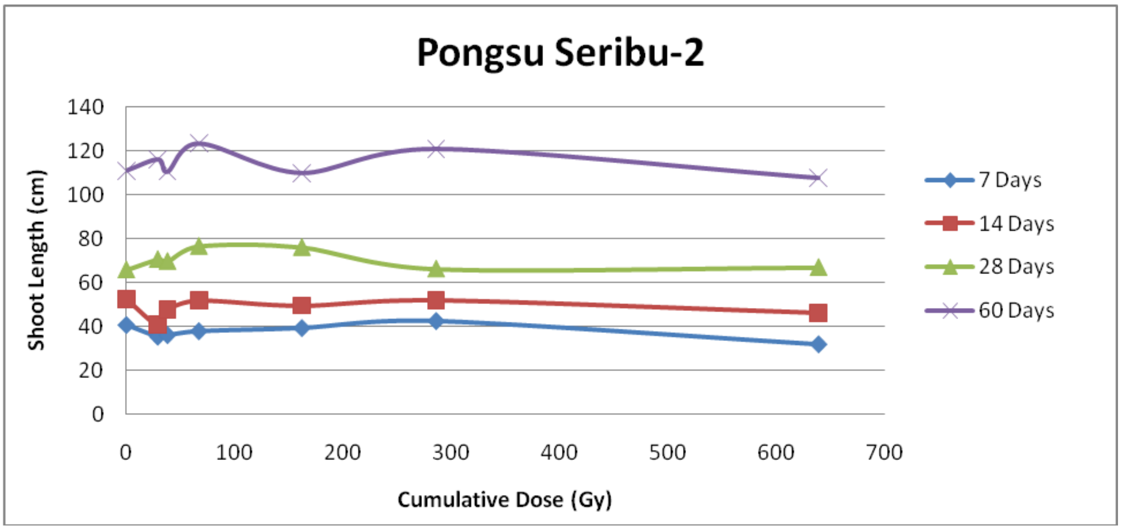

Figure 4: Plant height (cm) of Pongsu Seribu-2 at different days after irradiation

A linear dependency exists between plant height and the dosage supplied. In concept with this observation, our findings show that plant height decrease was not significant with the increase of dose except in higher dose (639 Gy) where sharp reduction was observed. However, the plant heights are not significantly reduced in all doses of gamma ray received (Figure 5). This radiation injury could be due to the inhibition of DNA synthesis or other physiological damage that not just appeared in plant height but could also be manifested in the form of plant survival and the number of plant organs (Nwachukwu et al., 2009). Similar finding also found on effective plant height reduction by (Aqsa Tabasum et al., 2011; Chakravarty, 2010; Haris et al., 2013).

