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Original Article

Genetic variability and interdependence of morphological traits in castorbean (*Ricinus communis* L) mutants

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Abstract

Morphological data pertaining to different attributes were recorded in M_4 and M_5 generations of gamma irradiated castorbean to study correlations, path analysis and some genetic parameters. Significant and positive correlation of capsule yield per plant with seed yield was observed. Hundred seed weight showed positive but non significant phenotypic and significant genotypic correlation with seed yield. Capsule yield per plant also showed high direct effect combined with high positive and significant genotypic correlation. Number of capsules of main spike, main spike length and number of spikes per plant showed high heritability coupled with high genetic advance which revealed the preponderance of additive genes and seed yield could be improved via these traits. However, length of spike and 100-seed weight may also be considered for improvement in seed yield. On contribution of different morphological traits, 16 mutants yielded higher than the check, however, the maximum seed yield per plant (mean of 02 years) was gained by CBM-7 (209.54 g) followed by CBM-17 (183.35 g) as against the check DS-30 (126.75 g). These prospective mutants can be tested for genetic stability and adaptability over different locations for variety release programme in the country.

Keywords: genetic analysis, variability, correlation, gamma radiation, mutant, castorbean

1. Introduction

Castorbean (*Ricinus communis* L.) is an industrial oil seed crop containing about 45-58 percent oil, which has tremendous application in petrochemicals, pharmaceuticals, cosmetics, textiles, chemicals, soap, leather, paints, varnishes, ink, nylon and plastic. Castor oil is traditionally associated with medicinal and veterinary use in the fields of obstetrics, dermatology etc. It is also used as laxative. Presently, its utilization as bio-diesel has magnified its importance. Its oil does not freeze even at high altitudes and it is one the best lubricants for jet engines. One of the major products derived from castor oil is the Rilsan B, developed by Atochem (France). This 100% castor-based product has numerous applications in industry such as rotating glass car-wipers, ski boots fixatives, and for use in air-brake systems on trucks. Many new uses, based on biodegradability of castor oil derived products, are expected in the future (Labalette *et al.,* 1996). The shell of castorbean is used as an organic termite control agent and its seed cake as manure in the soil (Moshkin, 1986, Maiti *et al.,* 1988).

In Pakistan, castorbean is grown on 3204 ha with an annual production of 2089 tones and average seed yield of 652 kg ha^{-1} This is very low (Anonymous, 2006) in comparison with the main castor growing countries of the world, India, China and Brazil, which are producing 1266, 909 and 850 kg ha^{-1} seed yield (Anonymous, 2000), respectively. Whereas world annual production of castor oil is about

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460,000 tones from 1.1 million tones of seeds. Although castor requires less water it is mainly grown on set-aside land and yields remain low. Under dry conditions, yields are low when compared with those on irrigated lands (Labalette *et al.,* 1996). Castorbean is generally a low input requiring crop and can be grown on marginal land otherwise farmers are not inclined to sow this crop due to non-availability of suitable and high yielding genotypes/ varieties that fit best in their cropping system. Much of the harvested crop is derived from semi wild genotype having tall growing and indeterminate habit, late and non synchronized maturity period. These traits need to be tailored to encourage the wide commercial production of castorbean and make it a high income cash crop of major economic importance. In order to evolve high yielding genotypes which suit the present cropping system, it is imperative to create genetic variability for selection and development of desirable varieties. The genetic diversity analysis of 41 accessions collected from surveying five continents and 35 countries revealed that genetic diversity in castor bean germplasm is relatively low (overall $H_e = 0.126$ for AFLPs and 0.188 for SSRs) in comparison with genetic diversity in other plant species (Gerard *et al.,* 2007). Induced mutation is an important supplementary approach for creation of positive genetic variability (Tepora, 1994). Furthermore, induced mutation has also potential to break the undesirable linkage between important economic traits. Mutation is capable of inducing permanent dormancy of axillary buds to stop iterative growth which is at the base of the perennial form of castorbean (Baldanzi *et al.,* 2003). Chemical mutagens were also successfully used for creation of variation in M_2 generation in castorbean and the greatest increase in variation was observed in yield components (Bokhan, 1989). Knowledge of genetic parameters is very important for breeding castorbean with special emphasis on certain characters. Selection based on yield components is advantageous if different yield related traits have been well documented (Johnson *et al*., 1955; Panse, 1957; Singh *et al*., 1995).

