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**Mayank Chaudhary**
Department of Genetics and Plant Breeding, Sardar Vallabh bhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

**Rohit Maurya**
SMS Horticulture (Vegetable Science) KVK Turki, Muzaffarpur, DRPCAU, Pusa, Samastipur, Bihar., India

**Corresponding Author:**
**Mayank Chaudhary**
Department of Genetics & Plant Breeding, Sardar Vallabh bhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

# Combining ability analysis of yield and yield components in forage sorghum (*Sorghum bicolor* L. Moench)

**Mayank Chaudhary and Rohit Maurya**

**Abstract**
The aim of this study was to estimate the general combining ability (GCA) of the parents and specific combining ability (SCA) to estimate heterosis in F 1 hybrids of sorghum [*Sorghum bicolor* (L.) Moench] with respect to yield and its components using ten hybrids considered for the development of high yielding and better quality cultivars of forage sorghum. Ten parents diallel set excluding reciprocals was made during the season of *kharif* 2018 and all the 45 crosses and their ten parents were grown during *kharif* season 2019. All the 45 $F_1$'s hybrids along with ten parents were sown in randomized block design with three replications. Analysis of variance for parents and crosses showed highly differed significantly for all the characters. Parents vs crosses exhibited highly significant for the attributes namely, days to 50% flowering, plant height, leaf breadth, leaf length, leaf area and green fodder yield, which indicated that wide genotypic differences among the parental lines and $F_1$'s hybrids. On the basis of overall gca effects and per se performance among the lines, UP Chari-1 and Pant Chari-5 were identified as good general combiners for maximum 7 traits including green fodder yield, HC-171 for 6 characters and HC-308 for 5 attributes., suggested that these parents may be used in the hybridization programme aimed devolvement of superior genotypes/varieties in forage sorghum. On the basis of overall results and fodder yield performance the $F_1$'s hybrids *viz.*, UP Chari-1 x HC-308, UP Chari-1 x Rajasthan Chari-1, HC-308 x UP Chari-2, HC-308 x HC-171, HC-308 x CSV-17, HC-171 x CSV-84 and Pant Chari-5 x Rajasthan Chari-1 were identified as best specific combiners for maximum attributes including green fodder yield for 9 to 10 other contributing traits, which may be utilized for obtaining transgressive segregates in the next generation.

**Keywords:** Sorghum, combining ability, GCA, SCA, yield

## Introduction
Sorghum [*Sorghum bicolor* (L) Moench] is an often-cross-pollinating crop with a genome, about 25 per cent the size of maize or sugarcane and having diploid (2n = 2x = 20) chromosomes. It is a $C_4$ plant with higher photosynthetic efficiency and higher tolerance to abiotic stress (1) and (2). It is the third most important food grain crop in India, next to rice and wheat. The importance of sorghum as a forage crop is growing in many regions of the world due to its high productivity and ability to utilize efficiently water even under drought conditions. It is highly palatable and digestible than maize and pearl millet as for as the nutritional quality is concerned. It produces a tonnage of dry matter having digestible nutrients (50%), crude protein (8%), fat (2.5%) and nitrogen free extracts (45%) (Azam *et al*., 2010) [15]. The farmers have a preference for sorghum as it can be utilized for different purposes like fresh fodder, hay and silage and grows well in hot and dry climate (Dara Singh and Sukhchain, (2010) [16]. It has quick growth habit, quick recovery or regeneration after cutting or grazing and its ability to provide highly palatable and nutritious fodder for cattle. As green fodder it is one of the cheapest sources of feed for milch, meat and draft animals.
Considering the importance of sorghum as a fodder crop in northern part of India, scientists have reported high amount of heterosis for fodder yield and advocated the possibility of economic exploitation of heterosis through the use of male sterile lines. Hence it is necessary to understand the genetic nature of the parents. General combining ability is average performance of a genotype in cross combinations involving a set of other

genotypes. Specific combining ability is average performance of a specific cross combination expressed as deviation from the population mean. Combining ability analysis helps in selection of suitable parents for hybridization, evaluation of inbreds in terms of their genetic value and identification of superior specific cross combinations (Sprague and Tatum, 1942) [17]. Like green revolution, India is contemplating for white revolution which is possible only with adequate supply of nutritious feeds and fodder. It is well known that the animal industry in any country revolves around sufficient quantity of good quality feed and fodder.

