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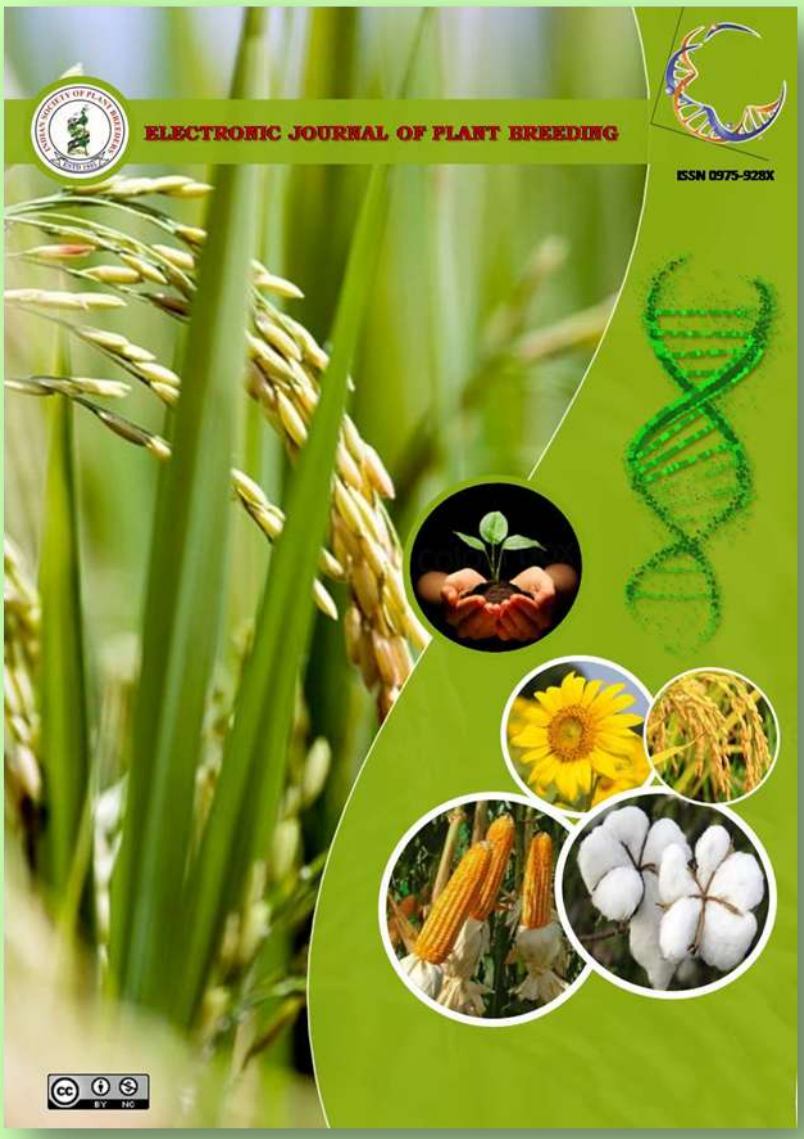

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Research Article

Combined mutagenic ability of gamma ray and EMS in horsegram (*Macrotyloma uniflorum* (Lam) Verdc.)

S. Priyanka[1], R. Sudhagar[2]*, C. Vanniarajan[3], K. Ganesamurthy[4] and J. Souframanien[5]
[1]Ph. D Scholar,Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu-641007.
[2]Associate Professor and Head (PBG), Sugarcane Research Station, Vellore, Tamil Nadu -635806
[3]Professor and Head (PBG), Agricultural College and Research Institute, Madurai, Tamil Nadu-625104
[4]Professor and Head (PBG), Department of Rice, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu-641007
[5]Principal Collaborator, NA&BTD, Bombay Atomic Research Centre, Trombay, Mumbai- 400 085.
***E-Mail**: sudhagar.r@tnau.ac.in

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Abstract
Two photosensitive and indeterminate varieties of horsegram *viz*., PAIYUR 2 and CRIDA 1-18 R were utilized for mutagenic study. M_2 populations of gamma ray (G) + EMS were statistically analyzed to determine the extent of variability and scope of selection for the trait improvement. In this study, mutant population exhibited considerable variation for most of the traits in comparison with respective controls. The negative shift in mean value was observed for most of the yield components in mutant population of both varieties. Combination treatments *viz*., G+EMS: 200 Gy+0.3% and G+EMS: 300 Gy+0.3% were found suitable for the improvement of single plant yield in both varieties. Based on the estimates of skewness and kurtosis, the nature of gene action was determined for the traits. Positively skewed distribution with leptokurtic curve was noticed for single plant yield suggesting for adoption of intense selection in existing variability for maximizing the genetic gain.

