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

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Abstract
Castor significantly pronounced as a potential leading non edible oil crop, this investigation is carried out to find out the heterosis of four lines and ten testers via line x tester biometrical approach, resulting in the development of 40 hybrids together with 14 parents and 1 standard check (GCH 9) were tested using randomized block design with three replications at Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh late *Kharif* 2024-25. The highest significant heterosis regarding positive direction over standard check were recorded by crosses *viz.*, SKP 84 x JI 518 (30.85%), IPC 30 × JI 518 (25.03%) and SKP 126 × JI 531 (25.00%) for seed yield. This highlights the promising prospects of castor as an economically viable annual crop with high seed yield potential.

Keywords: Castor (*Ricinus communis* L.), Heterosis, seed yield, yield component traits, line × tester analysis, hybrid performance, genetic improvement, non-edible oil crop, Junagadh agricultural University

Introduction
In the Indian economy, oilseeds crops account for about 10% of the total value of the country's agricultural commodities, among the non-edible oilseeds, castor (*Ricinus communis* L.) is a significant industrial crop cultivated in dry and semi-arid zone globally. As a member of the *Euphorbiaceae* family, it has a chromosome number of 2n=20. Castor is a naturally cross-pollinated species, with outcrossing rates typically ranging from 5-50%, although some dwarf cultivars can exhibit 90-100% outcrossing. The identification of male-sterile lines has proven valuable for breeding improved varieties (Anonymous, 2016) [2].
The primary product, castor oil, constitutes 40-55% of the seed's weight. The oil's exceptional nature is due to its unique chemical composition: approximately 90% is ricinoleic acid. Castor oil has distinct physical and chemical properties not found in other vegetable oils, including high viscosity, complete solubility in alcohol, and a lower heat requirement for conversion into biodiesel (Yadava *et al.*, 2012) [24].
The exploitation of heterosis (hybrid vigour) is a fundamental strategy in the genetic improvement of castor (Gopani *et al.*, 1968) [13]. A successful heterosis breeding program necessitates the systematic evaluation of genetically divergent parental genotypes in various cross-combinations to enhance seed yield and its contribute traits. The objective of research is to find best F_1 hybrids on the basis of magnitude and direction of their heterotic effects.
Utilization of genetically superior parents and per se performance of hybrids specially for yield contributing characters assure better results. However, proper information on magnitude of heterosis for seed yield per plant and its component characters involved in the inheritance of different parents and their crosses would be more helpful to plant breeders in selecting the elite parents and desirable cross combinations for commercial exploitation of hybrid vigour and also in formulating the efficient breeding programme for the improvement of seed yield and its component characters (Dangaria *et al.*, 1987) [8].

Material and Methods
The experimental material of proposed study was comprising of 55 entries which include 40 crosses developed through 4 lines × 10 testers mating design along with 14 parental lines and

one standard check GCH 9 were sown in Randomized Block Design with three replications at Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh.

Observations were recorded on six characters *viz*., length of the primary raceme, effective length of the primary raceme, number of capsules per primary raceme, 100-seed weight, seed yield per plant and oil content. For each genotype within every replication, data was collected from five randomly selected competitive plants to ensure accurate representation across the studied characters.

For testing the significance of difference among the genotypes for all the characters analysis of variance was conducted following fixed effect model as suggested by Panse and Sukhatme (1995) [16]. In this investigation, heterosis was quantified in relation to the better parent, denoted as heterobeltiosis, following the methodology described by Fonseca and Patterson (1968) [11]. Additionally, standard heterosis was computed by evaluating the performance of F_1 hybrids against that of the standard check hybrid, GCH 9, which is widely recognized for its agronomic efficacy.

Results and Discussion

Analysis of variance (ANOVA) was conducted to assess significant differences among genotypes, parents, hybrids, and the comparison between parents and hybrids across all six studied traits, as detailed in Table 1. The results demonstrated that the mean squares attributed to genotypes were highly significant for all traits, indicating substantial overall variability.

Further decomposition of genotypic mean squares into components attributable to parents, hybrids, and parents vs. hybrids revealed nuanced insights. Mean squares due to hybrids were statistically significant for all characters, while mean squares for the parents vs. hybrids comparison showed significance across all traits. The findings thus confirmed a substantial degree of genetic variability within the studied germplasm, affirming its suitability for investigating the expression of heterosis and evaluating the genetic parameters governing the inheritance of various agronomic traits in castor. The results are akin to those reported by Ramana *et al.* (2006) [19], Sapovadiya *et al.* (2015) [21] and Sadaiah *et al.* (2023) [20] in castor.

