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Mutagenic effectiveness and efficiency of gamma rays and ems on chilli (*Capsicum annum* L.)

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Abstract
The present investigation was carried out to find the efficiency and effectiveness of various mutagenic treatments of gamma rays and EMS on chilli var. Kashi Anmol. An experiment was conducted during winters of 2017-18 and 2018-19 at Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The experimental design was randomized block design. Treatments include one control, five doses of gamma rays (10 kR, 20 kR, 30 kR, 40 kR and 50 kR), five doses of EMS (10 mM, 20 mM, 30 mM, 40 mM and 50 mM) and their combinations (gamma rays 10 kR + 20 mM EMS, gamma rays 20 kR + 20 mM EMS, gamma rays 30 kR + 20 mM EMS, gamma rays 40 kR + 20 mM EMS and gamma rays 50 kR + 20 mM EMS). The observations revealed that plant lethality, pollen sterility and ovule sterility percentage increased with the increasing doses of gamma rays, EMS and their combinations. The gamma rays 10kR (0.072) was observed to be most effective, followed by EMS and combination treatments. The mutagenic efficiency calculated in M_2 Population on the basis of lethality, sterility and injury with respect to induced morphological mutations revealed variations depending upon the criteria selected for its estimation. As the efficiency was analysed based on lethality per cent, the highest mutagenic efficiency was observed for 10 kR + 20 mM (0.192). When the efficiency was assessed with reference to pollen sterility percentage, the maximum mutagenic efficiency was observed for 30kR (0.118). The higher doses of both mutagen lead to lethal injury and sterility.

Keywords: Chilly, EMS ethyl methane sulphonate, gamma rays, pollen sterility

Introduction
Chilli (*Capsicum annum* L.) is considered as one of the most important commercial spice crops and is widely used universal spice, named as wonder spice. Different varieties are cultivated for varied uses like vegetable, pickles, spice and condiments. It is an indispensable item in the kitchen, as it is consumed daily as a condiment in one form or the other. Among the five cultivated genus of the *Capsicum*, *C. annuum* is most widely cultivated in India and an important commercial spice and vegetable crop for small and marginal farmers (Reddy *et al*., 2014) [10]. At present people are much concerned about the fruit quality and yield. Therefore, attention is being paid for development of genotypes having high yield potential with desirable fruit quality characters in a short period of time (Meghvansi *et al*., 2014) [9]. The genetic variability for several desired characters can be induced successfully through mutations and its practical value in plant improvement programme is well established (Gupta *et al*., 2018 and Tiwari *et al*., 2008) [6, 14]. Many physical and chemical mutagens have been used for induction of useful mutations in number of crops. Mutation is the ultimate source of all genetic variation and provides the raw material for evolution (Saba and Mirza, 2002) [11]. Among different mutagenic agents gamma irradiation and EMS had been used successfully with several Solanaceous crop for creating variability. The usefulness of a mutagen in mutation breeding depends not only on its mutagenic effectiveness (mutations per unit dose of mutagens), but also its mutagenic efficiency (mutation in relation to undesirable changes like sterility, lethality, injury, etc.). The selection of effective and efficient mutagens is very essential to recover a high frequency and spectrum of desirable mutations (Gupta *et al*., 2018) [6]. Gamma rays are commonly used in crop breeding programme because these are known for their single application, good penetration, reproducibility, high mutation frequency and less disposal problems.

Physical and chemical mutagens have opened up new era in chemical research. Mutation induction and selection methodology provides a viable additional option to plant breeders for creating useful genetic variability.

Mutagenic efficiency is the promotion of mutation in relation to other associated undesirable biological effects such as lethality, sterility and gross chromosomal amelioration induced by the mutagen. Mutagenic effectiveness is a measure of the frequency of mutations induced by a unit dose of mutagen. The utility of a particular mutagen depends on its efficiency as well as effectiveness. The mutagenic effect of a mutagen is an index of appropriate choice which is evaluated in terms of effectiveness and efficiency (Knozak *et al*., 1965) [8]. Keeping this in view, an investigation was undertaken to gather information on the response of chilli variety Kashi Anmol to assess the efficiency and effectiveness of mutagens, gamma ray and ethyl methane sulfonate (EMS).

Materials and Methods

The present investigation was carried out during winters of 2017-18 and 2018-19. Uniform and healthy seeds of chilli var. Kashi Anmol were selected for mutagenic treatment. 500 seeds of var. Kashi Anmol per treatment were irradiated with five different dosses of gamma rays *viz.*, 10 kR, 20 kR, 30 kR, 40 kR and 50 kR at NBRI (National Botanical Research Institute), Lucknow. For treatment with EMS, seeds of each treatment were first soaked in distilled water for 12 hours at room temperature and consequently dried with the help of blotting paper and finally emerged in ethyl methane sulphonate (EMS) at five different concentration i.e., 10 mM, 20 mM, 30 mM, 40 mM and 50 mM in phosphate buffer (pH 7.0) for 06 hours and then washed thoroughly in running tap water to eliminate the residual effect of the chemical. 500 seeds already eradiated with five different dosses (10kR, 20kR, 30kR,40kR and 50kR) of gamma rays, were treated with 20 mM EMS solution, followed by washing in running tap water in the similar manner as described above for EMS treatment. The experimental design was randomized block design and replicated thrice. The efficiency and effectiveness of different treatment were calculated following the methods suggested by Konzak *et al*. (1965) [8].