Keywords
Horsegram, Mutant population, Variability, G + EMS

Introduction

Horsegram (*Macrotyloma uniflorum* (Lam) Verdc.) is a diploid autogamous crop of *fabaceae* family having maturity period of 120 to 180 days (Morris, 2008). It is being predominantly cultivated in Southern India as a multipurpose legume during *Rabi* season (September - December / January) because of its photosensitivity. Horsegram has a long tradition of cultivation as a food crop since 2000 BC (Mehra, 2000). The seeds are enriched with protein (17.9 to 25.3 percent), carbohydrates, iron, molybdenum (Bravo *et al*., 1999) and vitamins (Sodani *et al*., 2004) and thus sustain nutritional security in the developing countries. Further, it offers scope for cultivation in drought prone areas (Bhardwaj and Yadav, 2012), salinity affected lands (Reddy *et al.*, 1998) and heavy metal polluted soils (Reddy *et al*., 2005). In addition, owing to its genome plasticity it is being cultivated in low input lands where other legumes fail to survive and support. The medicinal values of horsegram are well documented and noteworthy. It's the main food ingredient in Indian ancient medicines used for clearing kidney stones, treating urinary diseases and piles (Yadava and Vyas, 1994). The horsegram soup serves as an excellent remedy for common cold, throat infection and fever (Perumal and Sellamuthu, 2007). Despite these supremacies, the potential yield of horsegram is not being realized due to its narrow genetic base and absence of targeted breeding programmes. Alongside, it experiences terminal drought due to its long duration. The prostrating growth habit makes it to lose 10 to 15% yield due to green immature pods at harvest. Therefore, the need arises to create variability for yield attributing traits, duration and growth types in horsegram.

Major emphasis on breeding aspects has to be implicated in this underutilized legume to restore the variability which was dwindled during selection (Wani and Anis, 2001). The success of widening the genetic base and varietal development through classical breeding methodologies in horsegram is limited due to complexities in hybridization, flower drop and low percent of pod set (2% - 3%). Induced mutagenesis play a vital role in generation of variability and thereby offers scope in crop improvement through selection of desired characters. Many studies on different mutagens and its combinations have been reported in legumes but it remains scanty in horsegram (Datir, 2016). Hence, the present investigation was carried out to explore the combined effect of gamma ray (G) and ethyl methane sulphonate (EMS) in inducing

variability and suggest scope of selection for improvement of yield attributing traits.

Materials and Methods

Two popular photosensitive and indeterminate varieties of horsegram *viz*., PAIYUR 2 released from Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu and CRIDA 1-18 R from Central Research Institute for Dry land Agriculture, Hyderabad, Telengana were considered for mutation studies with a view of inducing variability for yield, plant types and flowering habit. LD_{50} dosage value has been fixed in our previous experimental studies for EMS (0.3%) and gamma ray (200 - 300 Gy). High frequency of mutation induction was reported in concentration of 0.2% - 0.3% EMS (Bolbhat *et al*., 2012). Therefore, two treatment combinations of G + EMS *viz.*, 200 Gy + 0.3% and 300 Gy + 0.3% were utilized to study the extent of induced variability in both varieties. Irradiation treatments were carried at Bhabha Atomic Research Center (BARC), Trombay, Mumbai, India. The gamma irradiated seeds were soaked in distilled water for 10 hours and the presoaked seeds were treated with 0.3% EMS for 4 hours at pH 7.0 with intermittent shaking. The seeds were thoroughly washed in running water.

In M_1 generation, a total of 500 seeds per treatment were sown in 4m length row following spacing pattern of 30 x 15 cm. The experiment was conducted in randomized block design with two replications in the research farm of Department of Pulses, TNAU during *Rabi* 2017. The seeds of M_1 plants were harvested individually and forwarded to M_2 generation following plant to progeny row method during *Rabi* 2018.

In M_2 generation, normal looking plants as that of control in the treatments were selected for data documentation. The biometrical traits *viz*., days to 50 per cent flowering, days to maturity, plant height (cm), pod length (cm), number of primary branches per plant, number of pods per cluster, number of clusters per plant, number of pods per plant, number of seeds per pod, hundred seed weight (g), biological yield (g), single plant yield (g) and harvest index were recorded for identification of micro-mutations. Statistical analyses *viz*., mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) (Burton, 1952), broad sense heritability (H^2) (Lush, 1940), genetic advance as percent of mean (GAM) (Johnson *et al*., 1955), skewness and kurtosis (Snedecor and Cochran, 1967) were estimated to determine the extent and frequency pattern of variability in mutant population.

Results and Discussion

In India, horsegram covers an area of 325.99 thousand ha with a production and productivity of 116.65 thousand tones and 355 kg ha^{-1} respectively (Indiastat, 2016). Its cultivable area and production can be increased by breeding for ideal genotypes suitable for intensive agriculture (Sharma *et al*., 2015). The present day horsegram varieties are spreading types with medium to long duration and cultivated only in *Rabi* season due to photosensitivity in Southern India. Development of high yielding photo-insensitive varieties with altered duration would highly benefit marginal farming community in the developing countries. Early maturing types can evade terminal drought. Erect bushy types are suited for mechanical harvesting. The presence of wider genetic base is an essential pre-requisite for adopting any breeding strategy. Horsegram is a self pollinated crop having small sized flowers and hence put forth difficulties in creating variability for economic traits through classical breeding. Flower dropping after hybridization is also a grave concern. Induced mutation otherwise proved to be an effective breeding tool for creating variability in many crop plants. Being a diploid species, horsegram offers scope for getting high frequency of mutations at phenotypic level. Patel *et al*. (2010) reported the efficiency of physical mutagens in creating variability for morphological traits, duration and other yield attributes in horsegram. Chemical mutagens were also found to be equally effective for inducing morphological mutations in horsegram (Kulkarni and Mogle, 2013). But combination effects of physical and chemical mutagens in horsegram are to be studied as earlier works are very few.

