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RADIATION INDUCED VARIABILITY AND GENE EFFECTS FOR POLYGENIC TRAITS IN RICE BEAN (*Vigna umbellata* Thunb, Ohwi and Ohashi)

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SUMMARY

This study was conducted to induce variability and to identify the important radiation dose for induction of useful variation for maturity, yield and yield attributes. Two varieties of rice bean (BRS-1 and Totru Local) were treated with 3 different doses of gamma rays (30kR, 40kR and 50kR). The range, mean and coefficient of variation suggested that the mutagenic treatments created wide variability. In general, these genetic parameters were higher in M_3 generation than M_2. Both positive and negative shifts in means were observed for all the traits in both the cultivars in both generations. High heritability coupled with high genetic advance were observed for pods/cluster, seeds/pod and pod length in both BRS-1 and Totru Local indicating that breeding for these traits can be achieved by phenotypic selection. Most of the traits showed significant positive additive and dominance effects at 30 kR dose in both the genotypes indicating the dose to be most effective in inducing variability. Most of the traits showed over dominance suggesting that the selection should be deferred to the later generation so that the additive effects become more pronounced and fixed.

Keywords: Gamma-rays, induced additive effect, induced dominance effect, mutation, *Vigna umbellata*

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INTRODUCTION

Rice bean (*Vigna umbellata* Thunb, Ohwi and Ohashi) is a warm season annual pulse of high nutritional status which has remained in general, neglected for its improvement by breeding either by hybridization or other methods, especially in India. Till date, it has been a relatively neglected crop. It is being grown sporadically by farmers specifically in the remote areas of Himachal Pradesh and several other states of India. The nutritional quality of rice bean is higher as compared to many other legumes of the *Vigna* family (Katoch, 2013). It has been considered one of the best nutritionally balanced pulses in the world and has even been included in the school children's nutritional programs in the Philippines (NAS, 1979). Recently, with the emphasis given for the promotion of this crop to be cultivated by Indian farmers, Indian Council of Agricultural Research has started All India Coordinated Research Projects on underutilized crops since 1996 and rice bean is one of them. Under this project, work on the improvement of rice bean has been undertaken by the simplest techniques of germplasm evaluation and hybridization. However, in general, little work on mutation has been undertaken in this crop. With the increasing awareness

and concern among scientists and farmers, rice bean can emerge as an important grain legume crop, provided early, determinate and high yielding varieties are developed.

Variability is the pre-requisite for selection and varietal development in crop plants and mutation induction has become a proven way of creating variation within a crop species (Novak and Brunner, 1992). It offers the possibility of inducing desired attributes that either cannot be found in nature or have been lost during evolution. Shu (2009) reported the mutational enhancement of genetic diversity in 17 plant species. The mutants obtained can become an important genetic resource for breeding, gene discovery and functional analysis of various genes (Shu, 2009). Among the mutagens used gamma rays are the most widely and effectively used, resulting in about 70% of the worlds' mutant varieties (Nagatomi and Degi, 2009).

As the basic information of components of generated genetic variability is imperative in hybridization, similarly, in the case of mutation breeding it is important to know the nature and magnitude of various components of induced genetic variance for planning and executing appropriate breeding strategy to exploit it to the maximum. Also, the nature and magnitude of gene action involved in the expression of traits is important in deciding suitable breeding methodology for population improvement specifically of self-fertilizing crops either by hybridization or mutation. Therefore, meaningful genetic analysis of polygenic traits in the mutagenized populations demands for partitioning of genetic variance into additive, dominance and epistatic components. The aims of this study were to induce variability in 2 genotypes of rice bean, identify most appropriate dose for mutation induction and determine important characters that respond to mutation and to find out the nature of gene action in rice bean.

MATERIALS AND METHODS

Two contrasting rice bean genotypes *viz.*, BRS 1, having black grains (like urdbean) and Totru Local having creamish grains were used as experimental material. Since BRS-1 is late maturing but high yielding and on the other hand Totru Local is early but low yielder, so to induce earliness in BRS-1 and get high yielding lines in Totru Local the 2 genotypes were selected to remove the minor defects through induced mutations. On the basis of LD_{30} and LD_{50} values, 3 doses of radiations 30kR, 40kR and 50kR were selected for the present study.

