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

**Barad HR, Dobariya KL, Delvadiya IR, Vekaria DM and Sapara GK**

## Abstract
The experimental material consisting of 101 entries comprised of ten parents and their 45 hybrids and 45 F2s developed through half diallel mating design and one standard check (GCH 7) were evaluated in a randomized block design with three replications. The magnitude of standard heterosis in the positive direction was high for number of effective branches per plant and seed yield per plant; medium for 100-seed weight, effective length of primary raceme, length of primary raceme and low for oil content. Similarly, the magnitude of standard heterosis in the negative direction was high for number of nodes up to the primary raceme, plant height and medium for days to maturity of primary raceme and days to 50% flowering of primary raceme. The cross JI 368 x RG 2787 depicted significantly the highest and positive heterobeltiosis (51.08%), standard heterosis (40.15%) as well as the highest seed yield per plant (486.80 g). The crosses DPC 17 x SKI 343 and DPC 17 x JI 353 were the next best crosses exhibiting significant and positive heterobeltiosis (134.73% and 45.73%), standard heterosis (36.66% and 30.52%) and per se performance (474.67 g and 453.33 g). The range of inbreeding depression was from -37.45% (DPC 17 x SKI 215) to 34.18% (JI 372 x PCS 124) with a mean of 8.10%. Out of 45 crosses, none of the crosses showed significant positive inbreeding depression for seed yield per plant.

**Keywords:** Castor, heterosis, heterobeltiosis, standard heterosis and Inbreeding depression

## Introduction
Castor (*Ricinus communis* L., 2n=20) is an industrially important non-edible oil seed crop widely cultivated in the arid and semi-arid regions of the world. Castor is sexually polymorphic species with different sex forms viz., monoecious, pistillate, hermaphrodite and pistillate with interspersed staminate flowers (ISF). Among those; India, Brazil, China, Russia, Thailand and Philippines are the principle castor growing countries. In world, India ranks first in respect of area and production, contributing about 40% of the world requirements. In India, castor is being grown for oil under wide ranging environmental conditions in area of 8.23 lakh ha with production of 14.43 lakh tonnes and a productivity of 1754 kg/ha (Anonymous, 2018). Heterosis breeding is an important crop improvement method adopted in many crops all over the world. It is a quick and convenient way of combining desirable characters which has assumed greater significance in the production of $F_1$ hybrids. The superiority of hybrids depends on their yield potential over the better released varieties and the extent of heterosis for seed yield. The aim of heterosis analysis is to find out the best combination of crosses giving high degree of useful heterosis and characterization of hybrids for commercial exploitation. The estimation of inbreeding provides information about the nature of gene actions involved in the expression of yield and its component characters. Inbreeding depression points out whether the vigour observed in the $F_1$ generation can be fixed or not in later generations through selfing. The information of such estimates is essential to plan efficient breeding programmes as well as selection of parents so as to obtain good segregants for improvement of the crop yield.

## Materials and Methods
The experimental material comprised of a set of 10 diverse parents of castor which were used for half diallel mating design. The experimental material, consisting of 101 entries including 10 parents, 45 crosses, 45 $F_2$s and one check hybrid (GCH 7) was raised in a Randomized Block Design with three replications at the Main Oilseeds Research Station, JAU, Junagadh during *kharif* 2016-17. Each entry was accommodated in a single row of 7.2 m. length spaced at 90 cm apart with plant-to-plant spacing of 60 cm. Recommended agronomic practices and plant protection measures were adopted timely to raise the healthy crop. Five competitive plants from parental lines and $F_1$s and 20 plants from each $F_2$s from each replication were

randomly selected before flowering and tagged for the purpose of recording observations on different characters (except days to flowering and days to maturity) and their average values were used in the statistical analysis. The analysis of variance was performed to test the significance of differences among the genotypes for all the characters following fixed effect model as suggested by Panse and Sukhatme (1985) [21]. In the present investigation, heterosis was estimated over better parent (BP), which is referred to as heterobeltiosis as per Fonseca and Patterson (1968) [6]. In addition, an increase in $F_1$ over the standard check hybrid (standard heterosis) was also worked-out by using popular check hybrid, GCH 7. Inbreeding depression was also worked out as per the standard formula from $F_1$ and $F_2$.

**Results and Discussion**

The analysis of variance was performed to test the differences among the genotypes, parents, hybrids and parents *vs* hybrids for all the eleven characters studied and is presented in Table 1. The results revealed that the mean squares due to genotypes were highly significant for all the characters. The mean squares due to parents were further partitioned into mean squares due to parents, hybrids and parents *vs* hybrids. The analysis of variance revealed that the mean squares due to parents, hybrids and $F_2$s were highly significant for all the characters except for number of nodes up to primary raceme in parents. The mean squares due to parents *vs* hybrids differed significantly for all the characters, while the mean squares due to parents vs $F_2$s were found significant for days to 50% flowering, days to maturity, plant height, number of effective branches per plant, 100-seed weight and seed yield per plant. The results thus, indicated the presence of considerable amount of genetic variability in the material studied and also showed that the material was suitable for the study of manifestation of heterosis and genetic parameters involved in the inheritance of different traits in castor.

The magnitude of standard heterosis in the positive direction was high for number of effective branches per plant and seed yield per plant; medium for 100-seed weight, effective length of primary raceme, length of primary raceme and low for oil content. Similarly, the magnitude of standard heterosis in the negative direction was high for number of nodes up to the primary raceme, plant height and medium for days to maturity of primary raceme and days to 50% flowering of primary raceme.

With respect to the performance of hybrids for seed yield per plant, it was observed that 22 hybrids over better parent and 7 hybrids over standard check (GCH 7) exhibited significant and positive heterosis (Table 3). The range of heterosis over better parent was from -21.66 to 149.20%, while over standard check, it ranged from -27.32 to 40.15%. The cross JI 368 x RG 2787 depicted significantly the highest and positive heterobeltiosis (51.08%), standard heterosis (40.15%) as well as the highest seed yield per plant (486.80 g). The crosses DPC 17 x SKI 343 and DPC 17 x JI 353 were the next best crosses exhibiting significant and positive heterobeltiosis (134.73% and 45.73%, respectively), standard heterosis (36.66% and 30.52%, respectively) and *per se* performance (474.67 g and 453.33 g, respectively). In such cases, expression of heterotic response over better and standard parents indicated the real superiority of hybrids from the commercial point of view. High heterosis for seed yield in castor has also been reported by Manivel *et al.*, (1999) [14], Joshi *et al.*, (2001), Lavanya and Chandramohan, (2003) [12], Golakia *et al.*, (2004) [7], Thakkar *et al.*, (2005) [25], Patel and Pathak, (2006) [20], Sridhar *et al.*, (2009) [24], Barad *et al.*, (2009) [4], Chaudhari *et al.*, (2011) [3], Chaudhari and Patel, (2014) [2], Makani *et al.*, (2015) [13], Sapovadiya *et al.*, (2015) [20], Punewar *et al.* (2017) [19] and Delvadiya *et al.* (2018) [5]. 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. In present study, none of the crosses showed the significant positive inbreeding depression for seed yield which is highly desirable.