Scossiroli (1977) suggested the importance of estimating the magnitude of genetic variability for quantitative traits in M_2 population for framing out the selection programme. Mutant populations (M_2) of combination treatment *viz.*, G + EMS were statistically analyzed to determine the extent of variability for micro-mutations. Estimates of mean, range, shift in mean and coefficient of variation are depicted in Table 1. In this study, the coefficient of variation of mutant population was found to deviate from control due to change in shift of mean towards positive and negative directions. This proves that the mutagens employed were highly effective in inducing variability for the quantitative traits. The mean values of mutant population were lower than control for six traits *viz*., number of primary branches per plant, pod length (cm), number of pods per cluster, number of clusters per plant, number of pods per plant, biological yield (g), single plant yield (g) in both varieties

irrespective of doses. The negative shift in mean values for the above mentioned traits may be due to occurrence of detrimental mutants. Similar results were reported by Bolbhat *et al*. (2012) for yield and other attributing traits in horsegram. However dose and variety dependent extreme range (above control) in mean values were noticed. In variety PAIYUR 2, extreme values recorded for single plant yield (50.11 g: 200Gy+0.3% & 52.11 g: 300 Gy+0.3%), number of primary branches (14: 200Gy+0.3% & 12: 300 Gy+0.3%) , number of pods per cluster (3.14: 200Gy+0.3% & 3.33: 300 Gy+0.3%), number of pods per plant (132: 200Gy+0.3% & 138: 300 Gy+0.3%), biological yield (105 g: 200Gy+0.3% & 78 g: 300 Gy+0.3%), pod length (5.57 cm: 300Gy+0.3%), number of seeds per pod (6.67: 200Gy+0.3% & 6.45: 300 Gy+0.3%), 100 seed weight (4.12 g: 200Gy+0.3% & 4.54 g: 300 Gy+0.3%) and harvest index (0.54: 200Gy+0.3% & 0.56: 300 Gy+0.3%). Similarly, number of cluster per plant (95: 200 Gy+0.3%), number of pods per plant (146: 200Gy+0.3% & 132: 300Gy+0.3%), number of seeds per pod (6.87: 200Gy+0.3%), 100 seed weight (4.55 g: 200Gy+0.3% & 4.68 g: 300Gy+0.3%), single plant yield (60.12 g: 200 Gy+0.3%) and harvest index (0.54: 200Gy+0.3%) in case of CRIDA 1-18 R. Such positive transgressive segregants would bring improvement in polygenic traits upon further selection. The positive shift in mean values (increased days) was noted for days to 50% flowering and days to maturity in both varieties. A slight delay in flowering was noted in G+EMS treatments by Bolbhat *et al*. (2012) in horsegram. Similar reports on delayed duration in different legumes were given by Rudraswami *et al*. (2006), Manjaya and Nandanvar (2007), Ahire (2008) and Tambe (2009). Extreme earlier types for plant duration were not observed in this study. The genotypic difference was noted in the direction of shift in mean values for plant height, harvest index and hundred seed weight. Extreme dwarf types were observed in all doses in both varieties. The positive shift in mean value for hundred seed weight and harvest index was noted in mutant population of CRIDA1-18 R. Wani *et al*. (2012) reported similar results for hundred seed weight in chickpea.

Estimates of GCV and PCV are important to understand the genetic variability induced by mutagens. In this study, the variation found in control (untreated plants) was taken as environmental variance and variation of mutant population were considered as phenotypic variance. The phenotypic (PCV) and genotypic coefficient of variation (GCV) was calculated from the respective variances as per formula given by Burton (1952). Classification of PCV and GCV as low (below 10%); medium (10% - 20%) and high (above 20%) was done as per protocol suggested by Sivasubramanian and Menon (1973). Estimates of PCV, GCV, H^2 and GAM of mutant population are depicted in Table 2. The experimental traits exhibited all the above three classes of PCV and GCV. Trait *viz*., number of pods per plant exhibited high PCV (26.28) and GCV (27.79) value in G + EMS: 200 Gy + 0.3% mutant population of PAIYUR 2 cultivar. Similar results were noticed in mutant population of gamma ray and EMS by Patil *et al*. (2011) in soybean. Low and moderate values of PCV and GCV were observed for plant height, pod length, number of pods per cluster, number of clusters per plant, number of seeds per pod, biological yield and harvest index. Traits *viz*., days to 50% flowering, days to maturity and hundred seed weight recorded low PCV and GCV in both varieties irrespective of doses. Usharani and Kumar (2016) reported similar values of PCV and GCV for flowering duration in gamma ray and EMS treated population of black gram. While, moderate values of PCV and GCV were noted for number of primary branches and single plant yield. In general, the estimates of PCV were found to be slightly higher than GCV indicating the less influence of environmental factors in the expression of traits. Akin results were given by Tabasum *et al*. (2010) in green gram and Reddy *et al*. (2011) in black gram.

