Instituto Nacional de Investigación y Tecnología Agraria y Alimentación (INIA)
Available online at www.inia.es/sjar
Spanish Journal of Agricultural Research 2008 6(4), 629-634
ISSN: 1695-971-X

Short communication. Evaluation of castor (*Ricinus communis* L.) induced mutants for possible selection in the improvement of seed yield

G. Sarwar and M. Boota Chaudhry

Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan.

Abstract

The aim of the present work was to determine selection criteria suitable for developing castor ideotypes with high yield potentials. Nineteen M_4 generation castor mutants were obtained by gamma irradiation (100 to 1000 Gy) of DS30 castor seeds, and evaluated alongside this reference variety over 2006-07 for their possible use in the improvement of castor seed yield. Days to ripening, plant height, number of spikes/plant, length of main spike, number of main spike capsules, capsule weight, 100-seed weight and seed yield per plant were recorded for each mutant. Correlation coefficients were calculated, path analyses performed, and the genetic features of the different traits were determined. A significant, positive correlation was seen between capsule weight and seed yield. The 100-seed weight showed a positive but non-significant phenotypic relationship plus a significant genotypic relationship with seed yield. Capsule weight also showed a strong direct effect on seed yield, plus a strong positive and significant genotypic correlation with this variable. More than 50% heritability was observed for all the traits studied except the 100-seed weight and capsule weight. The number of main spike capsules showed the greatest genetic advance, followed by spike length and number of spikes. Traits such as the number of capsules, spike length and number of spikes showed strong heritability and good genetic advance. These traits are therefore governed by additive genes, and for the improvement of seed yield selection may be based directly on these attributes. In conclusion, for the improvement of seed yield the main emphasis should be placed on the number of spikes and capsule weight, via the selection of the highest yielding mutants among those tested. However, spike length and 100-seed weight should also be taken into account.

Additional key words: castorbean, genetic variables, mutation, yield and yield components.

Resumen

Comunicación corta. Evaluación de diferentes parámetros genéticos de mutantes de ricino (*Ricinus communis* L.)

Se obtuvieron mutantes de ricino a través de irradiación gamma de 100-1000 Gy. Durante 2006-07 se evaluaron 19 mutantes de la generación M_4, junto con la variedad control DS30, para los siguientes caracteres: tiempo de maduración, altura de la planta, número de espigas/planta, longitud de la espiga principal, número de cápsulas de la espiga principal, peso de la cápsula, peso de 100 semillas, y producción de semilla por planta. Se midieron el coeficiente de correlación, el análisis de ruta y parámetros genéticos de estos caracteres. Se observó correlación significativa y positiva del peso de la cápsula respecto a la producción de semilla. El peso de 100 semillas mostró una correlación fenotípica no significativa respecto a la producción de semilla, pero la correlación genotípica fue significativa. El peso de la cápsula también mostró un efecto directo alto combinado con un efecto positivo alto y correlación genotípica significativa. La heredabilidad fue de más del 50% en todos los caracteres, excepto en peso de 100 semillas y peso de cápsula. El número de cápsulas de la espiga principal presenta el máximo avance genético, seguido de la longitud de la espiga y nº de espigas. Caracteres como nº de cápsulas, longitud de la espiga y nº de espigas tienen una alta heredabilidad combinada con un alto avance genético. La selección puede basarse en estos caracteres, ya que parecen estar gobernados por genes de tipo aditivo y para la mejora de producción de la semilla. Puede concluirse que para la selección de variantes/mutantes altamente productivos de semilla se debe hacer énfasis principalmente en el nº de espigas y peso de cápsula. En menor medida, también debe considerarse la longitud de las espigas y peso de 100 semillas.

Palabras clave adicionales: componentes de la producción, mutación, parámetros genéticos, ricino.

* Corresponding author: sarwar_niab@yahoo.com; sarwar_niab@msn.com
Received: 18-10-07. Accepted: 29-08-08.