Four hundred dry and healthy seeds of each variety were treated with 3 doses of gamma rays (30kR, 40kR and 50kR). Treatment with gamma rays was done using ^{60}Co gamma –cell @2500 R/min installed in the Division of Genetics, at National Physical Laboratory, Indian Agricultural Research Institute, New Delhi. Untreated dry seeds were used as a control (checks).

Sowing of M_1 generation was done immediately after treatment with the mutagen during *kharif* 2005-2006 and single plants were harvested individually and planted as M_2 family rows during the next crop season. Half of the M_2 seeds of each plant were used for raising M_2 generation *kharif* 2006-2007 and half were kept for raising M_2 generation *kharif* 2007-2008 along with M_3 to avoid environmental effects. All M_2 family plots consisted of single 5 m long rows with spacing of 45 X 20 cm and 30 X 15 cm for BRS-1 and Totru Local, respectively. An augmented design was used to generate M_3 seeds. The next year, remaining M_2 seeds were sown along with M_3 seeds. M_2 generation was raised in single plant completely randomized design and M_3 generation was raised in RCBD with 2 replications.

The number of families studied in BRS-1 were 32, 31 and 29 in M_2 and 33, 27 and 16 in M_3; whereas in Totru Local these were 22, 32 and 15 in M_2 and 19, 28 and 11 in M_3 under 30, 40 and 50 kR doses, respectively. Data in M_2 generation were recorded on a single plant basis dose-variety wise, whereas in M_3 generation, the data were recorded on five plants from each line per replication dose-variety wise. Observations were recorded on days to flowering, days to maturity, pod clusters/plant, pods/cluster, seeds/pod, pod length (cm), seed yield/plant (g) and 100-seed weight (g).

Estimates of genetic parameters were computed according to Sharma (1998) and the additive and dominance components were estimated according to Yonezawa (1979).

RESULTS AND DISCUSSION

Estimates of genetic parameters

Analysis of variance for total number of mutagenized populations (1460 in M_2 and 1245 in M_3) exhibited significant differences for all the 8 traits studied, indicating the generation of considerable variability after treatment with gamma rays. In the control, no differences were revealed within each parental population for any of the trait, while the 2 populations as different units differed significantly for all the traits. Homogeneity of individual parental populations indicated that these were most suitable for treatment with mutagens to induce variability for breeding purpose.

Irradiated rice bean varieties exhibited wide range of PCV and GCV for quantitative traits providing ample evidence that mutagenic treatment has altered mean values and created additional genetic variability for quantitative traits. Phenotypic coefficients of variation were larger compared to genotypic coefficients of variation for all the traits indicating the influence of environment (Table 1).

During both generations, high to very high heritability along with high to very high genetic advance, was observed for pods/cluster, seeds/pod and pod length under 30kR dose in both the varieties. In addition to above traits in Totru Local, pod clusters/plant at 30, pods/cluster at 50kR, seeds/ pod at 40 and 50 kR, pod length at 40 kR and seed yield/plant at 50 kR and in BRS-1, 100-grain weight at 30 kR and pods/cluster at 40 kR were found to be important (these values are in both M_2 and M_3 generation). So in both the genotypes, 30 kR proved to be the most suitable dose where most of the traits showed moderate to very high PCV, GCV, h^2_{bs} and GA in both M_2 and M_3 generations (Table 1). Also, the 3 traits viz., pods/cluster, seeds/pod and pod length have been reported as main yield contributing traits and the data indicated that sufficient variability has been created for further improvement of these traits in both the varieties under 30kR dose. Induced greater variability in polygenic traits might be due to increased mutations and recombination induced by gamma rays. Increase in the variability parameters in mutagenized populations of rice bean have also been reported by Lokesha *et al.* (1991) and Lokesha and Veeresh (1993).

Estimates of mean values of irradiated populations

In BRS-1, at 30 kR dose at M_3 generation, 5 traits showed significantly negative shifts in mean values while, in Totru Local 6 traits shifted negatively. In BRS-1, days to flowering showed significantly negative shift in mean in M_2 generation and significantly positive shift in M_3 generation under all the doses (Table 1). The increase values could be due to the occurrence of polygenic mutations with cumulative effects. In Totru Local the shift towards earliness was shown only at 30kR dose in M_3 generation.