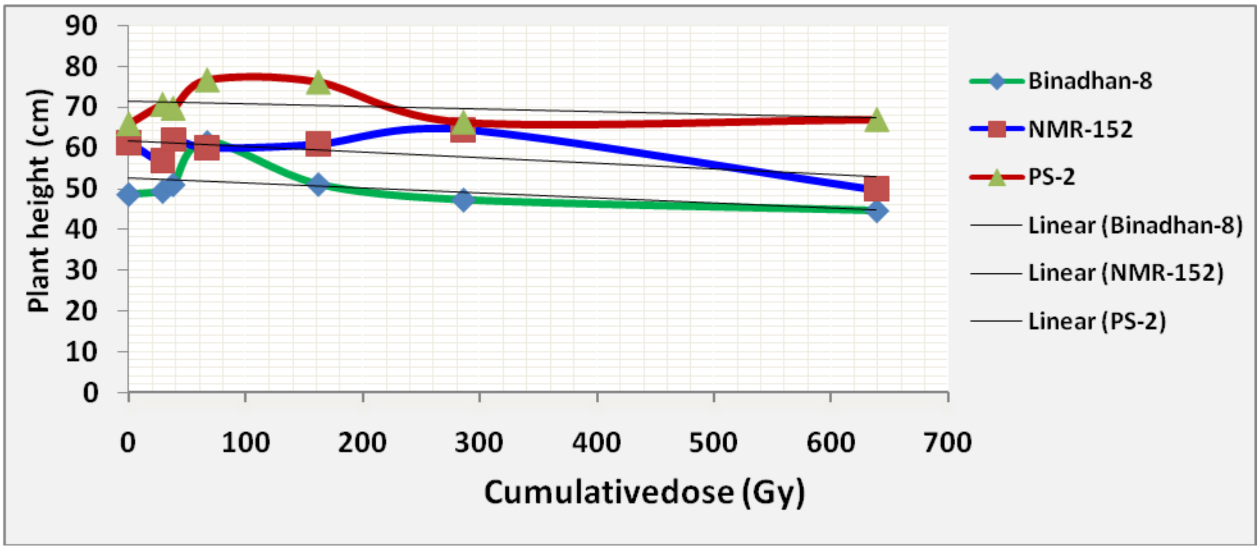

Figure 5: Effect of chronic gamma irradiation towards plant height on 28 days of exposure

Effect of Chronic Gamma Irradiation on Number of Tillers of Three Rice Varieties

Tillering or the production of lateral branches is an important agronomic trait that determines shoot architecture and grain production in grasses. Based on the findings, the number of tiller produced per plant was significantly influenced by the dose received (Figure 6). Binadhan-8 produced maximum (9.66) number of tiller at 162 Gy and NMR-152 produces maximum (10.33) number of tiller at 67 Gy and 286 Gy. On the other hand, Pongsu Seribu-2 produced maximum (11.00) number of tiller doses at 67 Gy. Increase in tillering with increasing dose might be due to radiation homeostasis. This amount of dose received could be beneficial or stimulating for plants growth thus creating variation. Another similar finding was also observed in macro mutation of rice in M_2 generation by Chakravarti et al. (2012) where different gamma ray treatment in acute mutation was found to induce tiller production.

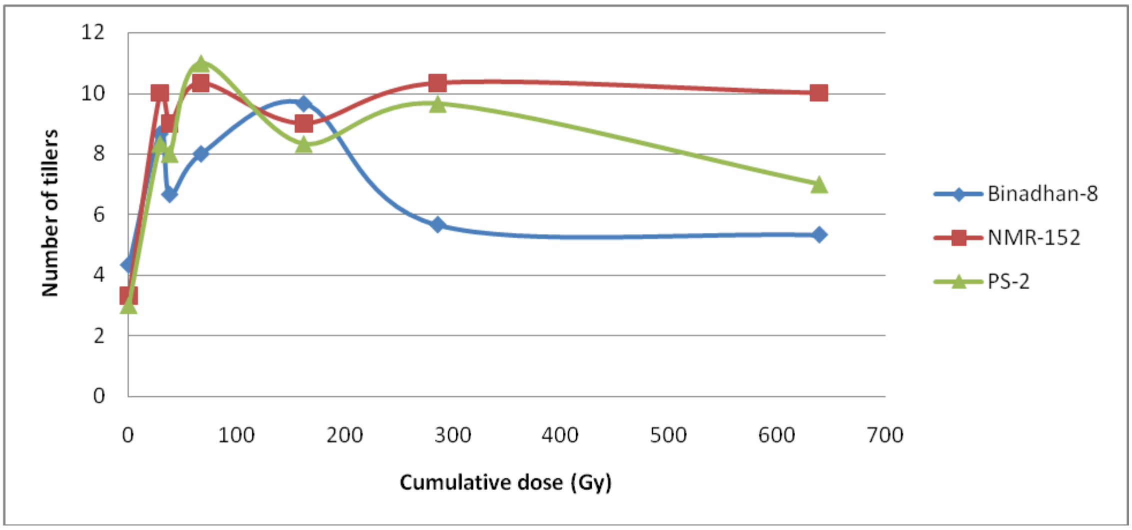

Figure 6: Effect of chronic gamma irradiation towards tiller number at different dose level

Effect of Chronic Gamma Irradiation on the Number of Filled Grain on Three Rice Varieties

Rice grain filling mainly depends upon temperature, timely application of fertilizer, water level and time of watering and the tillering behavior is most important because late formed tillers fail to produce filled grains. Grain yield is closely correlated with solar radiation during the ripening period by Tanaka et al. (1966). Radiation-use efficiency (RUE) is defined as the efficiency of using intercepted radiation to produce biomass by crops, and it is regarded as the only remaining major prospect for improving yield potential by Long et al. (2006). From the study, number of filled grain was highest at 67 and 162 Gy in both Binadhan-8 and NMR-152, whilst Pongsu Seribu-2 recorded the highest grain yield at 29, 67 and 162 Gy. This finding was also correlated to the number of tillering which recorded the highest number at the same doses. But the higher the dose received, the lower the grain fertility (Figure 7). The grain fertility decrease with increase in dose was also observed in Awan and Bari (1979).