Seed yield, being a complex and multifaceted trait, is an ultimate expression of different yield factors. Knowledge of the interrelationships among various developmental and productive traits is necessary for formulating an effective breeding program. Path coefficient is used in assessing the real contribution of various component characters towards seed yield.

Keeping in view the above facts, present research work was undertaken to search out the importance of different characters through the estimation of genetic parameters and path analysis, so that the suitable selection criteria may be framed for developing ideotypes possessing high yield potential.

2. Materials and Methods

Nineteen mutant lines in M_4 and M_5 generations evolved through gamma irradiation treatment ranging from 300-500 Gy were evaluated in comparison with a check variety DS-30 in a randomized complete block design (RCBD). Each genotype/ mutant was planted in 4 rows each 10 meters long keeping uniform inter and intra row spacing of 1 meter in three replications during summer 2006 and 2007 at the Nuclear Institute for Agriculture and Biology, (NIAB) Faisalabad, Pakistan. During 2006 (M_4), five single plants per each entry were randomly selected to record observations on different attributes on single plant basis viz., days to mature, plant height, number of spikes per plant, length of main spike, number of capsules of main spike, capsule yield per plant, 100-seed weight and seed yield. The seeds of the selected single plants were bulked entry wise during 2007 to grow the M_5 generation. Data were statistically analyzed following Steel and Torrie (1980). Genetic parameters and path analysis were computed to study the relationship and path of contribution of yield factors to seed yield as described by Singh and Chaudhry (1999).

3. Results and Discussion

Significant differences were illustrated in respect of all morphological traits in two generations over two years (Table 1). During 2007, M_5 mutant lines exhibited higher variances both phenotypic and genotypic (Table 3) and lower variance ratios were obtained due to greater values of error mean squares (Table 1) for morphological traits, revealing the significant impact of environmental influence apart from genotypic differences.

Mean values with respect to morphological traits of 19 castorbean mutants over two years viz., 2006 and 2007, are presented in the Table 2. Based on the mean of two years data, almost all mutant lines performed better in comparison with control, with the following exceptions CBM-18 for number of spikes per plant, length of main spike, capsule yield per plant, CBM-19 for length of main spike and capsule yield per plant, CBM-16 for number of capsule of main spike, and CBM-11 for capsule yield. All the mutant lines attained lower 100-seed weight than the control except for CBM-1, CBM-16 and CBM-19, which produced bold seeds than the control. The varying response of the yield-contributing traits resulted in 16 mutant lines exhibiting higher seed yield over the check. The maximum seed yield per plant was gained by CBM-7 (209.54 g) followed by CBM-17 (183.35 g) on average of the two years mean values.

During 2006 (Table 4), phenotypic correlation indicated that days to mature showed positive and highly significant correlation with plant height (0.6479) and main spike length exhibited positive and highly significant correlation with number of capsules (0.5816). Capsule yield showed significant and positive correlation with seed yield (0.4555). Number of spikes per plant was another character which showed positive association with seed yield. During 2007, number of capsules of main spike showed highly significant and positive correlation with length of spike (0.8247). Number of spikes per plant also showed positive and significant association with capsule yield (0.5509). Capsule yield exhibited

Table 1. Means, mean squares and variance ratios of morphological traits of M_4 (2006) and M_5 (2007) generations of castorbean