Since for days to flowering and maturity negative value (earliness) is of interest for the breeders so a shift in positive direction is required for fulfillment of Brock's hypothesis (1965). For days to flowering, Brock's hypothesis fitted well in M_3 generation under all the doses in BRS-1 and in Totru Local all doses except at 30 kR. For days to maturity, this hypothesis fitted well for all the doses in both the varieties except for 40kR in Totru. Therefore, the possibility of getting early mutants in Totru local under 40kR dose can be speculated.

The above results showed 30 kR to be the dose where most of the traits shifted their mean values from the previous generation. Similar shift in population mean were also reported by Kharkwal (2001) in chickpea and Singh *et al.* (2006) in cowpea.

Genetic component analysis of induced polygenic variation

Significant and positive additive and dominance effects were observed for all the traits except for days to maturity and seeds/pod at 30kR treatment; for 100 seed weight at 40kR and for pod length at 50kR in BRS-1 (Table 2). In Totru Local, positive and significant additive and dominance effects along with potent ratio in the range of over dominance were observed for days to flowering, pod clusters/plant, seed yield/plant and 100 seed weight in 30 kR; days to flowering, days to maturity and seeds/pod in 40kR and pods cluster/plant, seeds/pod, pod length, seed yield/plant and 100 seed weight in

50 kR. Virk *et al*. (1978) have attributed the induction of such positive additive effects due to fact that either decreasing alleles have high mutation rate or the parents contain more increasing alleles than decreasing one for the traits exhibiting positive additive effect. Jai Dev and Gupta (1997) in rajmash and Pathania *et al*. (2011) in chickpea also reported additive and dominance genetic effects for most of the traits after irradiation with gamma rays.

For the 30kR dose, significant additive and dominance effects were observed for 2 yield component traits (pod clusters/plant and 100-seed weight) and other yield contributing trait (days to flowering) in both the genotypes. Considering all the doses in both the genotypes, it was observed that most of the traits showed over dominance which suggested that the selection should be deferred to the later generation so that the additive effects become more pronounced and fixed.

Out of total 76 lines in M_3 generation of BRS-1, 18 lines were found to be promising for maturity duration (early maturing) and among them 15 lines were from 30 kR dose (Table 3). At 30 kR dose the progeny BR-30-3-32 (Table 4) was found to be desirable progenies for earliness as well as having high yield (seed yield per plant). This progeny also showed the best combinations of days to flowering, pods per cluster and seeds per pod (Table 4) and can be advanced and fixed in the subsequent generations for utilization as varieties or as parent for hybridization.

Out of 58 lines in M_3 generation of Totru Local, 51 lines were having superior yield than the control, among which 28 lines were obtained by treatment with 30 kR dose of gamma rays (Table 3). The lines TR-30-3-15 and 19 were not only early (like control) but also high yielding (Table 4). These lines also showed more number of clusters of pods per plant and seeds per pod (Table 4).

In the present study the 30kR dose have come out to be effective in inducing considerable variation for a number of characters of economic value. Yield contributing characters like pods/cluster, seeds/pod and pod length showed high heritability and genetic advance at one or other dose of mutagens in both the varieties. Therefore, the variation induced in these characters could pave the way for selection of high yielding mutants for further studies in late generation when the additive effects will become more pronounced and fixed. The 30 kR dose was found to be most suitable for isolating high yielding early maturing mutants. After treatment with the radiation dose of 30 kR, the BR-30-3-32 progeny of BRS-1 and TR-30-3-15 and 19 of Totru local wers having the best combination for most of the yield contributing traits and so these lines can be advanced and further tested for their stability and release.

REFERENCES

Brock RD (1965). Induced mutations affecting quantitative characters. *Radiation Botany* 5:451-464.

Jai Dev, Gupta VP (1997). Genetic parameters of radiation induced variability and appropriate mutagenic generation of effective selection for seed yield, harvest index and seed per pod in kidney beans (*Phaseolus vulgaris*). *Indian Journal of Agricultural Sciences* 67: 418-421.