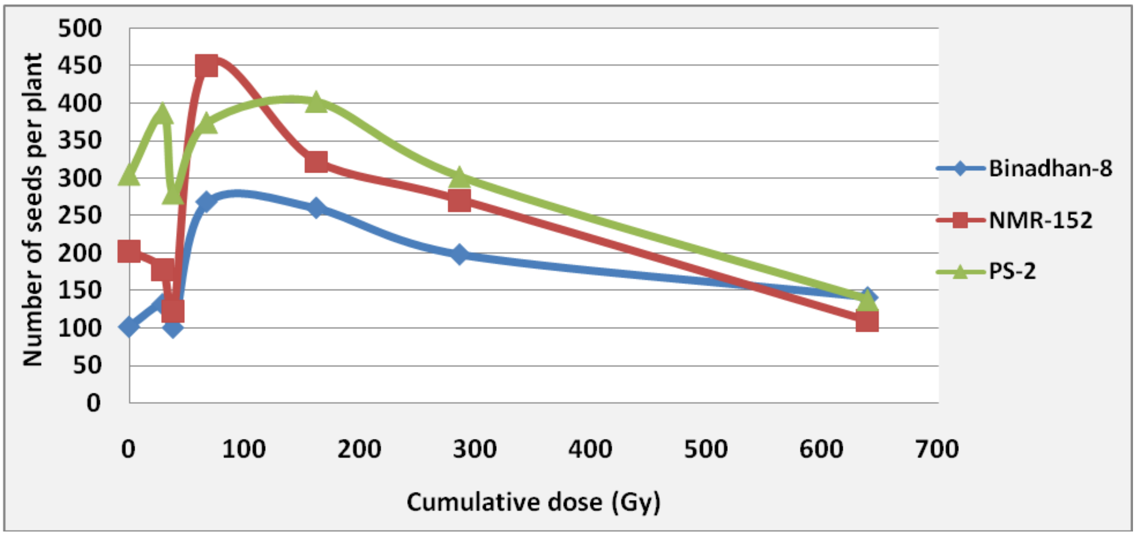

Figure 7: Effect of chronic gamma irradiation towards number of filled grain

The 1000-Seed -Weight at Different Dose of Irradiation

The 1000-grain-weight depends on the width and length of the rice grain. The highest 1000-grain-weight was recorded at 29 and 286 Gy (Binadhan-8 and NMR-152); 29 and 162 Gy (Pongsu Seribu-2). The other doses are not significantly different (Figure 8). This finding also agrees to Yoshida (1981), where 1000-grain-weight is a stable varietal character and does not represent individual grain.

