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Selection of high yielding, extra short duration lines of mungbean derived through gamma radiation

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Abstract

The present investigation was designed to improve the genetic constitution of mungbean through gamma radiation induced mutation breeding approach to identify some high yielding mutant genotypes having extra short maturity duration. Three mungbean germplasms lines were exposed to gamma irradiation with three different doses and desirable mutants were selected from M_2 through M_5 generations. A total number of twenty mutant individuals from M_5 generation were identified as promising mutants having early maturity duration (<55 days) with high yield (>25 g seed yield plant^{-1}). Among them, six were found to be extra ordinary mutants with extra early maturity dutation of <53 days with > 30g seed yield plant^{-1}. Such mutants were not only high yielding extra early maturing type than their parents but also had synchrony in pod maturity, non-shattering pod and top fruitbearing habit. The identified mutants may be directly released as cultivars after their multilocation trials and can also be used as donor for improvement of mungbean with respect to earliness and yield.

Key words: Gamma radiation, germplasm, mungbean, mutation breeding, seed yield

Introduction

Mungbean [*Vigna radiata* (L.) R. Wilczek var. *radiata*], an important food legume in Asia, is rapidly expanding to other parts of the world including sub Saharan Africa. Globally, more than 6 million hectares are cultivated, producing up to 3 million metric tonnes of grains that is consumed directly as *dahl* porridge and bean sprouts or processed into high value 'bean thread' noodles (Nair et al. 2013). Mungbeans are recognized for their high nutritive value, composed of about 24-28% dietary protein with an increased level of most of the amino acids, 59-65% carbohydrate on a dry weight basis and provides about 3400 kJ energy/kg grain. It is a warm season, self-pollinated annual legume, grown mostly as a rotational crop with cereals like wheat and rice. Being the largest producer and consumer of mungbean, India accounts for about 65% of the world acreage and 54% of the world production of this crop but, the production of mungbean has remained static (270000-285000 kg/ha) during the last decade (FAO 2016) due to different biotic and abiotic factors. As a result, the gap between supply and demand is spreading (Imran et al. 2015).

It is a short duration crop but pre harvest sprouting tendency in mungbean is a large threat for the farmers. If the crop witness rains at the time of pod-maturity, pre-harvest sprouting occurs which ultimately leading to deterioration of seed quality as well as yield (Singh et al. 2011). Thus, if the maturity duration of the improved cultivars is shortened up to 10-15 days, the crop can avoid the adverse effects of rain during reproductive stage and ultimately the productivity will be raised. Moreover, being a self-pollinated crop the naturally existing genetic variability may not be sufficient to achieve the desired improvement in mungbean. In recent times, geneticists and plant breeders have used mutation induction technology to supplement the naturally occuring genetic variability to improve various agronomic traits of crop plants (Sharma and Sharma 2014). In such situation, using artificially induced mutations, mungbean yield can be increased by improving the genetic makeup of the seed and also by incorporating the resistance capacity to withstand against different abiotic factors (Auti 2012). Mutation breeding is one of the important

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breeding methods, which is an effective tool for the improvement of crop production, maturity and other agro-morphological characters. Mutagenesis can be carried out by both using chemical and physical mutagenes. Gamma rays are used extensively for artificial induction, which can affect the plant growth by altering the agro-morpho-physiological as well as biochemical constitution of cells.

Therefore, the present investigation was carried out to study the mutagenic effectiveness and efficiency of gamma rays in three mungbean germplasms lines with the aim to indentify the stable mutants for high yield and short maturity duration.