Katoch R (2013). Nutritional potential of rice bean (*Vigna umbellata*): an underutilized legume. *Journal of Food Science* 78: 8-16.

Kharkwal MC (2001). Induced mutations in chickpea (*Cicer arietinum* L.) V. Evaluation of micromutations. *Indian Journal of Genetics and Plant Breeding* 61: 115-124.

Lokesha R, Veeresh LC (1993). Induced mutagenesis and genetic improvement of rice bean (*Vigna umbellata* (Thunb) Ohwi and Ohashi. *Legume Research* 16: 37-40.

Lokesha R, Vasanth KE, Veeresh LC, Shivashankar G (1991). Gamma-ray induced genetic divergence in rice bean (*Vigna umbellata* Thumb Ohwi and Ohashi). In: Golden Jubilee Symposium on Genetic Research and Education: Current trends and the next fifty years, Indian Society of Genetics and Plant Breeding. IARI, New Delhi, p.719.

Nagatomi S, Degi K (2009). Mutation breeding of chrysanthemum by gamma field irradiation and in *vitro* culture. In: Q.Y. Shu (ed.), Induced plant mutations in the genomics era. Food and Agriculture Organization of the United Nations, Rome, pp. 257-257

NAS (1979). Tropical legume: Resources for the future. National Academy of Sciences, Washington DC, pp. 331.

Novak FJ, Brunner H (1992). Plant breeding: Induced mutation technology for crop improvement. In: IAEA bulletin, 4. pp. 25-33.

Pathania A, Sood BC, Bhateria S (2011). Genetic architecture of radiation induced variability for quantitative traits in chickpea (*Cicer arietinum* L.). *Legume Research* 34:155-165.

Sharma JR (1998). Statistical and Biometrical Techniques in Plant Breeding. New Age International (P) Limited, p. 429.

Shu QY (2009). Induced plant mutations in the genomics era. *In:* IAEA. Food and Agriculture Organization of United Nationals, Rome, pp. 455-458.

Singh VV, Ramkrishna K, Arya RK (2006). Induced chemical mutagenesis in cowpea (*Vigna unguiculata* (L.) Walp.). *Indian Journal of Genetics and Plant Breeding* 66: 312-315.

Virk DS, Jinks JL, Pooni HS (1978). The assessment of induced continuous variation in pure-breeding lines following selfing. *Heredity* 40: 255-268.

Yonezawa K (1979). Some additional considerations on the method of genetical analysis for induced continuous variation of self-fertilizing plants. *Heredity* 43: 191-204.

Table 1. Estimates of mean values, shift in mean, coefficient of variation, heritability (h^2_{bs}) and genetic advance (GA as % of mean) for different traits in M_2 and M_3 generations in rice bean.