The characters like days to 50% flowering, days to maturity, plant height and number of nodes upto primary raceme are related to earliness in castor, where in the lower values are desirable. In the present study, five crosses *viz.*, DPC 17 x JI 368, DPC 17 x JI 372, JI 411 x JI 372, DCS 85 x JI 372 and DCS 85 x PCS 124 displayed significant negative heterobeltiosis and standard heterosis simultaneously for days to 50% flowering, days to maturity, plant height and number of nodes up to primary raceme. These high heterotic crosses may be considered as potential and be exploited in breeding for the development of early maturity and dwarf genotypes in castor. Similar findings for earliness were also reported by Patel *et al.* (1984) [16], Patel (1989), Mehta *et al.* (1991), Joshi *et al.* (2002) [11], Thakkar *et al.* (2005) [25], Golakia *et al.* (2008), Sodavadiya *et al.* (2010) [23], Chaudhari *et al.* (2011) [3] and Punewar *et al.* (2017) [19]. Hagberg (1952) [9] observed similar effect and termed it "combinational heterosis". In order to see whether similar situation exist in castor or not, a comparison of ten most heterotic crosses for seed yield per plant was made with other yield related characters along with average mean seed yield per plant (Table 4). The results revealed that the best three hybrids identified on the basis of *per se* performance and standard heterosis for seed yield per plant *viz.*, JI 368 x RG 2787, DPC 17 x SKI 343 and DPC 17 x JI 353 also depicted significant positive standard heterosis over GCH 7 for important yield contributing traits i.e. JI 368 x RG 2787 manifested significant standard heterosis for days to 50% flowering of primary raceme, days to maturity of primary raceme, oil content and seed yield per plant; DPC 17 x SKI 343 for days to 50% flowering, days to maturity, number of nodes up to primary raceme and seed yield per plant and DPC 17 x JI 353 for days to 50% flowering of primary raceme, days to maturity of primary raceme, plant height, number of nodes up to primary raceme, number of capsules on primary raceme and seed yield per plant (Table 4). This emphasized that high degree of heterosis for seed yield might be attributed to the heterosis observed for the component characters. Similar findings have been reported by Thakkar (1987), Manivel *et al.* (1999) [14], Patel *et al.* (1989) [18], Sridhar *et al.* (2009) [24], Sodavadiya (2010) [23], Sapovadiya *et al.* (2015) [22], Makani *et al.* (2015) [13], Punewar *et al.* (2017) [19] and Delvadiya *et al.* (2018) [5].

The range of inbreeding depression was from -37.45% (DPC 17 x SKI 215) to 34.18% (JI 372 x PCS 124) with a mean of 8.10%. Out of 45 crosses, none of the crosses showed significant positive inbreeding depression for seed yield per plant. 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. In present study, none of the crosses showed the significant positive inbreeding depression for seed yield which is highly desirable.

Overall, results indicated that significant and moderate to low estimates of heterobeltiosis and standard heterosis over GCH 7 were expressed for seed yield and its components under the present investigation. This indicated the possibility and scope of exploitation of heterosis in castor due to the availability of 100% pistillate lines.

**Table 1:** Analysis of variance for experimental design for different characters in castor

| Sources | D.F. | Days to 50% flowering of primary raceme | | Days to maturity of primary raceme | | Plant height up to primary raceme (cm) | | Number of nodes up to primary raceme | | Length of primary raceme (cm) | | Effective length of primary raceme (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 2.30 | | 20.90 | * | 40.78 | | 1.70 | | 29.65 | * | 542.30 | ** |
| Genotypes | 99 | 78.90 | ** | 373.65 | ** | 655.64 | ** | 6.52 | ** | 111.82 | ** | 103.54 | ** |
| Parents (P) | 9 | 119.55 | ** | 559.03 | ** | 327.17 | ** | 1.61 | | 154.52 | ** | 140.28 | ** |
| $F_1$s | 44 | 18.37 | ** | 212.50 | ** | 624.64 | ** | 8.95 | ** | 95.68 | ** | 84.53 | ** |
| Parents *vs* $F_1$s | 1 | 2598.41 | ** | 7124.57 | ** | 138.27 | * | 2.09 | | 17.48 | | 16.92 | |
| $F_2$s | 44 | 67.53 | ** | 346.66 | ** | 693.35 | ** | 4.67 | ** | 121.71 | ** | 116.50 | ** |
| Parents *vs* $F_2$s | 1 | 1021.73 | ** | 3635.62 | ** | 2044.82 | ** | 3.73 | * | 4.97 | | 9.48 | |
| Error | 198 | 2.67 | | 5.58 | | 35.19 | | 1.15 | | 9.49 | | 12.03 | |

| Sources | D.F. | Number of effective branches per plant | | Number of capsules on primary raceme | | 100-seed weight (g) | | Oil content (%) | | Seed yield per plant (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 10.90 | ** | 27.67 | | 3.00 | ** | 0.69 | | 175918.37 | ** |
| Genotypes | 99 | 2.04 | ** | 121.35 | ** | 40.91 | ** | 1.31 | ** | 13260.96 | ** |
| Parents (P) | 9 | 1.11 | ** | 157.76 | ** | 45.60 | ** | 0.79 | ** | 18804.50 | ** |
| $F_1$s | 44 | 1.99 | ** | 143.17 | ** | 29.43 | ** | 0.65 | ** | 9377.23 | ** |
| Parents *vs* $F_1$s | 1 | 0.00 | | 4.44 | | 43.04 | ** | 15.96 | ** | 341831.20 | ** |
| $F_2$s | 44 | 1.62 | ** | 96.37 | ** | 52.18 | ** | 1.36 | ** | 8721.30 | ** |
| Parents *vs* $F_2$s | 1 | 10.86 | ** | 5.46 | | 16.42 | ** | 0.74 | | 190097.76 | ** |
| Error | 198 | 0.25 | | 9.40 | | 0.20 | | 0.29 | | 3534.14 | |

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

**Table 2.1:** Per cent heterobeltiosis ($H_1$), standard heterosis ($H_2$) and Inbreeding depression (ID) for days to flowering of primary raceme, days to maturity of primary raceme and plant height up to primary raceme in castor