The estimates of H^2 act as a predictive tool in determining the reliability of observed effects. Categorization of H^2 into low (below 30%), medium (30% - 60%) and high (above 60%) was done as per scale given by Johnson *et al*. (1955). Most of the traits in the study exhibited high range of heritability suggesting adoption of simple selection techniques based on phenotypic expression of traits. Grouping of genetic advance as low (below 10%), medium (11% - 20%) and high (above 20%) was done as per Johnson *et al*. (1955). It refers to the improvement in the genotypic value of the selected population over the original population.

The combined estimates of H^2 and GAM act as a reliable measure in predicting the genetic gain under selection. High H^2 and GAM were noticed for number of primary branches per plant, number of clusters per pod, number of pods per plant and single plant yield for all treatment doses in PAIYUR 2 whereas single plant yield in case of CRIDA1-18 R suggesting the preponderance of additive gene effects in the expression of these traits and thus improvement can be made by adopting simple selection methods. On a nutshell, wider extent of variability coupled with H^2 and GAM were considered to determine the efficient

mutagenic doses for the improvement of concerned traits through selection. However the stability of genetic variability for the below mentioned traits should be analyzed in the subsequent generations.

Variety: CRIDA 1-18R		
Single plant yield	:	G +EMS : 200Gy + 0.3% and G +EMS : 300Gy + 0.3%
Biological yield and number of clusters per plant	:	G +EMS : 200Gy + 0.3%
Number of pods per plant	:	G +EMS : 300Gy + 0.3%
Variety: PAIYUR 2		
Single plant yield, number of pods per plant, number of clusters per plant and number of primary branches per plant	:	G +EMS : 200Gy + 0.3% and G +EMS : 300Gy + 0.3%
Plant height	:	G +EMS : 200Gy + 0.3%
Biological yield and harvest index	:	G +EMS : 300Gy + 0.3%

Skewness and kurtosis were estimated using SPSS software as per formula given by Snedecor and Cochran (1967). The significance was estimated by comparing calculated 't' value with table 't' value at (n-1) degrees of freedom and 0.05% probability. Skewness refers to asymmetry of the distribution curve which gives information on nature of gene action (Fisher *et al*., 1932). Positive skewed distributions (skewed towards right) are associated with dominant based complementary gene interactions while negatively skewed distributions (skewed towards left) are related with dominant based duplicate type of gene interactions. Kurtosis refers to the peakedness of the distribution curve which provides information on number of genes involved (Robson, 1956). Traits with leptokurtic (kurtosis < 3) and platykurtic (kurtosis > 3) distribution are governed by fewer and large number of genes respectively. The frequency distribution patterns were studied for 13 quantitative traits in G+EMS mutant population of cultivar PAIYUR 2 and CRIDA 1-18 R (Table 3).

Non significant skewness and kurtosis was noticed for number seeds per pod in both varieties suggesting no deviations from normality with absence of gene interactions. Traits *viz*., plant height and days to maturity (Fig. 1), positively skewed distribution with platykurtic curve for PAIYUR 2 while leptokurtic curve for CRIDA1-18 R was noticed. Intense selection from existing variability can be adopted for maximizing the genetic gain for these traits (Roy, 2000). Significant negative skewness with non significant kurtosis was noticed for pod length indicating absence of gene interactions in both varieties. Few genes with decreasing effect were observed for single plant yield (Fig. 2) in both varieties which suggest the adoption of intense selection in mutant population for the trait improvement. Similarly for biological yield, a leptokurtic and platykutic curve with positive skewed distribution was observed for PAIYUR 2 and CRIDA 1-18 R respectively. Absence of gene interaction was noticed for days to 50% flowering (Fig. 3) in cultivar CRIDA1-18 R whereas duplicate gene interactions for PAIYUR 2 suggesting for adoption of mild selection in improvement of trait. Few dominant genes with decreasing effect indicating complementary gene interaction in inheritance of number of clusters per plant and number of primary branches per plant in cultivar CRIDA 1-18 R. Mild selection is sufficient for the improvement of number of clusters per plant in PAIYUR 2 since it possess large number of genes with increasing effect. A leptokurtic curve with complementary gene interaction suggest to adopt high selection intensity to increase number of pods per plant in CRIDA 1-18 R and number of pods per cluster in PAIYUR 2 respectively.