The information on the magnitude and nature of prevalent genetic variation is essentially needed to infer about genetic potential of a particular population. The development of the concept of combining ability helps in choosing the parents for hybridization. Combining ability studies are regarded useful to select good combining parents, which on crossing would produce more desirable segregants. Such studies also elucidate nature and magnitude of gene action in an inheritance of yield and its components, which will decide the breeding programme to be followed in segregating generations.

Before initiating hybridization programme, the selection of suitable parents is one of the most important steps because selection of the parent on the basis of phenotypic performance alone is not a sound procedure since phenotypically superior lines may yield poor hybrids. The lines or parents which produce good progenies on crossing are of immense use to the breeder. This necessitates the testing of parents for their combining ability which in turn will help in identifying the best combiners which may be hybridized either to exploit heterosis or to accumulate desirable genes through selection. For the identification of parents having good potentials to transmit desirable characteristics to their progenies and also to help in sorting out of promising crosses for fodder yield and its related traits, combining ability analysis is powerful tool. The gca is attributed to additive genetic effects which are theoretically fixable. On the other hand, sca attributable to non-additive gene action may be due to dominance, additive x dominance and dominance x dominance or higher order interactions and is unfixable. The presence of non-additive genotypic variance is the primary justification for initiating the hybrid programme (Cockerham, 1961) [18]. At the time, it also elucidates the nature of gene action involved in the inheritance of the characters. Sprague and Tatum (1942) [17] proposed the concept of gca and sca as a measure of gene effects. Therefore, the present investigation was undertaken with a view to study the performance of different hybrids, extent of heterosis, combining ability of genotypes (females, males, hybrids and checks together) for thirteen characters through line x tester mating design in fodder sorghum having diverse male sterile lines and pollen fertility restorers.

## Materials and Methods

The present investigation was conducted during kharif 2018 and 2019 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut U.P. The soil of experimental site was sandy loam well drained and had fairly good moisture holding capacity. Ten genotypes of sorghum were studied in this experiment. Ten genotypes consisted five lines namely, UP Chari-1, HC-308, UP Chari-2, HC-171, Pant Chari-8, CSV-17, Pant Chari-6, CSV-84, Pant Chari-5 and Rajasthan Chari-1. These parents were crossed in a line x tester mating design and resultant fourty five hybrids along with their parents were raised in Complete Randomized Block Design with three replications during kharif 2019. Fourty five hybrids and ten parents were also evaluated to study the combining ability analysis. The combining ability analysis was carried out as per the method suggested by Kempthorne [1].

## Results and Discussion

Analysis of variance for all the traits *i.e.*, days to 50% flowering, plant height, leaves per plant, leaf breadth, leaf length, leaf area, stem girth, leaf stem ratio, total soluble solids and green fodder yield was carried out for 'F' test (Table-1). The variance due to treatments was further partitioned in to parents, crosses and parents vs crosses. All genotypes had highly significant variance for all the characters. Parents and crosses significantly differed among themselves for all the attributes, while parents vs crosses were found high significant differences for the traits *viz*., days to 50% flowering, plant height, leaf breadth, leaf length, leaf area and green fodder yield. The estimates of genotypic coefficient of variation, phenotypic coefficient of variation, as percent of mean for different characters are given in Table-2.

## Genotypic coefficient of variation (GCV)

Genotypic coefficient of variation (more than 25%) was observed high for leaf stem ratio (28.54) and green fodder yield (29.54), whereas recorded moderate (10-25%) for plant height (11.27), leaves per plant (16.31), leaf area (12.77) and stem girth (10.17). Noted low (less than 10%) for days to 50% flowering (6.18), leaf breadth (8.29), leaf length (7.17) and total soluble solids (7.28).

## Phenotypic coefficient of variation (PCV)

Phenotypic coefficient of variation (more than 25%) was estimated high for leaf stem ratio (28.92) and green fodder yield (29.58), while moderate (10-25%) was found for plant height (11.37), leaves per plant (17.14), leaf area (12.85) and stem girth (10.59). Showed low (less than 10%) for days to 50% flowering (6.36), leaf breadth (9.28), leaf length (7.54) and total soluble solids (7.66)

Analysis of variance for parents and crosses showed highly differed significantly for all the characters i.e., days to 50% flowering, plant height, leaf breadth, leaf length, stem girth, leaves per plant, leaf area, leaf stem ratio, total soluble solids and green fodder yield. Parents vs crosses exhibited highly significant for the attributes namely, days to 50% flowering, plant height, leaf breadth, leaf length, leaf area and green fodder yield, which indicated that wide genotypic differences among the parental lines and F1's hybrids.