Castor (*Ricinus communis* L.) is an oil seed crop, the seeds of which contain about 45-58% oil. It has tremendous potential in the petrochemical, pharmaceutical, cosmetic, textile, chemical, soap, leather, paint, varnish, ink, nylon, and plastic industries. Castor oil is traditionally associated with medical and veterinary uses, for example in obstetrics and dermatology, as a purgative, and as a laxative. Its current use in bio-diesel production has increased its importance. Further, its oil does not freeze even at -60^{o}C, so it can be used in aeroplanes, helicopters and other vehicles operating at high altitudes or in low temperatures. Moreover, it is the best lubricant for jet engines. The shell of the castor bean is used in organic termite control in the soil, and its seed cake can be used as a manure (Maiti *et al.* 1988, Moshkin, 1986).

In Pakistan some 3934 ha are devoted to castor, with an annual production of 2500 Mg. The average seed yield is 635 kg ha^{-1}, which unfortunately is very low (Anonymous, 2006) compared to that achieved in the main castor-growing countries of the world. For example, India, China and Brazil produce seed yields of 1266, 909 and 850 kg ha^{-1} respectively. Although castor is a low input-requiring crop and can be grown on marginal land, farmers are not inclined to sow it in Pakistan due to the lack of suitable high yielding genotypes/varieties that would fit in with the country's cropping system. Much of the harvested crop is derived from semi-wild, tall-growing plant habitat, is not ripe until late in the season (about 7 months after sowing in June/July), and even then it becomes harvestable in an unsynchronised fashion. Thus, castor has a number of undesirable traits that act as deterrents to the species' wide cultivation, and these need to be improved to encourage its commercial production as a high income cash crop of major economic importance.

To develop high yielding castor genotypes that fit into the present cropping system it is imperative to create genetic variability for the selection of desirable variants. Induced mutation, an important supplementary approach for creating this variability (Tepora, 1994), has the potential to break undesirable linkages between traits.

Selection based on yield components is advantageous if different yield-related traits are well documented with respect to genetic behaviour (Johnson *et al.*, 1955; Panse, 1957; Singh *et al.*, 1995). Seed yield is a complex and multifaceted trait, and represents the ultimate expression of different yield factors. Path coefficients can be used to assess the contribution of component traits towards seed yield, allowing the traits to be focused upon to be chosen.

The present work was undertaken to determine the importance of different traits in 19 castor mutants/genotypes, via the estimation of correlation coefficients, the performance of path analysis, and the recording of other variables. The aim was to determine selection criteria suitable for developing ideotypes with high yield potentials.

Nineteen true breeding mutant lines in the M_4 generation were obtained by gamma irradiation (100 to 1000 Gy) of dry DS30 castor seeds (moisture content approximately 12%). These were evaluated alongside this reference variety in a randomised complete block design during the summers of 2006-07 at the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan. Each genotype/mutant was planted in 4 rows (10 plants per row), all 10 m long, and with a uniform inter- and intra-row spacing of 1 m (three replicates). Data were collected on an individual plant basis, including days to ripening, plant height, number of spikes per plant, length of main spike, number of capsule on the main spike, capsule weight per plant, 100-seed weight, and seed yield. Data were statistically analysed following the method of Steel and Torrie (1980). Genetic variables were examined and path analysis performed using the method of Singh and Chaudhry (1999) and Dewey and Lu (1959). Path analysis was performed with seed yield as the dependent variable (*y*) and other traits as independent variables (*x*).