Combination treatment *viz*., G+EMS has induced variability for single plant yield in both varieties and thus can be employed in breeding programme for evolving yield mutants in horsegram. With respect to duration, delayed flowering was noticed in both the doses. Improvement in genetic gain can be achieved by following intense selection in existing variability for single plant yield since it exhibits positively skewed distribution with leptokurtic curve.

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Table 1. Mean ± standard error, shift in mean, range and co-efficient of variation for quantitative traits in M_2 generation of horsegram

Traits	Treatment (G + EMS)	Mean± Standard error		Shift in mean		Range		Co-efficient of variation	
		PAIYUR 2	CRIDA 1-18 R	PAIYUR 2	CRIDA 1-18 R	PAIYUR 2	CRIDA 1-18 R	PAIYUR 2	CRIDA 1-18 R
Days to 50% flowering	CONTROL	**55.17 ± 0.13**	**46.49 ± 0.10**	-	-	**58.00 - 51.00**	**56.00 - 46.00**	**2.81**	**2.55**
	200 Gy + 0.3 %	55.94 ± 0.18	52.78 ± 0.26	0.77	6.29	62.00 - 50.00	57.00 - 48.00	3.96	5.95
	300 Gy + 0.3 %	56.68 ± 0.23	52.73 ± 0.29	1.51	6.24	61.00 - 49.00	58.00 - 44.00	4.99	6.83
Days to maturity	CONTROL	**105.60 ± 0.15**	**96.13 ± 0.11**	-	-	**110.00 - 102.00**	**118.00 - 94.00**	**1.75**	**1.38**
	200 Gy + 0.3 %	106.82 ± 0.21	97.84 ± 0.26	1.21	1.71	112.00 - 103.00	118.00 - 94.00	2.45	3.25
	300 Gy + 0.3 %	107.42 ± 0.25	98.25 ± 0.29	1.82	2.12	120.00 - 100.00	111.00 - 96.00	2.80	3.60
Plant height(cm)	CONTROL	**72.29 ± 0.37**	**64.75 ± 0.27**	-	-	**80.90 - 64.10**	**108.90 - 64.20**	**6.27**	**5.11**
	200 Gy + 0.3 %	83.74 ± 0.94	59.83 ± 0.59	11.45	- 4.92	128.50 - 52.14	112.20 - 38.20	13.78	12.14
	300 Gy + 0.3 %	81.26 ± 0.75	64.32 ± 0.61	8.97	- 0.43	126.30 - 44.50	99.30 - 31.45	11.36	11.59
Pod length (cm)	CONTROL	**5.12 ± 0.02**	**5.07 ± 0.01**	-	-	**5.51 - 4.50**	**5.68 - 4.02**	**4.51**	**3.16**
	200 Gy + 0.3 %	4.46 ± 0.04	4.72 ± 0.02	- 0.66	- 0.35	5.43 - 3.21	5.40 - 3.53	10.84	6.38
	300 Gy + 0.3 %	4.57 ± 0.04	4.70 ± 0.03	- 0.55	- 0.38	5.57 - 3.21	5.43 - 3.53	10.01	8.08
Number of primary branches per plant	CONTROL	**8.62 ± 0.04**	**7.88 ± 0.03**	-	-	**10.00 - 7.00**	**12.00 - 5.00**	**5.95**	**4.86**
	200 Gy + 0.3 %	8.50 ± 0.09	6.93 ± 0.07	- 0.13	- 0.95	14.00 - 5.00	12.00 - 4.00	13.31	11.82
	300 Gy + 0.3 %	6.77 ± 0.11	6.66 ± 0.07	- 1.86	- 1.22	12.00 - 4.00	11.00 - 6.00	19.85	12.16