The information of three best performing parents and hybrids, top ranking heterotic hybrids are given in Table 2. The high yielding hybrid SKP 84 × JI 518 exhibited high magnitude of significant standard heterosis for various traits *viz.*, days to 50 % percent flowering, days to maturity, length of primary raceme, effective length of primary raceme, number of effective branches per plant, number of capsules on primary raceme, 100-seed weight. Hybrid IPC 30 × JI 518 shows significant heterosis for length of primary raceme, effective length of primary raceme, number of effective branches per plant, number of capsules on primary raceme, 100-seed weight and SKP 126 × JI 531 was significant for traits like length of primary raceme, effective length of primary raceme, number of effective branches per plant, number of capsules on primary raceme, shelling out turn and seed yield per plant.

With respect to the performance of hybrids for seed yield per plant, it was observed that 29 hybrids over better parent and 11 hybrids over standard check (GCH 9) exhibited significant and positive heterosis (Table 4B.). The range of heterosis over better parent was from -33.17 to 98.80 %, while over standard check, it ranged from -28.19 to 30.85 %. The cross SKP 84× JI 518 showing significantly the highest and positive heterobeltiosis (86.53 %), standard heterosis (30.85 %) as well as the highest seed yield per plant (481.72 g). IPC 30 × JI 518 and SKP 126 × JI 531 were the next best crosses exhibiting significant and positive heterobeltiosis (78.24 % and 48.19 %, respectively), standard heterosis (25.03 % and 25.00 %, respectively) and *per se* performance (460.29 g and 460.21 g, respectively). In such cases, appearance of heterotic response over better and check parents recommended the real advantage of hybrids from the economical point of view. High heterosis for seed yield in castor has also been reported by several workers Makani *et al.* (2015) [14], Sapovadiya *et al.* (2015) [21], Patted *et al.* (2016) [26], Chaudhari *et al.* (2017) [5], Gajbhe *et al.* (2017) [12], Delvadiya *et al.* (2018) [9], Barad *et al.* (2019) [3], Aher *et al.* (2020) [1], Yamunara *et al.* (2020) [25], Nivedha *et al.* (2023) [15] and Chaudhary *et al.* (2024) [7].

The number of cross combinations that exceeded over better parent and standard check for length of primary raceme were twnety-two and thirty-six respectively (Table 4A.). Heterobeltiosis ranged from -25.85 per cent (IPC 31 × JI 522) to 101.52 per cent (SKP 84 × JI 533), while standard heterosis varied from -8.63 per cent (IPC 31 × JI 531) to 55.83 per cent (SKP 126 × JI 524). The crosses SKP 126 × JI 523, IPC 30 × JI 523, IPC 30 × JI 522 and SKP 84 × JI 533 exhibited significantly the highest and positive standard heterosis for length of primary raceme. The hybrid SKP 84 × JI 533 showed significantly the maximum heterobeltiosis (101.52 %) and standard heterosis (48.53 %) for this trait. Significant results were also obtained by some previous workers *viz*., Singh *et al.* (2013) [22], Patted *et al.* (2016) [26], Gajbhe *et al.* (2017) [12], Delvadiya (2018) [9], Barad *et al.* (2019) [3], Yamunara *et al.* (2020) [25], Delvadiya *et al.* (2021) [10] and Nivedha *et al.* (2023) [15].

The number of cross combinations that exceeded over better parent and standard check for effective length of primary raceme were thirty-three and thirty-six respectively (Table 4A.). Heterosis over better parent ranged from -31.70 per cent (IPC 31 × JI 522) to 59.13 per cent (SKP 84 × JI 533), while heterosis over standard check ranged from - 9.08 per cent (IPC 31 × JI 526) to 57.25 per cent (SKP 126 × JI 524). The cross combination SKP 126 × JI 524, IPC 30 × JI 522, IPC 30 × JI 523, SKP 126 × JI 523 and SKP 84 × JI 523 showed significantly the highest and positive standard heterosis for effective length of primary raceme. The hybrid SKP 84 × JI 533 recorded significantly highest and positive heterobeltiosis (98.13 %) and standard heterosis (45.07 %) for effective length of primary raceme. Similar results for effective length of primary raceme have also been reported by Patted *et al.* (2016) [26], Gajbhe *et al.* (2017) [12], Delvadiya (2018) [9], Barad *et al.* (2019) [3], Yamunara *et al.* (2020) [25], Delvadiya *et al.* (2021) [10] and Nivedha *et al.* (2023) [15].