| Sr. No. | Hybrids | Days to 50% flowering of primary raceme $H_1$ (%) | | $H_2$ (%) | | ID (%) | | Days to maturity of primary raceme $H_1$ (%) | | $H_2$ (%) | | ID (%) | Plant height up to primary raceme (cm) $H_1$ (%) | | $H_2$ (%) | | ID (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | DPC 17 x JI 353 | -21.34 | ** | -15.69 | ** | 0.78 | | -16.27 | ** | -22.99 | ** | -30.94 | -19.98 | ** | -19.82 | ** | 17.28 |
| 2 | DPC 17 x JI 368 | -4.51 | | -16.99 | ** | -2.36 | | -2.81 | | -23.27 | ** | -34.66 | -29.81 | ** | -30.93 | ** | 1.72 |
| 3 | DPC 17 x JI 411 | -14.84 | ** | -13.73 | ** | 0.76 | | -14.93 | ** | -21.05 | ** | -4.91 | 12.62 | | 12.85 | | 47.23 |
| 4 | DPC 17 x DCS 85 | -19.16 | ** | -11.76 | ** | -4.44 | | -17.46 | ** | -18.84 | ** | 0.00 | -12.35 | | -12.17 | | -4.22 |
| 5 | DPC 17 x SKI 343 | -5.97 | | -17.65 | ** | -0.79 | | -1.42 | | -22.99 | ** | -1.44 | 23.91 | * | -0.16 | | 23.71 |
| 6 | DPC 17 x SKI 215 | -21.02 | ** | -9.15 | ** | 0.00 | | -23.48 | ** | -19.67 | ** | 0.00 | 6.25 | | 4.07 | | -27.81 |
| 7 | DPC 17 x JI 372 | -22.41 | ** | -11.76 | ** | 2.22 | | -26.12 | ** | -22.44 | ** | -13.93 | -28.08 | ** | -27.93 | ** | -24.09 |
| 8 | DPC 17 x PCS 124 | -22.65 | ** | -8.50 | ** | -2.14 | | -24.74 | ** | -18.28 | ** | -1.69 | -11.12 | | -10.94 | | 12.44 |
| 9 | DPC 17 x RG 2787 | -18.99 | ** | -5.23 | | -5.52 | | -16.35 | ** | -14.96 | ** | 0.65 | 14.40 | | 14.63 | | 23.74 |
| 10 | JI 353 x JI 368 | -1.50 | | -14.38 | ** | -2.29 | | -1.05 | | -21.88 | ** | 1.06 | -22.33 | ** | -23.58 | ** | -0.73 |
| 11 | JI 353 x JI 411 | -6.45 | * | -5.23 | | -14.48 | | -2.11 | | -9.97 | ** | 12.00 | 1.98 | | 6.36 | | 43.31 |
| 12 | JI 353 x DCS 85 | -9.76 | ** | -3.27 | | -14.86 | | 0.90 | | -7.20 | ** | 5.37 | -11.44 | | -10.93 | | 27.06 |
| 13 | JI 353 x SKI 343 | 1.49 | | -11.11 | ** | 0.74 | | -0.71 | | -22.44 | ** | -20.36 | 32.63 | ** | 6.87 | | 19.01 |
| 14 | JI 353 x SKI 215 | -10.37 | ** | -3.92 | | -15.65 | | 6.33 | ** | -2.22 | | -4.53 | 35.16 | ** | 32.38 | ** | 35.16 |
| 15 | JI 353 x JI 372 | -12.20 | ** | -5.88 | * | -7.64 | | 1.51 | | -6.65 | ** | -4.45 | -3.28 | | 0.87 | | 9.75 |
| 16 | JI 353 x PCS 124 | -8.54 | ** | -1.96 | | -7.33 | | 5.42 | ** | -3.05 | * | 10.00 | -6.15 | | -5.57 | | -9.18 |
| 17 | JI 353 x RG 2787 | -8.54 | ** | -1.96 | | -15.33 | | 10.24 | ** | 1.39 | | 23.77 | 10.70 | | 15.45 | * | -1.23 |
| 18 | JI 368 x JI 411 | -5.26 | | -17.65 | ** | -19.84 | * | 7.72 | ** | -14.96 | ** | 11.73 | -21.43 | ** | -22.70 | ** | 19.99 |
| 19 | JI 368 x DCS 85 | -7.52 | * | -19.61 | ** | -27.64 | ** | 8.42 | ** | -14.40 | ** | 9.39 | -3.94 | | -5.49 | | 29.40 |
| 20 | JI 368 x SKI 343 | -1.50 | | -14.38 | ** | -21.37 | * | 11.35 | ** | -13.02 | ** | 9.87 | 21.55 | * | -2.06 | | 16.82 |
| 21 | JI 368 x SKI 215 | 0.00 | | -13.07 | ** | -15.79 | | 8.07 | ** | -14.68 | ** | -0.65 | 17.9 5 | * | 15.52 | * | 3.79 |
| 22 | JI 368 x JI 372 | -3.01 | | -15.69 | ** | -7.75 | | 1.75 | | -19.67 | ** | -5.86 | 4.42 | | 2.74 | | 19.83 |
| 23 | JI 368 x PCS 124 | -4.51 | | -16.99 | ** | -4.72 | | -2.81 | | -23.27 | ** | -7.94 | -24.66 | ** | -25.87 | ** | -9.84 |
| 24 | JI 368 x RG 2787 | 2.26 | | -11.11 | ** | -18.38 | * | 20.35 | ** | -4.99 | ** | 15.16 | 28.94 | ** | 26.87 | ** | 28.01 |
| 25 | JI 411 x DCS 85 | -15.48 | ** | -14.38 | ** | -10.69 | | -16.72 | ** | -22.71 | ** | -8.24 | 21.56 | ** | 22.26 | ** | 29.01 |

| Sr. No. | Hybrids | Days to 50% flowering of primary raceme $H_1$ (%) | | $H_2$ (%) | | ID (%) | | Days to maturity of primary raceme $H_1$ (%) | | $H_2$ (%) | | ID (%) | Plant height up to primary raceme (cm) $H_1$ (%) | | $H_2$ (%) | | ID (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | JI 411 x SKI 343 | -5.97 | | -17.65 | ** | -14.29 | | -0.71 | | -22.44 | ** | -29.64 | 10.42 | | -11.03 | | 19.96 |
| 27 | JI 411 x SKI 215 | -15.48 | ** | -14.38 | ** | -3.05 | | -14.93 | ** | -21.05 | ** | -34.39 | 21.01 | ** | 18.52 | * | -1.71 |
| 28 | JI 411 x JI 372 | -16.77 | ** | -15.69 | ** | -1.55 | | -15.52 | ** | -21.61 | ** | -1.77 | -32.22 | ** | -19.67 | ** | -19.27 |
| 29 | JI 411 x PCS 124 | -17.42 | ** | -16.34 | ** | -2.34 | | -16.12 | ** | -22.16 | ** | -9.25 | -13.05 | | -12.51 | | -8.33 |
| 30 | JI 411 x RG 2787 | -17.42 | ** | -16.34 | ** | -8.59 | | -15.82 | ** | -21.88 | ** | -12.06 | 23.42 | ** | 35.31 | ** | 10.89 |
| 31 | DCS 85 x SKI 343 | -1.49 | | -13.73 | ** | -4.55 | | 1.42 | | -20.78 | ** | -7.34 | 23.19 | * | -0.74 | | 2.94 |
| 32 | DCS 85 x SKI 215 | -23.95 | ** | -16.99 | ** | -3.15 | | -21.69 | ** | -22.99 | ** | -5.40 | -2.14 | | -4.16 | | 7.85 |
| 33 | DCS 85 x JI 372 | -23.35 | ** | -16.34 | ** | 2.34 | | -23.10 | ** | -24.38 | ** | -7.33 | -17.64 | * | -17.16 | * | -16.93 |
| 34 | DCS 85 x PCS 124 | -16.77 | ** | -9.15 | ** | -7.91 | | -17.18 | ** | -18.56 | ** | 6.12 | -19.64 | ** | -19.18 | * | -17.32 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 35 | DCS 85 x RG 2787 | -17.96 ** | -10.46 ** | -9.49 | -16.62 ** | -18.01 ** | 0.68 | -1.51 | -0.95 | -1.52 |
| 36 | SKI 343 x SKI 215 | -5.22 | -16.99 ** | -6.30 | -0.35 | -22.16 ** | 2.14 | 43.31 ** | 15.47 * | 5.86 |
| 37 | SKI 343 x JI 372 | -3.73 | -15.69 ** | -13.95 | -0.35 | -22.16 ** | -3.56 | 8.99 | -12.18 | -6.90 |
| 38 | SKI 343 x PCS 124 | 0.00 | -12.42 ** | -5.97 | 1.06 | -21.05 ** | -14.74 | 6.59 | -14.12 | -13.83 |
| 39 | SKI 343 x RG 2787 | -2.24 | -14.38 ** | -6.11 | -1.06 | -22.71 ** | -29.03 | 39.84 ** | 12.67 | -3.13 |
| 40 | SKI 215 x JI 372 | -28.16 ** | -18.30 ** | -8.00 | -27.18 ** | -23.55 ** | -35.51 | 10.25 | 7.98 | -9.71 |
| 41 | SKI 215 x PCS 124 | -21.59 ** | -9.80 ** | -14.49 | -18.47 ** | -14.40 ** | 0.65 | 27.02 ** | 24.40 ** | 5.58 |
| 42 | SKI 215 x RG 2787 | -19.32 ** | -7.19 * | -26.06 ** | -4.09 ** | -2.49 | -6.82 | 38.45 ** | 35.60 ** | 8.75 |
| 43 | JI 372 x PCS 124 | -22.41 ** | -11.76 ** | -6.67 | -22.16 ** | -18.28 ** | -4.41 | 2.33 | 2.96 | 1.41 |
| 44 | JI 372 x RG 2787 | -25.86 ** | -15.69 ** | -8.53 | -21.80 ** | -20.50 ** | -9.41 | 9.72 | 20.29 ** | 13.82 |
| 45 | PCS 124 x RG 2787 | -18.44 ** | -4.58 | -19.18 * | -10.35 ** | -8.86 ** | -7.29 | 19.67 ** | 20.41 ** | 8.45 |
| Range | | -28.16 to 2.26 | -19.61 to 1.96 | -27.64 to 2.34 | -27.18 to 20.35 | -24.38 to 1.39 | -35.51 to 23.77 | -32.22 to 43.31 | -30.93 to 35.60 | -27.81 to 47.23 |
| Mean Heterosis/Inbreeding depression | | -12.12 | -12.33 | -8.5 | -7.33 | -17.21 | -5.53 | 4.43 | 0.99 | 7.04 |
| S.E ± | | 1.25 | 1.25 | 0.94 | 1.7 | 1.7 | 1.41 | 6.15 | 6.15 | 3.57 |
| Number of crosses showing significant positive heterosis/inbreeding depression | | 0 | 0 | 0 | 8 | 0 | 0 | 15 | 12 | 0 |
| Number of crosses showing significant negative heterosis/inbreeding depression | | 29 | 38 | 6 | 22 | 42 | 0 | 9 | 9 | 0 |