Number of pods per cluster	CONTROL	**2.83 ± 0.01**	**2.77 ± 0.01**	-	-	**2.92 - 2.51**	**3.67 - 2.21**	**4.34**	**5.18**
	200 Gy + 0.3 %	2.04 ± 0.02	2.36 ± 0.02	- 0.79	- 0.41	3.14 - 1.54	3.33 - 1.33	9.26	10.49
	300 Gy + 0.3 %	1.77 ± 0.02	2.61 ± 0.02	- 1.07	- 0.16	3.33 - 1.45	3.33 - 1.33	15.38	8.63
Number of clusters per plant	CONTROL	**47.41 ± 0.23**	**46.54 ± 0.18**	-	-	**58.00 - 44.00**	**58.00 - 35.00**	**5.91**	**4.73**
	200 Gy + 0.3 %	45.85 ± 0.59	44.01 ± 0.44	- 1.56	- 2.53	58.00 - 23.00	95.00 - 31.00	15.77	12.23
	300 Gy + 0.3 %	40.77 ± 0.60	38.59 ± 0.30	- 6.64	- 7.95	52.00 - 23.00	47.00 - 31.00	18.01	9.56
Number of pods per plant	CONTROL	**111.47 ± 0.51**	**111.24 ± 0.41**	-	-	**124.00 - 105.00**	**121.00 - 41.00**	**5.63**	**4.54**
	200 Gy + 0.3 %	69.19 ± 1.58	82.08 ± 0.75	- 42.28	- 29.16	132.00 - 31.00	146.00 - 37.00	27.89	11.20
	300 Gy + 0.3 %	63.86 ± 1.14	64.94 ± 0.89	- 47.61	- 46.30	138.00 - 41.00	132.00 - 34.00	21.88	16.82
Number of seeds per pod	CONTROL	**5.32 ± 0.02**	**5.38 ± 0.02**	-	-	**5.70 - 4.68**	**6.67 - 5.00**	**5.69**	**3.87**
	200 Gy + 0.3 %	5.14 ± 0.05	5.14 ± 0.03	- 0.18	- 0.23	6.67 - 4.00	6.87 - 3.64	11.97	7.65
	300 Gy + 0.3 %	5.30 ± 0.03	5.66 ± 0.04	- 0.03	0.28	6.45 - 4.22	6.33 - 3.67	7.09	9.53
Hundred seed weight (g)	CONTROL	**3.94 ± 0.01**	**3.54 ± 0.01**	-	-	**4.11 - 3.81**	**4.44 - 3.40**	**2.55**	**2.84**
	200 Gy + 0.3 %	3.57 ± 0.02	4.18 ± 0.01	- 0.37	0.65	4.12 - 3.15	4.55 - 3.21	7.02	3.59
	300 Gy + 0.3 %	3.75 ± 0.02	3.77 ± 0.02	- 0.18	0.23	4.54 - 2.55	4.68 - 2.94	5.81	5.89
Biological yield (g)	CONTROL	**64.62 ± 0.24**	**55.88 ± 0.20**	-	-	**69.00 - 61.00**	**92.00 - 27.00**	**4.64**	**4.46**
	200 Gy + 0.3 %	62.46 ± 0.52	51.20 ± 0.55	- 2.17	- 4.68	105.00 - 51.00	92.00 - 32.00	10.28	13.16
	300 Gy + 0.3 %	54.32 ± 0.69	37.27 ± 0.32	- 10.30	- 18.61	78.00 - 32.00	61.00 - 25.00	15.54	10.43
Single plant yield (g)	CONTROL	**27.86 ± 0.10**	**23.13 ± 0.11**	-	-	**28.91 - 25.21**	**42.50 - 16.30**	**4.27**	**5.83**
	200 Gy + 0.3 %	23.20 ± 0.24	18.82 ± 0.32	- 4.66	- 4.31	50.11 - 15.24	60.12 - 12.78	12.78	20.62
	300 Gy + 0.3 %	21.53 ± 0.30	16.59 ± 0.21	- 6.34	- 6.54	52.11 - 14.21	39.55 - 10.20	17.34	15.67
Harvest index	CONTROL	**0.40 ± 0.002**	**0.41 ± 0.002**	-	-	**0.46 - 0.37**	**0.53 - 0.20**	**5.45**	**5.89**
	200 Gy + 0.3 %	0.32 ± 0.005	0.49 ± 0.003	- 0.09	0.08	0.54 - 0.25	0.54 - 0.25	18.08	8.40
	300 Gy + 0.3 %	0.30 ± 0.004	0.44 ± 0.003	- 0.10	0.03	0.56 - 0.21	0.50 - 0.25	17.05	7.78

