Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(6): 1660-1663
Received: 09-09-2019
Accepted: 11-10-2019

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Induction of mutations for morphological and yield parameters in ginger (*Zingiber officinale* Rosc.) during vM_1 generation

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Abstract
An experiment was conducted to access the influence of physical and chemical mutagens on plant growth and yield of ginger (*Zingiber officinale* Rosc.) local variety Mahim in vM_1 generation. The experiment was conducted at Main garden, Department of Horticulture, Dr. PDKV, Akola, during 2016-17. The ginger rhizomes were irradiated with gamma rays at 0.5, 0.75, 1.00 and 1.25 kR and EMS concentrations at 0.5%, 0.75%, 1.00% and 1.25% along with control (untreated) respectively. The treatment of rhizomes to both gamma rays and EMS showed reduction in growth and yield parameters like plant height, no. of leaves, no. of tillers, days to maturity, yield plant^{-1}, yield plot^{-1} and yield ha^{-1}.

Keywords: Mahim, gamma rays, EMS, vM_1, plant height, no. of tillers, yield.

Introduction
Ginger (*Zingiber officinale* Rosc.) a member of the family Zingiberaceae is an important tropical horticultural perennial herbaceous monocotyledon, (usually grown as annual) is known to human generations as a medicinal and spice crop (Kandiannan *et al*., 1996) [12]. The whole plant is refreshingly aromatic and the underground rhizome, raw or processed, is valued as spice. Ginger is a slender perennial herb, 30-50 cm tall with palmately branched rhizome bearing leafy shoots. The leafy shoot is a pseudostem formed by leaf sheath and bears 8 to 12 distichous leaves. The economic part is the underground rhizome, which is pungent and aromatic. Fresh ginger, dry ginger powder, oleoresin and oil are used in food processing. Ginger has been considered indispensable in the culinary art for flavoring of foods. India is a leading producer of ginger in the world and during 2016-17 the country produced 1081.40(‘000 MT) of the spice from an area of 164.70(‘000 hectares) and 6.5 MT/HA productivity (source: Anon., 2017) [1]. Ginger is cultivated in most of the states in India. The leading states in area wise, production and productivity are Assam, Assam and Gujarat with 18.70(‘000 Ha), 166.50(‘000 MT) and 15.46 MT/Ha respectively (source: Anon., 2017) [1]. The contribution of Maharashtra in ginger production is 8.50(‘000 Ha) area with 125.50(‘000 MT) production and 14.76 MT/HA productivity (source: Anon., 2017) [1]. The major drawbacks of Indian ginger are its high fibre content, high cost of production and susceptibility to various diseases. Hence development of high yielding varieties possessing low fibre content, high volatile oil and oleoresin assumes importance from the point of view of export. However breeding of ginger is seriously handicapped by poor flowering and seed set (Giridharan and Balakrishnan, 1992) [6, 7]. The Most crop improvement programmes of this species are confined to evaluation and selection of naturally occurring variations. Mutation induction has become a proven way of creating variation within a crop variety. It offers the possibility of inducing desired attributes that either cannot be expressed in nature or have been lost during evolution (Novak and Brunner, 1992) [14]. In non-seed setting vegetatively propagated crops like ginger mutation breeding is one of the methods of creating genetic variability which could be used for subsequent improvement.

Materials and Method
The ginger rhizomes were irradiated with gamma rays at 0.5, 0.75, 1.00 and 1.25 kR in the Bhabha Atomic Research Centre (BARC), Trombay, Mumbai, Maharashtra, India. Rhizomes were presoaked in EMS concentrations at 0.5%, 0.75%, 1.00% and 1.25% for 4 h. The treated rhizomes were immediately sown in poly bags along with control and later transplanted in main field at 60 days after sowing. The experiment was laid out in Randomized Block Design (RBD) with three replications.