Traits	Means ± S.E.		Mean squares		Variance Ratio	
	M_4	M_5	M_4	M_5	M_4	M_5
Days to mature	116.40±0.66	105.76±0.62	175.10	56.17	134.59**	36.15**
Plant height (cm)	204.80±2.79	219.50±11.69	1870.61	7866.29	79.66**	14.37**
No. of spikes/plant	9.08±0.84	7.03±0.96	10.39	21.29	4.88**	5.74**
Length of main spike (cm)	44.50±1.88	40.13±4.07	257.22	537.64	24.25**	8.08**
No. of capsule of main spike	46.18±5.45	96.40±13.76	1202.13	4958.95	13.49**	6.54**
Capsule yield/plant (g)	284.80±19.02	248.91±35.87	2624.55	14509.71	2.41*	2.81**
100-seed weight (g)	24.20±1.25	25.11±0.85	16.18	34.38	3.43**	11.75**
Seed yield/plant (g)	152.10±12.39	145.10±22.78	2460.50	5567.04	5.33*	2.68**

*, ** significance at .05 and .01 probability levels

Table 2. Mean values of morphological traits of M_4 (2006) and M_5 (2007) generations of 19 castorbean lines

Genotypes	Days to mature	Plant height (cm)	No. of spikes/ plant	Length of main spike (cm)	No. of capsule of main spike	Capsule yield/ plant (g)	100-seed weight (g)	Seed yield/ plant (g)
CBM-1	111.67	198.67	9.93	43.83	45.67	316.67	28.67	170
	102	**194.25**	**5.5**	**43.5**	**136.25**	**289.5**	**25.25**	**169.25**
	106.84	*196.46*	*7.72*	*43.67*	*90.96*	*303.09*	*26.96*	*169.63*
CBM-2	111	200.33	10.67	43	27	260.67	26.33	154.33
	104.75	**169.25**	**10.5**	**37.25**	**72.25**	**283.75**	**24**	**157.5**
	107.88	*184.79*	*10.59*	*40.13*	*49.63*	*272.21*	*25.17*	*155.92*
CBM-3	112	204.33	8.67	46.83	34.33	275	24.67	109
	104.75	**144.5**	**10**	**35.5**	**71.5**	**268.75**	**26.75**	**159.75**
	108.38	*174.42*	*9.34*	*41.17*	*52.92*	*271.88*	*25.71*	*134.38*
CBM-4	111.67	211	11	45.5	33	258	22.67	148
	103.75	**177.5**	**8.25**	**37**	**91.5**	**273.75**	**26**	**157.75**
	107.71	*194.25*	*9.63*	*41.25*	*62.25*	*265.88*	*24.34*	*152.88*
CBM-5	111.67	212.67	10.67	42	30	266.33	24	162.67
	106	**215**	**7**	**32.75**	**64**	**237.5**	**26.75**	**143.75**
	108.84	*213.84*	*8.84*	*37.38*	*47.00*	*251.92*	*25.38*	*153.21*
CBM-6	111.67	212	10.17	42.67	32.33	326.67	25	167
	106.75	**228.25**	**7.5**	**35.5**	**70.75**	**225.5**	**27.5**	**128**
	109.21	*220.13*	*8.84*	*39.09*	*51.54*	*276.09*	*26.25*	*147.50*
CBM-7	112.33	210.67	10.33	47.33	33.33	323.33	23.33	199.33
	103	**218.75**	**9.75**	**37.75**	**108.5**	**374**	**20.75**	**219.75**
	107.67	*214.71*	*10.04*	*42.54*	*70.92*	*348.67*	*22.04*	*209.54*
CBM-8	116	200	7.33	45.53	48.5	327.33	22.33	190.33
	101.5	**283.5**	**8.75**	**32.25**	**67.25**	**213.75**	**28.75**	**162.75**
	108.75	*241.75*	*8.04*	*38.89*	*57.88*	*270.54*	*25.54*	*176.54*
CBM-9	116.67	179.67	8.33	57.67	50.67	325	24.67	150.33
	104.5	**247**	**6.75**	**48.25**	**110.25**	**304**	**24.75**	**175.5**
	110.59	*213.34*	*7.54*	*52.96*	*80.46*	*314.50*	*24.71*	*162.92*
CBM-10	117.33	165.67	6.67	62.33	101.67	282.67	24	153
	105.5	**233**	**5**	**67.5**	**182.5**	**254**	**22**	**146**
	111.42	*199.34*	*5.84*	*64.92*	*142.09*	*268.34*	*23.00*	*149.50*