On the basis of overall gca effects and per se performance among the lines, UP Chari- 1 and Pant Chari-5 were identified as good general combiners for maximum 7 traits including green fodder yield, HC-171 for 6 characters and HC-308 for 5 attributes., suggested that these parents may be used in the hybridization programme aimed devolvement of superior genotypes/varieties in forage sorghum.

On the basis of overall results and fodder yield performance the F1's hybrids *viz*., UP Chari-1 x HC-308, UP Chari-1 x Rajasthan Chari-1, HC-308 x UP Chari-2, HC-308 x HC- 171, HC-308 x CSV-17, HC-171 x CSV-84 and Pant Chari-5 x Rajasthan Chari-1 were identified as best specific combiners for maximum attributes including green fodder yield for 9 to 10 other contributing traits, which may be utilized for obtaining transgressive segregates in the next generation.

**Table 1:** Analysis of variance for combining ability of fodder yield and its components in forage sorghum (*Sorghum bicolor* L. Moench)

| Source of variation | df | Days to 50% flowering | Plant height (cm) | Leaves per plant | Leaf breadth (cm) | Leaf length (cm) | Leaf area ($cm^2$) | Stem girth (mm) | Leaf stem ratio | Total soluble solids (%) | Green fodder yield (g/plant) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GCA | 9 | 141.59** | 3495.14** | 14.91** | 0.97** | 59.98** | 6896.18** | 13.89** | 0.84** | 1.29** | 35643.00** |
| SCA | 45 | 6.36** | 324.84** | 1.54** | 0.78** | 18.35** | 571.90** | 0.96** | 0.73** | 0.94** | 1107.29** |
| Error | 108 | 0.58 | 5.25 | 0.13 | 0.02 | 0.86 | 6.26 | 0.09 | 0.08 | 0.12 | 9.00 |

### Estimation variance due to

| Source of variation | Days to 50% flowering | Plant height (cm) | Leaves per plant | Leaf breadth (cm) | Leaf length (cm) | Leaf area ($cm^2$) | Stem girth (mm) | Leaf stem ratio | Total soluble solids (%) | Green fodder yield (g/plant) |
|---|---|---|---|---|---|---|---|---|---|---|
| □□g | 11.75 | 290.82 | 1.23 | 0.08 | 4.93 | 574.16 | 1.15 | 0.09 | 0.11 | 2969.50 |
| □□g | 15.78 | 319.60 | 1.42 | 0.15 | 17.49 | 585.64 | 1.87 | 0.10 | 0.15 | 3098.29 |
| □□g/□□s | 2.03 | 0.91 | 0.87 | 0.51 | 0.28 | 1.02 | 1.31 | 1.12 | 0.71 | 2.70 |
| (□□g/□□s)$^{0.5}$ | 1.43 | 0.95 | 0.93 | 0.72 | 0.53 | 1.01 | 1.15 | 1.06 | 0.84 | 1.64 |

*, ** significant at 5% and 1% level, respectively

**Table 2:** Estimates of GCA effect and Per se performance of parents for fodder yield and its components in forage sorghum (*Sorghum bicolor* L. Moench)

| Parents | Days to 50% flowering | Plant height (cm) | Leaves per plant | Leaf breadth (cm) | Leaf length (cm) | Leaf area ($cm^2$) | Stem girth (mm) | Leaf stem ratio | Green fodder yield (g/plant) |
|---|---|---|---|---|---|---|---|---|---|
| UP Chari-1 | -4.29** | 14.85** | 0.35 | 0.93** | 1.66** | 5.46** | 0.94** | 2.09** | 69.40** |
| HC-308 | -0.33 | 8.92** | 0.46 | 0.45 | 3.51** | 26.94** | 0.11 | 1.07** | 79.61** |
| UP Chari-2 | 5.13** | 9.07** | 0.98** | -0.25 | 3.18** | 41.22** | 2.00** | -0.04 | -6.34 |
| HC-171 | 2.05** | 8.47** | 0.21 | 0.37 | 1.72** | 28.81** | -0.53 | 1.01** | 39.88** |
| Pant Chari-8 | -0.19 | 15.27** | 0.97 | -0.17 | 3.55** | 40.78** | -0.62 | -0.03 | -5.55 |
| CSV-17 | 1.47** | 24.33** | 1.55** | 0.04 | 0.59 | 3.77** | 1.08** | -0.01 | 5.61 |
| Pant Chari-6 | -0.02 | -17.60** | 1.19** | 0.04 | -0.74 | 4.26** | 0.87 | 2.06** | 57.12** |
| CSV-84 | -0.22 | -22.27** | 11.45** | 0.09 | 1.35** | 10.36** | -0.31 | -0.05 | 74.19** |
| Pant Chari-5 | 6.48** | 22.36** | 1.58** | -0.06 | 1.57** | 5.23** | 1.87** | -0.04 | 80.25** |
| Rajasthan Chari-1 | 1.64** | -6.04** | -0.72 | 0.04 | 1.22** | -0.62 | -0.03 | -0.06 | 48.97** |
| SE (gi) | 0.20 | 0.62 | 0.09 | 0.04 | 0.25 | 0.68 | 0.08 | 0.02 | 0.82 |
| SE (gi-gj) | 0.31 | 2.64 | 0.17 | 0.06 | 0.37 | 1.02 | 0.33 | 0.03 | 1.22 |