Days to ripening (Table 1) showed a positive and highly significant phenotypic correlation (0.6479) with plant height. Spike length showed a positive and highly significant correlation with the number of capsules (0.5816). Capsule weight per plant showed a significant and positive correlation with seed yield. The 100-seed weight showed a positive but non-significant correlation with seed yield, as did the number of spikes. Path analysis (Table 2) showed the number of spikes (0.0384), capsule weight per plant (0.4939) and 100-seed weight (0.2929) to have a strong, positive, direct effects on seed yield. Capsule weight per plant showed the strongest indirect effects via length of spike (0.203) and 100-seed weight (0.1172). Capsule number showed the third strongest indirect effect (0.1161), via 100-seed weight, as well as a positive indirect effect via plant height (0.0944). Plant height exhibited an indirect effect (0.0875) via spike length. Days to ripening, plant height and capsule number showed negative direct effects on seed yield along with negative genotypic correlations (Table 2). Length of spike had a negative direct effect on seed yield, but showed a positive corre-

Table 1. Phenotypic correlation coefficients among different traits in the 19 castor mutant/genotypes

Characters	Days to mature	Plant height (cm)	No. of spike/plant	Length of main spike (cm)	No. of capsule of main spike	Capsule weight/plant (g)	100 seed weight (g)
Plant height (cm)	0.6479**						
No. of spike/ plant	-0.4144	-0.213					
Length of main spike (cm)	-0.449*	-0.7408**	-0.1351				
No. of capsule of main spike	-0.0992	-0.4245	-0.467*	0.5816**			
Capsule weight/plant (g)	-0.1195	-0.2141	-0.1839	0.1819	0.0804		
100 seed weight (g)	0.167	0.0744	-0.0029	-0.2033	-0.2904	-0.0118	
Seed yield/ plant (g)	-0.1404	-0.1769	0.1127	-0.0283	-0.1905	0.4555*	0.2038

**P<0.01, *P<0.05.

lation with seed yield. In a situation like this, where the correlation coefficient is positive but the direct effect is negative or negligible, the indirect effects seem to be the cause of the correlation. Thus, all direct causal effects on seed yield should be considered simultaneously. In some cases, the direct effect was positive and strong but correlations were negative; under these circumstances a restricted simultaneous selection model should be followed, i.e., restrictions should be imposed to neutralise the undesirable indirect effects, allowing use to be made of the desired direct effects (Singh and Kakar, 1977). Capsule weight per plant (0.5732) and 100-seed weight (0.5352) showed positive and significant genotypic correlations (Table 2), combined with strong, positive, direct effects. This indicates that selection for the improvement of seed yield may be directly based on these two traits. Moshkin (1986) indicated a close relationship between seed yield and number of spikes, number of capsules, and size of seed, and reported it to have a positive relationship with plant height and green mass. Number of seeds per plant had the greatest direct effect on seed yield, while the direct effects of central spikes and lateral spikes were much weaker. The height of the castor plants and their green mass had no direct effect on seed yield, while the 100-seed weight had a slight but positive effect. Phenotypic correlation coefficients are always higher than genotypic coefficients, perhaps due to the pleiotropic action of genes on different characteristics (Moshkin, 1986). Studying different types of castor population (hybrids and inbred lines), Dorairaj *et al.* (1973a) observed positive correlations between main raceme length, branch and capsule number/plant and seed yield, and correlation studies of different castor traits (Yadava and Singh, 1973) revealed positive associations between seed yield and the height and length of the main shoot, along with negative relationships with capsule number/spike and 100-seed weight. Spike number per plant and capsule number per spike were negatively associated with one another. Ramu *et al.* (2005) studied 15 castor hybrids for character associations and performed path analysis involving the parents. These authors observed significant positive associations between oil yield and the total number of spikes per plant, the total number of capsules on the main spike, and seed yield per plant. Path analysis showed the importance of seed yield per plant, total number of spikes per plant, and oil content. It was stressed that traits such as spikes per plant, seed

Table 2. Direct (in parenthesis) and indirect effects of the different traits on seed yield