	BRS-1						Totru Local					
Traits	30kR		40kR		50kR		30kR		40kR		50kR	
Generations	M_2	M_3	M_2	M_3	M_2	M_3	M_2	M_3	M_2	M_3	M_2	M_3
Days to Flowering												
Mean ± SE	76.98^{n} ±0.14	77.54^{p} ± 0.05	77.48^{n} ±0.18	79.29^{p} ±0.06	76.70^{n} ±0.15	78.69^{p} ±0.10	69.43^{p} ±0.18	64.70^{n} ±0.10	69.69^{p} ±0.09	68.87 ±0.05	70.28^{p} ±0.06	70.18^{p} ±0.07
PCV	5.93	13.39	13.19	6.28	13.19	8.98	10.88	12.15	4.04	6.40	-	2.71
GCV	5.13	13.23	12.86	5.96	12.86	8.75	10.38	11.90	2.43	5.97	-	1.50
h^2_{bs}(%)	74.85	97.67	95.01	89.87	95.05	94.96	91.08	95.93	36.09	87.04	-	30.46
GA	9.14	26.93	25.82	11.63	25.83	17.56	20.41	24.02	3.00	11.47	-	1.70
Days to Maturity												
Mean ± SE	130.71^{p} ±0.08	131.00^{p} ±0.30	131.07^{p} ±0.09	133.52^{p} ±0.14	133.23^{p} ±0.07	135.73^{p} ±0.20	110.54^{p} ±0.07	111.51^{p} ±0.15	109.16^{n} ±0.06	105.18^{n} ±0.18	111.70^{p} ±0.11	111.89^{p} ±0.25
PCV	6.88	8.78	4.90	6.87	3.36	4.17	4.63	4.03	3.33	5.50	2.90	4.74
GCV	6.75	8.24	4.72	6.20	3.11	2.98	4.36	1.91	2.92	4.02	2.47	3.16
h^2_{bs}(%)	96.38	88.18	92.94	81.44	85.72	51.19	88.80	22.53	77.06	53.30	73.02	44.48
GA	13.65	15.95	9.38	11.53	5.94	4.40	8.47	1.87	5.29	6.04	4.36	4.34
Pod clusters/plant												
Mean ± SE	12.66^{n} ±0.03	11.78^{n} ±0.03	13.95^{p} ±0.03	13.97^{p} ±0.04	12.32^{n} ±0.03	12.34^{n} ±0.04	6.89^{n} ±0.04	5.82^{n} ±0.04	7.52^{p} ±0.04	7.91^{p} ±0.04	7.52^{p} ±0.04	7.09^{n} ±0.04
PCV	11.45	12.30	14.44	11.62	9.76	13.46	46.49	35.08	34.19	17.47	16.35	26.11
GCV	8.59	9.25	12.99	9.39	6.73	11.01	42.86	31.01	32.12	12.62	11.34	22.37
h^2_{bs}(%)	56.35	56.56	80.86	65.37	47.63	66.93	84.97	78.13	88.21	52.20	48.11	73.39
GA	13.29	14.33	24.06	15.64	9.57	18.56	81.38	56.47	62.14	18.79	16.20	39.48
Pods/cluster												
Mean ± SE	4.63^{n} ±0.03	4.49^{n} ±0.03	6.02^{p} ±0.04	5.74^{p} ±0.03	5.02^{p} ±0.03	5.53^{p} ±0.04	3.29^{n} ±0.04	3.23^{n} ±0.04	4.61^{p} ±0.04	4.45^{p} ±0.03	4.01^{p} ±0.05	3.98^{p} ±0.06
PCV	49.60	52.41	35.05	39.89	17.26	33.47	67.72	57.12	22.12	46.37	43.11	63.10
GCV	45.47	47.96	32.30	36.31	5.34	28.73	61.67	49.01	11.90	41.18	38.07	58.42

