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Impact of gamma irradiation on sweet potato [*Ipomoea batatas* (L.) Lam.] CV. Gouri

Manish Kalal, RS Rathore and Laxman Jat

Abstract

This study aimed to evaluate the effect of γ-irradiation on growth, yield and quality parameters and induce variability in sweet potato [*Ipomoea batatas* (L.) Lam.] cv. Gouri. The experiment was carried out during the Kharif season of 2017 and 2018. The cuttings were irradiated with gamma rays (15, 30, 45, 60, 75 and 90 Gy) and sown in the field. Untreated cuttings were served as control. Various vegetative parameters like vine length, number of leaves, leaf width, above ground dry weight per plant, tuber diameter, dry matter content in tuber and harvest index were observed during the study period. The results suggested that vegetative parameters such as vine length at 30 and 60 days, no. of leaves, harvest index, tuber diameter, above ground dry weight were recorded lowest in irradiated plants over the control. Finally we concluded that gamma irradiation significantly affected the vegetative attributes and showed a decreasing trend by increasing the irradiation dose level.

Keywords: Gamma irradiation, Gouri, vine, sweet potato

Introduction

Sweet potato [*Ipomoea batatas* (L.) Lam.] is a popular starchy food crop in tropical and subtropical regions that is used as row, food, and feed material globally. Carbohydrates, vitamins, and protein are abundant in sweet potato tubers. Sweet potato is a tuber crop that grows vegetatively in the dicot family Convolvulaceae. Sweet potato originated from hexaploid species namely *Ipomoea trifida* and has the chromosomal number 2n=6x=90 (Wang *et al.*, 2011) [12]. An *Ipomoea* genus has 400 species and mostly is tropical origin. It has high yield potential and the ability to grow in a wide range of environments (Wang *et al.*, 2011) [12]. Sweet potato is also a raw material for generating bio-energy (Zang *et al.*, 2009) [13]. In India, sweet potato has cover 1.31 lakh hectare areas and produces 15.00 lakh tonnes tubers, with the productivity of 11.32 metric tonnes per hectare. The major sweet potato growing states are Orissa, Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, Karnataka, and Rajasthan (Anonymous, 2018) [1]. Sweet potato is a highly heterozygous and cross-pollinated crop with ongoing diversity in several aspects. Traditional breeding approaches for sweet potato plant improvement have several limitations. Sweet potato's self- and cross-incompatibility limits the use of genetic resources and makes cross breeding challenging for breeders. Because the species is very heterozygous, there is a great deal of variation within it (Gupta *et al*., 2018) [5]. Because sweet potato is a clonally propagated crop, mutation breeding may be employed as a primary strategy in crop development. Mutation occurs as a result of a random alteration in the DNA or cytoplasm organelles caused by gamma irradiation. Induced mutagenesis is a well-established approach for plant improvement in which plant genes are changed by treating plant parts or seeds with a physical mutagen (Shu, 2009) [9]. Hence, we studied the mutagenesis effect of gamma irradiation on morphological and yield attributes of sweet potato [*Ipomoea batatas* (L.) Lam.].

Materials and Methods

Experimental site

During the Kharif season of 2017 and 2018, we performed the experiment at the AICRP of Tuber Crops experimental field, Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, which is in the southern portion of Rajasthan. This is located at an elevation of 582.17 metres above mean sea level, 24º35' N latitude, and 74°42' E longitude in agro-climatic zone IVa, i.e., Rajasthan's "Sub-humid Southern Plain and Aravalli Hills."

The climate in this zone is semi-arid and subtropical, with warm winters and mild summers, as well as high relative humidity from July to September.

Experimental set-up

We treated sweet potato (cv. "Gouri") vines free from disease-free with gamma irradiation. Treated cuttings directly transfer to the field in M_1 generation. We brought the cuttings from the M_1 generation and used them as planting material in the M_2 generation. All the treated cutting used triplicates under Randomized Block Design (RBD) experiment.

Mutagenesis

We took sweet potato cuttings (20-25 cm length) of Gouri cultivar for experiment. Twenty cuttings per treatment were treated in triplicates and sown in prepared fields at a spacing of 30 cm × 30 cm in plots. The untreated cuttings were as a control. Leaves of the 20 cuttings per treatment were removed and submitted to gamma irradiation treatment at 15, 30, 45, 60, 75, and 90 Gy. Irradiation was performed using a source of cobalt^{60} (Gamma cell 220, Atomic Energy of Canada Pvt. Ltd) at the Nuclear Agriculture and Biotechnology Division, Baba Atomic Research Center, Mumbai.