Table 2. Estimates of variability parameters, heritability and genetic advance in mutant populations (M_2) of horsegram

Traits	Treatment (G + EMS)	GCV (%)		PCV (%)		H^2 (%)		GAM	
		P 2	CR	P 2	CR	P 2	CR	P 2	CR
Days to 50% flowering	200 Gy + 0.3 %	2.82	5.49	3.95	5.93	50.88	85.73	4.14	10.47
	300 Gy + 0.3 %	4.16	6.43	4.97	6.81	69.88	89.16	7.16	12.50
Days to maturity	200 Gy + 0.3 %	1.73	2.88	2.44	3.19	50.24	81.97	2.53	5.38
	300 Gy + 0.3 %	2.21	3.33	2.79	3.59	62.33	85.93	3.59	6.35
Plant height(cm)	200 Gy + 0.3 %	12.63	10.78	13.73	12.10	84.55	79.29	23.92	19.77
	300 Gy + 0.3 %	9.87	10.35	11.32	11.55	75.88	80.32	17.70	19.11
Pod length (cm)	200 Gy + 0.3 %	9.49	5.39	10.81	6.36	77.14	71.79	17.17	9.41
	300 Gy + 0.3 %	8.61	7.30	9.98	8.05	74.47	82.18	15.30	13.64
Number of primary branches per plant	200 Gy + 0.3 %	11.82	10.41	13.26	11.78	79.42	78.16	21.70	18.96
	300 Gy + 0.3 %	18.28	10.68	19.78	12.12	85.40	77.64	34.80	19.38
Number of pods per cluster	200 Gy + 0.3 %	7.02	8.52	9.23	10.46	57.88	66.34	11.01	14.29
	300 Gy + 0.3 %	13.67	6.64	15.33	8.60	79.54	59.60	25.11	10.56
Number of clusters per plant	200 Gy + 0.3 %	14.50	11.13	15.72	12.19	85.10	83.30	27.55	20.92
	300 Gy + 0.3 %	16.61	7.65	17.95	9.53	85.56	64.47	31.64	12.66
Number of pods per plant	200 Gy + 0.3 %	26.28	9.33	27.79	11.16	89.42	69.78	51.20	16.05
	300 Gy + 0.3 %	19.48	14.86	21.81	16.76	79.81	78.58	35.85	27.14
Number of seeds per pod	200 Gy + 0.3 %	10.38	6.47	11.93	7.63	75.74	72.03	18.61	11.32
	300 Gy + 0.3 %	4.17	8.76	7.06	9.50	34.81	85.10	5.07	16.65
Hundred seed weight (g)	200 Gy + 0.3 %	6.41	2.66	6.99	3.58	83.95	55.32	12.09	4.07
	300 Gy + 0.3 %	5.14	5.24	5.79	5.87	78.85	79.60	9.41	9.63
Biological yield (g)	200 Gy + 0.3 %	9.05	12.19	10.24	13.12	78.14	86.31	16.49	23.32
	300 Gy + 0.3 %	14.47	7.97	15.48	10.39	87.35	58.84	27.86	12.59
Single plant yield (g)	200 Gy + 0.3 %	11.67	19.27	12.74	20.55	83.92	87.94	22.03	37.23
	300 Gy + 0.3 %	16.39	13.36	17.29	15.62	89.86	73.14	32.00	23.53
Harvest index	200 Gy + 0.3 %	16.63	6.74	18.01	8.37	83.95	64.89	12.09	11.19
	300 Gy + 0.3 %	15.38	5.49	16.99	7.76	81.87	50.17	28.66	8.02

Variety: **P 2** - PAIYUR 2; Variety: **CR** - CRIDA 1-18 R
PCV (%) - Phenotypic coefficient of variation; **GCV (%)** - Genotypic coefficient of variation; H^2 (%) - Heritability; GAM - Genetic advance as per cent of mean

Table 3. Estimates of frequency distribution pattern in M_2 population of horsegram

Traits	Skewness		Kurtosis	
	PAIYUR 2	CRIDA 1-18 R	PAIYUR 2	CRIDA 1-18 R
Days to 50% flowering	-0.86*	-0.21	1.34*	-1.24*
Days to maturity	1.05*	2.93*	2.14*	8.46*
Plant height(cm)	0.83*	1.08*	1.95*	9.65*
Pod length (cm)	-0.33*	-0.38*	0.20	0.39
Number of primary branches per plant	0.28*	1.66*	0.82*	7.43*
Number of pods per cluster	2.21*	-0.09	8.82*	2.93*
Number of clusters per plant	-0.46*	3.37*	0.65*	33.59*
Number of pods per plant	0.15	0.52*	0.59*	3.69*
Number of seeds per pod	0.14	-0.22	0.20	0.33
Hundred seed weight (g)	0.23	-0.55*	1.01*	0.41
Biological yield (g)	0.72*	0.82*	4.19*	1.64*
Single plant yield (g)	4.32*	7.02*	31.42*	77.63*
Harvest index	1.26*	-1.75*	2.49*	6.03*

