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Effect of mutagens on quantitative characters in M_2 generation of castor (*Ricinus communis* L.)

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Abstract
The mutagenic effects of two different doses of gamma rays (500 and 750 Gy) on three castor (*Ricinus communis* L.) genotypes JP-94, JI-444 and GP-15-1 were investigated. The quantitative characters studied include; days to 50% flowering of primary raceme, days to maturity of primary raceme, plant height up to primary raceme, number of nodes up to primary raceme, length of primary raceme, effective length of primary raceme, number of effective branches per plant, number of capsules on primary raceme, shelling out turn, seed yield per plant, 100-seed weight and oil content. Both negative and positive shifts in mean values were recorded as a result of the physical treatments. The results indicate the possibilities of evolving higher yield variants through proper selection.

Keywords: Gamma rays, castor, quantitative characters, mean values, selection

Introduction
Castor (*Ricinus communis* L., 2n = 2x = 20) is an industrially important non-edible oilseed crop widely cultivated in the arid and semi-arid regions of the world (Govaerts *et al.*, 2000). Castor is a very ancient oilseed crop cultivated because of high oil content of the seeds, which ranges between 42 to 58%. The castor oil is unique in the sense that 84-90% of it is composed of a single fatty acid, i.e. *ricinoleic* acid. Castor oil has tremendous industrial value and is mainly utilized in the production of lubricants, greases, wax blends, plastics, nylon, hydraulic fluid, artificial leather etc. The refined oil also has a good domestic market as medicines and storage grains preservatives. The castor oil is different from other vegetable oils in the sense that it does not freeze even under adverse temperatures of -12 ºC to -18 ºC. It is, therefore, considered as the best lubricating agent particularly for both high speed engines and aeroplanes.

Induced mutagenesis is recognized as a potential tool for crop improvement. Mutants are produced by treating seeds, pollens or other plant parts by radiation or chemical. Such mutants are either directly released as varieties or used in breeding programme to improve existing cultivars. Mutations have played an important role in the crop evolution. Moreover, through mutagenic treatments new variants differing on morphological or quantitative characters are also produced. Thus, through this technique desired variability could be obtained with little alteration in whole genome.

Materials and Methods
Seeds of the castor (*Ricinus communis* L.) were treated with a ^{60}Co gamma cell 2.8 kR per minute at Bhabha Atomic Research Center, Trombay, Bombay. Basic experimental material consisted of three genotypes of castor *viz.*, JP-96, JI-444 and GP-15-1 obtained from the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat. The seeds were subjected to 500 and 750 Gy of gamma radiation. A set of unirradiated seeds of same lot of varieties were used as control. Treated seeds of castor were sown and plants were selfed and seeds collected from each plant separately. These seeds were sown in M_2 generation. M_2 generation was raised in a compact family block design with three replications. The experiment consisted of 9 treatments and 90 progenies. Ten plants were selected from each treatment of M_1 and ten seeds selected randomly from each progeny for rising M_2 generation in a plant to progeny method.

All the necessary plant production methods like irrigation and weeding were carried out during the period of crop growth and also measured the morphological and yield parameters *viz.*, days to 50% flowering of primary raceme, days to maturity of primary raceme, plant height up to primary raceme, number of nodes up to primary raceme, length of primary raceme, effective length of primary raceme, number of effective branches per plant, number of capsules on primary raceme, shelling out turn, seed yield per plant, 100-seed weight and oil content.

Results and Discussion

Quantitative characters in M_2 generations

In the present investigation, gamma radiations proved to be very effective to induce variability in quantitative traits in M_2 generations (Table-1).

Days to 50% flowering of primary raceme

In JP-96 mean value for days to 50% flowering was decreased in treated family as compared to control and early variants were observed in 500 Gy treatment (52.26). In JI-444 mean values was shifted in both the direction indicated presence of good variability. Early variants were observed in 750 Gy (54.10). In GP-15-1 mean values mostly shifted towards lateness in both the treatments. Late variants were observed in 750 Gy (65.03).

Mean values in regards to days to 50% flowering of primary raceme in castor had been shifted towards earliness in JP-96 and lateness in GP-15-1 due to radiation treatments. Same results were obtained by Ramani and Jadon (1991) [15]; Tshilenge *et al*. (2013) [19] and Gunasekaran and Pavadai (2015) [11] in groundnut and Ravichandran and Jayakumar (2015) [16, 17] in sesamum. Mean values shifted towards both directions in JI-444. Same results were obtained by Emrani *et al*. (2012) [8] in canola, Elangovan and Pavadai (2015) [11] in okra and Pavadai and Gopinath (2015) [11] in soyabean.

Days to maturity of primary raceme

In JP-15 mean number of the days to maturity of primary raceme for both the treatments is lower than control (140.66). Early variants were observed in 500 Gy (128.70) treatment. In JI-444 Lowest mean was observed in 500 Gy (142.63) treatment. Mean value for was decreased in treated family as compared to control and early variants were observed in 500 Gy (145.46) treatment followed by 750 Gy (148.60).