Methodology used for recording observations

Vine length was measured on 30 and 60 days by using measuring scale. Number of fully emerged leaves were counted and expressed as number of leaves per plant at 30 and 60 days. Width of the fully opened leaf was measured with a measuring scale at 120 days after planting and expressed in centimetre. Vines of randomly labelled plants were air dried for 24 h and then dried in hot air oven for 24 h at 65 ºC to a constant weight. The dried sample was weighed on an electric balance and average dry weight was recorded. Tuber diameter was measured in centimetres using "Verneer Calipers" from three different locations on the tuber and averaged. Ratio between net tuber weight and gross weight of plant was calculated and recorded in term of the following formula: -

$$\text{Harvest index} = \frac{\text{Tuber yield per plant}}{\text{Gross weight of plant}} \times 100$$

The tuber from randomly selected plant were washed and rasped. The rasped tuber was air dried for 24 hour and then oven dried at 65 ºC for 24 hour. The dry tuber weight was weighed and average weight was recorded.

Result and Discussion

Vine length at 30 and 60 days (cm)

The effect of gamma irradiation on vine length was recorded during M_1 and M_2 generations. In M_1 generation the vine length was significantly affected by gamma irradiation treatment at 30 DAP (Table 1). The maximum vine length (59.20 cm) was recorded in control followed by (34.90 cm) in 15 Gy and (32.60 cm) in 30 Gy. Whereas, the minimum vine length (16.10 cm) was observed in 90 Gy. During M_2 generation the maximum vine length (62.30 cm) was recorded in control followed by (58.60 cm) in 15 Gy and (56.40 cm) in 30 Gy. However, minimum vine length (50.50 cm) was recorded in 90 Gy at 30 DAP. While, at 60 DAP minimum vine length (135.40 cm) was observed in 90 Gy and maximum vine length (158.56 cm) was again recorded in control followed by (152.30 cm) in 15 Gy and (148.50 cm) in 30 Gy. Vine length (cm) at 60 days influenced by different gamma irradiation doses (15-90 Gy). Maximum vine length (137 cm) was obtained in the control at 60 DAP, followed by (78.80 cm) in the 15 Gy. In contrast, the minimal vine length (38.10 cm) was measured in 90 Gy. During M_2 generation, the minimal vine length (135.40 cm) was seen in 90 Gy, while the maximum vine length (158.56 cm) was observed in control, followed by (152.30 cm) in 15 Gy. The reduction in the number of cells due to injury to the shoot apex, the internodes and auxin breakdown, interference in normal mitosis and mitotic aberrations, failure of assimilatory mechanisms, increasing plant growth inhibitor, and reduction of auxin synthesis in the vine might be the cause of the reduction in vine length of sweet potato with increasing doses of gamma irradiation (Fadli *et al*., 2018) [4]. The main causes of plant growth decrease are chromosome damage and cell division inhibition in sweet potato as observed by Asare and Akama, (2014) [2] are validate the results of this study.

Number of leaves per vine at 30 and 60 days

We recorded the influence of gamma irradiation on a number of leaves per plant during M_1 and M_2 generations (Table 1). In M_1 generation the maximum number of leaves (16.40) was recorded in control followed by (10.30) in 15 Gy and (9.80) in 30 Gy. Whereas, the minimum number of leaves (4.50) was observed in 90 Gy at 30 DAP. During M_2 generation the maximum number of leaves (18.50) was observed in control followed by (17.70) in 15 Gy and (17.20) in 30 Gy. However, minimum number of leaves was recorded in 90 at 30 DAP. Gamma irradiation doses significantly affected the number of leaves per plant (15-90 Gy). At 60 DAP maximum number of leaves (26.40) was recorded in control followed by (19.50) in 15 Gy. Whereas, minimum leaves (10.25) were recorded in the treatment 90 Gy. During M_2 generation, the maximum number of leaves at 60 DAP minimum number of leaves (25.80) was observed in 90 Gy. Maximum number of leaves (35.50) was recorded in control followed by (34.20) in 15 Gy. It might be because gamma irradiation affects cell components, chromosomal, and genetic damage caused in dividing cells and reducing cell division. All this cause vegetative growth inhibition and reduces the number of leaves. The present investigation agreed with Nwachukwu *et al*. (2014) [6] in white yam and Tirkey *et al*. (2019) [11] in gladiolus.