to be continued

Table 2. Continued

Genotypes	Days to mature	Plant height (cm)	No. of spikes/ plant	Length of main spike (cm)	No. of capsule of main spike	Capsule yield/ plant (g)	100-seed weight (g)	Seed yield/ plant (g)
CBM-11	114.67	156.33	8	60.17	48.67	288.67	23.33	163.67
	106.75	**134.5**	**6.5**	**42.5**	**126.25**	**186.5**	**20.25**	**96.75**
	110.71	*145.42*	*7.25*	*51.34*	*87.46*	*237.59*	*21.79*	*130.21*
CBM-12	113	218.67	10	46.33	71	225	18	86.67
	97.25	**232.25**	**5.25**	**44**	**125.5**	**261.5**	**24.75**	**143**
	105.13	*225.46*	*7.63*	*45.17*	*98.25*	*243.25*	*21.38*	*114.84*
CBM-13	112.67	185.67	8.83	49.33	73.67	291.33	23.67	128.33
	105.25	**228.75**	**6**	**71.5**	**158.75**	**288**	**21.75**	**168**
	108.96	*207.21*	*7.42*	*60.42*	*116.21*	*289.67*	*22.71*	*148.17*
CBM-14	114.33	202.33	8.83	55.33	74	294	21.67	141
	105.75	**266.25**	**8.5**	**44.25**	**99**	**301.25**	**21.75**	**170.75**
	110.04	*234.29*	*8.67*	*49.79*	*86.50*	*297.63*	*21.71*	*155.88*
CBM-15	117.67	217.67	9.53	35	41	303.33	22.67	158.67
	112	**232**	**7.5**	**35.25**	**99.75**	**244.25**	**27.25**	**137.75**
	114.84	*224.84*	*8.52*	*35.13*	*70.38*	*273.79*	*24.96*	*148.21*
CBM-16	119.67	211.67	13.87	34	19.67	238.67	27.67	148
	108.75	**193**	**9.25**	**27.25**	**58.5**	**263**	**30**	**158.25**
	114.21	*202.34*	*11.56*	*30.63*	*39.09*	*250.84*	*28.84*	*153.13*
CBM-17	117.33	209.33	8.67	35.67	38	262.33	26.67	208.67
	108.75	**199.25**	**9.25**	**40**	**96.5**	**251.25**	**23.25**	**158**
	113.04	*204.29*	*8.96*	*37.84*	*67.25*	*256.79*	*24.96*	*183.34*
CBM-18	120.67	219.67	6.33	33.33	38.33	288.33	24	136.67
	106	**240.5**	**3**	**27.75**	**63**	103.5	**24**	**50.75**
	113.34	*230.09*	*4.67*	*30.54*	*50.67*	*195.92*	*24.00*	*93.71*
CBM-19	120	198.67	7.83	35.17	50.17	279	25	137.33
	115	**232.25**	**3**	**27.75**	**61.5**	**130**	**30.25**	**74.5**
	117.50	*215.46*	*5.42*	*31.46*	*55.84*	*204.50*	*27.63*	*105.92*
DS-30	146	282.33	6	29.33	32.67	263.33	26	129
(Control)	**107.25**	**320.25**	**3.5**	**35**	**64.5**	**224.5**	**27**	**124.5**
	126.63	*301.29*	*4.75*	*32.17*	*48.59*	*243.92*	*26.50*	*126.75*

Bold figures describe 2007 (M_5) results; CBM = castorbean mutant; italic figures = average of means of M_4 (2006) & M_5 (2007).

