Electronic Journal of Plant Breeding, 4(2): 1180-1183 (Jun 2013)
ISSN 0975-928X

Research Note

Heterosis and inbreeding depression for seed yield and its component traits in castor (*Ricinus communis* L.)

Singh A. P., Mehta D. R. and Desale C. S.
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh-362 001 (Gujarat), India
Email: ravallata@rediffmail.com

(Received: 11 Mar 2013; Accepted: 14 May 2013)

Abstract
The present investigation was undertaken with a view to generate genetic information on heterosis and inbreeding depression for seed yield and its component traits. The heterosis over better parent was found significant in desirable direction for number of capsules on main raceme in JP 96 x JI 368; for length of main raceme, effective length of main raceme and number of capsules on main raceme in cross JP 96 x JI 372; and for oil content in cross JP 101 x SKI 215. Inbreeding depression was observed significant for shelling outturn, seed yield per plant and 100-seed weight in JP 96 x JI 368; for length and effective length of main raceme, number of capsules per plant and oil content in cross JP 96 x JI 372; and for days to maturity, plant height, number of nodes and 100-seed weight in cross JP 101 x SKI 215. In majority of cases, a close agreement was seen between the observed and the expected values of relative heterosis, heterobeltiosis and inbreeding depression in all the three castor crossses with few exemptions.

Key words: Heterosis, inbreeding depression, gene model

Exploitation of hybrid vigour in castor has been recognized a practical tool in providing the plant breeders a mean improving seed yield and other important traits. On the other hand, the inbreeding depression reflects through the reduction in vigour . Most of the area under castor crop is covered by hybrids. Higher seed yield of hybrid is due to the presence of heterosis for seed yield and yield components. Therefore, estimation of heterosis and inbreeding depression is of immense importance for development of hybrids in castor. Gene system is useful to compare observed heterosis and inbreeding depression with expected ones.

The basic set of twelve generations *viz*., P_1, P_2, F_1, F_2, B_1 (F_1 x P_1), B_2 (F_1 x P_2), B_{1S} (B_1 selfed), B_{11} (B_1 x P_1), B_{12} (B_1 x P_2), B_{2S} (B_2 selfed), B_{21} (B_2 x P_1) and B_2 (B_2 x P_2) derived from three castor crosses namely JP 96 x JI 368 (cross 1), JP 96 x JI 372 (cross 2) and JP 101 x SKI 215 (cross 3) were sown in compact family block design with three replications at Instructional Farm, Junagadh Agricultural University, Junagadh during *Kharif*, 2011. The plots of various generations contained different number of rows i.e., parents and F_1 in single row; B_1 and B_2 in two rows and F_2, B_{1S}, B_{11}, B_{12}, B_{2S}, B_{21} and B_{22} in four rows. Each row was of 7.2 m in length with 90 cm and 60 cm inter and intra row spacing, respectively. All the recommended agronomical practices and necessary plant protection measures were followed timely to raise a good crop. Observations were recorded on individual plant basis in each replication on randomly selected five plants from P_1, P_2 and F_1; ten plants from first backcross (B_1 and B_2) and twenty plants of F_2, B_{1S}, B_{11}, B_{12}, B_{2S}, B_{21}, B_{22} generations for twelve traits (Table 1). The heterotic effects in term of superiority of F_1 over better parent (heterobeltiosis) as per Fonseca and Patterson (1968); over mid parent value (relative heterosis) as per Briggle (1963); and inbreeding depression was worked out as loss in vigour due to inbreeding and difference between mean of F_1 and F_2. The expected heterosis and inbreeding depression for different characters were calculated as under. All notations were used as per Mather and Jink (1977) and statistical analysis was done in SPAR1 software.

