SUPPLEMENTARY MATERIAL AVAILABLE ONLINE

Indian Journal of Agricultural Sciences **96** (3): 287–292, March 2026/Article
https://doi.org/10.56093/ijas.v96i3.164484

Assessment of combining ability, heterosis and heterotic status of grain sorghum (*Sorghum bicolor*) hybrids

KARTIK SHIVANAND ANGADI[1]*, SOMU G[2] and VIJAY KUMAR L[3]

AICRP on Sorghum (University of Agricultural Sciences, Bengaluru, Karnataka),
Chamarajanagar, Karnataka 571 127, India

Received: 04 February 2025; Accepted: 26 February 2026

ABSTRACT

The study was carried out during rainy (*kharif*) season of 2023 and 2024 at AICRP on Sorghum, Agriculture Research Station, Chamarajanagar, Karnataka to study the magnitude of combining ability and quantify the extent of heterosis among 40 hybrids, which were evaluated in comparison with two checks (CSH-30 and CSH-14) in randomised complete block design (RCBD). The parental materials consisted of four male sterile lines, viz. 279 A, 463 A, 456 A and 415 A and 10 restorer lines namely SOR 3350, SOR 3289, SOR 11938, SOR 11942, SOR 11943, SOR 3182, SOR 6852, SOR 5002, SOR 3570 and SOR 4346. Parents 456 A and SOR 3570 (with GCA status 'H') were ascertained as the best general combiners for most of the yield and its component traits. The elite crosses, namely, 456 A × SOR 3570, 463 A × SOR 3570 and 463 A × SOR 4346 were identified with high per se performance, highly significant SCA effects coupled with highly significant standard heterotic effects for grain yield/plant over both the checks and overall heterotic status of these hybrids were of either H × H or H × L/L × H cross combinations.

Keywords: Combining ability, Heterosis, Overall heterotic status, Sorghum

Sorghum [*Sorghum bicolor* (L.) Moench] which is said to have been originated in Africa, has been classified under the family Poaceae, sub-family Panicoideae, tribe Andropogoneae with diploid chromosome number 2n = 20 and a genome size of 730 Mb (Paterson *et al.* 2004). Being a vital millet crop, it occupies the 5th position globally after wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), maize (*Zea mays* L.) and barley (*Hordeum vulgare* L.), serving as a principal staple for over 300 million people and fodder for livestock across Asia and Africa (Tanwar *et al.* 2023).

In India, where the population continues to rise and cultivable land is limited, enhancing crop productivity is essential for ensuring food and nutritional security (Rana *et al.* 1998). Despite historical successes in increasing sorghum productivity, there's a constant need for further enhancement due to increased demand and environmental pressures. Although heterosis and combining ability studies are classical breeding approaches, they remain highly relevant for identifying superior parental lines and hybrids capable of sustaining yield under diverse agro-ecological conditions. Continuous evaluation of combining ability and heterosis is necessary to develop high-yielding, stable hybrids and to formulate appropriate breeding strategies for maximising productivity (Patil *et al.* 2014).

Combining ability analysis provides beneficial insights concerning the selection of parental lines based on hybrid performance. This analytical approach elucidates the nature and magnitude of distinct categories of gene action governing the manifestation of quantitative traits (Dhillon 1975). Sprague and Tatum (1942) characterised general combining ability (GCA) as 'The average performance of a line in hybrid combinations' and specific combining ability (SCA) as 'Instances wherein particular combinations perform relatively superior or inferior than anticipated from the average performance of involved lines.'

Heterosis has been designated as a crucial milestone in plant breeding, uncovering hybrid potential. The extent and direction of heterosis are critically important. It is imperative to evaluate the existence of pronounced heterotic effects in productivity for harnessing hybrid vigour. The yield and its component traits are often interrelated, either positively or negatively. Parents may exhibit desirable GCA for certain traits and unfavourable effects for others, while crosses may show variable SCA or heterosis. Therefore, GCA, SCA and overall heterotic status are determined by considering the performances of parents and hybrids across all yield and yield-attributing traits, which aids in the selection of the

---

[1]Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga, Karnataka; [2]AICRP on Sorghum (University of Agricultural Sciences, Bengaluru, Karnataka), Chamarajanagar, Karnataka; [3]University of Agricultural Sciences, Bengaluru, Karnataka. *Corresponding author email: akartik2016@gmail.com

right parents as well as hybrids (Soumya *et al.* 2018). Hence, initiatives were made to study the heterosis and combining ability effects for yield and its component traits in sorghum to quantify the superior hybrids and parents for yield and its contributing traits.