Materials and methods

Three popular germplasms of West Bengal, namely, B1, Pusa-9632 and K-851 were selected for mutagenesis on the basis of their average yield of >20g per plant and maturity duration of <60 days. Three hundred gram of dry seeds (with 10% moisture) of each germplasms line were collected and further sub divided into 3 equal parts containing 100g seeds each. They were exposed to 10kR, 20kR and 30kR doses of gamma rays, respectively with a dose rate of 1.087kR min^{-1} in the gamma radiation cell of UGC-DAE CSR, Kolkata Center, Salt Lake, Jadavpur University Campus, West Bengal, India in 2012. Untreated seeds were considered as control. The M_1 generation with control was grown during pre-*kharif* season at Calcutta University Experimental Farm, Baruipur (22^{o}N, 88.26^{o}E and 9.75 m above the sea level). All the healthy M_1 plants were sown in the next pre *kharif* season to raise M_2 generation. Twenty five healthy plants from each doses of all the germplasms were selected in M_2 generation to raise M_3 generation. On the basis of improved performance over control, plants were selected and further used to raise the subsequent generations upto M_5. All the generations were raised in pre *kharif* season and randomized block design was followed for M_3 to M_5 generations with three replications. The length of rows in each replication was 1.5 m. Seed were placed at the depth of 3cm in each pit at a distance of 20cm two rows 30cm apart. Plot size varied between generation to generation depending on the number of selected lines. Normal inter culture operations were practiced throughout the growing period. Illustration of selection method is presented in Fig. 1. All the statistical tests were performed using, IBM SPSS software (IBM SPSS *ver*. 21.0).

Results and discussion

In M_1 generation each investigated parameter, except for days to maturity, registered lower values than their respective controls.This may be due to the complex genetic constitution of quantitative traits controlled by a large number of genes interacting with one another and hence, variations in both directions are expected (Wani 2011). Khan et al. (2006) in mungbean and

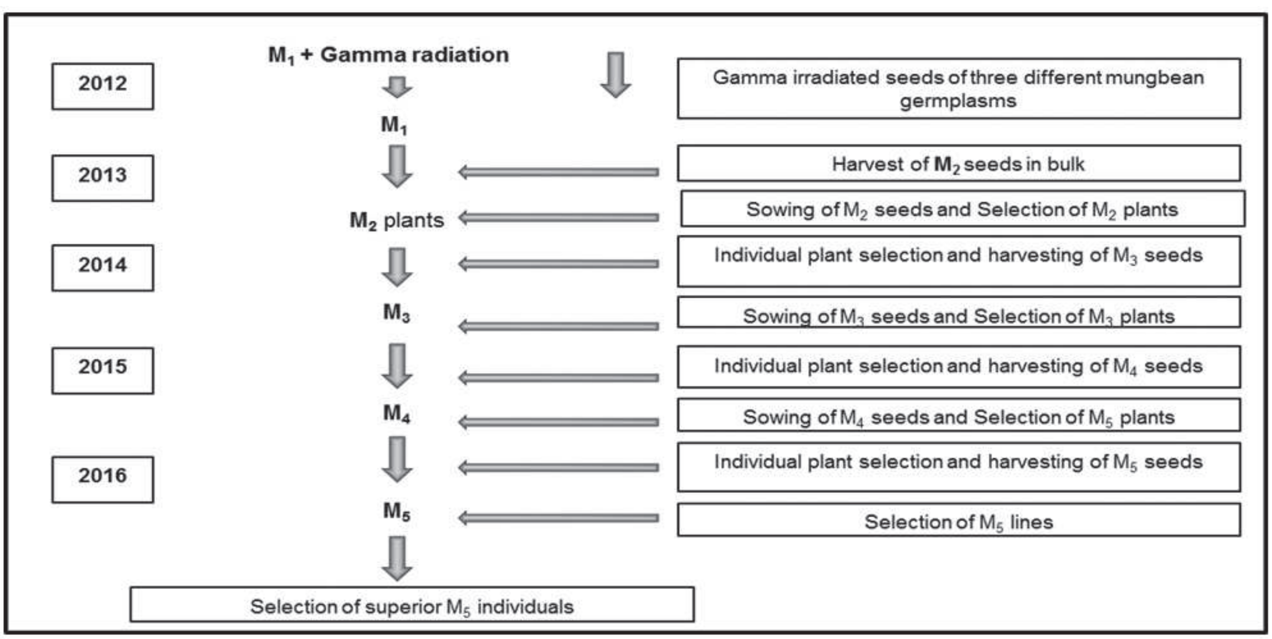

Fig. 1. Diagram of the selection methods during 2012-2016

Mudibu et al. (2012) in soybeans reported positive shift, whereas Singh et al. (1991) in greengram, Sinha and Lal (2007) in lentil reported negative shift of yield components in earlier generations. But with the positive significant correlation with seed yield plant^{-1} as well as days to maturity (Tables 1 and 2). Days to maturity and pods plant^{-1} showed positive significant correlation with seed yield plant^{-1} in earlier as well as