Leaf width

The response of gamma irradiation on leaf width was recorded during M_1 and M_2 generation presented in Table 2. The leaf length was significantly affected by gamma irradiation doses (15-90 Gy). The maximum leaf width (9.31cm) was observed in control, followed by (8.32 cm) in 15 Gy and (7.80 cm) in 30 Gy. Moreover, minimum leaf length (5.80 cm) was recorded in 90 Gy during M_1 generation. During M_2 generation minimum leaf length (6.90 cm) was observed in 90 Gy. While, maximum leaf length (9.80 cm) was recorded in control followed by (8.74 cm) in 15 Gy and (8.26 cm) in 30 Gy. Leaf length was decreasing with increasing dose of gamma irradiation due to reduced level of endogenous growth hormones, such as cytokinin's, as a result of breakdown or lack of synthesis (Sharavani *et al*., 2019) [8] in tuberose and (Taheri *et al*., 2014) [14] in *Curcuma alismatifolia*.

Above ground dry weight per plant (g)

It is explicit from data presented in Table 2 that dry weight per plant (above ground) of sweet potato found significant for various gamma irradiation doses (15-90 Gy) during M_1 and M_2 generation. The maximum dry weight (246.11 g) was observed in control, followed by (184.04 g) in 15 Gy and (150.06 g) in 30 Gy. While, minimum dry weight (48.06 g) was recorded in 90 Gy during M_1 generation. The treatment 90 Gy was found at par with treatment 75 Gy in M_1 generation. During M_2 generation maximum dry weight of sweet potato (272.05 g) was again recorded in control followed by (256.17 g) in 15 Gy and (234.06 g) in 30 Gy. While, minimum dry weight (190.15 g) was observed in 90 Gy. Reduction in vegetative growth due to changes in auxin level or due to in activation of auxin or inhibition of auxin synthesis so that decrease in vegetative growth and it is associated with dry matter of sweet potato plant. Higher dose of gamma irradiation inhibited dry weight of turmeric recorded by (Ilyas and Naz, 2014) [15] in turmeric and (Sharavani *et al.*, 2019) [8] in tuberose.

Tuber diameter (cm)

Result regarding the effect of gamma irradiation on tuber diameter was observed in sweet potato during M_1 and M_2 generation and presented in Table 2. The tuber diameter was significantly affected by gamma irradiation doses (15-90 Gy) during M_1 and M_2 generation. The maximum tuber diameter (5.24 cm) was recorded in control followed by (5.01 cm) in 15 Gy and (4.55 cm) in 30 Gy. Moreover, minimum tuber diameter (3.02 cm) was observed in 90 Gy treatment during M_1 generation. In M_2 generation maximum tuber diameter (5.30 cm) was recorded in again control followed by (5.18 cm) in 15 Gy and (5.11 cm) in 30 Gy. While, minimal tuber diameter (4.87 cm) was observed in 90 Gy treatment. This may be due to decrease in photosynthetic activity which decrease the dry matter production, which lead to decrease in diameter. Similar findings were observed by Devi *et al.* (2019) [3] in gladiolus and Asare and Akama (2014) in sweet potato.

Harvest index (%)

Different doses of gamma irradiation significantly affect the harvest index of sweet potato in M_1 and M_2 generation depicted in Table 2. The highest harvest index (52.56%) was observed in control followed by (50.27%) in 15 Gy and (48.57%) in 30 Gy. However, lowest harvest index (42.70%) was recorded in 90 Gy during M_1 generation. During M_2 generation maximum harvest index (54.45%) was recorded in control followed by (51.32%) in 15 Gy and (50.58%) in 30 Gy. While, minimum harvest index (47.34%) was observed in 90 Gy. The treatment 90 Gy was at par with treatment 75 Gy in M_1 generation and the treatment 15 Gy was at par with control. The reduced harvest index after high doses seems indicative of a retarded tuber initiation or of later maturing. Similar result was recorded by Rahimi and Bahrani (2011) [10] in wheat.