**Table 3:** Estimation of SCA effect and per se performance of crosses for yield component in sorghum (*Sorghum bicolor* L. Moench)

| S. No. | Parents | Days to 50% flowering | | Plant height (cm) | | Leaves per plant | | Leaf breadth (cm) | | Leaf length (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SCA Effect | Mean | SCA Effect | Mean | SCA Effect | Mean | SCA Effect | Mean | SCA Effect | Mean |
| 1 | UP Chari-1 x HC 308 | 6.86** | 92.00 | 35.68** | 236.79 | 3.53** | 14.03 | 1.23** | 6.59 | 9.02** | 74.07 |
| 2 | UP Chari-1 x UP Chari-2 | -0.60 | 80.73 | -10.58** | 223.90 | -0.47 | 10.60 | -0.32 | 5.35 | -3.04** | 64.37 |
| 3 | UP Chari-1 x HC-171 | -3.08** | 85.33 | 23.09** | 275.11 | -0.13 | 12.13 | 0.43 | 6.71 | 2.59** | 73.89 |
| 4 | UP Chari-1 x Pant Chari-8 | 0.06 | 90.33 | 3.72 | 262.53 | 0.25 | 13.27 | -0.16 | 5.58 | 0.36 | 67.40 |
| 5 | UP Chari-1 x CSV-17 | -2.66** | 86.33 | 16.33** | 284.21 | -0.93 | 12.67 | -0.40 | 5.55 | 2.45** | 73.63 |
| 6 | UP Chari-1 x Pant Chari-6 | 1.23** | 91.67 | 7.22 | 268.37 | 1.16** | 14.40 | -0.51** | 5.44 | -2.18** | 67.67 |
| 7 | UP Chari-1 x CSV-84 | -0.58 | 86.67 | -1.25 | 220.03 | 0.33 | 10.93 | -0.05 | 5.95 | 1.04** | 72.98 |
| 8 | UP Chari-1 x Pant Chari-5 | -2.61** | 94.33 | -4.49 | 216.70 | -1.14** | 9.33 | -0.27 | 5.58 | 0.39 | 69.41 |
| 9 | UP Chari-1 x Rajasthan Chari-1 | 4.56** | 96.67 | 37.73** | 229.77 | 4.20** | 11.13 | 1.68** | 6.63 | 8.92** | 72.73 |
| 10 | HC 308 x UP Chari-2 | 2.28** | 83.00 | 12.74** | 270.99 | 1.76** | 12.93 | 0.42 | 7.07 | 5.73** | 74.99 |
| 11 | HC 308 x HC-171 | 5.80** | 80.00 | 32.33** | 273.45 | 3.30** | 12.07 | 1.56** | 5.70 | 9.60** | 63.55 |
| 12 | HC 308 x Pant Chari-8 | -1.66** | 84.00 | 10.44** | 293.03 | -1.52** | 11.60 | 0.81** | 7.53 | -4.43** | 64.46 |
| 13 | HC 308 x CSV-17 | 5.62** | 88.00 | 22.87** | 268.77 | 2.16** | 13.87 | 0.91** | 7.35 | 7.76** | 76.79 |
| 14 | HC 308 x Pant Chari-6 | -1.82** | 84.00 | 21.10** | 306.01 | -0.08 | 13.27 | -0.07 | 6.87 | 0.71 | 72.40 |
| 15 | HC 308 x CSV-84 | -0.30 | 82.33 | -5.08 | 239.96 | -1.11** | 9.60 | 0.27 | 7.26 | 0.93 | 74.72 |
| 16 | HC 308 x Pant Chari-5 | 0.34 | 92.67 | -12.31** | 232.65 | -2.28** | 8.30 | -0.12 | 6.71 | 0.58 | 71.45 |
| 17 | HC 308 x Rajasthan Chari-1 | -0.82 | 86.67 | -0.41 | 260.87 | 0.56 | 12.00 | -0.24 | 6.70 | 0.23 | 73.89 |
| 18 | UP Chari-2 x HC-171 | -1.00 | 78.00 | -10.24** | 247.56 | -0.07 | 10.87 | 0.37 | 6.93 | 1.61** | 68.07 |
| 19 | UP Chari-2 x Pant Chari-8 | 4.81** | 85.67 | 3.76 | 268.35 | 1.58** | 13.27 | 0.64** | 6.67 | 9.46** | 71.65 |
| 20 | UP Chari-2 x CSV-17 | -0.58 | 79.00 | 12.20** | 285.85 | -0.47 | 11.80 | 0.43 | 6.67 | -1.96** | 64.37 |
| 21 | UP Chari-2 x Pant Chari-6 | 1.98** | 83.00 | 18.84** | 285.76 | -2.54** | 9.37 | -0.04 | 6.20 | -1.62** | 63.38 |
| 22 | UP Chari-2 x CSV-84 | -3.50** | 74.33 | 4.29 | 231.35 | 0.06 | 9.33 | 0.20 | 6.49 | 4.77** | 71.87 |