Table 1. Significant correlations with yield and its component traits in different mutant generations

		Branch plant^{-1}	Days to maturity	Pods plant^{-1}	Pod length (cm)	Seed pod^{-1}	100 seed weight (g)	Seed yield plant^{-1}(g)
Plant height (cm)	B1	M3*	M5*	M4*	M4*	M4*	M4*	M4*
	Pusa-9632	M5*	M4*, M5**	M5*	M5*	M4**	-	M3*, M4*, M5**
	K-851		M4**, M5*	M5*	M5**	M5*	M4*	M4**
Branch plant^{-1}	B1		M4**	M4*, M5*	M5**	M5*	M4*	M4*, M5**
	Pusa-9632		M4*, M5*	M5*	M4*, M5*	M5**	M3*	M3*, M4*, M5**
	K-851		M4**, M5*	M4*, M5*	M5*	M5**	M4*	M4**, M5**
Days to maturity	B1			M3*, M4*,	-	-	-	M3**, M4*, M5*
	Pusa-9632			M4*, M5*	-	-	-	M3*, M4*, M5**
	K-851			M5**	-	-	-	M4*, M5**
Pods plant^{-1}	B1				M5*	M4**	M5*	M4*, M5**
	Pusa-9632				M4*, M5**	M5*	M5**	M3**, M5*
	K-851				M5**	M4*	-	M3*, M5*
Pod length (cm)	B1					M4*	M5**	M4*, M5**
	Pusa-9632					M5**	M4**	M3*, M4*, M5**
	K-851					M5**	M5*	M3*, M4*,M5**
Seed pod^{-1}	B1						M4*	M4**
	Pusa-9632						M5**	M3*, M4**
	K-851						M4*, M5*	M3**, M4*
100 seed weight (g)	B1							M4*,M5*
	Pusa-9632							M3*, M4**
	K-851							M3*, M4*

*Significant at 5% level, **Significant at 1% level

Table 2. Co-efficient of variation in different mutation generations

		Plant height (cm)	Branch plant^{-1}	Days to maturity	Pods plant^{-1}	Pod length (cm)	Seed pod^{-1}	100 seed weight (g)	Seed yield plant^{-1}(g)
M3	B1	4.11	45.98	10.59	6.00	5.69	6.36	3.65	8.74
	Pusa-9632	4.06	45.21	10.46	6.09	5.46	6.59	2.98	7.98
	K-851	3.92	45.33	10.22	5.97	5.66	6.44	2.99	8.56
M4	B1	3.14	34.21	10.00	5.46	4.39	5.23	2.46	6.39
	Pusa-9632	3.00	34.05	9.98	5.42	4.26	5.08	2.40	6.58
	K-851	3.28	33.46	9.99	5.66	4.33	5.11	2.52	6.99
M5	B1	2.56	25.33	9.11	4.23	3.69	4.36	1.66	4.59
	Pusa-9632	2.43	25.41	9.16	4.59	3.52	5.00	2.00	4.66
	K-851	2.51	25.19	9.17	4.80	3.22	4.89	1.79	4.82

advancement of the generations the yield components registered higher values over their respective controls.

