



# Elucidation of Heterosis for Seed Yield and its Attributes in Pigeonpea [*Cajanus cajan* (L.) Millsp.]

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## ABSTRACT

**Background:** Pigeonpea is one of India's most essential pulse crops and it is the handiest food legume with widespread uses as food, feed, fodder and fuel. To fulfil the peoples nutrient demand, the urgent need for developing nutritious and higher productive cultivar become imperative. Therefore, this research paper seeks to explore heterotic effects of various cross among the traits in pigeonpea, with the ultimate goal of advancing the development of enhanced varieties.

**Methods:** An experiment was conducted in pigeonpea using Line  $\times$  Tester mating design to carried out heterosis analysis. 20 hybrids were developed by using five female lines crossed with four male testers.

**Result:** The analysis of variances revealed significant differences of genotypes for all characters studied, indicating sufficient genetic variability for the characters. Crosses viz, GT 102  $\times$  SKNP 1408 and GT 103  $\times$  BDN 2004-01 were found to be the exerted good amounts of heterosis, heterobeltiosis and standard heterosis for yield and its attributes. The hybrid GT 102  $\times$  SKNP 1408 was found the most promising and may be exploited in further breeding programmes for pigeonpea.

**Key words:** Combining ability, Heterosis, Line  $\times$  tester, Pigeonpea.

## INTRODUCTION

Pulses play a crucial role in the vegetarian Indian diet, serving as essential components that contribute significantly to protein and calorie intake. Pulses are regarded as "poor man's meat" because they are high in protein, high dietary fiber and low in fat. Pigeonpea is famous with different names as tur, red gram and arhar. Barbados gave the name "pigeonpea" to the plant because its seeds are used to make pigeon feed (Gowda *et al.*, 2011). Pigeonpea belongs to the family 'Fabaceae' and sub-family 'Faboideae'. Pigeonpea crop is diploid ( $2n = 2\times$ ), with a genomic size of  $1C = 858$  Mbp and a chromosomal number of 22. It is an often-cross-pollinated crop in which 25 to 70 per cent natural out-crossing observed (Saxena *et al.*, 1990). It is the handiest food legume with widespread uses as food, feed, fodder and fuel. The protein content of commonly grown pigeonpea cultivars ranges from 17.9 to 24.3 per cent for whole grain and split-grain. Moreover, pigeonpea seeds contain 0.6 to 3.8 per cent lipids, 1.2 to 8.1 per cent crude fibre and 57.3 to 58.7 per cent carbohydrates (Sinha, 1977). Critical amino acids such as lysine, tyrosine, cysteine and arginine are abundant in pigeonpea seeds. Additionally, pigeonpea are a good provider of iodine and iron. One of the factors attributed to the low productivity levels is the inherent low yield potential of the currently accessible cultivars. The crop's low yield potential is mainly caused by cultivation on marginal ground, a lack of robust and high-yielding cultivars. Therefore, must need arise to develop high-yielding and stable cultivars through efficient breeding programme to eliminate this factor. Heterosis has been shown to be a useful tool for increasing yields in a variety of crops by breaking the existing yield barrier. Gaining an understanding of heterosis is essential to identifying particular

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cross combinations that can be used to strategically exploit hybrid vigour or accumulate fixable genes through selective breeding. The pre sent investigation was undertaken to find out the extent of various types of heterosis (Economic heterosis, Heterobeltiosis and Standard heterosis) for seed yield and its component traits.

## MATERIALS AND METHODS

The five females (Banas, GT 102, GT 103, GT 100 and GT 1) used as lines and four males (SKNP 1408, SKNP 1406, Vaishali and BDN 2004-01) used as testers were crossed in Line  $\times$  tester mating design during *kharif* 2019 to produce 20 F<sub>1</sub>'s under insect proof net house. Thus, the 31 genotypes including 9 parents, 20F<sub>1</sub>'s and two checks were grown during *kharif* 2020 at Pulses Research Station,

Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar using randomized block design with three replications. Each male and female lines were grown in a single row of 3.0 m length keeping an inter-row and intra-row distance of 60 cm and 20 cm respectively. The observations were recorded from five randomly chosen plants for each genotype in each replication for thirteen characters viz., days to flowering, days to maturity, plant height (cm), number of branches per plant, number of pods per plant, pod length (cm), number of seeds per pod, test weight (g), seed yield per plant (g), biological yield per plant (g), harvest index (%), total protein content (%) and leaf area per plant (cm<sup>2</sup>). The data were compiled for analysis of the variance of different traits using the method suggested by Panse and Sukhatme (1978). Heterosis was estimated as *per cent* increase or decrease in the mean value of F1 hybrid over the mid parent *i.e.*, relative heterosis (Briggle, 1963), over the better parent, *i.e.*, heterobeltiosis (Fonseca and Patterson, 1968) and standard check, *i.e.*, standard heterosis (Meredith and Bridge, 1972) for each other.

## RESULTS AND DISCUSSION

The variations observed among both parental lines and hybrids across the 13 attributes assessed. Notably, the results unveiled significant mean squares attributed to genotypes across all traits, underscoring the ample genetic variability inherent in the studied materials. The values of relative heterosis, heterobeltiosis and standard heterosis of all crosses for various characters are presented in Table 1 to 5. Sixteen out of twenty hybrids exhibited significant positive relative heterosis for seed yield per plant. In which, Banas × BDN 2004-01, Banas × Vaishali and Banas × SKNP 1406 showed the most significant and positive heterosis over mid-parent. Heterobeltiosis revealed that nine hybrids had significant positive heterosis. Upon scrutinizing the results, it became evident that all hybrids displayed noteworthy and positive standard heterosis when compared to both reference checks GTH 1 and GT 101. Crosses, GT 1 × Vaishali, GT 1 × BDN 2004-01 and GT 102 × SKNP 1408 displayed maximum standard heterosis over both checks (Table 1). The results are in accordance with similar findings of Kumar *et al.* (2009), Gedam *et al.* (2013), Chethana *et al.* (2015), Soni *et al.* (2017) and Patel *et al.* (2020).