Dry matter content in tuber (%)

The data with regard to dry matter content in sweet potato tuber was found significantly during M_1 and M_2 generation were presented in Table 2. There were significantly differences on dry matter content among treatment in M_1 generation. The maximum dry matter content in tuber (27.03%) was recorded in control followed by (26.05%) in 15 Gy and (23.83%) in 30 Gy. While, minimum dry matter in tuber (20.75%) was observed in 90 Gy treatments. In M_2 generation maximum dry matter in tuber (26.27%) was recorded again in control followed by (24.96%) in 15 Gy and (24.70%) in 30 Gy. While, minimum dry matter content in tuber (21.24%) was observed in 90 Gy treatment. Effect of gamma irradiation was based on the contact of atoms in the cell, mostly with H_2O to make free radicals. Plant cell can be damage by radical's important components have been reported to affect differently the morphology, biochemistry, anatomy and physiology of plants differently depending on the level irradiation. These effects include changes in plant cellular structure and metabolism, both of which reduce the dry matter content (Kebeish *et al.*, 2015) [7] in garlic.

Table 1: Effect of gamma irradiation on vine length at 30, 60 days, number of leaves at 30, 60 days and days of sweet potato cv. Gouri

Dose	Vine length (30d)		Vine length (60 d)		No. of leaves (30 d)		No. of leaves (60 d)	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Control	59.20	62.30	137.00	158.56	16.40	18.50	26.40	35.50
15 Gy	34.90	58.60	78.80	152.30	10.30	17.70	19.50	34.20
30 Gy	32.60	56.40	70.00	148.50	9.80	17.20	18.70	32.90
45 Gy	25.50	55.75	58.83	145.38	8.60	16.80	17.40	32.50
60 Gy	21.57	53.20	45.53	142.70	6.20	16.30	15.30	28.50
75 Gy	19.47	52.10	42.83	138.60	5.60	16.00	12.20	26.52
90 Gy	16.10	50.50	38.10	135.40	4.50	15.50	10.25	25.80
S.Em±	0.942	1.088	3.700	4.330	0.147	0.305	0.321	0.737
$P \geq 0.05\%$	2.901	3.351	11.399	13.342	0.453	0.940	0.989	2.270
C.V.%	5.45	3.39	9.52	5.14	2.90	3.14	3.25	4.14

Table 2: Effect of gamma irradiation on leaf width, above ground dry weight, tuber diameter, harvest index and dry matter content in tuber of sweet potato cv. Gouri

Dose	Leaf width (cm)		Above ground dry weight (g/vine)		Tuber diameter (cm)		Harvest index (%)		Dry matter content in tuber (%)	
	M_1	**M_2**	**M_1**	**M_2**	**M_1**	**M_2**	**M_1**	**M_2**	**M_1**	**M_2**
Control	9.31	9.80	246.11	272.05	5.24	5.30	52.56	54.45	27.03	26.27
15 Gy	8.32	8.74	184.06	256.17	5.01	5.18	50.27	51.32	26.05	24.96
30 Gy	7.80	8.26	150.06	234.06	4.55	5.11	48.57	50.58	23.83	24.70
45 Gy	7.70	7.84	126.08	216.07	3.87	5.00	47.64	50.01	23.01	23.23

60 Gy	7.40	7.71	92.06	204.13	3.53	4.98	46.76	49.07	22.54	22.72
75 Gy	6.60	7.27	64.03	196.05	3.24	4.96	45.80	47.83	21.33	21.89
90 Gy	5.80	6.90	48.06	190.15	3.02	4.87	42.70	47.34	20.75	21.24
S.Em±	0.218	0.223	5.507	9.420	0.081	0.085	0.788	0.663	0.773	0.657
$P \geq 0.05\%$	0.670	0.688	16.968	29.027	0.251	0.263	2.429	2.041	2.382	2.025
C.V.%	4.98	4.79	7.33	7.28	3.46	2.93	2.86	2.29	5.70	4.83

Conclusion

The study results concluded that the growth parameters (vine length, number of leaves, leaf width, above ground dry weight per plant, tuber diameter, dry matter content in tuber and harvest index) was significantly affected by gamma irradiation doses. The growth parameters like vine length (cm), number of leaves and leaf width were significantly decreased as gamma irradiation doses increased. The number of leaves plant^{-1} significantly reduced with the increased doses of gamma rays during both the generations. Above ground dry weight, tuber diameter, dry matter content in tuber and harvest index was reduced with the increased doses of gamma rays.

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