Selection for high productivity and short maturity duration was done on the basis of traits showing advanced generation in all the germplasms. Therefore, these traits could have strong selective advantage for identification of mutant families with high yield. On the other hand, branch plant^{-1} and pod length in B1, plant height, branch plant^{-1} and pod length in Pusa-9632 and branch plant^{-1}, pod length and seed pod $^{-1}$ in K-851 should be given due consideration for selection of high productive mutant lines for their positive significant association with seed yield plant^{-1}. Tah (2006) and Khan and Goyal (2009) reported that some desired mutants with large number of pods, large pod size and early maturity duration were generated from mungbean varieties, namely, PS 16, K-851, Sona with the 10 to 30kR doses of gamma radiation. At the same time, plant height in respect of B1, plant height, branch plant^{-1} considering Pusa-9632 and plant height, branch plant^{-1} for K-851 should be given due consideration for selection of early maturing mutant lines as these traits registered significant association with days to maturity. Yaqoob and Rashid (2001) and Lavanya et al. (2011) reported early flowering and early maturing mutants in mungbean with gamma radiation. Table 2 presents a successive reduction in coefficient of variation in all the traits within the selected mutants for all the germplasms. This indicate the scope of achieving highly uniform population in mutant lines with respect to days to maturity, seed yield and its other attributing components through selection in advanced generations.

A comparative yield component study in M_3 to M_5 generations reported the desired improvement in yield and maturity duration over control population (Table 3). The improvements were successively maintained within selected mutant lines from all the germplasms. In advanced generations dwarfing is reported in all the populations which is a sign of earliness in maturity duration by shortening the vegetative growth period. Earlier findings of Auti and Apparoa (2009) reported dwarf mutant plant in mungbean, chickpea, cowpea and other pulse crops. Rampure et al. (2017) identified dwarf, highly branched, high test weight and high oil content lines mutant in safflower in gamma irradicated M_3 population. Jana (1962) reported that the early maturing mutants are produced as a result of physiological changes and increased production of flowering hormones. Present investigation reports that all the mutant lines showed shorter maturity duration over their respective controls in advanced generations. On the basis of an extra early maturity time, some individuals were identified from M_5 lines (Table 4) matured in 53-55 days, which recorded 15-18% reduction over control B1 and 11-14% reduction over controls, Pusa-9632 and K-851. These selected individuals also registered shorter plant height (13-40% reduction over control) with more number of branches than their respective controls (Table 4). The earliness is generally achieved due to early transition of vegetative meristem to a reproductive one, which is largely under genetic control. Sarkar et al. (2016) reported thar plant height is negatively correlated with days to maturity but positively correlated with seed yield. On the other hand branch plant^{-1} is also positively correlated with yield. So, if induced mutation could generate dwarf plant with many branches, it could ultimately generate early maturing high productive plants. Individuals selected from M_5 generation recorded yield improvement of 34%, 28% and 39% over control B1, Pusa-9632 and K-85, respectively. Similarly, selected M_5 individuals recorded earliness in order of 19%, 12% and 15% over B1, Pusa-9632 and K-851, respectively (Table 4). All the selected individuals had also shown maximum improvement over controls with respect to pods plant^{-1} (24-51% increase), pod length (19-32% increase) and seeds pod^{-1} (14-34% increase). Sarwar and Ahmed (2003) and Singh and Kumar (2009) reported that screening for high productivity, early maturing, and disease resistance mutant populations is mostly originated from a lower mutagen dose. El-Rahman (2016) also isolated mutants in mungbean which showed higher values for height, no. of branches, no. of pods/plant and seed weight. Some of the yield component traits, *viz*., pod length, no. of seeds/pod and 100-seed weight were enhanced in mungbean when subjected to low doses chemical mutagens (Wani et al. 2017). Less increase in 100 seed weight (1-11% over control) could establish the scope for the development of small seeded variety which will ultimately satisfy the consumer's preference. Mutants also registered synchrony in maturity which could be beneficial in reducing the cost of harvesting the crop. Kumar et al. (2009) reported some dwarf, early maturing mutant lines with synchronous maturity and high yield in two mungbean varieties, PS 16 and Sona treated with 10 to 60 kR gamma radiation dose. During heat stress, abscission of reproductive organs (Rainey and Griffiths 2005) and rain during pod maturity pre-harvest sprouting (Ahmad et al. 2014) were the major constraint of yield loss in mungbean. So the extra short duration varieties which can mature in about less than 55 days have an increased importance towards yield improvement in mungbean. The selected mutant individuals addresses the above mentioned objective very neatly. Moreover, grouping of mean values of M_5 individuals on the basis of positive or negative shifting of values from their respective controls registered that a maximum number of lines posted a positive shift for