positive and highly significant correlation with seed yield (0.8131). Number of spikes per plant showed significant and positive correlation with seed yield (0.486). With regard to direct effects during 2006 (Table 5), capsule yield and 100-seed weight exhibited positive and significant genotypic correlation coefficient values combined with high positive direct effects which suggested that direct selection might be based on these two characters for the improvement of seed yield. During 2007, number of capsules showed highest positive direct effect (0.7952) followed by number of spikes per plant (0.7941). Plant height, capsule yield and 100-seed weight also showed positive direct effects. Number of spikes, number of capsules and capsule yield also showed positive genotypic correlation with seed yield. It also indicated that characters like number of spikes, number of capsules and capsule yield may be selected directly for the improvement of seed yield (Table 5). Moshkin (1967) documented a close relationship between seed and number of spikes, number of capsules, and size of seed. There was a positive relationship with height of plant and green mass. Number of seeds from one plant had the greatest direct effect on seed yield. The direct effect of central spikes and lateral spike is much lower. Similarly height of plant and green mass had no direct effect. Hundred seed weight had slight but positive effect. Salikh and Khidir (1975) explained that phenotypic correlation coefficient values were always higher than the genotypic which might be due to pleiotropic action of genes on different characteristics. Yadava and Singh (1975), reported positive association of seed yield with height and length of the main shoot and negative association with capsule number/ spike and 100-seed weight, whereas spike number per plant and capsule number per spike were negatively associated. Lima

Table 3. Genetic parameters of different morphological traits of M_4 (2006) and M_5 (2007) generations of castorbean

Characters	G.VAR.	G.COV. (%)	P.VAR.	P.COV. (%)	h^2_{bs} (%)	GA (% of mean)
Days to mature	57.936 **13.654**	6.539 **3.494**	59.237 **15.208**	6.612 **3.687**	97.800 **89.800**	11.370 **1.490**
Plant height (cm)	615.713 **1829.804**	12.112 **19.488**	639.193 **2376.879**	12.341 **22.211**	96.300 **77.000**	20.920 **30.100**
No. of spikes/plant	2.755 **4.397**	18.275 **29.796**	4.881 **8.106**	24.322 **40.456**	56.500 **54.200**	24.090 **38.630**
Length of main spike (cm)	82.208 **117.793**	20.367 **27.049**	92.813 **184.267**	21.640 **33.831**	88.600 **63.900**	33.740 **38.040**
No. of capsule of main spike	371.008 **1050.275**	41.707 **33.618**	460.115 **1808.133**	46.446 **40.110**	80.600 **58.100**	66.040 **45.100**
Capsule yield/plant (g)	512.785 **2340.526**	7.952 **19.436**	1598.982 **7488.132**	14.041 **34.765**	32.100 **31.300**	7.930 **19.150**
100-seed weight (g)	3.823 **7.864**	8.074 **11.167**	8.570 **10.789**	12.067 **13.080**	44.800 **72.900**	9.510 **16.780**
Seed yield/plant (g)	666.544 **872.563**	16.974 **20.356**	1127.412 **2949.350**	22.076 **37.425**	59.100 **29.600**	22.950 **19.49**

Bold figures describe 2007 (M_5) results; G. VAR. = Genotypic variance, G. COV. = Genotypic coefficient of variation, P.VAR. = Phenotypic variance, P.COV. = Phenotypic Coefficient of variation h^2_{bs}=heritability in broad sense, GA = Genetic advance

Table 4. Phenotypic correlation coefficients among different traits of M_4 (2006) and M_5 (2007) generations of castorbean