| 23 | UP Chari-2 x Pant Chari-5 | 5.14** | 92.67 | 3.70 | 230.67 | -0.68 | 8.47 | -0.35 | 5.79 | 0.10 | 64.28 |
| 24 | UP Chari-2 x Rajasthan Chari-1 | 1.31** | 84.00 | -8.63 | 234.65 | -0.10 | 9.90 | 0.26 | 6.50 | 0.17 | 67.15 |
| 25 | HC-171 x Pant Chari-8 | 0.40 | 87.33 | -24.98** | 257.15 | -1.15** | 11.73 | 0.16 | 6.80 | 4.09** | 70.19 |
| 26 | HC-171 x CSV-17 | -0.32 | 82.33 | -17.07** | 274.12 | -0.20 | 13.27 | -0.04 | 6.81 | 3.44** | 73.67 |
| 27 | HC-171 x Pant Chari-6 | 0.90 | 85.00 | 5.61 | 290.07 | 1.30** | 14.40 | 0.07 | 6.93 | -0.75 | 68.16 |
| 28 | HC-171 x CSV-84 | 6.43** | 81.33 | 27.65** | 216.94 | 3.20** | 10.27 | 0.96** | 6.74 | 9.21** | 61.79 |
| 29 | HC-171 x Pant Chari-5 | -1.94** | 88.67 | -2.95 | 241.55 | 0.53 | 10.87 | 0.36 | 7.11 | 4.09** | 72.17 |
| 30 | HC-171 x Rajasthan Chari-1 | 4.23** | 90.00 | 43.09** | 303.91 | -0.20 | 11.00 | -0.04 | 6.82 | -4.34** | 66.53 |
| 31 | Pant Chari-8x CSV-17 | 0.48 | 85.00 | 25.36** | 323.35 | -0.28 | 13.93 | -0.04 | 6.28 | -5.45** | 60.52 |
| 32 | Pant Chari-8x Pant Chari-6 | 0.04 | 86.00 | -3.10 | 288.17 | 0.31 | 14.17 | 0.11 | 6.43 | 6.53** | 71.16 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | Pant Chari-8x CSV-84 | -0.44 | 82.33 | 41.92** | 293.31 | 1.45** | 12.67 | -0.07 | 6.30 | -2.90** | 63.83 |
| 34 | Pant Chari-8x Pant Chari-5 | -1.80** | 90.67 | -7.35 | 243.95 | 0.51 | 11.60 | 0.04 | 6.25 | -0.15 | 63.66 |
| 35 | Pant Chari-8 x Rajasthan Chari-1 | -3.30** | 84.33 | -0.05 | 267.57 | -0.02 | 11.93 | -0.53** | 5.79 | -2.75** | 63.85 |
| 36 | CSV-17 x Pant Chari-6 | -1.69** | 83.00 | -24.35** | 275.97 | 0.49 | 14.93 | 0.12 | 6.65 | 0.33 | 69.10 |
| 37 | CSV-17 x CSV-84 | 3.51** | 85.00 | 38.21** | 298.66 | 3.13** | 14.93 | -0.06 | 6.52 | -4.33** | 66.53 |
| 38 | CSV-17 x Pant Chari-5 | -0.19 | 91.00 | -16.58** | 243.78 | -1.08** | 10.60 | -0.08 | 6.35 | -7.42** | 60.52 |
| 39 | CSV-17 x Rajasthan Chari-1 | -1.69** | 84.67 | -3.74 | 272.95 | -1.73** | 10.80 | -0.13 | 6.40 | 0.41 | 71.15 |
| 40 | Pant Chari-6 x CSV-84 | 1.06** | 84.00 | -8.14 | 245.58 | -2.45** | 9.00 | 0.19 | 6.77 | -5.71** | 63.83 |
| 41 | Pant Chari-6 x Pant Chari-5 | -2.63** | 90.00 | 26.37** | 280.00 | 2.75** | 14.07 | -0.02 | 6.40 | -3.74** | 62.87 |
| 42 | Pant Chari-6 x Rajasthan Chari-1 | -0.80 | 87.00 | -20.04** | 249.91 | -1.04** | 11.13 | 0.59** | 7.12 | 2.08** | 71.49 |
| 43 | CSV-84 x Pant Chari-5 | -1.44** | 88.00 | -3.48 | 210.28 | 0.56 | 9.24 | 0.26 | 6.73 | 3.06** | 71.77 |
| 44 | CSV-84 x Rajasthan Chari-1 | -1.27** | 83.33 | -18.49** | 211.59 | 0.40 | 9.93 | -0.13 | 6.45 | 4.12** | 75.63 |
| 45 | Pant Chari-5 x Rajasthan Chari-1 | 6.70** | 95.00 | 45.36** | 235.35 | 2.79** | 11.20 | 0.69** | 6.31 | 4.27** | 68.85 |
| | SE (sij) | 0.70 | | 2.11 | | 0.33 | | 0.14 | | 0.85 | |
| | SE (sij-sik) | 1.03 | | 3.10 | | 0.48 | | 0.21 | | 1.26 | |