Number of capsules on primary raceme is a vital factor controling the seed yield in castor. The number of cross combinations which exceeded better and standard parental values for number of capsules on primary raceme was twenty-four and twenty-seven crosses, respectively (Table 4A.). The heterobeltiosis for number of capsules on primary raceme ranged from -13.90 per cent (IPC 31 × JI 526) to 85.80 per cent (SKP 84 × JI 518), while standard heterosis varied from -1.81 per cent (IPC 31 × JI 526) to 82.03 per cent (SKP 126 × JI 531). The cross combination SKP 126 × JI 531 also exhibited significantly the highest and positive standard heterosis followed by SKP 84 × JI 518, IPC30 × JI 533, IPC 30 × JI 531 and SKP 126 × JI 532. The top performing hybrid (SKP 126 × JI 531) for number of capsules on primary raceme (115.56) also recorded the significant and positive heterobeltiosis (30.14 %) and standard heterosis (42.24 %) for this trait. High magnitude of desirable heterosis for this trait was also reported by Sridhar *et al.* (2008) [23], Patted *et al.* (2016) [26], Chaudhari *et al.* (2011) [6], Patel *et al.* (2014) [4], Singh *et al.* (2013) [22], Delvadiya (2018) [9], Barad *et al.* (2019) [3] and Delvadiya *et al.* (2021) [10].

For 100-seed weight, twenty-six crosses showed significant and positive heterobeltiosis, while thirty crosses showed significant and positive standard heterosis (Table 4B.). Heterobeltiosis for 100-seed weight ranged from -19.25 per cent (IPC 30 × JI 526) to 62.40 per cent (IPC 30 × JI 533), while standard heterosis varied from -7.44 per cent (IPC 30 × JI 526) to 35.51 per cent (IPC 30 × JI 531). the maximum positive and significant standard heterosis was recorded in the cross combination IPC 30 × JI 531 followed by SKP 84 × JI 522, SKP 126 × JI 525, IPC 30 × JI 518 and IPC 30 × JI 533. The cross combination IPC 30 × JI 531 recorded the significant and positive standard heterosis (35.51%), as well as significant and positive Heterobeltiosis (36.33 %). Significant estimates of heterosis for l00-seed weight have been also reported by Sridhar *et al.* (2008) [23], Chaudhari *et al.* (2011) [6], Patel *et al.* (2013) [17], Delvadiya *et al.* (2018) [9], Barad *et al.* (2019) [3], Yamunara *et al.* (2020) [25], Delvadiya *et al.* (2021) [10] and Nivedha *et al.* (2023) [15].

The heterobeltiosis and standard heterosis for oil content ranged from -3.48 per cent (SKP 126 × JI 525) to 5.19 per cent (IPC 31 × JI 528) and -3.17 per cent (SKP 126 × JI 522) to -0.14 per cent (SKP 126 × JI 528), respectively (Table 4B.). Out of 40 crosses, two and none cross combinations exhibited positive and significant heterobeltiosis and standard heterosis, respectively, and sixteen and seven crosses combinations revealed significant and negative heterobeltiosis and standard heterosis, respectively. The cross combination IPC 31 × JI 528 recorded significantly the highest and desirable magnitude of heterobeltiosis (5.19 %) followed by IPC 31 × JI 522 (4.59 %) for oil content. High magnitude of beneficial heterosis for this trait was also reported by Singh *et al.* (2013) [22], Chuadhari and Patel (2014) [4], Rajani *et al.* (2015) [18], Sapovadiya *et al.* (2015) [21], Gajbhe *et al.* (2017) [12], Yamunara *et al.* (2020) [25], Delvadiya *et al.* (2021) [10] and Nivedha *et al.* (2023) [15].

Conclusion

Based on the present findings, it can be concluded that the experimental materials had sufficient genetic variation for seed yield and its components. The two hybrids, names SKP 84 × JI 518 and SKP 126 × JI 531 exhibited high *per se* performance along with high magnitude of relative heterosis, heterobeltiosis for seed yield per plant and could be used as promising crosses for practical plant breeding programmes.

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