Among the twenty hybrids evaluated, six displayed significant relative heterosis in the desired (negative) direction, in which Banas × Vaishali displayed maximum value among them. None of the hybrids exhibited negative significant heterobeltiosis in the desired direction. While, four hybrids exhibited negative and significant standard heterosis in desired direction. Out of which, GT 102 × SKNP 1406, GT 102 × BDN 2004-01 and GT 102 × SKNP 1408 are the best one (Table 1). For days to maturity, none of the hybrids exhibited negative significant heterobeltiosis in the desired direction. Whereas, one out of twenty hybrids (GT 102 × BDN 2004-01) showed early maturity in terms of relative heterosis. GT 102 × BDN 2004-01, GT 102 × SKNP

1406 and GT 102 × SKNP 1408 were the top three superior hybrids over standard check for days to maturity (Table 1).

Only one cross, GT 100 × Vaishali exerted negative significant relative heterosis and heterobeltiosis for plant height. While, crosses, GT 100 × Vaishali, GT 100 × BDN 2004-01 and GT 103 × BDN 2004-01 were the best performing hybrids with significant negative standard heterosis over standard check. (Table 2) Above results are in accordance with the findings of Mhasal *et al.* (2015), Soni *et al.* (2017) and Patel *et al.* (2020) for traits like, days to flowering, days to maturity and plant height. Plants with a greater number of primary branches per plant are closely associated with higher seed yields. Out of 20 hybrids assessed, nine hybrids recorded significant and positive heterosis over mid-parent in the desirable direction. Crosses, Banas × SKNP 1406, GT 1 × Vaishali and GT 100 × SKNP 1406 illustrated positive significant heterosis in desirable direction over mid-parent and also for heterobeltiosis (Table 2). For number of pods per plant, thirteen out of twenty hybrids were found significant positive heterosis over mid-parents and eight hybrids demonstrated significant and positive heterosis over the better parents. In both the parameters, GT 1 × BDN 2004-01, GT 1 × Vaishali and GT 102 × BDN 2004-01 were the superior crosses among them. For standard heterosis, GT 102 × Vaishali, GT 102 × BDN 2004-01 and GT 1 × Vaishali most promising hybrids showed significant positive heterosis for this trait (Table 2). Similar findings were recorded by Soni *et al.* (2017) and Patel *et al.* (2020) for number of branches per plant and number of pods per plant. Twelve hybrids exhibited significant and positive relative heterosis, while eight hybrids showed significant and positive heterobeltiosis for pod length. While, GT 1 × Vaishali, GT 1 × SKNP 1408 and GT 1 × BDN 2004-01 were the top three hybrids exerted significant and positive standard heterosis over the checks (Table 3). The results are in accordance with findings of Ajay *et al.* (2015) and Soni *et al.* (2017) for pod length.

For number of seeds per pod, Banas × Vaishali, Banas × BDN 2004-01 and Banas × SKNP 1408 were top three best crosses exhibited superior performance for relative heterosis. While, eighteen out of twenty hybrids exhibited significant and positive standard heterosis over both the standard checks for this trait (Table 3). Mhasal *et al.* (2015) and Soni *et al.* (2017) observed similar results for number of seeds per pod. For biological yield per plant, GT 103 × Vaishali was the best cross exhibits positive and significant relative heterosis, heterobeltiosis and standard heterosis (Table 4). Similar results obtained by Soni *et al.* (2017) and Patel *et al.* (2020) for this trait. Banas × SKNP 1406 and GT 102 × SKNP 1408 were the superior crosses exerted significant and positive relative heterosis and heterobeltiosis for harvest index. While, GT 1 × Vaishali and GT 1 × BDN 2004-01 displayed standard heterosis in desired direction (Table 4). For the trait like total protein content, Banas × Vaishali was the common and superior performing cross with significant and positive heterosis for all three

**Table 1:** Estimates of relative heterosis, heterobeltiosis and standard heterosis for seed yield per plant, days to flowering and days to maturity.