[A] When simple additive-dominance model was adequate:

Heterosis over better parent

(i) $\overline{F_1} - \overline{P_1}$ =[h] - [d]

(ii) $\overline{F_1} - \overline{P_2}$ = [h] - [-d]

Heterosis over mid parent = [h]

Inbreeding depression = [h]/2

[B] When six parameters model was adequate:

Heterosis over better parent

(i) $\overline{F_1} - \overline{P_1}$ = ([h] + [1]) - ([d] + [i])

(ii) $\overline{F_1} - \overline{P_2}$ = ([h] + [1]) - (-[d] + [i])

Heterosis over mid parent = ([h] + [1]) - [i]

Inbreeding depression = (1/2) [h] + (3/4) [l]

[C] When trigenic interaction model was adequate:

Heterosis over better parent

(i) $\overline{F_1} - \overline{P_1}$ = ([h] +[l] +[z]) - ([d] + [i] + [w])

(ii) $\overline{F} - \overline{P_2}$ = ([h] +[l] + [z]) - ([-d] + [i] - [w])

Heterosis over mid parent

= ([h] + [l] + [z]) - [i]

Inbreeding depression

= (1/2) [h] + (3/4) [l] + (7/8) [z]

Where, (d) = Additive gene effect, (h) = Dominance gene effect, (i) = Additive x additive gene effect, (j) = Additive x dominance gene effect, (l) = Dominance x dominance gene effect, (w) = Additive x additive x additivegene effect, (x) = Additive x additive x dominance gene effect, (y)

Electronic Journal of Plant Breeding, 4(2): 1180-1183 (Jun 2013)
ISSN 0975-928X

= Additive x dominancex dominance gene effect and (z) = Dominance x dominance x dominance gene effect.

The perusal of results of observed and expected relative heterosis, heterobeltiosis and inbreeding depression are presented in Table 1. The results showed that the extent of heterosis over mid parent and better parent was not pronounced for various characters recorded in three crosses. For the characters like days to 50% flowering of main raceme, days to maturity of main raceme, plant height and number of nodes up to main raceme, the low scoring parent was taken as better parent. The heterosis over better parent was significant and positive for days to 50% flowering and plant height in all the three crosses; days to maturity in the crosses JP 96 x JI 368 and JP 101 x SKI 215; number of nodes upto main raceme and oil content in the cross JP 101 x SKI 215; indicating delayed flowering , tall plant height, late maturity, more nodes with high oil content, respectively. length of main raceme and effective length of main raceme in the cross JP 96 x JI 372 and for number of capsules on main raceme in the crosses JP 96 x JI 368 and JP 96 x JI 372. Plant height up-to main raceme in the cross JP 96 x JI 372, length of main raceme in the crosses JP 96 x JI 368 and JP 96 x JI 372, effective length of main raceme and number of capsules on main raceme in all the crosses, shelling outturn in the crosses JP 96 x JI 368 and JP 101 x SKI 215, seed yield per plant and 100-seed weight in the cross JP 96 x JI 368 and oil content in the crosses JP 96 x JI 372 and JP 101 x SKI 215 showed significant and positive heterosis over mid parent. The rest of the estimates of calculated heterosis over mid parent and better parent were either smaller than their standard errors or not significantly larger than them.

Several research workers have also reported heterosis in desired direction for various characters in castor like days to flowering and maturity of main raceme (Pathak *et al*., 1988, Mehta *et al*., 1991; Manivel *et al*., 1999; Joshi *et al*., 2002; Lavanya and Chandramohan, 2003 and Patel and Pathak, 2006), plant height and number of nodes up to main raceme (Pathak *et al*., 1988; Mehta *et al*., 1991; Chakrabarty, 1997; Joshi *et al*., 2002 and Patel and Pathak, 2006), shelling out turn (Saiyed *et al*., 1997), 100-seed weight (Dangaria *et al*., 1987; Pathak *et al*., 1988; Dobariya *et al*., 1989; Saiyed *et al*., 1997; Manivel *et al*., 1999; Joshi *et al*., 2002; Lavanya and Chandramohan, 2003; Golakia *et al*., 2004 and Patel and Pathak 2006), oil content (Gopani *et al*., 1968; Pathak *et al*., 1986; Dobariya *et al*., 1989; Chakrabarty, 1997; Saiyed *et al*., 1997; Joshi *et al*., 2002; Lavanya and Chandramohan, 2003; Thakker *et al*., 2005 and Patel and Pathak, 2006).