Table 3. Mean performance of selected mutant lines in different generations

	Dose (kR)		Plant height (cm)				Branch plant^{-1}				Days to maturity				Pods plant^{-1}			
			M_2	M_3	M_4	M_5	M_2	M_3	M_4	M_5	M_2	M_3	M_4	M_5	M_2	M_3	M_4	M_5
B1	0	Mean	68.70	68.39	67.55	68.73	10.96	9.23	9.41	9.66	64.94	64.22	65.52	65.22	40.19	40.59	42.70	45.35
		SEM	2.76	2.36	2.00	2.10	0.51	0.66	0.59	0.28	0.22	0.39	0.46	0.39	5.61	3.55	4.23	1.98
	10	Mean	54.12	59.44	61.12	59.32	10.34	10.08	10.11	7.42	56.89	58.44	56.32	56.35	39.02	65.12	69.47	68.22
		SEM	1.61	0.98	1.65	1.56	0.93	0.56	0.69	0.16	0.49	0.59	0.62	0.59	1.35	2.63	1.98	1.50
	20	Mean	52.26	60.06	65.09	65.33	9.05	7.69	8.69	8.23	58.70	58.70	57.02	56.06	30.40	59.36	61.45	62.33
		SEM	0.38	1.22	1.58	1.79	0.60	0.49	0.58	0.39	1.09	0.89	0.96	0.53	1.07	1.39	1.45	1.07
	30	Mean	48.25	62.82	66.02	66.00	8.26	8.32	9.63	9.63	60.13	60.44	60.45	59.89	25.81	57.40	59.88	59.98
		SEM	1.72	1.98	1.55	1.52	0.42	0.56	0.49	0.69	0.86	0.70	0.66	0.82	1.32	1.36	1.44	1.32
Pusa-9632	0	Mean	67.32	64.22	66.09	67.09	10.24	9.01	9.99	10.14	60.32	60.33	61.22	61.00	41.42	46.35	48.40	52.40
		SEM	.06	1.46	1.29	1.96	0.86	0.88	1.00	0.76	1.07	1.23	0.98	0.79	1.72	1.59	1.64	1.57
	10	Mean	6.57	56.66	62.31	65.33	9.78	10.36	10.76	9.68	58.67	59.15	57.26	57.10	35.75	65.11	68.47	68.98
		SEM	1.32	1.74	1.88	1.29	0.83	0.96	0.55	0.67	0.59	0.69	0.46	0.86	1.42	1.59	1.23	1.95
	20	Mean	51.99	61.09	68.37	69.33	9.44	9.43	9.99	9.64	59.03	59.25	58.11	55.39	29.27	64.90	68.40	65.33
		SEM	1.14	0.99	1.69	1.20	0.25	0.82	0.39	0.29	0.59	0.88	0.69	1.00	3.12	3.22	3.06	1.66
	30	Mean	42.09	65.24	68.90	65.33	7.83	9.23	9.89	9.66	60.98	60.74	59.31	57.19	26.35	58.22	61.70	62.90
		SEM	1.74	1.58	1.75	1.20	0.55	0.66	0.59	0.47	0.67	0.59	0.63	1.00	1.73	1.56	1.00	1.46
K-851	0	Mean	65.31	68.80	71.05	68.56	10.98	8.13	9.06	9.97	61.47	60.82	61.66	62.34	46.43	44.90	46.05	50.44
		SEM	0.61	0.97	1.46	0.89	0.18	0.29	0.38	0.26	0.77	0.62	0.86	0.76	1.52	1.23	0.98	1.52
	10	Mean	60.01	68.55	67.04	68.23	9.28	9.78	10.59	9.99	59.38	57.82	56.11	56.06	48.89	66.01	72.11	75.32
		SEM	1.34	1.69	1.66	1.50	0.70	0.99	1.00	0.46	1.17	1.06	0.98	0.09	1.22	2.33	1.56	1.63
	20	Mean	5.19	62.19	65.03	66.30	8.11	9.73	9.90	10.33	59.05	59.00	56.77	55.06	36.70	62.70	65.41	60.99
		SEM	1.23	1.44	0.98	1.12	0.56	0.65	0.60	0.59	0.63	0.96	0.80	0.70	1.54	1.96	1.42	1.31
	30	Mean	55.40	68.04	69.32	69.05	8.01	7.99	9.63	9.86	60.80	59.89	59.44	59.31	32.40	55.41	57.13	59.63
		SEM	0.98	1.29	0.86	1.75	0.31	0.41	0.39	0.39	0.86	0.69	0.44	0.20	1.20	1.36	1.45	1.22