MATERIALS AND METHODS

The study was carried out during rainy (*kharif*) seasons of 2023 and 2024 at AICRP on Sorghum, Agriculture Research Station, Chamarajanagar (11.9307° N, 76.9328° E), Karnataka. The parental materials consisted of four male sterile lines, viz. 279 A, 463 A, 456 A and 415 A and ten restorer lines namely SOR 3350, SOR 3289, SOR 11938, SOR 11942, SOR 11943, SOR 3182, SOR 6852, SOR 5002, SOR 3570 and SOR 4346. In *kharif* 2023, crossing between male sterile lines (female) and restorer lines (male) was carried out in an L × T (Line × Tester) mating design, resulting in 40 hybrids. In the second season i.e. *kharif* 2024, evaluation of the resultant 40 hybrids along with two checks (CSH-30 and CSH-14) was implemented in randomised complete block design (RCBD). Each experimental plot encompassed two rows, each extending 4 m in length, with an inter-row spacing of 45 cm and an intra-row spacing of 10 cm. Standard agronomic practices, meticulously adhered to, were employed to cultivate a thriving crop, ensuring optimal phenotypic expression of the desired traits. The observations were recorded on five randomly selected F_1 plants from each genotype in each replication for all the traits, viz. Days to 50 per cent flowering (DFF), Days to maturity (DM), Plant height (cm) (PHT), Number of leaves/plant (NL), Leaf length (cm) (LL), Ear head length (cm) (EHL), Ear head width (cm) (EHW), Ear head weight (g) (EHWT), Number of primary branches/panicle (NPP), 100-seed weight (g) (HSW), Stem diameter (SD) and Grain yield/plant (g) (GYPP). The mean values were computed and subjected to statistical analysis in WINDOWSTAT 9.2. The overall status of a parent or cross with respect to GCA effects or SCA effects and heterosis respectively, was determined by a method suggested by Arunachalam and Bandyopadhyay (1979), which was further modified by Mohan Rao *et al.* (2004).

RESULTS AND DISCUSSION

Combining ability analysis: The variations among parents were exceedingly significant across all characters (Supplementary Table 1). ANOVA for combining ability (Supplementary Table 2) inferred that high significance of line × tester influence for all the quantitative traits being studied suggested that non-additive gene action (such as dominance and epistasis) plays a paramount role in the expression of the characteristics studied. This evokes that, the interaction between lines and testers is a key contributor to the observed variation. Similar effects were observed in the previous findings of El-Sherbeny *et al.* (2019), Saikiran *et al.* (2021), Vinoth *et al.* (2021) and Kavya *et al.* (2022). A very low ratio of σ^2 GCA /σ^2 SCA (less than unity) was observed for all the traits (Fig. 1), which implies that the magnitude of Specific combining ability (SCA) variance was higher than that of General combining ability (GCA) variance, indicating the presence of non-additive gene action for all the traits. Thus, non-additive gene action played an important role in the inheritance of all the characters, which emphasised the use of the heterosis breeding approach to exploit the available vigour. The preponderance of non-additive type of gene action in sorghum was reported earlier by Kumar and Chand (2015), Patil and Kute (2015), Dehinwal *et al.* (2017) and Jadhav and Deshmukh (2017).

General Combining Ability (GCA) and GCA status of lines and testers: For the principal trait grain yield/plant (GYPP), the parents SOR 3570 (24.78), SOR 5002 (5.51), 463 B (5.70), SOR 3350 (4.25) and 456 B (3.52) displayed favourable GCA effects, indicating their potential contribution to enhancing yield through their genetic influence (Table 1, Supplementary Table 3). High GCA estimates suggested the importance of additive gene action in the inheritance of the trait and these parents are more likely to contribute positively to the general performance of hybrids, making it pivotal in parent selection strategies (Fasahat *et al.* 2016). A similar trend was observed in the previous research of Saikiran *et al.* (2021), Kavya *et al.* (2022), ABD- Elraheem *et al.* (2023) and Pattanashetti *et al.* (2025). The GCA status of the parents, when ascertained