$$\text{Mutagenic effectiveness} = \frac{\text{Mutation frequency}}{\text{Dose or (time} \times \text{concentration)}}$$

$$\text{Mutagenic efficiency} = \frac{\text{Mutation frequency}}{\text{Biological damage}}$$

Results and Discussion

Mutagenic efficiency is the promotion of mutation in relation to other associated undesirable biological effects such as lethality, sterility and gross chromosomal amelioration induced by the mutagen. Mutagenic effectiveness is a measure of the frequency of mutations induced by a unit dose of mutagen. The utility of a particular mutagen depends on its effectiveness as well as efficiency (Konzak *et al*., 1965) [8].

The plants lethality, pollen sterility and ovule sterility percentage increased with the increase in doses of gamma ray, EMS and their combinations. The gamma ray 10kR (0.072) was observed to be most effective, followed by EMS and then the combination treatments. The mutagenic efficiency calculated in M_2 population on the basis of legality, sterility and injury with respect to induced morphological mutations revealed variation depending upon the criteria selected for its estimation. As the efficiency was analysed based on lethality percentage, the highest mutagenic efficiency was observed for 10 kR + 20 mM (0.192) and lowest for 10 kR (0.107). When the efficiency was assessed with reference to pollen sterility percentage, the maximum mutagenic efficiency was observed for 30 kR (0.118) and lowest for 30 kR+20mM (0.060). If analysis was done with reference to ovule sterility percentage, the maximum mutagenic efficiency was recorded for 40mM and 40 kR (0.57) whereas the minimum for 10 kR (0.025). The present finding was supported by Ichiro Honda *et al*. (2006) [7], Devi and Mullainathan (2011) [12] Daudu and Falusi (2011) [1], Gulfishan *et al.* (2012) [5] Devi and Selvakumar (2013) [13] and Gaur *et al*. (2014) [4]. The present results indicated that the mutagenic effectiveness decreased with the increasing dosses of gamma rays and combined treatments of both the mutagens. This was in agreement with the results obtained by Dhulgande *et al*. (2011) [2] and Gaur *et al.* (2015) [3]. This might be due the biological damage increased with the increase in doses at the rate greater than the frequency of mutation (Konzak *et al*., 1965) [8].

Mutagenic efficiency did not show a definite pattern for increase or decrease with increase in doses of gamma rays, EMS or treatment combinations. It was quite apparent that different mutagens could be of immense help in the recovery of large range of distinct mutant types and one can very well increase the mutation rate through the selective application of appropriate mutagen. The efficiency of mutagenic agents not only depends on the biological system but also on the physiological damage chromosomal aberrations and sterility induced in addition to mutation.

Table 1: Mutagenic effectiveness and efficiency of gamma rays, EMS and their combinations on Chilli var. 'Kashi Anmol'

	Biological damage				Effectiveness		Efficiency	
Mutagenic treatments	**Mutated families (Msf) %**	**Plant survival reduction %**	**Pollen sterility % (PS)**	**Ovule sterility % (OS)**	**Msf/dose**	**Msf/L**	**Msf/ps**	**Msf/OS**
Gamma Rays (kR)								
10	0.72	6.67	10.72	28.2	0.072	0.107	0.067	0.025
20	1.09	10.00	15.23	31.65	0.054	0.109	0.071	0.034
30	1.99	13.33	16.80	34.78	0.066	0.149	0.118	0.057
40	2.21	15.00	21.88	38.70	0.055	0.147	0.101	0.057
50	2.23	16.67	24.20	41.40	0.044	0.133	0.092	0.053
EMS (mM)								
10	1.53	8.33	13.46	32.80	0.015	0.183	0.113	0.046
20	1.53	11.67	17.58	35.34	0.076	0.131	0.087	0.043
30	1.94	11.67	20.80	38.65	0.064	0.166	0.093	0.050
40	2.47	13.40	22.88	42.40	0.061	0.184	0.107	0.057
50	1.78	10.00	24.40	44.20	0.035	0.178	0.074	0.040
Gamma Rays (kR) + EMS (mM)								
10	0.96	5.00	15.23	37.60	0.009	0.192	0.063	0.025

20	1.28	8.33	20.80	41.70	0.006	0.153	0.061	0.030
30	1.56	10.00	25.68	45.90	0.005	0.156	0.060	0.033
40	1.80	14.00	28.40	48.40	0.004	0.128	0.063	0.037
50	2.49	20.00	31.78	51.78	0.003	0.122	0.078	0.048

Conclusion

The results indicated that the mutagenic effectiveness decreased with the increasing dosses of gamma rays, EMS and combined treatments of the mutagens. Mutagenic efficiency did not show a definite pattern for increase or decrease with increase in doses of gamma rays, EMS or combined treatments.

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