* and ** significant at 5% and 1% levels of significance, respectively

**Table 2.2:** Per cent heterobeltiosis ($H_1$), standard heterosis ($H_2$) and Inbreeding depression (ID) for number of nodes up to primary raceme, length of primary raceme and effective length of primary raceme in castor

| Sr. | Hybrids | Number of nodes up to primary raceme | | | Length of primary raceme (cm) | | | Effective length of primary raceme (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | | $H_1$ (%) | $H_2$ (%) | ID (%) | $H_1$ (%) | $H_2$ (%) | ID (%) | $H_1$ (%) | $H_2$ (%) | ID (%) |
| 1 | DPC 17 x JI 353 | -8.30 | -16.00 ** | 0.36 | -26.01 ** | -13.77 * | 4.23 | -23.17 ** | -6.50 | 10.90 |
| 2 | DPC 17 x JI 368 | -21.83 ** | -29.80 ** | -23.36 ** | -34.60 ** | -23.78 ** | -16.28 | -32.85 ** | -18.29 * | -12.72 |
| 3 | DPC 17 x JI 411 | 10.66 | -6.60 | 13.81 ** | -16.69 ** | -2.90 | 2.00 | -15.71 * | 2.58 | 4.11 |
| 4 | DPC 17 x DCS 85 | -4.87 | -14.00 * | -0.70 | -34.85 ** | -24.07 ** | -31.60 * | -31.81 ** | -17.01 * | -21.88 |
| 5 | DPC 17 x SKI 343 | 2.92 | -15.40 ** | -3.88 | -27.12 ** | -15.06 * | 4.81 | -23.56 ** | -6.98 | 13.36 |
| 6 | DPC 17 x SKI 215 | 4.37 | -9.20 | -7.56 * | -20.37 ** | -7.19 | 3.58 | -16.75 ** | 1.31 | 9.98 |
| 7 | DPC 17 x JI 372 | -21.79 ** | -31.80 ** | -15.66 ** | -44.11 ** | -34.86 ** | -35.69 ** | -41.75 ** | -29.12 ** | -26.29 |
| 8 | DPC 17 x PCS 124 | 6.67 | -13.60 * | 4.51 | -32.94 ** | -21.85 ** | -17.80 | -33.05 ** | -18.53 * | -14.81 |
| 9 | DPC 17 x RG 2787 | 0.89 | -9.20 | -2.20 | -34.42 ** | -23.57 ** | -27.97 * | -32.66 ** | -18.05 * | -21.33 |
| 10 | JI 353 x JI 368 | -8.46 | -17.80 ** | -2.92 | -1.78 | -29.07 ** | -36.44 ** | -2.83 | -28.96 ** | -40.53 ** |
| 11 | JI 353 x JI 411 | 15.17 * | -2.80 | 22.86 ** | -14.35 * | -12.05 * | 13.45 | -11.38 | -8.25 | 15.54 |
| 12 | JI 353 x DCS 85 | -5.09 | -14.20 * | 21.35 ** | -14.08 | -32.79 ** | 9.36 | -12.07 | -31.51 ** | 9.88 |
| 13 | JI 353 x SKI 343 | 12.41 | -7.60 | 12.27 ** | -6.13 | -12.48 * | 14.30 | -4.48 | -8.25 | 17.49 |
| 14 | JI 353 x SKI 215 | 19.08 ** | 3.60 | 16.80 ** | 1.90 | -7.76 | 20.93 | 4.06 | -2.04 | 23.01 |
| 15 | JI 353 x JI 372 | 4.13 | -9.20 | 4.74 | -9.27 | -35.65 ** | -38.67 ** | -5.58 | -29.91 ** | -31.42 * |
| 16 | JI 353 x PCS 124 | 14.32 * | -7.40 | 5.29 | 0.09 | -21.35 ** | 0.09 | -2.65 | -21.15 ** | -0.91 |
| 17 | JI 353 x RG 2787 | 17.11 ** | 5.40 | 11.29 ** | 14.52 | -9.19 | 24.39 | 12.69 | -11.60 | 23.53 |
| 18 | JI 368 x JI 411 | 6.64 | -10.00 | 29.56 ** | 1.39 | 4.10 | 27.61 * | -2.31 | 1.15 | 20.87 |
| 19 | JI 368 x DCS 85 | -0.22 | -10.40 | 9.93 ** | -2.19 | -23.49 ** | 7.88 | -3.89 | -25.14 ** | 4.93 |
| 20 | JI 368 x SKI 343 | 1.70 | -16.40 ** | 3.47 | -11.43 | -17.42 ** | -0.91 | -7.55 | -11.20 | 5.61 |
| 21 | JI 368 x SKI 215 | 10.34 | -4.00 | 0.42 | -8.06 | -16.77 ** | -14.38 | -6.68 | -12.15 | -11.02 |
| 22 | JI 368 x JI 372 | 0.46 | -12.40 * | 11.42 ** | 12.18 | -18.99 ** | 9.89 | 8.91 | -19.16 * | 9.02 |
| 23 | JI 368 x PCS 124 | 6.67 | -13.60 * | 6.25 | 9.74 | -13.77 * | 11.15 | 7.37 | -13.03 | 8.61 |
| 24 | JI 368 x RG 2787 | 18.93 ** | 6.80 | 19.10 ** | 21.28 ** | -3.83 | 20.07 | 11.57 | -12.47 | 13.15 |
| 25 | JI 411 x DCS 85 | 10.66 | -6.60 | 15.63 ** | 3.76 | 6.54 | 16.81 | -8.46 | -5.22 | 1.55 |
| 26 | JI 411 x SKI 343 | 9.00 | -10.40 | 5.69 | -4.32 | -1.76 | -8.17 | 0.31 | 3.85 | -4.87 |
| 27 | JI 411 x SKI 215 | 23.70 ** | 4.40 | 7.18 * | -10.86 | -8.48 | -29.15 * | -5.38 | -2.04 | -26.30 |
| 28 | JI 411 x JI 372 | -18.01 ** | -30.80 ** | -17.43 ** | -33.84 ** | -32.07 ** | -3.53 | -30.77 ** | -28.32 ** | 0.44 |
| 29 | JI 411 x PCS 124 | 8.64 | -12.00 * | 3.95 | -14.00 * | -11.70 | -21.38 | -17.31 * | -14.38 | -28.56 * |
| 30 | JI 411 x RG 2787 | 17.54 ** | -0.80 | 8.75 * | -7.38 | -4.90 | -1.69 | -4.92 | -1.56 | -2.59 |
| 31 | DCS 85 x SKI 343 | 4.62 | -14.00 * | -3.12 | -17.94 ** | -23.49 ** | 13.83 | -22.06 ** | -25.14 ** | 8.83 |
| 32 | DCS 85 x SKI 215 | 1.61 | -11.60 * | 4.64 | -24.96 ** | -32.07 ** | -11.32 | -28.09 ** | -32.30 ** | -15.41 |
| 33 | DCS 85 x JI 372 | -14.68 * | -25.60 ** | -18.68 ** | -17.64 * | -35.58 ** | -25.42 | -16.16 | -34.69 ** | -29.02 * |
| 34 | DCS 85 x PCS 124 | -6.42 | -24.20 ** | -13.67 ** | -21.75 ** | -38.51 ** | -18.14 | -21.34 * | -36.29 ** | -17.31 |
| 35 | DCS 85 x RG 2787 | -4.00 | -13.60 * | 6.32 | 1.44 | -19.56 ** | 5.16 | -10.66 | -29.91 ** | -9.38 |
| 36 | SKI 343 x SKI 215 | 19.46 ** | -1.80 | 17.84 ** | 17.79 ** | 9.82 | 12.23 | 23.38 ** | 18.51 * | 12.94 |
| 37 | SKI 343 x JI 372 | -5.60 | -22.40 ** | -16.78 ** | -11.81 | -17.77 ** | -26.27 | -10.45 | -13.99 | -26.57 |
| 38 | SKI 343 x PCS 124 | -5.93 | -23.80 ** | -13.81 ** | -6.06 | -12.41 * | -34.70 * | -10.70 | -14.22 | -45.13 ** |
| 39 | SKI 343 x RG 2787 | 13.14 | -7.00 | -1.46 | 9.05 | 1.67 | -8.11 | -4.15 | -7.93 | -24.71 |
| 40 | SKI 215 x JI 372 | 5.06 | -8.60 | 5.80 | -4.82 | -13.84 * | -7.25 | -1.86 | -7.61 | -7.98 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | SKI 215 x PCS 124 | 33.33 | ** | 8.00 | | 8.83 | * | -5.21 | | -14.20 | * | 3.33 | | -3.55 | | -9.21 | | 1.40 | |
| 42 | SKI 215 x RG 2787 | 33.79 | ** | 16.40 | ** | 15.12 | ** | 7.90 | | -2.33 | | 9.15 | | 8.80 | | 2.42 | | 11.08 | |
| 43 | JI 372 x PCS 124 | 0.74 | | -18.40 | ** | -5.83 | | -10.46 | | -29.64 | ** | 0.48 | | -17.99 | | -33.58 | ** | -9.63 | |
| 44 | JI 372 x RG 2787 | 6.88 | | -6.80 | | 14.64 | ** | -13.26 | | -31.22 | ** | -24.74 | | -15.74 | | -33.90 | ** | -34.22 | ** |
| 45 | PCS 124 x RG 2787 | 21.73 | ** | -1.40 | | 0.41 | | 0.09 | | -20.63 | ** | -6.67 | | 1.28 | | -17.97 | * | -2.96 | |
| Range | | -21.83 to 33.79 | | -31.80 to 16.40 | | -23.36 to 29.56 | | -44.11 to 21.28 | | -38.51 to 9.82 | | -38.67 to 27.61 | | -41.75 to 23.38 | | -36.29 to 18.51 | | -45.13 to 23.53 | |
| Mean Heterosis/Inbreeding depression | | 5.27 | | -10.37 | | 3.58 | | -9.81 | | -16.66 | | -4.7 | | -10.27 | | -14.84 | | -5.32 | |
| S.E ± | | 0.67 | | 0.67 | | 0.64 | | 2.83 | | 2.83 | | 1.85 | | 3.19 | | 3.19 | | 2.09 | |
| Number of crosses showing significant positive heterosis/inbreeding depression | | 11 | | 1 | | 17 | | 2 | | 0 | | 1 | | 1 | | 1 | | 0 | |
| Number of crosses showing significant negative heterosis/inbreeding depression | | 4 | | 21 | | 8 | | 16 | | 31 | | 7 | | 14 | | 20 | | 6 | |