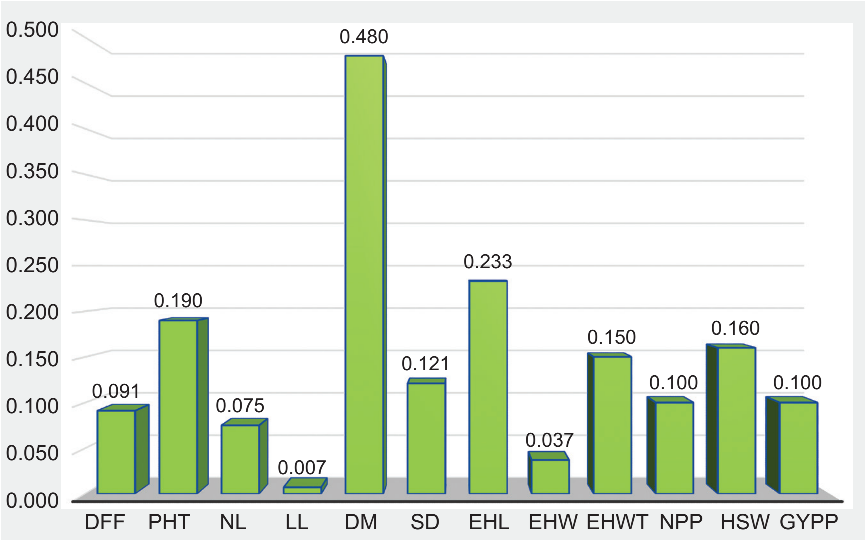

Fig. 1 Estimates of σ^2 GCA/ σ^2 SCA variances for all yield and yield attributing traits of Sorghum hybrids.
DFF, Days to fifty per cent flowering; PHT, Plant height (cm); NL, No. of leaves/plant; LL, Leaf length (cm); DM, Days to maturity; SD, Stem diameter (mm); EHL, Ear head length (cm); EHW, Ear head width (cm); EHWT, Ear head weight (g); NPP, Number of primary branches/panicle; HSW, 100-seed weight (g); GYPP, Grain yield/plant (g).

Table 1 Estimates of GCA effects of lines and testers for the trait GYPP

Lines	GCA for GYPP
SOR 3350	4.25 **
SOR 3289	1.74
SOR 11938	-7.12**
SOR 11942	-2.84**
SOR 11943	-3.50 **
SOR 3182	-24.03 **
SOR 6852	2.03
SOR 5002	5.51 **
SOR 3570	24.78 **
SOR 4346	-0.84
SEM±	0.65
CD (p=0.05)	1.32
CD (p=0.01)	1.77
Testers	**GCA for GYPP**
279 B	-0.51
463 B	5.70**
456 B	3.52**
415 B	-8.71**
SEM±	1.03
CD (p=0.05)	2.09
CD (p=0.01)	2.80

* Significant at p=0.05; ** Significant at p=0.01; GCA, General combining ability; GYPP, Grain yield/plant.

Table 2 Estimates of specific combining ability effects of sorghum hybrids for the trait grain yield/plant

Cross combinations	SCA effects for GYPP
279 A × SOR3350	11.68 **
279 A × SOR 3289	-2.16
279 A × SOR 11938	16.16**
279 A × SOR 11942	1.166
279 A × SOR 11943	-12.20**
279 A × SOR 3182	17.15**
279 A × SOR 6852	-10.97**
279 A × SOR 5002	17.78**
279 A × SOR 3570	-50.63**
279 A × SOR 4346	12.03**
463 A × SOR 3350	-36.71 **
463 A × SOR 3289	-22.13 **
463 A × SOR 11938	-9.85 **
463 A × SOR 11942	34.21 **
463 A × SOR 11943	-1.51
463 A × SOR 3182	-6.53 **
463 A × SOR 6852	-17.24 **
463 A × SOR 5002	-8.05 **
463 A × SOR 3570	22.96 **
463 A × SOR 4346	44.86 **
456 A × SOR 3350	-14.02 **
456 A × SOR 3289	19.98 **
456 A × SOR 11938	-21.81 **
456 A × SOR 11942	-27.94 **
456 A × SOR 11943	-1.98
456 A × SOR 3182	-10.90 **
456 A × SOR 6852	40.29 **
456 A × SOR 5002	14.71 **
456 A × SOR 3570	38.10 **
456 A × SOR 4346	-36.43 **
415 A × SOR 3350	39.07 **
415 A × SOR 3289	4.31 *
415 A × SOR 11938	15.50 **
415 A × SOR 11942	-7.44 **
415 A × SOR 11943	15.70 **
415 A × SOR 3182	0.28
415 A × SOR 6852	-12.08 **
415 A × SOR 5002	-24.44 **
415 A × SOR 3570	-10.43 **
415 A × SOR 4346	-20.46 **
SEM±	2.07
CD (p=0.05)	4.19
CD (p=0.01)	5.62

* Significant at p=0.05; ** Significant at p=0.01; SCA, Specific combining ability; GYPP, Grain yield/plant.

over all the characters, showed that 50% of the parents had GCA status allotted 'H' (High overall GCA status) (Supplementary Table 4). Hence, by this data, we can conclude that the parents, SOR 3570 and 456 B (both with High overall GCA status), were recognised as valuable reservoirs of advantageous genes, pivotal for augmenting grain yield through an array of yield-contributing attributes, as they had greater GCA effects for many yield-attributing characters, along with that of grain yield/plant. It was ascertained that employing these parental lines to enhance grain productivity in sorghum would yield greater economic returns. Consequently, it becomes imperative to thoroughly comprehend the combining ability of these parental lines, particularly within the context of hybrid cultivar development, to refine and optimise the breeding strategy.