The estimates of observed heterosis over mid parent and better parent either significant or non-significant showed a close agreement to estimated heterosis for most of the characters except for days to maturity, number of capsules on main raceme and seed yield per plant in cross JP 96 x JI 368; for shelling outturn and seed yield per plant in cross JP 96 x JI 372; and only over better parent for length of main raceme, seed yield per plant and oil content which indicated that the estimation of genetic parameters, on which the expected heterosis was based, has been carried out using most suitable model. The suitability of model was different for different traits for various crosses. Discrepancy observed between calculated and expected relative heterosis and heterobeltiosis in above cases might be due to involvement of higher order interaction and/or presence of linkage. According to Mather and Jinks (1977), if heterosis is measured on which an additive-dominance model is adequate, the positive and negative heterosis can occur only when ±[h] is greater than [d]. For this [h] must be greater than [d] for some or all genes, that is there must be super dominance or over dominance at some or all the loci. Secondly, there must be dispersion of completely or incompletely dominant genes. Unfortunately neither degree of dominance nor degree of association can be estimated from generation means. The distinction between these two causes of heterosis cannot be made without recourse to second degree statistics *viz*., variances and covariances.

If the heterosis in measured either on digenic or trigenic interaction model, its specification becomes more complex and there are many ways in which heterosis could arise. Nevertheless, it is more likely to arise and to arise with a greater magnitude when [h], [l] and [z] have the same sign, that is, interaction is predominantly of a complementary kind as well as the interacting pairs of genes are dispersed so that their contribution to the degree of association is either very small or zero and hence their contribution to [d], [i] and [w] is negligible. In the present study, the presence of duplicate type of epistasis, whenever found in experiment as a whole, support the low magnitude of observed heterosis for most of the characters recorded in all the three crosses. Though linkage does not affect the specification of the parental and F_1 means, the estimates of three of the four components of heterosis *viz*., [h], [i] and [l] for digenic interaction and five of the six components of heterosis *viz*., [h], [i], [l], [w] and [z] is biased. So if linkage is present, it will distort the relative magnitude of these components and affect the interpretation of the causes of heterosis. The evidence of linkage, however, was not possible to obtain in the present study. The observed heterosis was found to have resulted either due to the action of dominance component only or due to the combinations with either digenic or trigenic types of epistasis for different characters in three crosses of castor. In most of the cases in the above mentioned crosses, the observed heterosis was either due to dominance [h], dominance x dominance [l] interaction and dominance x dominance x dominance [z] interaction or only due to dominance [h] effect especially in the case where an additive-dominance model was adequate.

It is also noticed that cross JP 96 x JI 368 had high mid parental heterotic effect for seed yield per plant and majority of traits in desirable direction. The varied degree of heterosis for seed yield and its components in castor has been reported by Pathak *et al*. (1988), Saiyed *et al*. (1997), Joshi *et al*. (2002), Lavanya and Chandramohan (2003), Golakia *et al*. (2004) and Patel and Pathak (2006). The characters like days to flowering of main raceme and number of nodes up to main raceme are not directly related to seed yield but they are important in determining the maturity period. Usually dwarf lines with less number of nodes, mature earlier than the tall lines with greater number of nodes. Thus, from the viewpoint of developing early maturing and dwarf varieties/hybrids, the trend of negative heterosis for number of nodes up to main raceme is most desirable and an essential feature.

High inbreeding depression for seed yield and its component traits is undesirable in castor crop as vigour decline from generation to generation and delay the development of inbred lines. The estimates for inbreeding depression was found significant but negative for days to maturity, plant height, number of nodes up to main raceme and number of effective branches in cross JP 101 x SKI 215; length of main raceme, effective length of main raceme and number of capsules in main raceme in the crosses JP 96 x JI 368 and JP 101 x SKI 215; shelling outturn in the cross JP 96 x JI 372 and for seed yield per plant in the crosses JP 96 x JI 372 and JP 101 x SKI 215.

The crosses with significant and positive inbreeding depression was observed for plant height, length of main raceme, effective length of main raceme, number of capsules on main raceme and oil content in the cross JP 96 x JI 372; seed yield and shelling outturn in the cross JP 96 x JI 368 and for 100-seed weight in the crosses JP 96 x JI 368 and JP 101 x SKI 215. The significant and positive inbreeding depression was reported by Pathak *et al*. (1988) for 100-seed weight and seed yield per plant and by Golakiya *et al*. (2004) for total length of primary raceme, effective length of primary raceme, and 100-seed weight and seed yield per plant which supports the results obtained in the present study. It is desirable to have high, significant and positive heterosis with low inbreeding depression for seed yield and its components. This is equally applicable to developmental traits.

References

Briggle, L. W. 1963. Heterosis in wheat - a review. *Crop Sci*., **6**:220.