... Contd

Table 3. contd.....

	Dose (kR)		Pod length (cm)				Seed pod^{-1}				100 seed weight (g)				Seed yield plant^{-1}(g)			
			M_2	M_3	M_4	M_5	M_2	M_3	M_4	M_5	M_2	M_3	M_4	M_5	M_2	M_3	M_4	M_5
B1	0	Mean	7.21	9.63	9.82	9.78	9.97	10.22	10.57	10.59	3.18	3.19	3.27	3.31	20.23	20.13	22.00	22.68
		SEM	0.36	0.48	0.52	0.36	0.39	0.59	0.42	0.60	0.18	0.26	0.11	0.11	1.19	1.56	1.44	1.04
	10	Mean	6.60	11.00	11.30	11.66	8.18	12.05	12.69	12.75	3.40	3.43	3.43	3.45	20.01	28.56	29.41	29.95
		SEM	0.30	0.29	0.48	0.49	0.21	0.46	0.39	0.60	0.16	0.29	0.18	0.29	0.37	0.49	0.96	0.85
	20	Mean	6.48	10.89	11.24	11.56	8.11	12.55	12.44	12.46	3.26	3.29	3.28	3.40	18.98	25.98	27.80	29.19
		SEM	0.30	0.62	0.47	0.36	0.51	0.44	0.59	0.53	0.16	0.32	0.11	0.20	1.43	1.33	1.29	1.00
	30	Mean	6.33	10.29	10.00	10.55	8.02	10.74	10.00	10.65	3.22	3.24	3.29	3.38	16.40	22.41	23.96	24.50
		SEM	0.36	0.59	0.32	0.26	0.69	0.72	0.66	0.62	0.28	0.20	0.11	0.15	1.03	0.86	0.48	0.13
Pusa-9632	0	Mean	7.75	9.82	9.79	9.86	9.00	9.78	9.93	9.63	3.39	3.45	3.49	3.50	21.40	22.32	22.44	24.56
		SEM	0.19	0.30	0.22	0.13	0.54	0.63	0.49	0.50	0.21	0.22	0.10	0.11	0.82	0.42	0.66	0.46
	10	Mean	7.48	10.59	11.58	11.69	10.90	13.11	12.04	11.90	3.68	3.72	3.74	3.80	17.62	30.50	32.70	32.86
		SEM	0.52	0.49	0.66	0.47	0.58	0.29	0.47	0.59	0.07	0.09	0.13	0.19	1.22	0.53	0.92	1.11
	20	Mean	7.07	11.00	12.00	12.00	9.28	12.77	12.44	12.57	3.85	3.90	4.09	4.25	15.08	28.49	29.71	29.87
		SEM	0.29	0.42	0.39	0.27	0.46	0.53	0.40	0.59	0.11	0.19	0.11	0.23	1.74	1.66	1.55	1.20
	30	Mean	6.50	11.00	11.06	11.00	9.55	10.59	11.77	11.09	3.75	3.80	3.92	3.96	14.33	27.44	28.05	26.66
		SEM	0.20	0.33	0.20	0.28	0.55	0.66	0.49	0.54	0.11	0.19	0.16	0.55	1.39	1.90	1.58	1.19
K-851	0	Mean	8.05	8.00	8.16	8.76	9.53	9.40	9.76	9.96	3.66	3.89	3.92	4.00	18.85	19.39	24.51	24.66
		SEM	0.19	0.22	0.10	0.11	0.51	0.63	0.40	0.43	0.10	0.08	0.11	0.11	0.35	0.57	0.62	0.25
	10	Mean	8.34	10.90	11.82	11.68	10.44	13.70	12.92	13.53	4.10	4.18	4.26	4.40	20.47	31.77	33.40	34.56
		SEM	0.22	0.16	0.30	0.19	0.49	0.59	0.63	0.59	0.16	0.18	0.10	0.12	0.69	0.73	0.85	0.39
	20	Mean	8.34	10.10	10.22	10.59	9.76	10.55	11.40	11.76	4.16	4.23	4.29	4.36	18.09	28.56	29.97	30.22
		SEM	0.30	0.28	0.39	0.39	0.39	0.42	0.50	0.30	0.19	0.22	0.15	0.12	1.39	1.46	1.55	1.62
	30	Mean	8.28	9.64	9.08	9.66	9.15	10.44	10.63	10.75	4.00	4.20	4.34	4.32	15.21	25.33	27.02	29.06
		SEM	0.27	0.36	0.22	0.56	0.39	0.44	0.50	0.32	0.18	0.16	0.14	0.10	0.99	0.82	0.80	0.29