Characters	Days to mature	Plant height (cm)	No. of spikes/plant	Length of main spike (cm)	No. of capsule of main spike	Capsule yield/ plant (g)	100-seed weight (g)
Days to mature							
Plant height (cm)	0.6479** **0.0068**						
No. of spikes/plant	-0.4144 **-0.1373**	-0.2130 **-0.0358**					
Length of main spike (cm)	-0.4490* **-0.2293**	-0.7408** **0.0358**	-0.1351 **-0.1325**				
No. of capsule of main spike	-0.0992 **-0.2530**	-0.4245 **-0.0855**	-0.4670* **-0.1274**	0.5816** **0.8247****			
Capsule yield/plant (g)	-0.1195 **-0.2813**	-0.2141 **-0.1149**	-0.1839 **0.5509***	0.1819 **0.3307**	0.0804 **0.3823**		
100-seed weight (g)	0.1670 **0.3030**	0.0744 **0.1661**	-0.0029 **-0.0359**	-0.2033 **-0.5167***	-0.2904 **-0.5606****	-0.0118 **-0.2907**	
Seed yield/plant (g)	-0.1404 **-0.2967**	-0.1769 **-0.0573**	0.1127 **0.4860***	-0.0283 **0.2611**	-0.1905 **0.3217**	0.4555* **0.8131****	0.2038 **-0.1983**

Bold figures describe 2007 (M_5) results; *, ** significance at .05 and .01 probability levels

et al. (1998) found that castorbean seed yield was positively correlated with plant height and number of capsules per plant. Reddy *et al.,* (1999) observed correlation of seed yield with earliness, capsule weight and number of capsules per plant under rainfed and irrigated conditions. Aswani *et al.* (2003) reported that capsules in the primary spike, number

Table 5. Direct (parenthesis) and indirect effects different traits of M_4 (2006) and M_5 (2007) generations of castorbean on seed yield.

Characters	Days to mature	Plant height (cm)	No. of spikes/ plant	Length of main spike (cm)	No. of capsule of main spike	Capsule yield/plant (g)	100-seed weight (g)	Genotypic correlation with Seed Yield
Days to mature	(0.0759) **(-0.0179)**	-0.073 **0.0023**	-0.0207 **-0.1552**	0.0251 **0.1030**	0.0205 **-0.2766**	-0.1203 **-0.3426**	0.0729 **0.1095**	-0.1713 **-0.5771**
Plant height (cm)	-0.0503 **-0.0001**	(-0.1102) **(0.4339)**	0.0060 **-0.3752**	0.0413 **-0.0101**	0.0944 **-0.0834**	-0.1775 **-0.0649**	0.0201 **0.0704**	-0.1829 **-0.0294**
No. of spikes/ plant	0.0409 **0.0035**	0.0017 **-0.2051**	(0.0384) **(0.7941)**	0.006 **0.0395**	0.0809 **-0.1486**	-0.2009 **0.4113**	0.0849 **-0.0353**	0.0519 **0.8593**
Length of main spike (cm)	0.0367 **0.0052**	0.0875 **0.0123**	-0.0044 **-0.0879**	(-0.052) **(-0.3565)**	-0.1288 **0.7508**	0.2030 **0.2726**	-0.1360 **-0.2066**	0.0061 **0.3900**
No. of capsule of main spike	0.0081 **0.0062**	0.0541 **-0.0455**	-0.0162 **-0.1483**	-0.0348 **-0.3366**	(-.1923) **(0.7952)**	0.0337 **0.2309**	-0.1770 **-0.2221**	-0.3243 **0.2798**
Capsule yield/ plant (g)	0.0184 **0.0101**	0.0395 **-0.0464**	-0.0156 **0.5381**	-0.0213 **-0.1601**	-0.0131 **0.3026**	(0.4959) **(0.6069)**	0.6936 **-0.1328**	0.5732 **1.1183**
100-seed weight (g)	-0.0189 **-0.0063**	-0.0076 **0.0987**	0.0111 **-0.0905**	0.0241 **0.2379**	0.1161 **-0.5706**	0.1172 **-0.2603**	(0.2929) **(0.3096)**	0.5352 **-0.2815**

Bold figures describe 2007 (M_5) results

of spikes per plant, number of days to 50% flowering and maturity, length of primary spike and 100-seed weight were the major yield-contributing characters in castor.