| Hybrids                | Seed yield per plant (g) |          |          |          |         |         | Days to flowering |          |         |         |          |         | Days to maturity |         |          |         |          |         |
|------------------------|--------------------------|----------|----------|----------|---------|---------|-------------------|----------|---------|---------|----------|---------|------------------|---------|----------|---------|----------|---------|
|                        | Heterosis over           |          |          |          |         |         | Heterosis over    |          |         |         |          |         | Heterosis over   |         |          |         |          |         |
|                        | MP                       | BP       | SHGTH1   | SHGT 101 | MP      | SHGTH1  | BP                | SHGTH1   | SHGT101 | MP      | BP       | SHGTH1  | MP               | BP      | SHGTH1   | SHGT101 | SHGTH1   | SHGT101 |
| Banas × SKNP 1408      | 36.18**                  | 6.16     | 69.82**  | 81.64**  | -5.03** | 2.17    | -3.09             | -2.42    | 0.35    | 0.94    | -1.84    | 2.15    | 0.94             | -1.84   | 2.15     | 0.94    | -1.84    | 2.15    |
| Banas × SKNP 1406      | 46.57**                  | 43.86**  | 33.62*   | 42.92**  | 0.69    | 5.42**  | 0.00              | 0.69     | -0.12   | 2.12    | -0.69    | 3.35    | -0.12            | 2.12    | -0.69    | 3.35    | -0.69    | 3.35    |
| Banas × Vaishali       | 58.92**                  | 15.90*   | 126.08** | 141.81** | -5.41** | 7.22**  | 1.72              | 2.42     | 3.59    | 8.96**  | 5.97*    | 10.27** | 3.59             | 8.96**  | 5.97*    | 10.27** | 5.97*    | 10.27** |
| Banas × BDN 2004-01    | 65.33**                  | 31.92**  | 98.03**  | 111.81** | -5.01** | 6.14**  | 0.69              | 1.38     | 2.70    | 7.55**  | 4.59     | 8.84**  | 2.70             | 7.55**  | 4.59     | 8.84**  | 4.59     | 8.84**  |
| GT 102 × SKNP 1408     | 38.86**                  | 17.09**  | 172.88** | 191.87** | 0.00    | 22.17** | -7.54**           | -6.90**  | 0.90    | 11.93** | -9.64**  | -5.97*  | 0.90             | 11.93** | -9.64**  | -5.97*  | -9.64**  | -5.97*  |
| GT 102 × SKNP 1406     | 31.63**                  | -7.96    | 114.52** | 129.45** | -3.05   | 14.93** | -13.02**          | -12.42** | -1.89   | 10.8**  | -10.56** | -6.93*  | -1.89            | 10.8**  | -10.56** | -6.93*  | -10.56** | -6.93*  |
| GT 102 × Vaishali      | 25.81**                  | 15.56*   | 169.32** | 188.06** | -3.15   | 25.34** | -5.14**           | -4.49*   | 0.24    | 16.76** | -5.74*   | -1.91   | 0.24             | 16.76** | -5.74*   | -1.91   | -5.74*   | -1.91   |
| GT 102 × BDN 2004-01   | 31.42**                  | 8.03     | 151.78** | 169.30** | -5.15** | 20.81** | -8.57**           | -7.94**  | -5.15*  | 9.94**  | -11.24** | -7.64** | -5.15*           | 9.94**  | -11.24** | -7.64** | -11.24** | -7.64** |
| GT 103 × SKNP 1408     | 9.49                     | -2.32    | 99.23**  | 113.10** | -1.90   | -0.96   | 6.17**            | 6.90**   | 2.23    | 6.76*   | 5.05     | 9.31**  | 2.23             | 6.76*   | 5.05     | 9.31**  | 5.05     | 9.31**  |
| GT 103 × SKNP 1406     | -8.11                    | -33.13** | 36.38**  | 45.87**  | 0.32    | 1.98    | 5.83**            | 6.56**   | 0.00    | 2.71    | 4.36     | 8.60**  | 0.00             | 2.71    | 4.36     | 8.60**  | 4.36     | 8.60**  |
| GT 103 × Vaishali      | 32.51**                  | 29.63**  | 164.38** | 182.78** | -3.92** | 1.92    | 9.25**            | 10.00**  | 1.18    | 1.28    | 8.49**   | 12.89** | 1.18             | 1.28    | 8.49**   | 12.89** | 8.49**   | 12.89** |
| GT 103 × BDN 2004-01   | 46.02**                  | 26.75**  | 158.51** | 176.50** | -4.73** | -0.32   | 6.85**            | 7.59**   | 0.54    | 0.86    | 7.34**   | 11.70** | 0.54             | 0.86    | 7.34**   | 11.70** | 7.34**   | 11.70** |
| GT 100 × SKNP 1408     | 26.25**                  | 2.47     | 63.92**  | 75.33**  | -2.17   | 4.64*   | 0.35              | 1.04     | 3.35    | 6.14*   | -0.92    | 3.11    | 3.35             | 6.14*   | -0.92    | 3.11    | -0.92    | 3.11    |
| GT 100 × SKNP 1406     | 36.25**                  | 31.59*   | 31.20*   | 40.33**  | 1.54    | 5.71**  | 1.37              | 2.07     | 2.82    | 7.37*   | 0.23     | 4.30    | 2.82             | 7.37*   | 0.23     | 4.30    | 7.37*    | 4.30    |
| GT 100 × Vaishali      | 24.68**                  | -5.80    | 83.75**  | 96.54**  | -2.38   | 10**    | 5.48**            | 6.21**   | 1.71    | 9.34**  | 2.07     | 6.21*   | 1.71             | 9.34**  | 2.07     | 6.21*   | 2.07     | 6.21*   |
| GT 100 × BDN 2004-01   | 42.17**                  | 18.30    | 77.58**  | 89.94**  | -0.32   | 10.71** | 6.17**            | 6.90**   | 1.72    | 8.85**  | 1.61     | 5.73*   | 1.72             | 8.85**  | 1.61     | 5.73*   | 8.85**   | 5.73*   |
| GT 1 × SKNP 1408       | 6.62                     | -12.85*  | 119.63** | 134.91** | 2.86    | 7.21**  | 17.13**           | 17.94**  | 1.96    | 9.32**  | 7.57**   | 11.94** | 1.96             | 9.32**  | 7.57**   | 11.94** | 7.57**   | 11.94** |
| GT 1 × SKNP 1406       | 14.32                    | -21.77** | 97.14**  | 110.86** | 3.54*   | 10.89** | 15.07**           | 15.87**  | 0.64    | 6.09*   | 7.80**   | 12.18** | 0.64             | 6.09*   | 7.80**   | 12.18** | 6.09*    | 7.80**  |
| GT 1 × Vaishali        | 31.26**                  | 16.43**  | 193.41** | 213.83** | 2.73    | 3.47*   | 22.61**           | 23.45**  | -0.73   | 1.71    | 9.18**   | 13.61** | -0.73            | 1.71    | 9.18**   | 13.61** | 9.18**   | 13.61** |
| GT 1 × BDN 2004-01     | 36.80**                  | 9.15     | 175.05** | 194.19** | 0.29    | 0.88    | 18.16**           | 18.97**  | -2.20   | 0.65    | 7.12*    | 11.46** | -2.20            | 0.65    | 7.12*    | 11.46** | 7.12*    | 11.46** |
| Range minimum          | -8.11                    | -33.13   | 31.20    | 40.33    | -5.41   | -0.96   | -13.02            | -12.42   | -5.15   | 0.65    | -11.24   | -7.64   | -5.15            | 0.65    | -11.24   | -7.64   | -11.24   | -7.64   |
| Maximum                | 65.33                    | 43.86    | 193.41   | 213.83   | 3.54    | 25.34   | 22.61             | 23.45    | 3.59    | 16.76   | 9.18     | 13.61   | 3.59             | 16.76   | 9.18     | 13.61   | 9.18     | 13.61   |
| S.Em. <sub>±</sub>     | 3.16                     | 3.65     | 3.65     | 3.65     | 1.59    | 1.84    | 1.84              | 1.84     | 3.37    | 3.89    | 3.89     | 3.89    | 3.37             | 3.89    | 3.89     | 3.89    | 3.89     | 3.89    |
| No. of +ve significant | 16                       | 9        | 20       | 20       | 1       | 14      | 10                | 10       | 0       | 13      | 7        | 12      | 0                | 13      | 7        | 12      | 7        | 12      |
| No. of -ve significant | 0                        | 3        | 0        | 0        | 6       | 0       | 4                 | 4        | 1       | 0       | 4        | 3       | 1                | 0       | 4        | 3       | 4        | 3       |

\*, \*\* Significant at 5 per cent and 1 per cent levels of significance, respectively.