| S. No. | Parents | Leaf area ($cm^2$) | | Stem girth (mm) | | Leaf stem ratio | | Total soluble solids (%) | | Green fodder yield (g/plant) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SCA Effect | Mean | SCA Effect | Mean | SCA Effect | Mean | SCA Effect | Mean | SCA Effect | Mean |
| 1 | UP Chari-1 x HC 308 | 30.67** | 378.16 | 5.11** | 17.89 | 0.02 | 0.48 | 0.77** | 7.78 | 49.88** | 552.55 |
| 2 | UP Chari-1 x UP Chari-2 | -6.09 | 273.24 | 1.02** | 15.70 | -0.05 | 0.31 | -0.20 | 7.19 | 25.14** | 481.86 |
| 3 | UP Chari-1 x HC-171 | 16.45** | 365.80 | -1.33** | 14.82 | 0.02 | 0.44 | 0.41 | 8.21 | -18.87 | 434.31 |
| 4 | UP Chari-1 x Pant Chari-8 | -23.38** | 256.39 | -0.74 | 15.33 | 0.00 | 0.37 | -0.26 | 7.69 | 22.96** | 490.47 |
| 5 | UP Chari-1 x CSV-17 | 10.66** | 334.97 | 0.62 | 18.38 | -0.08 | 0.31 | 0.02 | 8.36 | -12.35 | 455.10 |
| 6 | UP Chari-1 x Pant Chari-6 | -14.03** | 310.77 | -0.94 | 16.61 | -0.14 | 0.31 | 0.20 | 7.70 | -0.54 | 435.40 |
| 7 | UP Chari-1 x CSV-84 | 7.91 | 338.81 | -0.15 | 16.22 | 0.08 | 0.43 | -0.13 | 7.33 | -19.48 | 547.77 |
| 8 | UP Chari-1 x Pant Chari-5 | -0.17 | 315.15 | -0.07 | 18.48 | 0.01 | 0.37 | -0.30 | 7.03 | 4.20 | 532.11 |
| 9 | UP Chari-1 x Rajasthan Chari-1 | 89.47** | 318.69 | 4.99** | 16.65 | 0.89** | 0.43 | 0.66** | 7.20 | 62.29** | 446.37 |
| 10 | HC 308 x UP Chari-2 | 81.77** | 382.58 | 1.33** | 16.55 | -0.01 | 0.33 | 0.52** | 8.70 | 27.73** | 369.21 |
| 11 | HC 308 x HC-171 | 75.91** | 294.93 | 5.00** | 14.70 | 0.72** | 0.37 | 0.99** | 8.00 | 72.36** | 321.03 |
| 12 | HC 308 x Pant Chari-8 | -21.63** | 279.62 | -0.59 | 16.03 | -0.04 | 0.31 | 0.22 | 8.57 | 36.15** | 443.88 |
| 13 | HC 308 x CSV-17 | 69.67** | 316.13 | 5.39** | 17.92 | 0.61** | 0.38 | 0.63** | 8.10 | 59.28** | 466.95 |
| 14 | HC 308 x Pant Chari-6 | -18.70** | 327.59 | 0.88 | 18.98 | 0.04 | 0.47 | -0.49 | 7.40 | 34.63** | 410.79 |
| 15 | HC 308 x CSV-84 | -19.68** | 332.70 | -0.46 | 16.46 | 0.07 | 0.39 | -0.29 | 7.56 | -10.98 | 496.49 |
| 16 | HC 308 x Pant Chari-5 | 26.76** | 363.56 | -0.98 | 18.13 | 0.09 | 0.42 | -0.01 | 7.71 | 5.62 | 519.14 |
| 17 | HC 308 x Rajasthan Chari-1 | -12.49** | 337.15 | 0.65 | 17.85 | -0.01 | 0.31 | -0.21 | 8.03 | -1.46 | 382.84 |