* and ** significant at 5% and 1% levels of significance, respectively

**Table 2.3:** Per cent heterobeltiosis ($H_1$), standard heterosis ($H_2$) and Inbreeding depression (ID) for number of effective branches per plant, number of capsules on primary raceme and 100-seed weight in castor

| Sr. | Hybrids | Number of effective branches per plant | | | | | | Number of capsules on primary raceme | | | | | | 100-seed weight (g) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | | $H_1$ (%) | | $H_2$ (%) | | ID (%) | | $H_1$ (%) | | $H_2$ (%) | | ID (%) | | $H_1$ (%) | | $H_2$ (%) | | ID (%) | |
| 1 | DPC 17 x JI 353 | 1.79 | | -4.20 | | -51.32 | ** | -0.81 | | 14.42 | * | 30.16 | * | -17.66 | ** | -16.64 | ** | -10.06 | |
| 2 | DPC 17 x JI 368 | 24.42 | | -10.08 | | -71.21 | ** | -36.00 | ** | -26.17 | ** | -18.13 | | -15.48 | ** | -20.30 | ** | -4.20 | |
| 3 | DPC 17 x JI 411 | -31.93 | ** | -31.93 | ** | -78.40 | ** | -10.42 | * | 3.34 | | 15.96 | | -11.05 | ** | -0.71 | | 16.09 | |
| 4 | DPC 17 x DCS 85 | -43.08 | ** | -37.82 | ** | -28.11 | ** | -25.87 | ** | -14.49 | * | -2.34 | | -13.07 | ** | -10.69 | ** | 22.01 | * |
| 5 | DPC 17 x SKI 343 | -33.64 | ** | -38.66 | ** | -35.62 | ** | -18.40 | ** | -5.87 | | 26.81 | | 6.39 | ** | -4.91 | ** | -19.76 | * |
| 6 | DPC 17 x SKI 215 | 0.97 | | -12.61 | | -29.33 | ** | -13.77 | ** | -0.53 | | 21.01 | | -3.75 | ** | -11.29 | ** | -18.04 | * |
| 7 | DPC 17 x JI 372 | 12.09 | | -14.29 | | 11.76 | ** | -42.13 | ** | -33.24 | ** | -17.30 | | -10.26 | ** | -8.36 | ** | -3.56 | |
| 8 | DPC 17 x PCS 124 | -34.56 | ** | -25.21 | * | -23.03 | ** | -31.02 | ** | -20.43 | ** | -1.93 | | 12.62 | ** | -14.18 | ** | 4.64 | |
| 9 | DPC 17 x RG 2787 | -4.35 | | -26.05 | * | -31.25 | ** | -21.93 | ** | -9.95 | | 3.52 | | 8.83 | ** | 10.60 | ** | 24.44 | ** |
| 10 | JI 353 x JI 368 | -7.14 | | -12.61 | | -40.87 | ** | -11.58 | | -26.64 | ** | -14.56 | | -2.69 | * | -1.48 | | -1.48 | |
| 11 | JI 353 x JI 411 | 13.45 | | 13.45 | | 11.11 | ** | -0.22 | | -10.48 | | 22.78 | | -10.02 | ** | 0.44 | | -0.87 | |
| 12 | JI 353 x DCS 85 | -21.54 | * | -14.29 | | -37.75 | ** | -24.14 | ** | -37.05 | ** | 12.41 | | -7.85 | ** | -5.33 | ** | 0.29 | |
| 13 | JI 353 x SKI 343 | -0.89 | | -6.72 | | -3.15 | | -5.41 | | -19.49 | ** | 9.45 | | 8.94 | ** | 10.30 | ** | -0.95 | |
| 14 | JI 353 x SKI 215 | 49.11 | ** | 40.34 | ** | 19.46 | ** | 9.22 | | -9.37 | | 25.16 | | -3.96 | ** | -2.77 | ** | -24.27 | ** |
| 15 | JI 353 x JI 372 | 8.04 | | 1.68 | | 3.75 | * | -19.23 | ** | -32.98 | ** | -34.16 | * | 6.47 | ** | 8.74 | ** | 2.77 | |
| 16 | JI 353 x PCS 124 | -8.82 | | 4.20 | | -6.45 | ** | 18.50 | ** | -1.67 | | 16.92 | | -5.89 | ** | -4.72 | ** | -23.84 | ** |
| 17 | JI 353 x RG 2787 | -5.36 | | -10.92 | | -18.87 | ** | 1.45 | | -15.82 | ** | 17.05 | | 18.18 | ** | 20.11 | ** | -2.98 | |
| 18 | JI 368 x JI 411 | -5.88 | | -5.88 | | 6.70 | ** | -13.47 | * | -22.36 | ** | 5.89 | | -14.05 | ** | -4.06 | ** | -2.55 | |
| 19 | JI 368 x DCS 85 | -29.23 | ** | -22.69 | * | -8.70 | ** | 6.58 | | -28.64 | ** | 10.57 | | -2.97 | ** | -0.31 | | -21.74 | * |
| 20 | JI 368 x SKI 343 | -15.45 | | -21.85 | * | -24.19 | ** | -4.94 | | -19.09 | ** | 6.02 | | 3.66 | ** | -2.25 | * | -3.63 | |
| 21 | JI 368 x SKI 215 | 13.59 | | -1.68 | | -33.76 | ** | 3.66 | | -14.89 | * | -5.61 | | 2.19 | | -3.63 | ** | -8.10 | |
| 22 | JI 368 x JI 372 | -8.79 | | -30.25 | ** | -89.76 | ** | 4.89 | | -21.23 | ** | 12.80 | | -4.50 | ** | -2.47 | * | 17.03 | * |
| 23 | JI 368 x PCS 124 | -25.00 | ** | -14.29 | | -37.25 | ** | 5.77 | | -19.23 | ** | 16.28 | | -11.84 | ** | -16.87 | ** | 7.43 | |
| 24 | JI 368 x RG 2787 | 4.35 | | -19.33 | | -25.52 | ** | 13.00 | | -22.23 | ** | 13.48 | | 0.26 | | 1.90 | | 6.20 | |
| 25 | JI 411 x DCS 85 | -26.15 | ** | -19.33 | | -41.15 | ** | 22.10 | ** | 9.55 | | 23.55 | | -7.79 | ** | 2.94 | ** | 18.19 | ** |