**Table 2:** Estimates of relative heterosis, heterobeltiosis and standard heterosis for Plant height, Number of branches per plant and Number of pods per plant.

| Hybrids                | Plant height (cm) |         |          |          | Number of branches per plant |          |         |          | Number of pods per plant |          |          |          |
|------------------------|-------------------|---------|----------|----------|------------------------------|----------|---------|----------|--------------------------|----------|----------|----------|
|                        | Heterosis over    |         |          |          | Heterosis over               |          |         |          | Heterosis over           |          |          |          |
|                        | MP                | BP      | SHGTH 1  | SHGT 101 | MP                           | BP       | SHGTH 1 | SHGT 101 | MP                       | BP       | SHGTH 1  | SHGT 101 |
| Banas × SKNP 1408      | -2.90             | -1.18   | -3.01    | 4.24     | 7.76                         | 1.54     | 26.93** | 21.11**  | 6.89                     | 0.07     | 0.85     | 51.42**  |
| Banas × SKNP 1406      | -3.99             | -1.49   | -8.10    | -1.24    | 71.43**                      | 70.69**  | 90.39** | 81.66**  | 15.85*                   | -8.12    | -19.23** | 21.28*   |
| Banas × Vaishali       | 1.48              | 15.89** | -11.41   | -4.80    | 13.36**                      | 6.06     | 34.62** | 28.45**  | 27.78**                  | 12.82*   | 29.49**  | 94.42**  |
| Banas × BDN 2004-01    | 7.98              | 36.68** | -12.41   | -5.88    | 11.11**                      | 5.47     | 29.81** | 23.86**  | 2.16                     | 1.45     | -9.57    | 35.79**  |
| GT 102 × SKNP 1408     | 0.12              | 1.76    | 3.42     | 11.14    | 8.37*                        | 4.62     | 30.77** | 24.78**  | 30.35**                  | 22.70**  | 40.09**  | 110.35** |
| GT 102 × SKNP 1406     | -0.44             | 5.79*   | -1.31    | 6.06     | 16.46**                      | 14.05**  | 32.70** | 26.61**  | 47.13**                  | 6.77     | 21.91**  | 83.04**  |
| GT 102 × Vaishali      | 4.54              | 24.03** | -5.19    | 1.90     | 16.21**                      | 11.36**  | 41.35** | 34.87**  | 47.60**                  | 47.22**  | 68.96**  | 153.69** |
| GT 102 × BDN 2004-01   | 8.09              | 42.56** | -8.65    | -1.83    | 4.42                         | 1.56     | 25.00** | 19.27**  | 49.40**                  | 33.03**  | 51.89**  | 128.06** |
| GT 103 × SKNP 1408     | 0.07              | 6.31*   | -3.94    | 3.23     | -9.63**                      | -12.86** | 17.31** | 11.93*   | 9.29                     | 7.97     | 11.50*   | 67.42**  |
| GT 103 × SKNP 1406     | 2.48              | 4.14    | -5.90    | 1.13     | -12.50**                     | -20.00** | 7.70    | 2.76     | 19.85**                  | -10.17   | -7.24    | 39.29**  |
| GT 103 × Vaishali      | -1.14             | 7.86*   | -17.55** | -11.40   | 2.94                         | 0.00     | 34.62** | 28.45**  | 21.64**                  | 15.54**  | 32.61**  | 99.11**  |
| GT 103 × BDN 2004-01   | -0.94             | 19.36** | -23.51** | -17.81** | 1.49                         | -2.86    | 30.77** | 24.78**  | 10.64*                   | 3.07     | 6.45     | 59.83**  |
| GT 100 × SKNP 1408     | 3.27              | 37.25** | -15.87*  | -9.60    | -4.25                        | -4.62    | 19.24** | 13.77*   | -1.66                    | -19.35** | -18.74** | 22.03**  |
| GT 100 × SKNP 1406     | 1.46              | 27.95** | -21.58** | -15.72*  | 20.00**                      | 13.95**  | 41.35** | 34.87**  | -0.94                    | -10.91   | -42.52** | -13.70   |
| GT 100 × Vaishali      | -18.77*           | -8.74*  | -44.06** | -39.89** | -20.31**                     | -21.21** | 0.01    | -4.59    | -0.33                    | -22.15** | -10.66   | 34.16**  |
| GT 100 × BDN 2004-01   | -3.92             | -1.74   | -39.77** | -35.28** | -1.17                        | -1.55    | 22.12** | 16.52**  | 23.90**                  | 6.78     | -4.81    | 42.94**  |
| GT 1 × SKNP 1408       | -1.56             | 0.97    | -2.40    | 4.89     | 3.97                         | 0.77     | 25.97** | 20.19**  | 33.81**                  | 20.63**  | 21.56**  | 82.52**  |
| GT 1 × SKNP 1406       | 0.93              | 2.75    | -4.14    | 3.02     | 1.68                         | -0.82    | 16.35** | 11.01    | 4.00                     | -14.88*  | -31.12** | 3.43     |
| GT 1 × Vaishali        | 1.47              | 14.89** | -12.17   | -5.62    | 21.26**                      | 16.67**  | 48.08** | 41.29**  | 51.68**                  | 29.32**  | 48.42**  | 122.85** |
| GT 1 × BDN 2004-01     | 4.45              | 31.01** | -16.05*  | -9.78    | 9.60*                        | 7.03     | 31.74** | 25.69**  | 62.94**                  | 55.42**  | 38.56**  | 108.04** |
| Range minimum          | -18.77            | -8.74   | -44.06   | -39.89   | -20.31                       | -21.21   | 0.01    | -4.59    | -1.66                    | -22.15   | -42.52   | -13.70   |
| Maximum                | 8.09              | 42.56   | 3.42     | 11.14    | 71.43                        | 70.69    | 90.39   | 81.66    | 62.94                    | 55.42    | 68.96    | 153.69   |
| S. Em.±                | 8.22              | 9.49    | 9.49     | 9.49     | 0.35                         | 0.40     | 0.40    | 0.40     | 6.36                     | 7.35     | 7.35     | 7.35     |
| No. of +ve significant | 0                 | 12      | 0        | 0        | 9                            | 5        | 18      | 17       | 9                        | 8        | 10       | 18       |
| No. of -ve significant | 1                 | 1       | 7        | 4        | 3                            | 3        | 0       | 0        | 0                        | 3        | 4        | 0        |

\*, \*\* Significant at 5 per cent and 1 per cent levels of significance, respectively.