| 18 | UP Chari-2 x HC-171 | -17.63** | 285.05 | -0.47 | 14.11 | -0.02 | 0.26 | -0.61** | 7.26 | 22.20** | 325.25 |
| 19 | UP Chari-2 x Pant Chari-8 | 4.70 | 237.79 | 1.89** | 16.39 | 0.04 | 0.28 | 0.28 | 8.30 | 31.87** | 393.65 |
| 20 | UP Chari-2 x CSV-17 | -7.33 | 270.31 | -0.77 | 15.43 | 0.03 | 0.29 | 0.07 | 8.48 | 37.17** | 324.55 |
| 21 | UP Chari-2 x Pant Chari-6 | 13.98** | 292.11 | -0.55 | 15.44 | 0.06 | 0.39 | -0.05 | 7.51 | -7.09 | 323.12 |
| 22 | UP Chari-2 x CSV-84 | 19.44** | 303.66 | -0.31 | 14.50 | 0.01 | 0.23 | -0.25 | 7.28 | 11.59 | 473.11 |
| 23 | UP Chari-2 x Pant Chari-5 | -38.35** | 230.29 | -1.89** | 15.10 | 0.03 | 0.23 | -0.04 | 7.36 | 17.53 | 485.10 |
| 24 | UP Chari-2 x Rajasthan Chari-1 | 8.49 | 289.97 | -0.51 | 14.57 | 0.02 | 0.22 | 0.84 | 8.76 | 24.78** | 313.58 |
| 25 | HC-171 x Pant Chari-8 | -8.95 | 294.17 | -0.25 | 15.72 | 0.11 | 0.41 | -0.06 | 8.37 | 21.48** | 336.75 |
| 26 | HC-171 x CSV-17 | 11.00** | 358.66 | 0.35 | 18.03 | 0.04 | 0.35 | 0.23 | 9.05 | 13.95 | 372.13 |
| 27 | HC-171 x Pant Chari-6 | 4.42 | 352.58 | 0.26 | 17.72 | 0.09 | 0.38 | -0.25 | 7.73 | 0.77 | 327.43 |
| 28 | HC-171 x CSV-84 | 31.32** | 352.93 | 5.72** | 17.00 | 0.74** | 0.23 | 0.82** | 7.62 | 83.10** | 541.08 |
| 29 | HC-171 x Pant Chari-5 | 29.83** | 368.50 | 3.27** | 21.73 | -0.03 | 0.25 | 0.18 | 7.99 | 27.50** | 491.53 |
| 30 | HC-171 x Rajasthan Chari-1 | 37.07** | 388.58 | -0.51 | 16.05 | 0.51** | 0.27 | 0.02 | 8.35 | -17.95 | 316.86 |
| 31 | Pant Chari-8x CSV-17 | 11.03** | 289.10 | 0.20 | 17.79 | -0.03 | 0.24 | 0.14 | 9.11 | 6.88 | 379.39 |
| 32 | Pant Chari-8x Pant Chari-6 | 24.12** | 302.69 | -0.29 | 17.08 | 0.03 | 0.37 | 0.01 | 8.14 | -4.48 | 336.52 |
| 33 | Pant Chari-8x CSV-84 | -4.23 | 280.43 | 0.80 | 17.00 | -0.01 | 0.22 | -0.19 | 7.90 | -3.37 | 468.94 |
| 34 | Pant Chari-8x Pant Chari-5 | -18.48** | 250.60 | -0.05 | 18.33 | 0.04 | 0.23 | 0.23 | 8.19 | -9.65 | 468.71 |
| 35 | Pant Chari-8 x Rajasthan Chari-1 | 8.33 | 290.25 | 0.00 | 16.47 | 0.07 | 0.22 | 0.18 | 8.67 | 21.31** | 327.84 |
| 36 | CSV-17 x Pant Chari-6 | 6.11 | 329.23 | -0.34 | 18.73 | 0.06 | 0.41 | -0.60** | 7.92 | -12.70 | 328.23 |
| 37 | CSV-17 x CSV-84 | -6.50 | 322.71 | 0.81 | 18.71 | -0.03 | 0.22 | 0.17 | 8.65 | 0.97 | 473.22 |