Results and Discussion

1. Plant height (cm)

The data on plant height (cm) were recorded at 60, 90 and 120 DAT. At 60 DAT, the significantly maximum plant height was recorded in treatment T_2 (44.85 cm), followed by the treatments T_3 (37.46 cm) and the minimum plant height was recorded in T_5 (22.38 cm), whereas at 90 DAT, the significantly maximum plant height was recorded in treatment T_2 (48.28 cm) followed by the treatments T_3 (41.82 cm) and the minimum plant height was recorded in T_5 (26.08 cm). At 120 DAT the significantly maximum plant height was recorded in treatment T_2 (51.16 cm), followed by the treatments T_3 (46.88 cm) and whereas the minimum plant height was recorded in T_5 (32.75 cm). There was a stimulatory effect of gamma rays at lower doses on increased plant height over control plants during vM_1 generation. The more concentration and higher dose of mutagen causes more damage to the genetical constitution of plant, therefore with increase dose of physical or chemical mutagens decreases the height of the plants. The destruction or damage to apical meristems or partial failure of the internodes to elongate so as to result in decreased number of proliferating cells. The height reduction with increase in dose may be interpreted in cytological, physiological, biochemical and anatomical viewpoints such as auxin destruction, interference in normal mitosis and mitotic aberrations, failure of assimilatory mechanisms, production of diffusible growth retarding substance, inhibition of auxin synthesis, inhibition in the rate of assimilation and consequent changes in the nutrient level of plants, changes in the specific activity of enzymes and delay in the onset of first mitosis. Low doses of ionizing radiation induce hermetic or hormesis effects which alter photosynthesis, stimulation of growth and other physiological processes. The chromosomal damage and inhibition of cell division are the chief causes of reduced seedling growth. The inhibition in seedling growth might be due to the gross injury caused at cellular level either due to gene controlled biochemical processes or acute chromosomal aberrations or both. A similar line of research work had been documented by Gupta *et al.*, (1982) [8] in Costus, Giridharan (1984) [5] in ginger, Nwachukwu *et al*., (1990) [15] in yams and Velu *et al*., (2012) [21] in cluster bean.

2. Number of leaves plant^{-1}

The data on number of leaves plant^{-1} were recorded at 60, 90 and 120 DAT. The significantly maximum number of leaves plant^{-1} at 60 DAT was recorded in treatment T_1 (20.53), followed by the treatments T_2 (19.13) and the minimum number of leaves plant^{-1} was recorded in T_5 (12.93). At 90 DAT, the significantly maximum number of leaves plant^{-1} was recorded in treatment T_1 (24.67) followed by the treatments T_2 (22.20) and the minimum number of leaves plant^{-1} was recorded in T_5 (15.47) whereas at 120 DAT, the significantly maximum number of leaves plant^{-1} was recorded in treatment T_1 (28.40), followed by the treatments T_2 (25.53) and the minimum number of leaves plant^{-1} was recorded in T_5 (17.87) followed by the treatments T_9 (18.80). With increase in the doses of irradiation and EMS, proportionate reduced height of the plant, might be contributory factors for reduction in the leaf characters. It may also be due to the direct effect of the gamma rays and EMS on the growing points.

Table 1: Effect of gamma rays and EMS on plant height, no. of leaves and no. of tillers of ginger in vM_1 generation.

Treatments	plant height (cm)			No. of leaves			No. of tillers
	60 DAT	90 DAT	120 DAT	60 DAT	90 DAT	120 DAT	120 DAT
T_1 - Control	34.27	39.47	44.60	20.53	24.67	28.40	3.67
Physical mutagen (Gamma rays)							
T_2 - 0.5 kR	44.85	48.28	51.16	19.13	22.20	25.53	7.40
T_3 - 0.75 kR	37.46	41.82	46.88	17.93	19.80	22.60	7.47
T_4 - 1.00 kR	33.07	37.12	40.66	13.00	16.53	19.80	6.47
T_5 - 1.25 kR	22.38	26.08	32.75	12.93	15.47	17.87	4.47
Chemical mutagen (Ethyl methane sulphonate)							
T_6 - 0.5 % EMS	31.37	35.85	39.46	16.13	18.93	22.67	5.20
T_7 - 0.75 % EMS	30.17	33.95	37.81	15.00	17.93	20.93	3.07
T_8 - 1.00 % EMS	27.69	31.41	35.28	14.07	16.67	19.07	5.53
T_9 - 1.25 % EMS	27.18	30.67	33.82	13.67	15.60	18.80	5.60
F test	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE(m)$\pm$	1.51	1.38	1.55	0.47	0.58	0.82	0.67
CD at 5%	4.57	4.18	4.70	1.43	1.75	2.48	2.04