**Table 3:** Estimates of relative heterosis, heterobeltiosis and standard heterosis for pod length, number of seeds per pod and test weight.

| Hybrids                | Pod length (cm) |         |         |          | Number of seeds per pod |         |         |          | Test weight (g) |         |         |          |
|------------------------|-----------------|---------|---------|----------|-------------------------|---------|---------|----------|-----------------|---------|---------|----------|
|                        | MP              | BP      | SHGTH 1 | SHGT 101 | MP                      | BP      | SHGTH 1 | SHGT 101 | MP              | BP      | SHGTH 1 | SHGT 101 |
| Banas × SKNP 1408      | 10.34           | 7.91    | -12.00  | -10.58   | 26.00**                 | 6.78    | 31.25** | 36.96**  | 15.49**         | 14.27** | 16.48** | -5.64    |
| Banas × SKNP 1406      | 16.97*          | 16.47*  | -9.20   | -7.74    | 9.68                    | -1.92   | 6.25    | 10.87    | 8.00*           | 2.03    | 1.80    | -17.54** |
| Banas × Vaishali       | 10.27           | 1.17    | -5.54   | -4.02    | 34.62**                 | 11.11   | 45.84** | 52.18**  | 10.73**         | 0.66    | 22.77** | -0.55    |
| Banas × BDN 2004-01    | 14.77*          | 10.38   | -6.82   | -5.32    | 31.37**                 | 9.84    | 39.59** | 45.66**  | 9.38**          | 3.24    | 16.04** | -6.01    |
| GT 102 × SKNP 1408     | 33.77**         | 31.93** | 10.66   | 12.44*   | 17.43**                 | 8.47    | 33.34** | 39.14**  | 17.35**         | 10.70** | 27.26** | 3.10     |
| GT 102 × SKNP 1406     | 8.01            | 3.77    | -12.97* | -11.57   | 21.57**                 | 19.23** | 29.17** | 34.79**  | 20.33**         | 6.60    | 22.55** | -0.73    |
| GT 102 × Vaishali      | 20.12**         | 14.02*  | 6.46    | 8.17     | 18.58**                 | 6.35    | 39.59** | 45.66**  | 19.18**         | 15.76** | 41.18** | 14.37**  |
| GT 102 × BDN 2004-01   | 17.47**         | 17.09*  | -1.16   | 0.44     | 17.12**                 | 6.56    | 35.42** | 41.31**  | 24.39**         | 23.01** | 41.41** | 14.56**  |
| GT 103 × SKNP 1408     | 17.35**         | 6.79    | 6.21    | 7.92     | 11.11                   | 1.69    | 25.00** | 30.44**  | 7.96*           | 2.45    | 16.30** | -5.79    |
| GT 103 × SKNP 1406     | 14.05*          | 1.35    | 0.80    | 2.42     | -0.99                   | -3.85   | 4.17    | 8.70     | 11.37**         | -0.79   | 12.62** | -8.77**  |
| GT 103 × Vaishali      | 10.98           | 7.59    | 7.00    | 8.72     | 17.86**                 | 4.76    | 37.50** | 43.48**  | 8.20**          | 4.46    | 27.40** | 3.21     |
| GT 103 × BDN 2004-01   | 9.17            | 0.92    | 0.37    | 1.98     | 14.55*                  | 3.28    | 31.25** | 36.96**  | 13.14**         | 12.58** | 27.80** | 3.53     |
| GT 100 × SKNP 1408     | 22.50**         | 13.32*  | 8.71    | 10.46    | 9.73                    | 5.08    | 29.17** | 34.79**  | 7.43*           | 1.86    | 15.86** | -6.15    |
| GT 100 × SKNP 1406     | 8.85            | -1.71   | -5.73   | -4.21    | 15.09*                  | 12.96   | 27.09** | 32.61**  | 12.93**         | 0.51    | 14.33** | -7.39*   |
| GT 100 × Vaishali      | 7.85            | 6.41    | 2.07    | 3.72     | 12.82*                  | 4.76    | 37.50** | 43.48**  | 22.31**         | 18.19** | 44.15** | 16.77**  |
| GT 100 × BDN 2004-01   | 11.71           | 5.01    | 0.74    | 2.36     | 11.3*                   | 4.92    | 33.34*  | 39.14**  | 8.90**          | 8.25*   | 23.13** | -0.26    |
| GT 1 × SKNP 1408       | 32.08**         | 14.99** | 26.54** | 28.58**  | 5.79                    | 3.23    | 33.34** | 39.14**  | 18.84**         | 11.66** | 29.46** | 4.88     |
| GT 1 × SKNP 1406       | 18.71**         | 1.05    | 11.20   | 12.99*   | 12.28*                  | 3.23    | 33.34** | 39.14**  | 13.08**         | -0.19   | 15.72** | -6.26    |
| GT 1 × Vaishali        | 24.84**         | 15.38** | 26.97** | 29.01**  | 16.8**                  | 15.87** | 52.09** | 58.70**  | 19.67**         | 16.72** | 42.35** | 15.32**  |
| GT 1 × BDN 2004-01     | 29.20**         | 14.16*  | 25.63** | 27.65**  | 17.07**                 | 16.13** | 50.00** | 56.53**  | 23.85**         | 21.96** | 41.41** | 14.56**  |
| Range minimum          | 7.85            | -1.71   | -12.97  | -11.57   | -0.99                   | -3.85   | 4.17    | 8.70     | 7.43            | -0.79   | 1.80    | -17.54   |
| Maximum                | 33.77           | 31.93   | 26.97   | 29.01    | 34.62                   | 19.23   | 52.09   | 58.70    | 24.39           | 23.01   | 44.15   | 16.77    |
| S. Em.±                | 0.29            | 0.33    | 0.33    | 0.33     | 0.22                    | 0.25    | 0.25    | 0.25     | 0.25            | 0.29    | 0.29    | 0.29     |
| No. of +ve significant | 12              | 8       | 3       | 5        | 15                      | 3       | 18      | 18       | 20              | 10      | 19      | 5        |
| No. of -ve significant | 0               | 0       | 1       | 0        | 0                       | 0       | 0       | 0        | 0               | 0       | 0       | 3        |

\*, \*\* Significant at 5 per cent and 1 per cent levels of significance, respectively.