Values for mean days to maturity of primary raceme were lower than control in all the genotypes indicated early maturity of genotypes than control. This result was in confirmation with Abdullah *et al*. (2005) [1] in mustard and Emrani *et al*. (2012) [8] in canola.

Plant height up to primary raceme (cm)

In JP-96 short mutant was observed in 500 Gy treatment (52.88). Both the doses of mutagens effectively decreased the mean plant height as compared to control. In JI-444 the short variants were observed in 500 Gy treatment (50.74). In GP-15-1 short variants were observed in 750 Gy (76.44) and tall variants were observed in 500 Gy (83.06) treatment.

Mean values for plant height were shifted in both directions in JP-96 and GP-15-1 indicated good variability present for this character. Same results in mean value were obtained by Ankineedu *et al*. (1967) [2] in castor, Emrani *et al*. (2012) [8] in canola, Elangovan and Pavadai (2015) [11] in okra, Pavadai and Gopinath (2015) [11] in soyabean and Ravichandran and Jayakumar (2015) [16, 17] in sesamum. Mean values were less than control in mutagenic treatments and as dose increases plant height decreased in JI-444. This result was in accordance with Ankineedu *et al*. (1967) [2] in castor, Ramani and Jadon (1991) [15]; Sanjay *et al*. (1997) [18] and Gunasekaran and Pavadai (2015) [11] in groundnut, Gonge and Kale (1996) [9] in okra, Abdullah *et al*. (2005) [1] in mustard, Gvozdenovic *et al*. (2009) [12] in sunflower and Dhakshinamoorthy *et al*. (2010) [6] in jatropha.

Number of nodes up to primary raceme

In JP-96 lowest phenotypic mean was observed in 500 Gy (14.26) treatment as compared to control (16.37). In JI-444 both the doses of gamma rays effectively reduced the mean number of nodes up to primary raceme as compared to control (16.24) and lowest mean value was observed in 750 Gy (12.68) treatment. In GP-15-1 mean number of nodes was lower in both the treatments than control and lowest value was observed in 750 Gy (16.74) treatment.

The mean values for number of nodes up to primary raceme were decreased in both the treatments as compared to control. Similar results were obtained by Gonge and Kale (1996) [9] in okra.

Length of primary raceme (cm)

In JP-96 the mean value of length of primary raceme decreased due to radiation treatments. In JI-444 mean length of primary raceme was decreased with increased dosage and it was lower as compared to control (77.36). In GP-15-1 Mean value of the mutagenic treatment is lower than the control (77.33) and it was lowest in 750 Gy (73.98) treatment.

For length of primary raceme, mean values were decreased due to radiation treatment in all the three genotypes as compared to control. Same result was obtained by Gonge and Kale (1996) [9] in okra.

Effective length of primary raceme (cm)

In JP-96 the mean value of effective length of primary raceme decreased due to radiation treatments. In JI-444 Mean was decreased with increased dosage and it was lower as compared to control (77.36). In GP-15-1 treatment mean was shifted in both the directions in mutagenic treatments as compared to control (73.37).

Mean values for effective length of primary raceme were shifted in both directions in GP-15-1 indicated good variability present for this character. Same results for mean values were obtained by Deshmukh *et al*. (2018) [5] in sorghum. Mean values were less than control in JI-444 and JP-96. This result was in accordance with Gonge and Kale (1996) [9] in okra.

Number of effective branches per plant

In JP-96 mean values of the mutagenic treatments were lower than the control (8.71). In JI-444 the treatment mean values were lower in both the gamma rays treatments as compared to control (17.16). In GP-15-1 mean value was highest in control (13.33) than both the treatments.

The mean values for number of effective branches per plant were decreased in both the treatments as compare to control for all the three genotypes. Same results for mean values were obtained by Gonge and Kale (1996) [9] in okra and Avinash (2013) [4] in pea.

Number of capsules on primary raceme

In JP-96 mean values was shifted in both the direction indicated presence of good variability and it was highest in 500 Gy (89.86) treatment. In JI-444 mean value was decreased due to radiation treatments as compared to control (110.36). In GP-15-1 Maximum mean value (100.49) was observed in 500 Gy treatment and both the treatments had higher mean values than control.

Mean values for number of capsules on primary raceme showed bidirectional shifts in JP-96 and GP-15-1 indicated good variability was present for this character. Same results for mean values were obtained by Dakshinamoorthy *et al*. (2010) [6] in jatropha, Avinash (2013) [4] in pea, Emrani *et al*. (2012) [8] in canola and Tshilenge *et al*. (2013) [19] in groundnut. Mean value was less than control in JI-444. This result was in accordance with Gonge and Kale (1996) [9] in okra and Ravichandran and Jayakumar (2015) [16, 17] in sesamum.