Chakrabarty, S. K. 1997. Combining ability and heterosis studies in castor (*Ricinus communis* L.). *J. Oilseeds Res*., **14**(2):182-188.

Dangaria, C. J., Dobaria, K. L., Fatteh, U. G. and Patel, V. J. 1987. Heterosis and combining ability analysis in castor. *J. Oilseeds Res*., **4**(1):46-53.

Dobariya, K. L., Patel, I. D., Patel, P. S. and Patel, V. J. 1989. Combining ability and genetic architecture of oil content in castor (*Ricinus communis* L.). *J. Oilseeds Res*., **6**(1):92-96.

Fonseca, S. and Patterson, F. 1968. Hybrid vigour in a seven parent diallel crosses in common winter wheat (*Triticum aestivum* L.). *Crop Sci*., **8**:85-86.

Golakiya, P. R., Madaria, R. B., Kavani, R. H. and Mehta, D. R. 2004. Gene effects, heterosis and inbreeding depression in castor. *J. Oilseeds Res*., **21**(2): 270-273.

Gopani, D. D., Kabaria, M. M. and Patel, R. H. 1968. Study of hybrid vigour in castor. Indian J. Agric. Sci., **38**:520-527.

Joshi, H. J., Mehta, D. R. and Jadon, B. S. 2002. Heterosis for seed yield and its components in castor hybrids. *Indian J. Agric. Res*., **36**:264-268.

Lavanya, C. and Chandramohan, Y. 2003. Combining ability and heterosis for seed yield and yield components in castor. *J. Oilseeds Res*., **20**(2):220-224.

Manivel, P., Hussain, H. S. J., Dharmalingam, V. and Pandian, I. S. 1999. Heterosis for yield and its components over environments in castor (*Ricinus communis* L.). *Madras Agric. J*., **86**(1-3):65-68.

Mather, K. and Jinks, J. L. 1977. Introduction to Biometrical Genetics. Chapman and Hall Ltd., London.

Mehta, D. R., Vashi, P. S. and Kukadia, M. U. 1991. Hybrid vigour in castor. *Gujarat Agric. Univ. Res. J*., **17**(1):16-22.

Patel, J. B. and Pathak, H. C. 2006. Heterosis for seed yield per plant and components in castor (*Ricinus communis* L.). *J. oilseeds Res*., **23**(1):93-95.

Pathak, H. C., Dangaria, C. J. and Parmar, S. K. 1986. Heterosis and genetic architecture of oil content in castor (*Ricinus communis* L.). *Madras Agric. J*., **73**(6):328-333.

Pathak, H. C., Dixit, S. K. and Patel, P. G. 1988. Gene effects and heterosis in castor (*Ricinus communis* L.). *Indian J. Agric. Sci*., **58**(6):476-478.

Saiyed, M. P., Shukla, P. T. and Dhameliya, H. R. 1997. Heterosis for yield and yield components in castor (*Ricinus communis* L.) over environments. *Gujarat Agric. Univ. Res. J*., **23**(1): 22-27.

Thakkar, D. A., Jadon, B. S., Patel, K. M. and Patel, C. J. 2005. Heterosis over environments for seed yield and other attributes in Castor (*Ricinus communis* L.). *J. Oilseeds Res*., **22**(2):324-326.

Electronic Journal of Plant Breeding, 4(2): 1180-1183 (Jun 2013)
ISSN 0975-928X

Table 1 Estimates of observed and expected heterosis and inbreeding depression for twelve characters in three castor crosses