Some of the growing points depending upon the physiological and developmental stages might have been killed or inactivated by dose of gamma rays and EMS toxic to them and hence reduction in number of leaves were observed at higher doses. In the cells of growing shoot, mitotic and meiotic aberrations occur during mutation which may cause inhibitory effect on growth rate. Inhibition of vegetative growth may be due to radiation effect on the chromosomal material, genetic injury induced in dividing cells and deficiency of some physiological pre requisite to cell division. The present investigation also is in agreement with the earlier work of Gupta *et al.*, (1982) [8] who observed that gamma irradiation caused reduction in leaf production, Giridharan (1984) [5] indicated a reduction in leaf production as a result of radiation treatments in ginger. Nwachukwu *et al*., (1994) [16] stated that number of leaves decreased by increased doses of gamma rays in ginger. In a similar way, in a study conducted on cluster bean species by Velu *et al*., 2012 [21], it was observed that an increase in both gamma rays and EMS dose led to the decrease in leaf number. These results are also in accordance with findings of Choudhary and Dnyansagar (1980) [4] in garlic, Jayachandran and Mohankumaran (1992) [11] in ginger, Ramakrishna (2006) [18] in turmeric, Aruldoss and Mullainathan (2014) [2] in chilli and Priya *et al*., (2014) [17] in turmeric.

3. Number of tillers plant^{-1}

The significantly maximum number of tillers plant^{-1} at 120 DAT were recorded in treatment T_3 (7.47), followed by the treatments T_2 (7.40) and the minimum number of tillers plant^{-1} was recorded in T_7 (3.07). There was stimulatory effect of gamma rays and EMS on the production of tillers, as the dose of gamma rays increased upto certain level. Tillering was the highest in the treatment 0.75 kR followed by 0.5 kR. The mutagenic treatments exhibited greater number of tillers than the other control. The increase in the number of tillers at gamma rays and EMS in the present study may be due to the direct effect of radiation treatments on the growing points which are responsible for tiller production. The increase in vegetative growth occurred not by direct stimulation but as a consequence of radiation injury elsewhere in the plant. It was likely that increased tillering was initiated by the damage to the primary growth meristems. The similar findings of increased tillers are reported by Gupta *et al.* (1982) [8] in costus and Giridharan (1984) [5] in ginger.

4. Days to maturity

The significantly maximum days to maturity was recorded in treatment T_2 (230.07 days), followed by the treatments T_1 (219.00 days) and whereas the minimum days to maturity was recorded in T_9 (168.07 days). Varied response for days to maturity was noticed in respect of different doses of gamma rays and EMS. Days to maturity was found to be early in all mutagenic treatments during both the generations except the T_2 treatment during vM_1 generation. Earliness in maturity may be attributed to the triggering of metabolic activities by the lower doses of gamma rays. The triggering of metabolism would have resulted in diverting the source – sink relationship and thereby breaking the vegetative phase in an advanced phase. The physiological damage of the gamma rays and EMS is generally more in the initial stages of plant growth than at the later stages. The induction of mutation generally occurs necessarily when DNA synthesis and chromosomal reproduction are progressing. Matured cells or differentiated cells are incapable of responding to mutagenic treatments. This is in concordance with the earlier reports of Jayachandran (1989) [10] in ginger, Chezhiyan and Shanmugasundaram (2000) [3] isolated short duration variety BSR-2 turmeric and Usha Nandini Devi and Chezhiyan (2007) [20] in turmeric.