| Sr. | Hybrids | Number of effective branches per plant | | | | | | Number of capsules on primary raceme | | | | | | 100-seed weight (g) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | | $H_1$ (%) | | $H_2$ (%) | | ID (%) | | $H_1$ (%) | | $H_2$ (%) | | ID (%) | | $H_1$ (%) | | $H_2$ (%) | | ID (%) | |
| 26 | JI 411 x SKI 343 | -11.76 | | -11.76 | | -20.95 | ** | 17.86 | ** | 5.74 | | 13.19 | | -11.36 | ** | -1.05 | | -8.81 | |
| 27 | JI 411 x SKI 215 | 4.20 | | 4.20 | | -20.97 | ** | 1.04 | | -9.35 | | -16.61 | | -5.34 | ** | 5.67 | ** | 10.24 | |
| 28 | JI 411 x JI 372 | -10.08 | | -10.08 | | 15.42 | ** | -30.51 | ** | -37.65 | ** | 0.16 | | -1.76 | | 9.67 | ** | 8.16 | |
| 29 | JI 411 x PCS 124 | -25.74 | ** | -15.13 | | -15.35 | ** | -10.86 | | -20.03 | ** | -18.49 | | -15.14 | ** | -5.27 | ** | -1.34 | |
| 30 | JI 411 x RG 2787 | -15.13 | | -15.13 | | -52.97 | ** | -3.72 | | -13.62 | * | -4.71 | | 6.66 | ** | 19.06 | ** | 20.21 | ** |
| 31 | DCS 85 x SKI 343 | -32.31 | ** | -26.05 | * | -20.45 | ** | -22.12 | ** | -33.71 | ** | -19.34 | | -13.76 | ** | -11.40 | ** | -6.88 | |
| 32 | DCS 85 x SKI 215 | -13.85 | | -5.88 | | 4.02 | * | -17.56 | * | -32.31 | ** | -14.55 | | -4.68 | ** | -2.06 | | 18.63 | ** |
| 33 | DCS 85 x JI 372 | -27.69 | ** | -21.01 | | -15.96 | ** | -23.91 | ** | -42.86 | ** | -34.52 | * | -4.63 | ** | -2.02 | | 12.05 | |
| 34 | DCS 85 x PCS 124 | -22.79 | * | -11.76 | | -36.67 | ** | -15.38 | * | -35.38 | ** | -5.06 | | -17.56 | ** | -15.30 | ** | 3.10 | |
| 35 | DCS 85 x RG 2787 | -23.08 | * | -15.97 | | -15.00 | ** | -11.06 | | -38.79 | ** | -12.05 | | 10.22 | ** | 13.24 | ** | 10.53 | |
| 36 | SKI 343 x SKI 215 | 1.82 | | -5.88 | | -16.96 | ** | 19.92 | ** | 2.07 | | 13.44 | | 6.97 | ** | -1.41 | | 5.83 | |
| 37 | SKI 343 x JI 372 | -24.55 | * | -30.25 | ** | -18.07 | ** | -10.20 | | -23.56 | ** | -24.24 | | -6.33 | ** | -4.34 | ** | -5.28 | |
| 38 | SKI 343 x PCS 124 | -29.41 | ** | -19.33 | | -44.79 | ** | -13.57 | * | -26.44 | ** | -45.83 | ** | 8.59 | ** | -2.94 | ** | 10.83 | |
| 39 | SKI 343 x RG 2787 | -18.18 | | -24.37 | * | -11.11 | ** | -4.47 | | -18.69 | ** | -21.51 | | 6.43 | ** | 8.17 | ** | 5.35 | |
| 40 | SKI 215 x JI 372 | 1.94 | | -11.76 | | -29.52 | ** | 7.80 | | -11.48 | * | 4.00 | | 8.55 | ** | 10.86 | ** | 3.96 | |
| 41 | SKI 215 x PCS 124 | 53.68 | ** | 75.63 | ** | 23.92 | ** | 10.24 | | -9.48 | | 4.42 | | -4.50 | ** | -11.98 | ** | -3.74 | |
| 42 | SKI 215 x RG 2787 | 59.22 | ** | 37.82 | ** | 12.20 | ** | 7.93 | | -11.38 | | 7.72 | | 8.54 | ** | 10.31 | ** | -0.10 | |
| 43 | JI 372 x PCS 124 | -36.03 | ** | -26.89 | * | -27.01 | ** | 6.99 | | -18.29 | ** | 10.78 | | -4.74 | ** | -2.72 | * | -1.00 | |
| 44 | JI 372 x RG 2787 | -4.35 | | -26.05 | * | -30.11 | ** | -22.40 | ** | -41.72 | ** | -32.47 | * | 9.23 | ** | 11.55 | ** | -2.73 | |
| 45 | PCS 124 x RG 2787 | -17.65 | | -5.88 | | -12.50 | ** | 3.67 | | -20.83 | ** | 7.50 | | -15.01 | ** | -13.62 | ** | 5.34 | |
| Range | | -43.08 to | | -38.66 to | | -89.76 to | | -42.13 to | | -42.86 to | | -45.83 to | | -17.66 to | | -20.30 to | | -24.27 to | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 59.22 | 75.63 | 23.92 | 22.10 | 14.42 | 30.16 | 18.18 | 20.11 | 24.44 |
| Mean Heterosis/Inbreeding depression | -8.13 | -10.81 | -22.13 | -6.76 | -18.27 | 0.17 | -2.55 | -1.37 | 0.01 |
| S.E ± | 0.43 | 0.43 | 0.29 | 2.94 | 2.94 | 1.86 | 0.33 | 0.33 | 0.26 |
| Number of crosses showing significant positive heterosis/inbreeding depression | 3 | 3 | 9 | 4 | 1 | 1 | 15 | 13 | 6 |
| Number of crosses showing significant negative heterosis/inbreeding depression | 16 | 13 | 35 | 18 | 31 | 4 | 27 | 23 | 5 |