**Table 4:** Estimates of relative heterosis, heterobeltiosis and standard heterosis for Biological yield per plant, Harvest index and Total protein content.

| Hybrids                | Biological yield per plant (g) |         |          |          |          |          | Harvest index (%) |          |          |         |         |         | Total protein content (%) |         |          |    |    |         |
|------------------------|--------------------------------|---------|----------|----------|----------|----------|-------------------|----------|----------|---------|---------|---------|---------------------------|---------|----------|----|----|---------|
|                        | Heterosis is over              |         |          |          |          |          | Heterosis is over |          |          |         |         |         | Heterosis is over         |         |          |    |    |         |
|                        | MP                             | BP      | SHGTH 1  | SHGT 101 | MP       | SHGTH 1  | BP                | SHGTH 1  | SHGT 101 | MP      | BP      | SHGTH 1 | BP                        | SHGTH 1 | SHGT 101 | MP | BP | SHGTH 1 |
| Banas × SKNP 1408      | 7.03                           | 0.42    | -2.23    | 73.47**  | 28.59**  | 73.06**  | 5.73              | 73.06**  | 4.66     | 15.20** | 7.83**  | 12.39** | 7.83**                    | 12.39** | 9.78**   |    |    |         |
| Banas × SKNP 1406      | 2.14                           | 0.16    | -14.54*  | 51.64**  | 43.66**  | 56.74**  | 39.06**           | 56.74**  | -5.22    | 16.35** | 11.55** | 10.52** | 11.55**                   | 10.52** | 7.96**   |    |    |         |
| Banas × Vaishali       | 29.92**                        | 23.28** | 17.18**  | 107.90** | 23.57**  | 91.91**  | -6.43             | 91.91**  | 16.06    | 17.59** | 8.99**  | 16.04** | 8.99**                    | 16.04** | 13.34**  |    |    |         |
| Banas × BDN 2004-01    | 24.40*                         | 23.03** | 4.99     | 86.26**  | 32.21**  | 88.64**  | 4.88              | 88.64**  | 14.08    | 13.25** | 5.71**  | 10.86** | 5.71**                    | 10.86** | 8.29**   |    |    |         |
| GT 102 × SKNP 1408     | 8.62                           | -1.30   | 17.56**  | 108.57** | 29.34**  | 131.78** | 19.03*            | 131.78** | 40.18**  | 2.18    | -1.00   | 10.05** | -1.00                     | 10.05** | 7.49**   |    |    |         |
| GT 102 × SKNP 1406     | 11.36*                         | -5.97   | 12.00*   | 98.70**  | 24.13**  | 90.80**  | -2.01             | 90.80**  | 15.39    | -0.65   | -6.05** | 4.44**  | -6.05**                   | 4.44**  | 2.02     |    |    |         |
| GT 102 × Vaishali      | 21.26**                        | 9.02    | 29.85**  | 130.37** | 3.69     | 107.28** | 1.07              | 107.28** | 25.36**  | 1.36    | -0.78   | 10.30** | -0.78                     | 10.30** | 7.73**   |    |    |         |
| GT 102 × BDN 2004-01   | 18.21**                        | 0.51    | 19.72**  | 112.40** | 11.99    | 109.75** | 7.71              | 109.75** | 26.85**  | 1.98    | -0.90   | 10.17** | -0.90                     | 10.17** | 7.61**   |    |    |         |
| GT 103 × SKNP 1408     | 40.95**                        | 17.57** | 71.32**  | 203.95** | -23.2*   | 28.92**  | -28.92**          | 16.32    | -29.66** | 10.81** | 10.53** | 15.21** | 10.53**                   | 15.21** | 12.53**  |    |    |         |
| GT 103 × SKNP 1406     | 37.15**                        | 7.18    | 56.18**  | 177.09** | -30.44** | -12.37   | -37.08**          | -12.37   | -47.01** | 2.73*   | 0.44    | 4.16**  | 0.44                      | 4.16**  | 1.74     |    |    |         |
| GT 103 × Vaishali      | 55.57**                        | 28.53** | 87.29**  | 232.28** | -18.40*  | 40.52*   | -31.49**          | 40.52*   | -15.03   | 2.43*   | 1.10    | 7.63**  | 1.10                      | 7.63**  | 5.13**   |    |    |         |
| GT 103 × BDN 2004-01   | 52.14**                        | 19.63** | 74.33**  | 209.29** | -7.26    | -17.72*  | -17.72*           | 47.98**  | -10.51   | 0.51    | -0.05   | 4.82**  | -0.05                     | 4.82**  | 2.38     |    |    |         |
| GT 100 × SKNP 1408     | 19.03**                        | -7.36   | -9.80    | 60.04**  | 4.67     | 81.95**  | -1.11             | 81.95**  | 10.04    | -1.17   | -3.89** | 6.01**  | -3.89**                   | 6.01**  | 3.55*    |    |    |         |
| GT 100 × SKNP 1406     | 0.50                           | -16.55* | -31.56** | 21.44*   | 28.51**  | 90.65**  | 3.61              | 90.65**  | 15.30    | 0.70    | -4.42** | 5.43**  | -4.42**                   | 5.43**  | 2.97*    |    |    |         |
| GT 100 × Vaishali      | 39.56**                        | 9.56    | 4.15     | 84.78**  | -9.55    | 75.99**  | -14.20            | 75.99**  | 6.43     | 2.24    | 0.46    | 10.81** | 0.46                      | 10.81** | 8.23**   |    |    |         |
| GT 100 × BDN 2004-01   | 43.99**                        | 18.75*  | -0.91    | 75.81**  | -1.68    | 78.85**  | -2.79             | 78.85**  | 8.17     | -0.99   | -3.42*  | 6.52**  | -3.42*                    | 6.52**  | 4.04**   |    |    |         |
| GT 1 × SKNP 1408       | 3.94                           | 0.37    | 4.94     | 86.18**  | 3.31     | 108.93** | -13.24*           | 108.93** | 26.35**  | -1.20   | -2.29   | 4.14**  | -2.29                     | 4.14**  | 1.72     |    |    |         |
| GT 1 × SKNP 1406       | -3.80                          | -14.16* | -10.26   | 59.23**  | 24.68**  | 120.40** | -8.49             | 120.40** | 33.29**  | -0.87   | -4.36** | 1.93    | -4.36**                   | 1.93    | -0.45    |    |    |         |
| GT 1 × Vaishali        | 5.88                           | 1.07    | 5.68     | 87.48**  | 23.75**  | 175.91** | 14.57*            | 175.91** | 66.87**  | -0.14   | -0.19   | 6.37**  | -0.19                     | 6.37**  | 3.90*    |    |    |         |
| GT 1 × BDN 2004-01     | 11.60*                         | 0.34    | 4.91     | 86.13**  | 24.48**  | 161.83** | 8.72              | 161.83** | 58.35**  | -0.41   | -1.21   | 5.29**  | -1.21                     | 5.29**  | 2.85     |    |    |         |
| Range minimum          | -3.80                          | -16.55  | -31.56   | 21.44    | -30.44   | -12.37   | -37.08            | -12.37   | -47.01   | -1.20   | -6.05   | 1.93    | -6.05                     | 1.93    | -0.45    |    |    |         |
| Maximum                | 55.57                          | 28.53   | 87.29    | 232.28   | 43.66    | 175.91   | 39.06             | 175.91   | 66.87    | 17.59   | 11.55   | 16.04   | 11.55                     | 16.04   | 13.34    |    |    |         |
| S. Em. ±               | 6.40                           | 7.38    | 7.38     | 7.38     | 2.83     | 3.26     | 3.26              | 3.26     | 3.26     | 0.23    | 0.27    | 0.27    | 0.27                      | 0.27    | 0.27     |    |    |         |
| No. of +ve significant | 13                             | 6       | 9        | 20       | 10       | 18       | 3                 | 18       | 7        | 7       | 5       | 19      | 5                         | 19      | 14       |    |    |         |
| No. of -ve significant | 20                             | 2       | 2        | 0        | 3        | 0        | 5                 | 0        | 2        | 0       | 5       | 0       | 5                         | 0       | 0        |    |    |         |