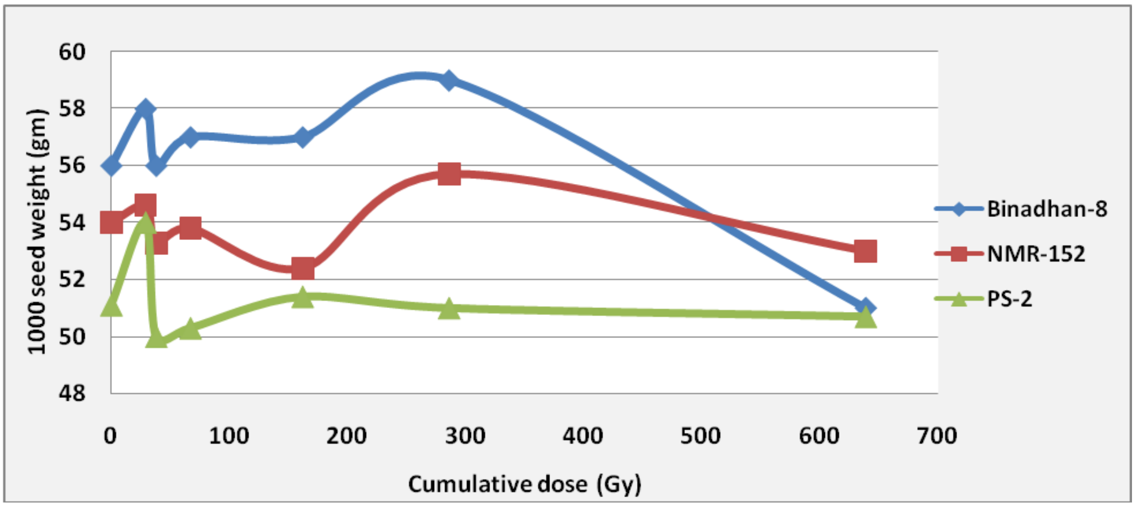

Figure 8: Effect of chronic gamma irradiation towards thousand grain weight

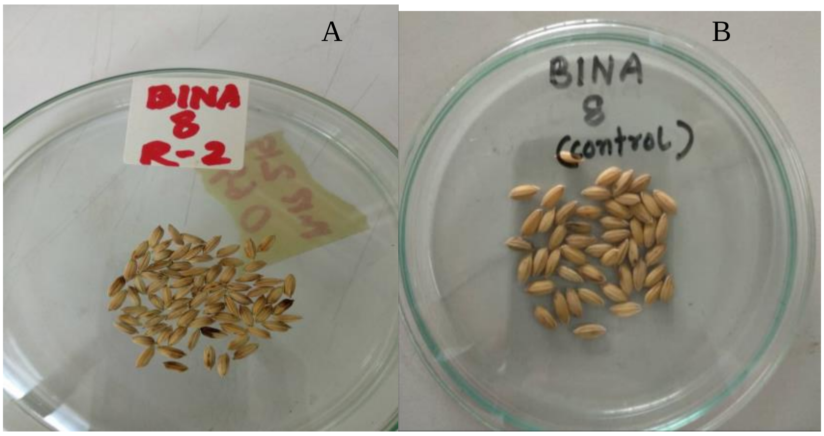

Figure 9: Photo of irradiated and non-irradiated (0 Gy) seed of Bina-10.
(A) Irradiated seed of Bina-10 at cumulative dose 639 Gy
(B) Non-irradiated of Bina-10 seed (0 Gy)

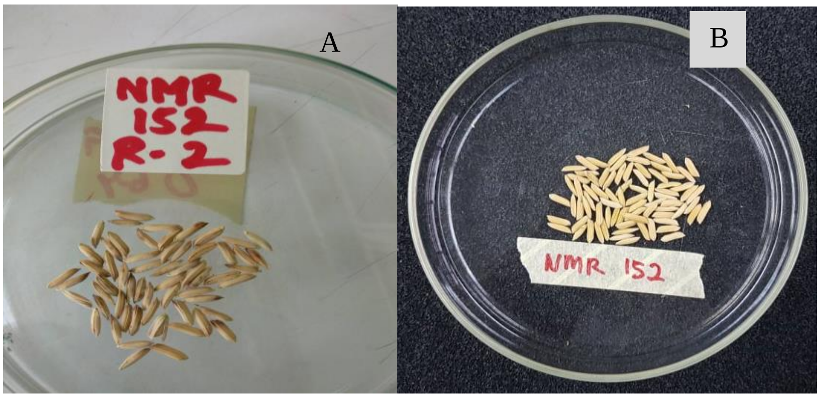

Figure 10: Picture of Irradiated and non- irradiated (0 Gy) seed of NMR-152.
(A) Irradiated seed of NMR 152 at cumulative dose 639 Gy
(B) Non-irradiated of NMR 152 seed (0 Gy)

CONCLUSIONS

Chronic gamma irradiation has radically affected the plant height, the number of tiller and number of grain in rice plant. The study revealed that at cumulative doses of 67 and 162 Gy (at 0.07 Gy/hr and 0.17 Gy/hr, respectively), the rice seedlings showed the highest plant height with maximum tillering and the highest number of filled grain. Those rates are stimulating to the growth and development of the plants.