Character	Days to mature	Plant height (cm)	No. of spike/ plant	Length of main spike (cm)	No. of capsule of main spike	Capsule weight plant (g)	100 seed weight (g)	Genotypic correlation with seed yield
Days to mature	(-0.0759)	-0.073	-0.0207	0.0251	0.0205	-0.1203	0.0729	-0.1713
Plant height (cm)	-0.0503	(-0.1102)	0.0060	0.0413	0.0944	-0.1775	0.0201	-0.1829
No. of spike/plant	0.0409	0.0017	(0.0384)	0.006	0.0809	-0.2009	0.0849	0.0519
Length of main spike (cm)	0.0367	0.0875	-0.0044	(-0.052)	-0.1288	0.203	-0.136	0.0061
No. of capsule of main spike	0.0081	0.0541	-0.0162	-0.0348	(-0.1923)	0.0337	-0.177	-0.3243
Capsule weight/plant (g)	0.0184	0.0395	-0.0156	-0.0213	-0.0131	(0.4959)	0.06936	0.5732**
100 seed weight (g)	-0.0189	-0.0076	0.0111	0.0241	0.1161	0.1172	(0.2929)	0.5352*

yield and oil content be given emphasis when developing high yielding castor genotypes.

The highest coefficient of genotypic variation (Table 3) was observed in the number of capsules (41.71%), followed by spike length and the number of spikes. The highest phenotypic coefficient was seen for number of capsules (46.45%), followed by number of spikes (24.32%) and spike length (21.64%). Days to ripening showed the maximum heritability (97.8%), followed by plant height (96.3%), spike length (88.6%) and number of capsules per plant (80.6%). Number of spikes and seed yield showed heritabilities of 50%; capsule weight and 100-seed weight showed values of <50%. Number of capsules showed the highest percentage genetic advance (66.04%) followed by spike length (33.74%) and the number of spikes (24.09%). The number of capsules, spike length and number of spikes showed high heritability combined with good genetic advance (Table 3). Thus, these traits were governed by additive genes. For the improvement of seed yield, selection may be based directly on these attributes (Johnson, 1955; Sarwar and Haq, 2005, 2006). Capsule weight and 100-seed weight showed less heritability and little genetic advance. Days to ripening showed good heritability but less genetic advance. These traits were therefore controlled by non-additive genes and therefore either dominant genes, epitasis, or their interaction; for their improvement a large population of diverse nature would be required along with vigorous selection pressure. Moshkin (1986) described the range of variation for castorbean oil content to range from 1.6 to 2.2%, and the green mass to range from 42.2 to 45.6%, 1000-seed weight and plant height to range from 10-20%, and the number of internodes, the height of the stem and the seed yield to range from 20-40%. It was also noted by Moshkin that the coefficient of variation was affected by plant spacing. The range of coefficient of variation for all traits except the height of the stem increased with close sowing. High heritability was estimated for oil content, seed hull and 1000-seed weight, and low heritability for plant height, number of internodes and green mass (Moshkin, 1986). Dorairaj *et al.* (1973b) estimated high heritability and medium genetic advance for 1000-seed weight, and moderate heritability and strong genetic advance for yield and number of branches in 65 castor varieties. Bhatt and Reddy (1981) observed a range of heritability from 0.152 for seed yield/plant to 0.0893 for the number of nodes on the primary raceme in 30 varieties of castor. The expected genetic advance was high for plant height and num-

Table 3. Genetic variables of different traits in 19 castor mutant/genotypes

Characters	Mean	GVAR	GCOV (%)	PVAR	PCOV (%)	h^2 (%)	GA (% of mean)
Days to mature	116.40	57.94	6.54	59.24	6.61	97.80	11.37
Plant height (cm)	204.80	615.71	12.11	639.19	12.34	96.30	20.92
No. of spikes/ plant	9.08	2.76	18.28	4.88	24.32	56.50	24.09
Length of main spike (cm)	44.50	82.20	20.37	92.81	21.64	88.60	33.74
No. of capsule of main spike	46.18	371.01	41.71	460.12	46.45	80.60	66.04
Capsule weight/plant (g)	284.80	512.76	7.95	1598.98	14.04	32.10	7.93
100 seed weight (g)	24.20	3.82	8.07	8.57	12.07	44.80	9.51
Seed yield/ plant (g)	152.10	666.54	16.98	1127.41	22.08	59.10	22.95