\*, \*\* Significant at 5 per cent and 1 per cent levels of significance, respectively.

types i.e., relative heterosis, heterobeltiosis and standard heterosis (Table 4). For leaf area per plant, crosses, GT 1 × Vaishali, GT 1 × BDN 2004-01 and GT 102 × Vaishali exhibited significant and positive heterosis in desired direction for relative heterosis, heterobeltiosis and standard heterosis parameters (Table 5). The results were

found similar with Saritha *et al.* (2012), Soni *et al.* (2017) and Patel *et al.* (2020) for leaf area per plant.

Table 6 illustrates that the hybrid GT 1 × Vaishali displayed the highest standard heterosis (193.41%) over GTH 1 for seed yield per plant. This finding aligns with previous studies conducted by Shobha and Balan (2010),

**Table 5:** Estimates of relative heterosis, heterobeltiosis and standard heterosis for leaf area per plant (cm<sup>2</sup>).

| Hybrids                | Leaf area per plant (cm <sup>2</sup> ) |          |          |          |
|------------------------|----------------------------------------|----------|----------|----------|
|                        | Heterosis over                         |          |          |          |
|                        | MP                                     | BP       | SHGTH 1  | SHGT 101 |
| Banas × SKNP 1408      | 13.97                                  | 2.98     | 3.57     | 17.06    |
| Banas × SKNP 1406      | 20.68                                  | 10.59    | -10.24   | 1.46     |
| Banas × Vaishali       | 45.40**                                | 28.24**  | 36.26**  | 54.00**  |
| Banas × BDN 2004-01    | 39.34**                                | 24.69**  | 28.18**  | 44.88**  |
| GT 102 × SKNP 1408     | 21.74*                                 | 6.35     | 6.95     | 20.88*   |
| GT 102 × SKNP 1406     | 27.21*                                 | 20.82    | -9.23    | 2.61     |
| GT 102 × Vaishali      | 52.45**                                | 30.12**  | 38.26**  | 56.27**  |
| GT 102 × BDN 2004-01   | 44.43**                                | 25.00**  | 28.50**  | 45.24**  |
| GT 103 × SKNP 1408     | 11.10                                  | 9.73     | 10.36    | 24.73*   |
| GT 103 × SKNP 1406     | 21.28*                                 | 2.43     | 0.47     | 13.55    |
| GT 103 × Vaishali      | 26.73**                                | 21.86*   | 29.48**  | 46.34**  |
| GT 103 × BDN 2004-01   | 22.15**                                | 19.35*   | 22.69**  | 38.67**  |
| GT 100 × SKNP 1408     | 9.92                                   | 5.52     | 6.12     | 19.95*   |
| GT 100 × SKNP 1406     | 15.85                                  | 0.24     | -7.26    | 4.83     |
| GT 100 × Vaishali      | 17.64*                                 | 10.04    | 16.93    | 32.16**  |
| GT 100 × BDN 2004-01   | 9.70                                   | 4.22     | 7.14     | 21.09*   |
| GT 1 × SKNP 1408       | 12.06                                  | 8.82     | 9.44     | 23.70*   |
| GT 1 × SKNP 1406       | 24.38*                                 | 6.56     | 0.96     | 14.12    |
| GT 1 × Vaishali        | 51.99**                                | 43.76**  | 52.75**  | 72.65**  |
| GT 1 × BDN 2004-01     | 45.81**                                | 40.10**  | 44.03**  | 62.79**  |
| Range minimum          | 9.70                                   | 0.24     | -10.24   | 1.46     |
| Maximum                | 52.45                                  | 43.76    | 52.75    | 72.65    |
| S. Em.±                | 253.1109                               | 292.2673 | 292.2673 | 292.2673 |
| No. of +ve significant | 13                                     | 8        | 8        | 14       |
| No. of -ve significant | 0                                      | 0        | 0        | 0        |

\*, \*\* Significant at 5 per cent and 1 per cent levels of significance, respectively.

**Table 6:** Best ten high yielding hybrids with heterosis (%) over better parent, standard check (GTH 1) and component traits showing significant standard heterosis.

| Ten best hybrids on the basis of seed yield | Mean seed yield per plant (g) | Heterosi (%) over |          | Significant standard heterosis for component traits in desired direction |
|---------------------------------------------|-------------------------------|-------------------|----------|--------------------------------------------------------------------------|
|                                             |                               | BP                | Best SC  |                                                                          |
| GT 1 × Vaishali                             | 81.18                         | 16.43**           | 193.41** | BP, PP, PL, SP, TW, HI, PC, LA                                           |
| GT 1 × BDN 2004-01                          | 76.10                         | 9.15              | 175.05** | PH, BP, PP, PL, SP, TW, HI, PC, LA                                       |
| GT 102 × SKNP 1408                          | 75.50                         | 17.09**           | 172.88** | DF, DM, BP, PP, SP, TW, BY, HI, PC                                       |
| GT 102 × Vaishali                           | 74.51                         | 15.56*            | 169.32** | DF, DM, BP, PP, SP, TW, BY, HI, PC, LA                                   |
| GT 103 × Vaishali                           | 73.14                         | 29.63**           | 164.38** | PH, BP, PP, SP, TW, BY, HI, PC, LA                                       |
| GT 103 × BDN 2004-01                        | 71.52                         | 26.75**           | 158.51** | PH, BP, SP, TW, BY, HI, PC LA                                            |
| GT 102 × BDN 2004-01                        | 69.66                         | 8.03              | 151.78** | DF, DM, BP, PP, SP, TW, BY, HI, PC, LA                                   |
| Banas × Vaishali                            | 62.55                         | 15.90*            | 126.08** | BP, PP, TW, BY HI, PC, LA                                                |
| GT 1 × SKNP 1408                            | 60.76                         | -12.85*           | 119.63** | BP, PP, PL, SP, SP, TW, HI, PC                                           |
| GT 102 × SKNP 1406                          | 59.35                         | -7.96             | 114.52** | DF, DM, BP, PP, SP, TW, BY, HI, PC                                       |