| 38 | CSV-17 x Pant Chari-5 | 0.13 | 313.76 | -0.27 | 19.81 | 0.06 | 0.32 | 0.65** | 9.00 | 19.37 | 497.67 |
| 39 | CSV-17 x Rajasthan Chari-1 | -11.85** | 314.62 | 0.04 | 18.21 | -0.02 | 0.22 | -0.21 | 8.67 | 24.90** | 324.19 |
| 40 | Pant Chari-6 x CSV-84 | -7.30 | 322.41 | 0.84 | 18.52 | 0.04 | 0.35 | 0.46 | 8.10 | -4.24 | 436.50 |
| 41 | Pant Chari-6 x Pant Chari-5 | 1.78 | 315.90 | 0.30 | 20.17 | -0.09 | 0.24 | -0.19 | 7.32 | -5.64 | 441.15 |
| 42 | Pant Chari-6 x Rajasthan Chari-1 | -3.12 | 323.85 | -0.67 | 17.29 | -0.03 | 0.28 | 1.03 | 9.07 | 9.30 | 326.87 |
| 43 | CSV-84 x Pant Chari-5 | 2.20 | 322.41 | -1.61 | 17.07 | -0.05 | 0.17 | -0.05 | 7.42 | 25.81** | 552.29 |
| 44 | CSV-84 x Rajasthan Chari-1 | 0.63 | 333.69 | -0.06 | 16.73 | -0.03 | 0.18 | -0.14 | 7.85 | 30.87** | 479.76 |
| 45 | Pant Chari-5 x Rajasthan Chari-1 | 32.98** | 314.49 | 1.52** | 20.48 | -0.01 | 0.21 | 0.83** | 7.54 | 97.82** | 552.77 |
| | SE (sij) | 2.31 | | 0.27 | | 0.01 | | 0.10 | | 2.76 | |
| | SE (sij-sik) | 3.39 | | 0.39 | | 0.01 | | 0.15 | | 4.06 | |

## Conclusion

Analysis of variance for parents and crosses showed highly differed significantly for all the characters. Parents vs crosses exhibited highly significant for the attributes namely, days to 50% flowering, plant height, leaf breadth, leaf length, leaf area and green fodder yield, which indicated that wide genotypic differences among the parental lines and F1's hybrids. UP Chari- 1 and Pant Chari-5 were identified as good general combiners for maximum 7 traits including green fodder yield, HC-171 for 6 characters and HC-308 for 5 attributes., suggested that these parents may be used in the hybridization programme aimed devolvement of superior genotypes/varieties in forage sorghum. UP Chari-1 x HC-308, UP Chari-1 x Rajasthan Chari-1, HC-308 x UP Chari-2, HC-308 x HC- 171, HC-308 x CSV-17, HC-171 x CSV-84 and Pant Chari-5 x Rajasthan Chari-1 were identified as best specific combiners for maximum attributes including green fodder yield for 9 to 10 other contributing traits, which may be utilized for obtaining trans gressive segregates in the next generation.

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