GVAR = Genotypic variance, GCOV = Genotypic coefficient of variation, PVAR = Phenotypic variance, PCOV = Phenotypic coefficient of variation, h^2 = heritability in a broad sense, GA = genetic advance as % of mean.

ber of days to flowering. These authors also reported a strong positive phenotypic correlation with seed yield/plant for all traits studied except for the number of days to flowering and the number of nodes on the primary raceme. The number of capsules/primary raceme and the number of secondary branches had strongly positive, direct effects on seed yield/plant. This indicates 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 breeding programmes.

In the present study, positive relationships were seen between seed yield and capsule weight and 100-seed weight. To improve seed yield, proper attention should therefore be paid to these traits at the time of selection; since they had strong, direct, positive effects on seed yield they should be directly selected. The number of capsules, spike length and number of spikes/plant showed high heritability combined with good genetic advance. This shows these traits are governed by additive genes and confirms that, for the improvement of seed yield, selection may be based directly on these attributes.

In conclusion, the main emphasis in the selection of high yielding variants should be placed on the number of spikes and capsule weight. To a lesser extent, the spike length and 100 seed weight may also be considered.

References

ANONYMOUS, 2006. Agricultural Statistics of Pakistan. Ministry of Food and Agriculture. Islamabad, Pakistan.

BHATT D., REDDY T.P., 1981. Correlation and path analysis in castor (*Ricinus communis* L.). Can J Genet Cytol 23, 525-531.

DEWY D.R., LU K.H., 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron J 51, 515-518.

DORAIRAJ S.M., KANDASAMI M., PALANISWAMY S., VARISAI S., 1973a. Correlation studies in *Ricinus communis* L. within inbreds and hybrids. Madras Agric J 60, 1481-1485.

DORAIRAJ S.M., KANDASAMI M.,VARISAI S.M., 1973b. Genetic variability in castor (*Ricinus communis* L). Madras Agric J 60, 1504-1507.

JOHNSON H.W., ROBINSON H.E., COMSTOCK R.E., 1955. Estimates of genetic and environmental variability in soybean. Agron J 47, 314-318.

MAITI S., HEGDE M.R., CHATTOPADHYAY S.B., 1988. Handbook of oilseed crops. Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi.

MOSHKIN V.A., 1986. Castor. Amerind Publishing Co. Pvt. Ltd., New Delhi.

PANSE V.G., 1957. Genetic of quantitative character in selection plant breeding. Ind J Genet 17, 318-328.

RAMU R., SREEDHAR N., LAVANYA C., 2005. Study of correlation and path analysis in castor *(Ricinus communis* L.*)***.** Research on Crops 6, 109-111.

SARWAR G., HAQ M.A., 2005. Radiation-induced variability for the improvement of yield and yield components in sesame (*Sesamum indicum L.*). Sesame and Safflower Newsletter 20, 42-47.

SARWAR G., HAQ M.A., 2006. Evaluation of sesame germplasm for genetic parameters and disease resistance. J Agric Res 44, 89-96.

SINGH R.K., KAKAR S.N., 1977. Control on individual trait means during index selection. Proc Third Congress SABRO, Canberra, Australia. pp. 22-25.

SINGH R.K., CHAUDHRY B.D., 1999. Biometrical method in quantitative genetic analysis. Kalyani Publ New Delhi, India.

SINGH I.S., HUE N.T.N., GUPTA A.K., 1995. Association and cause and effect analysis in some F_2 population of green gram. Leg Res 18, 137-142.

STEEL R.G.D., TORRIE J.H., 1980. Principals and procedures of statistics. McGraw Hill Book Company Inc, NY.

TEPORA N.M., 1994. Mutation breeding of oilseed crops. IAEA-TECDOC- 781. pp.149-157.

YADAVA T.P., SINGH H., 1973. Correlation studies in castor (*Ricinus communis* L). Oil seed J 3, 13-16.