* and ** significant at 5% and 1% levels of significance, respectively

**Table 2.4:** Per cent heterobeltiosis ($H_1$), standard heterosis ($H_2$) and inbreeding depression (ID) for oil content and seed yield per plant in castor

| Sr. | Hybrids | Oil content (%) | | | | | | Seed yield per plant (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | | $H_1$ (%) | | $H_2$ (%) | | ID (%) | | $H_1$ (%) | | $H_2$ (%) | | ID (%) |
| 1 | DPC 17 x JI 353 | -1.21 | | 0.58 | | 0.50 | | 45.56 | ** | 30.52 | ** | 21.65 |
| 2 | DPC 17 x JI 368 | 0.70 | | 0.48 | | 1.92 | | 24.55 | ** | 15.55 | | 12.36 |
| 3 | DPC 17 x JI 411 | -0.85 | | 0.03 | | 0.08 | | 64.87 | ** | -5.85 | | 21.71 |
| 4 | DPC 17 x DCS 85 | 1.50 | | 0.62 | | 3.50 | ** | 11.21 | | -17.47 | * | -0.05 |
| 5 | DPC 17 x SKI 343 | 1.43 | | 0.82 | | 0.54 | | 134.73 | ** | 36.66 | ** | 12.30 |
| 6 | DPC 17 x SKI 215 | 0.19 | | 0.59 | | -0.68 | | 67.73 | ** | -4.22 | | -37.45 |
| 7 | DPC 17 x JI 372 | -0.82 | | 0.65 | | 1.64 | | 21.63 | * | 0.19 | | 19.37 |
| 8 | DPC 17 x PCS 124 | 1.45 | | 2.11 | * | 1.33 | | 25.02 | ** | 9.98 | | 9.28 |
| 9 | DPC 17 x RG 2787 | 0.98 | | 1.45 | | 1.03 | | 112.77 | ** | 21.50 | ** | 6.33 |
| 10 | JI 353 x JI 368 | 0.51 | | 2.33 | * | 0.10 | | 30.76 | ** | 21.31 | ** | 3.48 |
| 11 | JI 353 x JI 411 | 1.55 | | 3.39 | ** | 2.10 | | -8.38 | | -17.85 | * | 5.06 |
| 12 | JI 353 x DCS 85 | 1.39 | | 3.23 | ** | 1.89 | | -3.89 | | -13.82 | | 1.92 |
| 13 | JI 353 x SKI 343 | 1.66 | | 3.50 | ** | 2.00 | | 13.99 | | 2.21 | | 5.69 |
| 14 | JI 353 x SKI 215 | 0.99 | | 2.82 | ** | 1.61 | | 10.24 | | -1.15 | | 6.75 |
| 15 | JI 353 x JI 372 | 2.08 | * | 3.93 | ** | 3.60 | ** | 10.67 | | -0.77 | | 8.34 |
| 16 | JI 353 x PCS 124 | 1.85 | * | 3.70 | ** | 0.62 | | 31.86 | ** | 18.23 | * | -6.58 |
| 17 | JI 353 x RG 2787 | 1.10 | | 2.94 | ** | 0.83 | | 16.19 | | 4.19 | | -6.21 |
| 18 | JI 368 x JI 411 | 0.37 | | 1.26 | | -0.33 | | -0.44 | | -7.64 | | -8.01 |
| 19 | JI 368 x DCS 85 | 1.88 | * | 1.65 | | -0.86 | | 2.48 | | -4.93 | | 15.05 |
| 20 | JI 368 x SKI 343 | 1.95 | * | 1.73 | | 1.06 | | -21.66 | * | -27.32 | ** | 0.21 |
| 21 | JI 368 x SKI 215 | 1.84 | * | 2.25 | * | 1.62 | | 3.63 | | -3.86 | | 16.41 |
| 22 | JI 368 x JI 372 | -0.80 | | 0.67 | | 2.81 | * | -13.99 | | -20.21 | * | 11.37 |
| 23 | JI 368 x PCS 124 | 1.80 | * | 2.46 | ** | 4.89 | ** | 16.63 | | 8.20 | | 17.01 |
| 24 | JI 368 x RG 2787 | 1.75 | | 2.23 | * | 1.43 | | 51.08 | ** | 40.15 | ** | 27.16 |
| 25 | JI 411 x DCS 85 | 1.24 | | 2.13 | * | 1.64 | | 20.67 | | -10.44 | | 2.33 |
| 26 | JI 411 x SKI 343 | 0.10 | | 0.99 | | 0.66 | | 65.17 | ** | -3.84 | | 12.69 |
| 27 | JI 411 x SKI 215 | 1.58 | | 2.48 | ** | 3.52 | ** | 132.45 | ** | 9.31 | | 12.44 |
| 28 | JI 411 x JI 372 | 1.11 | | 2.61 | ** | 1.86 | | -5.70 | | -22.32 | ** | -0.95 |
| 29 | JI 411 x PCS 124 | 0.54 | | 1.43 | | 1.08 | | 10.31 | | -2.96 | | 0.86 |
| 30 | JI 411 x RG 2787 | 1.38 | | 2.28 | * | 1.81 | | 116.37 | ** | 1.75 | | 9.28 |
| 31 | DCS 85 x SKI 343 | 1.14 | | 0.53 | | -0.08 | | 5.52 | | -21.69 | ** | 2.88 |
| 32 | DCS 85 x SKI 215 | 1.42 | | 1.82 | * | 4.78 | ** | 9.01 | | -19.10 | * | 12.36 |
| 33 | DCS 85 x JI 372 | 0.75 | | 2.24 | * | 1.93 | | 30.28 | ** | 7.31 | | 15.41 |
| 34 | DCS 85 x PCS 124 | 0.65 | | 1.30 | | -0.53 | | -14.41 | | -24.70 | ** | 5.49 |
| 35 | DCS 85 x RG 2787 | 1.69 | | 2.16 | * | 1.62 | | 31.72 | ** | -2.25 | | 24.89 |
| 36 | SKI 343 x SKI 215 | 1.89 | * | 2.30 | * | 1.70 | | 63.52 | ** | -4.80 | | 20.16 |
| 37 | SKI 343 x JI 372 | -0.26 | | 1.21 | | 0.23 | | 13.52 | | -6.49 | | 10.73 |
| 38 | SKI 343 x PCS 124 | 1.84 | * | 2.50 | ** | 1.77 | | 17.13 | | 3.04 | | 2.00 |
| 39 | SKI 343 x RG 2787 | 1.59 | | 2.06 | * | 0.99 | | 45.39 | ** | -15.36 | | 12.70 |
| 40 | SKI 215 x JI 372 | 0.93 | | 2.42 | ** | 0.35 | | 15.13 | | -5.16 | | 6.07 |
| 41 | SKI 215 x PCS 124 | 0.35 | | 1.00 | | -1.51 | | 24.58 | ** | 9.60 | | 10.30 |
| 42 | SKI 215 x RG 2787 | 2.24 | * | 2.72 | ** | 1.70 | | 149.21 | ** | -4.89 | | -7.64 |
| 43 | JI 372 x PCS 124 | 1.26 | | 2.76 | ** | 0.45 | | 40.18 | ** | 23.32 | ** | 34.18 |
| 44 | JI 372 x RG 2787 | -0.36 | | 1.12 | | -0.03 | | -1.41 | | -18.79 | * | 10.09 |
| 45 | PCS 124 x RG 2787 | 1.39 | | 2.04 | * | 0.07 | | 27.19 | ** | 11.89 | | 5.18 |
| Range | | -1.21 to 2.24 | | 0.03 to 3.93 | | -1.51 to 4.89 | | -21.66 to 149.21 | | -27.32 to 40.15 | | -37.45 to 34.18 |
| Mean Heterosis/Inbreeding depression | | 1.02 | | 1.90 | | 1.27 | | 32.06 | | -0.29 | | 8.10 |
| S.E ± | | 0.44 | | 0.44 | | 0.29 | | 28.64 | | 28.64 | | 32.75 |
| Number of crosses showing significant positive heterosis/inbreeding depression | | 9 | | 26 | | 6 | | 22 | | 7 | | 0 |
| Number of crosses showing significant negative heterosis/inbreeding depression | | 0 | | 0 | | 0 | | 1 | | 9 | | 0 |