h^2_{bs} (%)	84.03	83.74	84.94	82.84	9.58	73.67	82.94	73.61	28.97	78.85	78.00	85.71
GA	85.86	90.41	61.33	68.08	3.41	50.80	115.70	86.62	13.20	75.32	69.27	111.41
Seeds/pod												
Mean ± SE	5.38^{p} ±0.02	5.43 ±0.03	6.55^{p} ±0.03	6.50^{p} ±0.04	5.99^{p} ±0.02	5.89^{p} ±0.04	4.04^{n} ±0.03	4.13^{n} ±0.03	4.89^{p} ±0.05	4.70^{p} ±0.03	4.78^{p} ±0.03	3.82^{n} ±0.05
PCV	29.12	52.07	13.09	24.34	10.68	19.90	39.07	45.83	65.00	46.41	35.11	67.47
GCV	26.37	49.07	7.94	19.53	1.73	11.81	35.00	39.71	63.75	41.84	32.21	62.77
h^2_{bs} (%)	81.98	88.82	36.79	64.35	2.63	35.20	80.29	75.09	96.20	81.29	84.15	86.56
GA	49.18	95.27	9.92	32.27	0.58	14.43	64.61	70.89	128.81	77.72	60.86	120.31
Pod length (cm)												
Mean ± SE	6.70^{n} ±0.05	6.07^{n} ±0.03	8.01^{p} ±0.04	7.92^{p} ±0.03	7.30^{p} ±0.04	7.03^{n} ±0.06	4.02^{n} ±0.04	4.18^{n} ±0.04	5.31^{p} ±0.05	5.30^{p} ±0.03	4.94^{p} ±0.04	4.41^{n} ±0.05
PCV	31.36	34.38	18.86	23.55	18.47	19.58	45.83	42.92	31.39	40.91	-	45.64
GCV	27.11	30.82	13.98	20.45	11.39	14.50	36.12	36.77	24.23	36.99	-	40.53
h^2_{bs} (%)	74.70	80.35	54.94	75.37	38.04	54.82	62.13	73.40	59.60	81.76	-	78.85
GA	48.26	56.90	21.35	36.57	14.48	22.11	58.66	64.90	38.54	68.90	-	74.13
Seed yield/plant (g)												
Mean ± SE	10.99^{n} ±0.03	11.12^{n} ±0.04	13.01^{p} ±0.04	13.07^{p} ±0.05	12.31^{p} ±0.02	13.10^{p} ±0.07	6.52^{p} ±0.03	6.30 ±0.05	7.04^{p} ±0.04	7.36^{p} ±0.05	7.24^{p} ±0.04	6.35 ±0.08
PCV	13.67	15.00	13.22	14.44	13.01	10.73	11.35	24.49	15.44	20.44	20.80	31.53
GCV	11.89	10.75	11.96	11.37	11.68	6.03	2.09	16.08	11.62	12.97	18.05	25.67
h^2_{bs} (%)	75.68	51.40	81.83	62.04	80.52	31.60	3.40	43.13	56.67	40.24	75.26	66.28
GA	21.30	15.88	22.28	18.45	21.58	6.98	0.79	21.76	18.03	16.94	32.25	43.05
100 seed weight (g)												
Mean ± SE	6.99^{n} ±0.05	6.52^{n} ±0.04	8.32^{p} ±0.05	7.37^{n} ±0.04	7.73^{p} ±0.04	7.85^{p} ±0.07	5.30^{n} ±0.04	4.32^{n} ±0.04	5.86^{p} ±0.05	5.82^{p} ±0.04	6.02^{p} ±0.07	5.14^{n} ±0.05
PCV	31.01	32.31	23.66	-	14.48	23.51	21.83	60.69	27.48	26.54	-	22.92
GCV	25.93	26.95	19.96	-	5.14	18.26	4.80	54.39	21.92	17.48	-	3.53
h^2_{bs} (%)	69.92	69.54	71.15	-	12.60	60.33	4.83	80.33	63.63	43.35	-	2.37
GA	44.67	46.29	34.68	-	3.76	29.21	2.17	100.42	36.02	23.71	-	1.12

p = Significant positive shift in mean; n = Significant negative shift in mean

Table 2. Estimates of induced additive $[\hat{d}]_m$ and dominance $[\hat{h}]_m$ effects for different traits after treatment with different doses of radiations in rice bean.