Shelling out turn (%)
In JP-96 the mean shelling out turn increased in both the gamma rays treatments than control (48.69) and maximum value was recorded in 500 Gy (62.34). In JI-444 both the doses of mutation treatments effectively increased the mean shelling out turn as compared to control (61.54). In GP-15-1 highest mean value (51.9-71.9) was found in 750 Gy treatment and both treatments had higher mean than control.

Seed yield per plant (g)
In JP-96 mean value for seed yield per plant was decreased in treated family as compared to control. Mean value was less than control (486.09) in both the treatments. In JI-444 mean value for seed yield shifted in both the directions as compared to control. Highest mean value was observed in 750 Gy (393.82). In GP-15-1 control had highest yield variants than both the treatments.
The mean values for seed yield per plant were decreased in JP-96 and GP-15-1 for both the treatments as compared to control. Same results for mean value were obtained by Kumar *et al*. (1998) [13] in okra and Tshilenge *et al*. (2013) [19] in groundnut. Mean values showed bidirectional shifts in JI-444 indicated good variability for this character. This result was in accordance with Ankineedu *et al*. (1967) [2] in castor, Emrani *et al*. (2012) [8] in canola, Gunasekaran and Pavadai (2015) [11] in groundnut and Ravichandran and Jayakumar (2015) [16, 17] in sesamum.

100-seed weight (g)
In JP-96 highest mean value was noticed in control (34.28) than both the treated families. In JI-444 mean value was maximum in 500 Gy (32.21) treatments. In GP-15-1 mean value was decreased with increased gamma rays doses and control had highest (33.92) mean value.
The mean values for 100-seed weight were decreased in JP-96 and GP-15-1 in both the treatments as compared to control. Same results for mean value were obtained by Avinash (2013) [4] in pea and Emrani *et al*. (2012) [8] in canola. The mean values were increased in JI-444 in both the treatments as compared to control. This result was in confirmation with Abdullah *et al*. (2005) [1] in mustard and Tshilenge *et al*. (2013) [19] in groundnut.

Table 1: Effect of mutagens on quantitative characters in M_2 generation of castor (*Ricinus communis* L.)

Genotypes	Doses (Gy)	Days to 50% flowering of primary raceme	Days to maturity of primary raceme	Plant height up to primary raceme (cm)	Number of nodes up to primary raceme	Length of primary raceme (cm)	Effective length of primary raceme (cm)
JP-96	500	52.26	128.70	52.88	14.26	62.53	62.53
	750	56.90	133.56	57.21	14.73	68.74	68.74
	0	61.33	140.66	53.66	16.37	73.96	73.96
JI-444	500	58.90	142.63	50.74	14.25	70.36	70.36
	750	54.10	143.20	57.87	12.68	57.84	57.84
	0	58.66	147.33	84.96	16.24	77.36	77.36
GP-15-1	500	63.83	145.46	83.06	16.97	75.89	74.37
	750	65.03	148.60	76.44	16.74	73.98	72.50
	0	60.66	150.13	79.33	18.50	77.33	73.37

Genotypes	Doses	Number of effective branches per plant	Number of capsules on primary raceme	Shelling out-turn (%)	Seed yield per plant (g)	100-seed weight (g)	Oil content (%)
JP-96	500	8.07	89.86	62.34	301.08	30.10	48.82
	750	8.64	83.49	60.42	340.48	30.92	48.85
	0	8.71	87.03	48.69	486.09	34.28	49.46
JI-444	500	9.95	83.49	63.27	333.90	32.21	48.14
	750	13.77	73.47	62.82	393.82	32.40	48.70
	0	17.16	110.36	61.54	390.06	31.39	49.03
GP-15-1	500	8.27	100.49	63.88	324.21	32.76	48.51
	750	9.35	96.26	65.20	342.34	32.14	48.43
	0	13.33	97.77	62.31	415.50	33.92	48.43

Oil content (%)
In JP-96 the mean oil content decreased in both treatments as compare to control (49.46). In JI-444 mean value was highest in control (49.03) and lowest in 500 Gy (48.14) treatment. In GP-15-1 mean value was highest in control (48.43) and 750 Gy (48.43) treatment.
The mean values for oil content were decreased in JP-96 and JI-444 in both the treatments as compare to control. This result was in confirmation with Arslan *et al*. (2007) [3] in mustard. The mean values were increased in GP-15-1 in both the treatments as compared to control. The result was in agreement with the finding of Gunasekaran and Pavadai (2015) [11] in groundnut.

Conclusion
Present investigation has been found an efficient to induce variability for micro mutation in the castor and it is a supplement to conventional breeding methods. In M_2 generation a significant positive shift of mean performance was observed in plant height, effective length of primary raceme, number of capsules on primary raceme, shelling out turn, seed yield, 100-seed weight and oil content. Both the treatments of gamma rays showed higher results in most of all the characters when compared to control. The results indicated the possibilities of evolving higher yield variants through proper selection. Mutagenic treatments increase the genetic variability, which can be utilized for selection and improvement of castor plants.

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