SEM = standard error of mean (±)

Table 4. Performance of selected promising M_5 individuals

	Individual (M_5)	Dose	Characters							
			Plant height (cm)	Branch/ plant^{-1}	Days to maturity	Pods/ plant^{-1}	Pod length (cm)	Seed/ pod^{-1}	100-seed weight (g)	Seed yield plant^{-1}(g)
B1	-L_1P_4	Control	68.73	9.66	65.22	45.35	9.78	10.59	3.31	22.68
	-L_3P_3	10kR	54.55	9.19	54.58	65.92	10.85	12.26	3.41	26.58
	-L_5P_8		40.88	11.59	53.08	68.94	11.65	12.67	3.47	30.28
	-L_6P_2		57.22	11.55	54.25	69.77	11.26	12.08	3.36	29.01
	-L_7P_{10}		58.66	11.05	54.8	69.89	11.34	13.73	3.44	27.54
	-L_8P_9	20kR	52.13	10.72	54.46	60.35	11.68	12.96	3.44	26.62
	-$L_{10}P_{10}$		49.33	10.09	53.14	64.89	11.05	13.11	3.61	26.37
	-$L_{10}P_8$		52.63	9.83	53.21	59.63	10.86	12.98	3.63	27.56
Pusa-9632	-$L_{13}P_6$	Control	67.09	9.99	61.94	52.40	9.86	9.63	3.50	24.56
	-$L_{14}P_9$	10kR	42.33	11.75	53.23	66.84	11.46	11.14	3.79	30.31
	-$L_{14}P_2$		40.12	11.09	53.21	65.94	11.31	12.51	3.75	31.94
	-$L_{15}P_1$		50.47	11.79	54.23	68.98	12.30	11.59	3.82	32.91
	-$L_{16}P_9$		48.50	12.29	53.81	68.61	12.75	11.93	3.80	27.58
	-$L_{17}P_5$		43.66	12.05	53.57	65.63	11.73	11.59	3.83	31.47
	-$L_{17}P_3$		57.02	11.85	54.62	65.05	11.53	11.93	3.85	31.92
	-$L_{19}P_8$	20kR	51.23	10.62	54.96	65.32	12.02	12.59	3.68	29.93
K-851	-$L_{23}P_4$	Control	68.56	9.06	62.34	50.44	8.76	9.96	4.00	24.66
	-$L_{27}P_9$	10kR	56.09	11.55	54.13	70.21	11.04	12.06	4.19	27.05
	-$L_{27}P_5$		46.11	12.16	53.11	75.33	11.61	13.39	4.43	31.39
	-$L_{29}P_3$		55.31	12.18	53.57	76.22	11.31	12.21	4.41	30.61
	-$L_{30}P_8$	20kR	60.29	10.58	54.86	61.08	11.59	12.13	4.32	30.68
	-$L_{32}P_8$		55.12	11.38	54.07	64.02	11.37	11.68	4.06	29.79
	-$L_{34}P_5$	30kR	59.22	10.36	55.00	62.91	10.98	12.62	4.23	29.31