* and ** significant at 5% and 1% levels of significance, respectively

**Table 3:** Range of heterobeltiosis ($H_1$), standard heterosis ($H_2$) and inbreeding depression (ID) along with number of crosses showing significant estimates for various characters in castor

| Sr. No. | Characters | Range | | | Number of crosses showing significant estimates | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_1$ (%) | $H_2$ (%) | ID (%) | $H_1$ (%) | | $H_2$ (%) | | ID (%) | |
| | | | | | +Ve | -Ve | +Ve | -Ve | +Ve | -Ve |
| 1 | Days to 50% flowering of primary raceme | -28.16 to 2.26 | -19.61 to -1.96 | -27.64 to 2.34 | ***0*** | ***29*** | ***0*** | ***38*** | ***0*** | ***6*** |
| 2 | Days to maturity of primary raceme | -27.18 to 20.35 | -24.38 to 1.39 | -35.51 to 23.77 | ***8*** | ***22*** | ***0*** | ***42*** | ***0*** | ***0*** |
| 3 | Plant height up to primary raceme (cm) | -32.22 to 43.31 | -30.93 to 35.60 | -27.81 to 47.23 | ***15*** | ***9*** | ***12*** | ***9*** | ***0*** | ***0*** |
| 4 | Number of nodes up to primary raceme | -21.83 to 33.79 | -31.80 to 16.40 | -23.36 to 29.56 | ***11*** | ***4*** | ***1*** | ***21*** | ***17*** | ***8*** |
| 5 | Length of primary raceme (cm) | -44.11 to 21.28 | -38.51 to 9.82 | -38.67 to 27.61 | ***15*** | ***1*** | ***0*** | ***31*** | ***1*** | ***7*** |
| 6 | Effective length of primary raceme (cm) | -41.75 to 23.38 | -36.29 to 18.51 | -45.13 to 23.53 | ***1*** | ***14*** | ***1*** | ***20*** | ***0*** | ***6*** |
| 7 | Number of effective branches per plant | -43.08 to 59.22 | -38.66 to 75.63 | -89.76 to 23.92 | ***3*** | ***16*** | ***3*** | ***13*** | ***9*** | ***35*** |
| 8 | Number of capsules on primary raceme | -42.13 to 22.10 | -42.86 to 14.42 | -45.83 to 30.16 | ***4*** | ***18*** | ***1*** | ***31*** | ***1*** | ***4*** |
| 9 | 100-seed weight (g) | -17.66 to 18.18 | -20.30 to 20.11 | -24.27 to 24.44 | ***15*** | ***27*** | ***13*** | ***23*** | ***5*** | ***5*** |
| 10 | Oil content (%) | -1.21 to 2.24 | 0.03 to 3.93 | -1.51 to 4.89 | ***9*** | ***0*** | ***26*** | ***0*** | ***6*** | ***0*** |
| 11 | Seed yield per plant (g) | -21.66 to 149.20 | -27.32 to 40.15 | -37.45 to 34.18 | ***22*** | ***1*** | ***7*** | ***9*** | ***0*** | ***0*** |

**Table 4:** Ten best performing hybrids for seed yield per plant on the basis of *per se* performance along with heterobeltiosis ($H_1$), standard heterosis ($H_2$) and sca effect for component characters in castor

| Sr. No. | Hybrids | Seed yield per plant (g) | Heterosis (%) | | | | sca effect | | Significant desirable standard heterosis for component traits |
|---|---|---|---|---|---|---|---|---|---|
| | | | $H_1$ | | $H_2$ | | | | |
| 1 | JI 368 x RG 2787 | 486.80 | 51.08 | ** | 40.15 | ** | 143.53 | ** | DF, DM, OC |
| 2 | DPC 17 x SKI 343 | 474.67 | 134.73 | ** | 36.66 | ** | 143.37 | ** | DF, DM, NR |
| 3 | DPC 17 x JI 353 | 453.33 | 45.56 | ** | 30.52 | ** | 80.55 | ** | DF, DM, PH, NR, CR |
| 4 | DPC 17 x RG 2787 | 422.00 | 112.77 | ** | 21.50 | ** | 80.38 | ** | DM, SW |
| 5 | JI 353 x JI 368 | 421.33 | 30.76 | ** | 21.71 | ** | 46.89 | ** | DF, DM, PH, NR, OC |
| 6 | JI 353 x PCS 124 | 410.67 | 31.86 | ** | 18.23 | ** | 28.77 | | DM, OC |
| 7 | DPC 17 x JI 368 | 401.33 | 24.55 | ** | 15.55 | ** | 33.01 | | DF, DM, PH, NR |
| 8 | PCS 124 x RG 2787 | 388.63 | 27.19 | ** | 11.89 | ** | 37.90 | | DM, OC |
| 9 | DPC 17 x PCS 124 | 382.00 | 25.02 | ** | 9.98 | | 6.22 | | DF, DM, NR, OC |
| 10 | SKI 215 x PCS 124 | 380.67 | 24.58 | ** | 9.60 | | 52.83 | ** | DF, DM, EB |
| | GCH 7 (Check) | 347.33 | - | | - | | - | | - |

** Significant at 1% level of significance

DF= Days to 50% flowering of primary raceme, DM= Days to maturity of primary raceme, PH= Plant height up to primary raceme, NR= Number of nodes up to primary raceme, CR= Number of capsules on primary raceme, EB= Number of effective branches per plant, SW= 100-seed weight and OC=Oil content

## Conclusion

From the results and discussion, it can be concluded that considerable heterobeltiosis and standard heterosis observed for seed yield and other associated characters suggested the presence of large genetic diversity among the parents and also unidirectional distribution of allelic constitution contributing towards desirable heterosis in the present material. The cross JI 368 x RG 2787 depicted significantly the highest and positive heterobeltiosis (51.08%), standard heterosis (40.15%) as well as the highest seed yield per plant (486.80 g). The crosses DPC 17 x SKI 343 and DPC 17 x JI 353 were the next best crosses exhibiting significant and positive heterobeltiosis (134.73% and 45.73%), standard heterosis (36.66% and 30.52%) and per se performance (474.67 g and 453.33 g). The range of inbreeding depression was from -37.45% (DPC 17 x SKI 215) to 34.18% (JI 372 x PCS 124) with a mean of 8.10%. Out of 45 crosses, none of the crosses showed significant positive inbreeding depression for seed yield per plant.

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