Dose / Traits	Days to flowering	Days to maturity	Pod clusters /plant	Pods/cluster	Seeds/pod	Pod length (cm)	Seed yield /plant (g)	100 seed weight (g)
BRS-1								
30 kR								
$[\hat{d}]_m$	-0.43* ± 0.09	-0.56 ± 0.30	1.14* ± 0.04	0.28* ± 0.04	-0.04 ± 0.04	0.82* ± 0.04	0.21* ± 0.05	0.71* ± 0.06
$[\hat{h}]_m$	-1.12* ± 0.30	-0.58 ± 0.62	1.76* ± 0.08	0.28* ± 0.08	-0.10 ± 0.07	1.26* ± 0.12	0.26* ± 0.10	0.94* ± 0.13
$[\hat{h}]_m / [\hat{d}]_m$	2.60	–	1.54	1.00	–	1.53	1.24	1.33
40 kR								
$[\hat{d}]_m$	-1.93* ± 0.11	-2.91* ± 0.15	-0.41* ± 0.05	-0.28* ± 0.04	-0.52* ± 0.05	-0.37* ± 0.04	-0.73* ± 0.06	0.52* ± 0.06
$[\hat{h}]_m$	-3.62* ± 0.38	-4.90* ± 0.33	-0.04 ± 0.10	0.56* ± 0.10	0.10 ± 0.10	0.18 ± 0.10	-0.12 ± 0.13	1.90* ± 0.13
$[\hat{h}]_m / [\hat{d}]_m$	1.88	1.69	-	2.04	–	-	-	3.65
50 kR								
$[\hat{d}]_m$	-1.72* ± 0.13	-4.04* ± 0.21	0.41* ± 0.05	-0.57* ± 0.05	-0.19* ± 0.05	0.17* ± 0.07	-1.11* ± 0.07	-0.27* ± 0.08
$[\hat{h}]_m$	-3.98* ± 0.36	-5.00* ± 0.42	-0.04 ± 0.10	-1.02* ± 0.10	0.20* ± 0.09	0.54* ± 0.14	-1.58* ± 0.15	-0.28 ± 0.16
$[\hat{h}]_m / [\hat{d}]_m$	2.31	1.24	-	1.81	1.05	3.27	1.42	-
Totru Local								
30 kR								
$[\hat{d}]_m$	4.49* ± 0.14	-1.18* ± 0.16	1.24* ± 0.05	0.38* ± 0.05	-0.02 ± 0.04	0.16* ± 0.05	0.13* ± 0.05	1.10* ± 0.05
$[\hat{h}]_m$	9.46* ± 0.41	-1.94* ± 0.33	2.14* ± 0.11	0.12 ± 0.11	-0.18* ± 0.08	-0.32* ± 0.11	0.44* ± 0.12	1.96* ± 0.11
$[\hat{h}]_m / [\hat{d}]_m$	2.11	1.65	1.73	–	–	2.06	3.52	1.79
40 kR								
$[\hat{d}]_m$	0.45* ± 0.07	4.46* ± 0.19	-0.54* ± 0.05	-0.19* ± 0.04	0.17* ± 0.05	-0.32* ± 0.05	-0.68* ± 0.05	-0.13* ± 0.05
$[\hat{h}]_m$	1.64* ± 0.21	7.96* ± 0.38	-0.78* ± 0.11	0.32* ± 0.10	0.38* ± 0.12	0.02 ± 0.12	-0.64* ± 0.13	0.18 ± 0.13
$[\hat{h}]_m / [\hat{d}]_m$	3.64	1.78	1.46	1.73	2.30	–	0.95	–
50 kR								
$[\hat{d}]_m$	-0.56* ± 0.08	-0.98* ± 0.26	0.29* ± 0.05	-0.02 ± 0.07	0.66* ± 0.06	0.39* ± 0.06	0.44* ± 0.08	0.64* ± 0.07
$[\hat{h}]_m$	0.20 ± 0.18	-0.38 ± 0.55	0.86* ± 0.11	0.06 ± 0.16	1.92* ± 0.12	1.06* ± 0.13	1.78* ± 0.18	1.76* ± 0.17
$[\hat{h}]_m / [\hat{d}]_m$	–	–	3.02	–	2.91	2.75	4.09	2.77

*Significant at $P \leq 0.05$

Table 3. Number of M_3 lines excelling over the control for different traits under different doses of radiation in BRS-1 and Totru Local.

Variety	Dose of Gamma rays	Total number of lines	Days to flowering	Days to maturity	Seed yield/ plant
BRS-1	30kR	33	11	15	2
	40kR	27	2	3	26
	50kR	16	2	__	16
	Total	76	15	18	44
Totru local	30kR	19	19	2	28
	40kR	28	13	28	14
	50kR	11	__	__	9
	Total	58	32	30	51

Table 4. Promising M_3 lines observed under different doses of radiations for different traits in BRS-1 and Totru Local.

Traits	Gamma rays (30 kR dose)		
	BRS-1	Totru Local	
Days to flowering	BR-30-3—4, 10, 11, 16, 17, 20, 21, 25, 31, 32, 33	TR-30-3—1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19	
Days to maturity	BR-30-3—9, 11, 12, 14, 17, 18, 19, 20, 21, 22, 26, 28, 29, 30, 32	TR-30-3—15, 19	
Plant height (cm)	-	-	
Clusters of pods/ plant	-	TR-30-3—15, 19	
Pods/ cluster	BR-30-3—17, 24, 25, 32	-	
Seeds/ pod	BR-30-3—1, 2, 3, 5, 6, 7, 8, 10, 14, 15, 16, 25, 27, 29, 30, 31, 32, 33	TR-30-3—4, 6, 7, 8, 9, 10	
Pods/ plant	-	TR-30-3—7, 9, 19	
Seed yield/ plant (g)	BR-30-3—31, 32	TR-30-3—1, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19	