Table 5. Grouping of means for different agro-morphological parameters in M_5 generation

	Dose	Plant height (cm)			Branch plant^{-1}			Days to maturity			Pods plant^{-1}		
		(-)	N	(+)	(-)	N	(+)	(-)	N	(+)	(-)	N	(+)
B1	10kR	21	18	16	10	25	20	44	0	11	5	10	40
	20kR	9	12	19	8	15	17	17	9	14	9	6	25
	30kR	11	15	12	12	18	8	17	5	8	4	14	20
Pusa-9632	10kR	29	6	27	15	5	42	38	5	19	10	15	37
	20kR	17	8	14	19	9	11	25	8	6	9	6	24
	30kR	30	5	11	10	19	17	18	4	24	5	9	32
K-851	10kR	21	10	27	16	4	38	42	6	10	13	18	27
	20kR	10	9	20	20	10	9	16	7	16	8	9	22
	30kR	28	5	7	9	13	18	25	0	15	7	13	20
		Pod Length (cm)			Seed pod^{-1}			100 seed weight (g)			Seed yield plant^{-1}(g)		
		(-)	N	(+)	(-)	N	(+)	(-)	N	(+)	(-)	N	(+)
B1	10kR	6	10	39	5	9	41	5	31	19	9	6	40
	20kR	5	9	26	8	12	20	4	23	13	5	12	23
	30kR	9	8	21	6	8	24	9	19	10	8	10	20
Pusa-9632	10kR	9	15	38	9	16	37	6	37	19	6	10	46
	20kR	12	10	17	8	0	31	5	22	12	13	8	18
	30kR	4	9	33	3	19	24	0	36	10	8	9	29
K-851	10kR	12	8	38	10	19	29	12	37	12	9	15	34
	20kR	15	0	24	6	12	21	9	20	10	11	16	12
	30kR	9	12	19	8	11	21	4	25	11	15	18	7

(-) = negative shift, (+) = positive shift and N = no change number of branch plant^{-1}, number of pods plant^{-1}, pod length, no. of seeds pod^{-1}, seed yield plant^{-1} and negative shift for days to maturity (Table 5). This trend indicates the maximum possibility of recovering lines with improved seed potentiality as well as early maturity duration.

The present investigation evidently showed that such mutants were not only highly productive, early maturing type as compared to parents but also had synchrony in pod maturity, non-shattering pod and top fruitbearing habit, which are very useful and desirable traits. Thus, it is expected that these mutants may be responsive to low cost harvesting and threshing operations. The early-maturity characteristics of the mutants also make them more suitable for intercropping with a number of crops such as sugarcane, maize, sorghum, vegetables and fruits. These twenty mutant individuals identified from M_5 generations could be used in hybridization programme to incorporate the identified characters of early maturity and high yield into exotic large-seeded varieties of mungbean. Recognizing the potential of these mutants as a cultivar and donor for crossing programme, these mutant lines could be forwarded for variety registration for both high productivity and extra early maturity duration. The identified mutants can also fit well in different cropping systems.

Authors' contribution

Conceptualization of research (SK, MS); Designing of the experiments (MS, SK); Contribution of experimental materials (SK); Execution of field/lab experiments and data collection (MS); Analysis of data and interpretation (MS); Preparation of manuscript (MS).

Declaration

The authors declare no conflict of interest.

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