ACKNOWLEDGMENTS

Authors are grateful to the ‘‘Strengthening Research Activities and Sub-station Development (SRSD)’’ Project of BINA, BAU campus, Mymensingh-2202, Bangladesh for the financial support and the Agrotechnology and Biosciences Division, Malaysian Nuclear Agency, 43000 Kajang, Selangor, Malaysia for the irradiation and research facilities.

REFERENCES

Aqsa Tabasum, Akbar Ali Cheema, Amjad Hameed, Muhammad Rashid and Muhammad Ashraf (2011). Radio sensitivity of rice genotypes to gamma radiations based on seedling traits and physiological indices, *Pak. J. Bot.* 43(2): 1211-1222.

Ashby, W.C., Beggs, J.N., Kastner, J., Oltman, B. and Moses, H. (1967). Ecological dosimetry: Radiation levels influenced by plant growth, *Sci.* 155: 1430-1432.

Awan, M.A. and Bari, G. (1979). Mutagenic effects of fast neutrons and gamma rays in rice, *Nucleus* 16(1/2): 33-38.

Azhar, M. and Ahsanulkhaliqin, A.W. (2014). Gamma greenhouse: A chronic facility for crops improvement and agrobiotechnology, *AIP Conference*, 30 September – 2 October 2013, pp. 32-37, Kuala Lumpur, Malaysia. http://dx.doi.org/10.1063/1.4866100.

Aziliana, N., Shamsiah, M.Y., Faiz, A., Abdul Rahim, H., Rusli, I., Khairuddin, A.R. and Site Noorzuraini, A.R. (2015). The effect of chronic gamma irradiation on Malaysia upland rice (*Oryza sativa*) Kuku Belang, *Aust. J. Basic Appl. Sci.* 9(31): 1-6.

Chakravarty, S.K.R. (2010). Mutagenesis for genetic improvement of rice (*Oryza sativa* L.). Ph.D. Thesis, Banaras Hindu University, India (Unpubl.)

Chakravarti, S.K.R., Kumar, H., Lal J.P. and Vishwakarma, M.K. (2012). Induced mutation in traditional aromatic rice – frequency and spectrum of viable mutations and characterizations of economic values, *The Bioscan* 7(4): 739-742.

FAO/IAEA (2014). Mutant Variety Database, IAEA, Vienna., https://mvd.iaea.org/ (Access on 20 Mei 2018).

Haris, A., Abdullah, Bakhtiar, Subaedah, Aminah, Kamaruzzaman, J. (2013). Gamma ray radiation mutant rice on local aged dwarf, *Middle East J. Sci. Res.* 15(8): 1160-1164.

IAEA (1977). Technical Reports Series No 119: Manual on mutation breeding, Second Edition IAEA, Vienna.

Lee, Y.I., Lee, I.S. and Lim, Y.P. (2002). Variation in seed potato regenerates from gamma rays irradiated embryogenic callus, *J. Plant Biotech*. 4: 163-170.

Long, S., Zhu, X., Naidu, S. and Ort, D. (2006). Can improvement in photosynthesis increase crop yields, *Plant Cell Environ.* 29: 315-330.

Nwachukwu, E.C., Mbanso, E.N.A. and Nwosu, K.I. (2009). The development of new genotypes of the white yam by mutation induction using yam mini-tubers. In induced plant mutations in the genomics era, Food and Agriculture Organization of the United Nations (FAO), Rome, pp: 309-312.

Sheikh, S.A., Wani, M.R., Lone, M.A., Tak, M.A. and Malla, N.A. (2012). Sodium azide induced biological damage and variability for quantitative traits and protein content in wheat (*Triticum aestivum* L.), *J. Plant Genomics* 2(10): 34-38.

Tanaka, A., Kawano, K., and Yamaguchi, J. (1966) Photosynthesis, respiration and plant type of the tropical rice plant, International Rice Research Institute (IRRI), *Tech. Bull*. 7, 46 pp.

Yoshida, S. (1981). Fundamentals of rice crop science. Physiological analysis of rice, International Rice Research Institute 226-237.