During 2006 (Table 3), the highest values of genotypic coefficient of variation were observed for number of capsule (41.707%) followed by main spike length and number of spikes. Phenotypic coefficient values were maximum in case of number of capsules (46.446%) followed by number of spikes per plant (24.322%) and main spike length (21.64%). Maximum heritability was estimated in days to mature (97.8%) followed by plant height (96.3 %), main spike length (88.6%) and capsule per plant (80.6%). In the case of number of spikes per plant and seed yield, more than 50% heritability was observed. Number of capsules showed the highest value of genetic advance (66.04%) followed by main spike length and number of spikes. During 2007, highest heritability was observed for days to mature (89.80%) followed by plant height (77.00%), 100-seed weight (72.90%) and length of spike (63.90%). Number of spikes per plant and number of capsules also showed more than 50% heritability (Table 3). Maximum genetic advance was noted in number of capsules (45.10) followed by number of spikes per plant (38.63) and length of spike (38.04).The combination of high heritability and high genetic advance in respect of number of spikes, length of spikes, number of capsules and 100-seed weight indicated that these characters were controlled by additive type of genes. Characters like days to mature and capsule yield showed high genetic advance and low heritability, which suggested that these were controlled by non additive type of genes (dominant, epistasis or their interactions).

Sachli (1972) reported the range of variation for various parameters such as oil content (1.6 - 2.2 %), green mass (42.2-45.6%), 1000-seed weight and plant height (10-20%), number of internodes, height of stem and seed yield (20-40%). The coefficient of variation was also affected by plant spacing. The range of coefficient of variation increases with narrow sowing for all characters except height of the stem. In seed yield and oil content the increase in negative variability was statistically significant. Moshkin (1972) and Sachli (1972) estimated high heritability for two varieties in case of oil content, seed hull and 1000-seed weight and low for plant height, number of internodes and green mass. Bhatt and Reddy (1981) observed the range of heritability (0.152-0.089) for seed yield/ plant and number of nodes on the primary raceme in 30 varieties of castor bean. Expected genetic advance was high for height and number of days to flowering. High positive phenotypic correlation with seed yield/plant was shown with all 8 characters studied except number of days to flowering and number of nodes on the primary raceme. Number of capsules/ primary raceme and the number of secondary branches had large positive direct effect on seed yield/plant. This indicated that semi dwarf lines with a large number of capsules/primary raceme and a moderate number of primary and secondary branches should be used as parents in a breeding programme. Dhapke (1992) reported high heritability coupled with high genetic advance and genotypic variability for branches per plant, capsules per main spike, length of pistilate region, capsules per plant and seeds per pant. This suggested the influence of additive gene action providing scope for further selection. Solanki and

Joshi (2000) reported additive gene effects for inheritance of length of primary spike, capsules per primary spike, 100-seed weight and capsules per spike while spikes per plant and seed yield per plant were mainly governed by non-additive gene effects. Characters like number of capsules, main spike length and number of spikes per plant showed high heritability combined with high genetic advance, showing that these characters were governed by additive type of genes and selection may be based directly on these attributes (Johnson, 1955, Sarwar *et. al*., 2005 & 2006). It was also recommended to select for improved yield components under environmental conditions for which the genotype is best adapted (Reddy *et al.,* 1999).

Our genetic study of 2006, showed that positive relationships of capsule yield per plant and 100-seed weight existed with seed yield. Hence, for improvement of these characters, proper attention should be given at the time of selection. Furthermore, these characters had high direct effect and direct selection would be more effective. Number of capsules, main spike length and number of spikes per plant showed high heritability combined with high genetic advance. This showed that these characters were governed by additive type of genes and selection may be based directly on these attributes.

During 2007, number of spikes and capsule yield showed significant and positive correlation with seed yield. Number of spikes, number of capsules and capsule yield showed high direct effect combined with high and positive genotypic correlation, hence these characters may be selected directly for the improvement of seed yield. Characters like number of capsules, number of spikes per plant and to some extent length of spikes showed high heritability combined with high genetic advance. Selection for these traits for the improvement of seed yield may also be performed directly.

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