Gupta *et al.* (2011), Chethana *et al.* (2015), Soni *et al.* (2017) and others, which also reported higher standard heterosis for this trait. Notably, eight out of ten hybrids exhibited positive heterobeltiosis for seed yield per plant, indicating promising hybrid vigor. The results are in accordance with Chandra *et al.* (2024). Furthermore, these hybrids demonstrated significant heterosis for various component traits such as the number of branches per plant, number of pods per plant, number of seeds per pod, test weight, biological yield per plant, harvest index, total protein content and leaf area per plant.

## CONCLUSION

Hybrids which displayed significant heterotic effects over their better parents and over the checks may use to produce synthetic populations to utilize heterosis in this crop. From the resultant crosses, GT 102 × SKNP 1408 and GT 103 × BDN 2004-01 were produced good amounts of heterosis, heterobeltiosis and standard heterosis for various characters. While, hybrid GT 102 × SKNP 1408 was found to be the most promising based on its per se performance and standard heterosis, which may be exploited in further breeding programmes for pigeonpea.

## Conflict of interest

All authors declare that they have no conflict of interest.

## REFERENCES

- Ajay, B.C., Byregowda, M., Veerakumar, G.N., Reena, M., Prashanth, B.H. and Ganapathy K.N. (2015). Heterosis and inbreeding depression for yield attributing characters in  $F_2$  and  $F_3$  generations of pigeonpea. *National Academy of Sciences*. 38(2): 179-181.
- Briggle, L.W. (1963). Heterosis in wheat-A-Review. *Crop Science*. 3: 407-412.
- Chandra D., Verma S.K., Gaur A.K., Bisht C., Gautam A., Chauhan C., Yadav H. (2024). Heterosis, combining ability, genetic diversity and their interrelationship in pigeonpea [*Cajanus cajan* (L.) Millspaugh]. *Legume Research*. 47(2): 183-189.
- Chethana, C.K., Dharmaraj, P.S., Lokesh, R., Girisha, G., Muniswamy, S., Yamanura, N.K. and Vinayaka, D.H. (2015). Genetic analysis for quantitative traits in pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Journal of Food Legumes*. 25(1): 1-18.
- Gedam, A.H., Jadav, A.B., Begade, A.B. and Madrap, I.A. (2013). Identification of heterotic hybrids for seed yield and its attributing traits in pigeonpea. *Legume Research*. 38: 335-358.
- Gowda, C.L.L., Saxena, K.B., Srivastava, R.K., Upadhyaya, H.D. and Silim, S.N. (2011). Pigeonpea: From an orphan to leader in food legumes. In *Biodiversity in Agriculture: Domestication, evolution and sustainability*. Cambridge University Press. University of California, Davis, USA. pp. 361-373.
- Gupta, D.K., Acharya, S. and Patel, J.B. (2011). Combining ability and heterosis studies in pigeonpea using  $A_2$  cytoplasm from *Cajanus scarabaeoides* as source of male sterility. *Journal of Food Legumes*. 24(1): 58-64.
- Kumar, C.V.S., Sreelakshmi, C.H. and Varma, P.K. (2009). Studies on combining ability and heterosis in pigeon pea (*Cajanus cajan* L.). *Legume Res*. 32: 92-97.
- Meredith, W.R. and Bridge, R.R. (1972). Heterosis and gene action in cotton (*Gossypium hirsutum*). *Crop Science*. 12(3): 304-310.
- Mhasal, G.S., Marawar, M.W., Solanke, A.C. and Tayade, S.D. (2015). Heterosis and combining ability studies in medium duration pigeonpea  $F_1$  hybrids. *Journal of Agricultural Sciences*. 53(1): 11-22.
- Panase, V.G. and Sukhatme, P.V. (1978). "Statistical methods for Agricultural Workers". Indian Council of Agricultural Research. New Delhi.
- Patel, H.S., Patel, A.M., Chaudhary, N.B. and Kugashiya, K.G. (2020). Exploitation of heterosis in hybrids developed using cytoplasmic genetic male sterility (CGMS) system in pigeonpea [*Cajanus cajan* (L.) Millspaugh]. *Journal of Pharmacognosy and Phytochemistry*. 9(4): 1147-1151.
- Saritha, K.S., Pujari, B.T., Basavarajappa, R., Naik, M.K., Babu, R. and Desai, B.K. (2012). Growth of pigeonpea [*Cajanus cajan* (L.) Millsp.] and nutrient status of soil after the harvest of crop as influenced by plant densities, different irrigation and nutrient levels. *Karnataka Journal of Agricultural Science*. 25(1): 134-136.
- Saxena, K.B., Singh, L. and Gupta, M.D. (1990). Variation for natural out-crossing in pigeonpea. *Euphytica*. 46: 143-148.
- Shoba D. and Balan A. (2010). Heterosis in CMS/GMS based pigeonpea [*Cajanus cajan* (L.) Millsp.] hybrids. *Agriculture Science Digest*. 30(1): 32-36.
- Sinha, S.K. (1977). Food legumes: Distribution, adaptability and biology of Yield. In: *FAO Plant Production and Protection Paper 3*, Food and Agriculture Organization (FAO), Rome, Italy. pp. 1-102.
- Soni, N., Patel, P.T., Suresh, K. and Tak, V. (2017). Heterosis for yield and its component traits in  $F_1$  hybrids involving CMS lines and restorer lines in pigeon pea [*Cajanus cajan* (L.) Millsp.]. *Research Journal of Agricultural Sciences*. 8(2): 286-293.