a) CRIDA 1-18 R **b) PAIYUR 2**

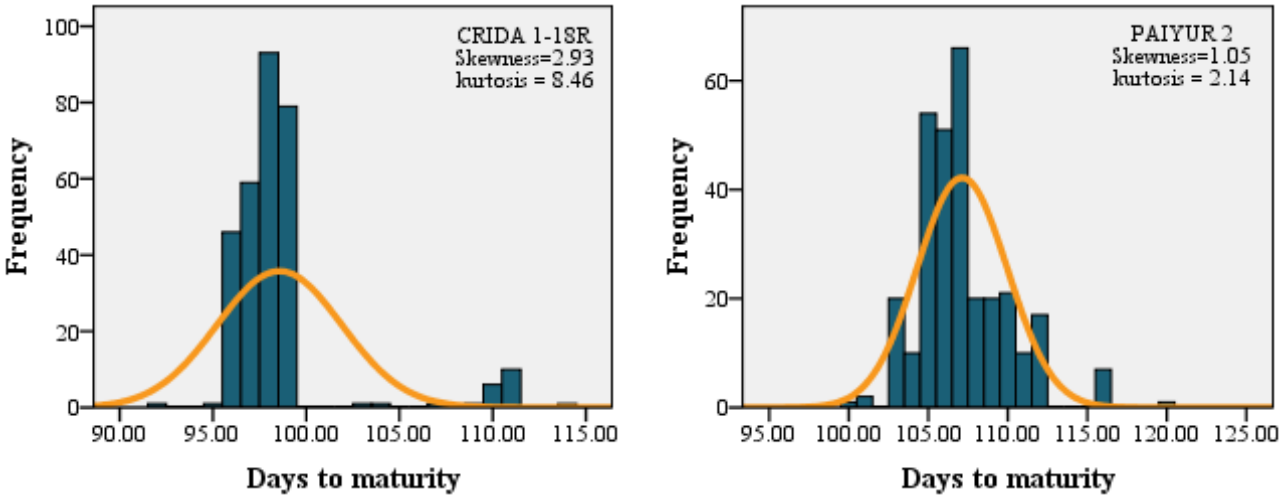

Fig. 1. Frequency distribution pattern for days to maturity

a) CRIDA 1-18 R **b) PAIYUR 2**

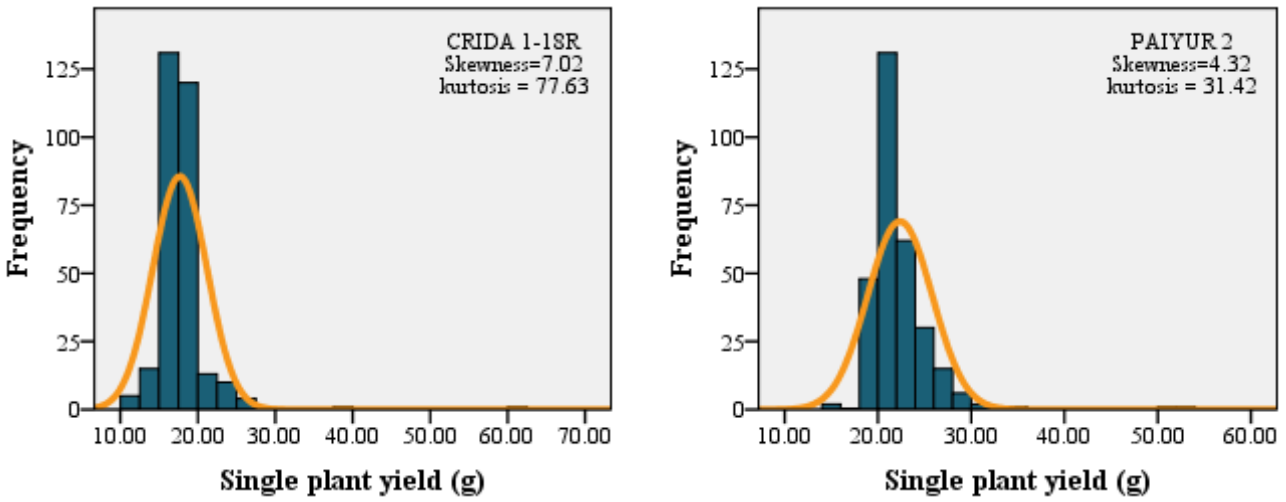

Fig. 2. Frequency distribution pattern for single plant yield (g)

a) CRIDA 1-18 R **b) PAIYUR 2**

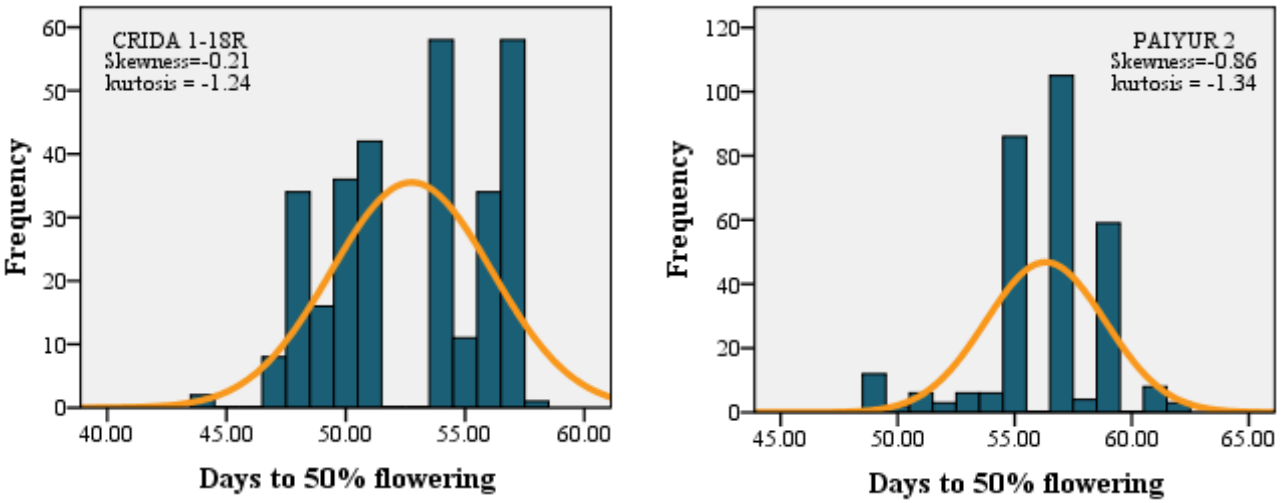

Fig. 3. Frequency distribution pattern for days to 50% flowering

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