Table 2: Effect of gamma rays and EMS on days to maturity, yield plant^{-1} (g), yield plot^{-1} (kg) and yield hectare^{-1} (t/ha) of ginger in vM_1 generation

Treatments	Days to maturity	Yield plant^{-1} (g)	Yield plot^{-1} (kg)	Yield hectare^{-1} (t/ha)
T_1 – Control	219.00	299.61	14.98	19.01
Physical mutagen (gamma rays)				
T_2 - 0.5 kR	230.07	250.67	12.53	15.91
T_3 - 0.75 kR	211.73	203.63	10.18	12.92
T_4 - 1.00 kR	193.80	186.83	9.34	11.86
T_5 - 1.25 kR	185.87	137.07	6.84	8.70
Chemical mutagen (Ethyl methane sulphonate)				
T_6 - 0.5 % EMS	201.60	221.67	11.08	14.07
T_7 - 0.75 % EMS	187.67	172.27	8.61	10.93
T_8 - 1.00 % EMS	174.87	152.80	7.64	9.69
T_9 - 1.25 % EMS	168.07	120.17	6.01	7.62
F test	Sig	Sig	Sig	Sig
SE(m)$\pm$	0.33	4.68	0.23	0.29
CD at 5%	0.99	14.51	0.71	0.89

5. Yield of rhizomes plant^{-1} (g), Yield plot^{-1} (kg) and Yield hectare^{-1} (tonnes)

The significantly maximum yield plant^{-1} of ginger was recorded in treatment T_1 (299.61 g) followed by the treatments T_2 (250.67 g), whereas the minimum yield plant^{-1} was recorded in T_9 (120.17 g) followed by the treatments T_5 (137.07 g) and T_8 (152.80 g). The significantly maximum yield plot^{-1} of ginger was recorded in treatment T_1 (14.98 kg) followed by the treatments T_2 (12.53 kg) and whereas the minimum yield plant^{-1} was recorded in T_9 (6.01 kg). The significantly maximum yield hectare^{-1} of ginger was recorded in treatment T_1 (19.01 t/ha) followed by the treatments T_2 (15.91 t/ha), whereas the minimum yield hectare^{-1} was recorded in T_9 (7.62 t/ha).

The yield per plant, per plot and per hectare decreased as the dose of gamma rays and EMS increased. Reduction in yield may be due to reduced plant growth, leaf number. Increased dose adversely affected leaf production and height of the plant especially during the early stages of growth. As the growth period advanced, the plants could more or less recover from the adverse effect noted during early stages in respect of the above characters. However, the recovery of growth parameters achieved during the later stages of growth did not appear to have sufficient contribution to the rhizome development even though the number of tillers increased. This might be the reason for low yield irrespective of the fact that the plants could recover from the shock of mutagenic treatments later in their growth period. Gamma rays doses affecting the plant cell on a cellular level leaves a wide impact in minimizing the plant development that reduces the yield. The yield per plant decreased as the dose of gamma rays and EMS increased. The reason for reduction in yield in higher concentrations of EMS and gamma rays may be due to high disturbance in genome architecture of cell which might have resulted in physiological disturbances, chromosomal damage, and failure or restricted pairing, delay in DNA synthesis. The reason for the increased yield in lower concentrations may be attributed to the enhancing effect and growth regulatory effect of mutagen. The Similar line of research work of reduced yield by increased doses of gamma rays and EMS was also reported by Jayachandran (1989) [10] in ginger, Neopaney (1994) [13] in ginger, Usha Nandini Devi and Chezhiyan (2006) in turmeric and Jadhav *et al*., (2013) [9] in okra.

Conclusion

The results of the present study indicate that both the gamma rays and EMS found be to effective mutagens for mutagenesis of ginger.

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