Heterosis/ Inbreeding depression	Observed/ Expected values	Days to 50% flowering of main raceme	Days to maturity of main raceme	Plant height up to main raceme (cm)	Number of nodes up to main raceme	Length of main raceme (cm)	Effective length of main raceme (cm)	Number of effective branches per plant	Number of capsules on main raceme	Shelling out turn (%)	Seed yield per plant (g)	100-seed weight (g)	Oil content (%)
JP 96 x JI 368 (Cross 1)													
Mid parent	Observed	1.23**	-1.23	0.71	0.30	4.20**	3.33**	0.50	2.70**	4.31**	23.27**	1.57*	0.83
		± 0.46	± 0.71	± 1.26	± 0.50	± 0.78	± 0.91	± 0.26	± 0.82	± 1.13	± 2.17	± 0.78	± 1.10
	Expected	1.26	-42.21	2.57	-0.19	4.49	3.53	0.46	318.6	4.66	13.38	1.57	1.16
Better parent	Observed	4.07**	2.67**	8.17**	0.40	-2.53**	-3.07**	0.33	1.67*	1.98	1.53	0.60	-1.94**
		± 0.47	± 0.90	± 1.42	± 0.50	± 0.78	± 0.96	± 0.33	± 0.75	± 1.17	± 2.23	± 0.86	± 0.10
	Expected	3.71	-38.32	9.57	0.77	-2.22	-2.88	0.32	317.52	-2.43	-8.46	0.66	-1.34
Inbreeding depression	Observed	0.88	-0.92	0.18	-1.03	-5.18**	-5.60**	0.40	-3.90**	4.52**	4.27*	3.32**	0.95
		± 0.61	± 0.74	± 1.44	± 0.61	± 0.99	± 1.07	± 0.29	± 1.28	± 1.30	± 2.09	± 0.80	± 1.05
	Expected	0.90	-36.90	2.59	-0.63	-4.85	-5.36	0.29	233.02	4.98	-9.50	3.31	1.55
JP 96 x JI 372 (Cross 2)													
Mid parent	Observed	0.87*	-0.33	17.35**	-0.77	8.70**	10.77**	0.03	16.37**	-1.58**	-9.47**	-2.33**	4.12**
		± 0.41	± 0.57	± 1.66	± 0.51	± 0.62	± 0.76	± 0.32	± 0.71	± 0.53	± 1.90	± 0.78	± 0.65
	Expected	0.97	-0.18	17.68	-0.43	8.34	10.83	0.11	16.33	27.23	-2.32	-2.31	4.12
Better parent	Observed	3.13**	0.87	30.12**	0.73	2.13**	5.27**	-0.47	11.20**	-3.10**	-40.87**	-5.60**	0.34
		± 0.53	± 0.58	± 1.86	± 0.54	± 0.59	± 0.93	± 0.34	± 0.98	± 0.70	± 1.99	± 0.80	± 0.75
	Expected	3.24	1.04	30.51	1.07	2.61	5.87	-18.61	11.08	25.64	-33.96	-5.49	0.60
Inbreeding depression	Observed	-0.87	-1.02	2.73**	-1.20	4.77**	6.40**	-0.60	11.77**	-1.24*	-33.17**	-1.70	3.14**
		± 0.64	± 0.71	± 0.20	± 0.65	± 0.75	± 0.83	± 0.34	± 0.95	± 0.60	± 1.99	± 0.88	± 0.64
	Expected	-0.74	-0.82	3.10	-0.80	5.27	7.12	-0.51	11.86	24.03	-25.10	-1.82	3.14
JP 101 x SKI 215 (Cross 3)													
Mid parent	Observed	2.73**	-0.57	0.55	-1.63**	2.07	2.00**	-0.17	7.30**	2.80**	-2.07	-0.87	5.75**
		± 0.70	± 0.62	± 1.05	± 0.35	± 1.37	± 0.12	± 0.19	± 1.64	± 0.82	± 2.11	± 0.60	± 0.83
	Expected	3.12	-0.36	-0.14	-1.70	3.88	3.40	-0.16	7.62	2.69	1.70	-0.87	6.03
Better parent	Observed	4.53**	1.67**	6.97**	2.27**	-6.87**	-4.80**	-0.60**	2.67	1.40	-20.13**	-3.20**	2.73**
		± 0.74	± 0.64	± 1.32	± 0.54	± 1.42	± 0.13	± 0.21	± 1.90	± 0.98	± 2.46	± 0.60	± 0.81
	Expected	4.90	1.84	6.22	2.04	-4.89	-3.28	0.66	3.33	1.11	-2.67	-3.08	8.83
Inbreeding depression	Observed	-0.62	-3.12**	-13.83**	-2.55**	-8.32**	-8.23**	-0.98**	-6.98**	0.53	-37.03**	2.20**	1.34
		± 0.90	± 0.83	± 2.04	± 0.53	± 1.48	± 1.35	± 0.23	± 1.93	± 0.79	± 2.12	± 0.68	± 1.00
	Expected	-0.22	-2.95	-14.35	-2.49	-6.35	-6.76	-0.97	-6.55	0.18	-33.18	2.26	1.73

*, ** Significant at 5% and 1% levels, respectively