Specific Combining Ability (SCA) and SCA status of hybrids: In essence, Specific Combining Ability (SCA) is predominantly governed by non-additive genetic influences, including factors like dominance and intricate epistatic interactions between genes (Begna 2021). These non-additive effects play a fundamental role in determining the hybrid vigour or heterosis exhibited by specific parental pairings, making SCA a crucial metric in evaluating the genetic potential and compatibility of parental lines in hybrid breeding programmes. The SCA effects of all the crosses for the trait grain yield/plant (GYPP) are displayed

Table 3 Estimates of standard heterosis in comparison with two checks for yield and yield attributing traits in sorghum hybrids

S. no.	Hybrids	GYPP		S. No.	Hybrids	GYPP	
		CSH-30	CSH-14			CSH-30	CSH-14
1	279 A × SOR 3350	0.19	2.5	21	456 A × SOR 3350	-24.29 **	-22.54 **
2	279 A × SOR 3289	-18.27 **	-16.38 **	22	456 A × SOR 3289	11.30 **	13.87 **
3	279 A × SOR 11938	-7.57	-5.43	23	456 A × SOR 11938	-45.93 **	-44.68 **
4	279 A × SOR 11942	-19.69 **	-17.83 **	24	456 A × SOR 11942	-48.02 **	-46.82 **
5	279 A × SOR 11943	-35.54 **	-34.05 **	25	456 A × SOR 11943	-19.44 **	-17.57 **
6	279 A × SOR 3182	-25.56 **	-23.84 **	26	456 A × SOR 3182	-52.71 **	-51.62 **
7	279 A × SOR 6852	-27.89 **	-26.23 **	27	456 A × SOR 6852	34.58 **	37.69 **
8	279 A × SOR 5002	8.56	11.07 **	28	456 A × SOR 5002	9.63	12.17 **
9	279 A × SOR 3570	-47.01 **	-45.78 **	29	456 A × SOR 3570	57.80 **	61.45 **
10	279 A × SOR 4346	-5.16	-2.97	30	456 A × SOR 4346	-55.37 **	-54.34 **
11	463 A × SOR 3350	-47.46 **	-46.24 **	31	415 A × SOR 3350	21.88 **	24.70 **
12	463 A × SOR 3289	-33.81 **	-32.28 **	32	415 A × SOR 3289	-20.21 **	-18.37 **
13	463 A × SOR 11938	-29.94 **	-28.32 **	33	415 A × SOR 11938	-17.59 **	-15.68 **
14	463 A × SOR 11942	24.66 **	27.54 **	34	415 A × SOR 11942	-38.67 **	-37.25 **
15	463 A × SOR 11943	-16.44 **	-14.51 **	35	415 A × SOR 11943	-13.28 **	-11.27 **
16	463 A × SOR 3182	-45.31 **	-44.05 **	36	415 A × SOR 3182	-53.90 **	-52.83 **
17	463 A × SOR 6852	-27.97 **	-26.30 **	37	415 A × SOR 6852	-38.42 **	-36.99 **
18	463 A × SOR 5002	-13.62 **	-11.62 **	38	415 A × SOR 5002	-48.42 **	-47.23 **
19	463 A × SOR 3570	43.16 **	46.47 **	39	415 A × SOR 3570	-10.85 *	-8.79
20	463 A × SOR 4346	38.95 **	42.17 **	40	415 A × SOR 4346	-51.13 **	-50.00 **

* Significant at p=0.05; ** Significant at p=0.01; GYPP, Grain yield/plant.

in Table 2, and for other yield and its component traits that were studied are given in Supplementary Table 5. For the trait grain yield/plant, the hybrids that exhibited pivotal positive SCA effects for grain yield/plant were 463 A × SOR 4346 (44.86), 456 A × SOR 6852 (40.29), 415 A × SOR 3350 (39.07), 456 A × SOR 3570 (38.10) and 463 A × SOR 11942 (34.21). When all the traits were taken into consideration, the hybrid 456 A × SOR 3570 had SCA status H × H, while the rest exhibited H × L/L × H SCA status (Supplementary Table 6). These combinations suggested preponderance of non-additive gene action and underscore the relevance of population improvement to enhance genetic diversity and isolate superior genotypes, which can lead to enhanced growth, more effective resource utilisation, and ultimately, expediting the development of high-yielding hybrids (Zhang *et al.* 2024). Selecting these hybrids allows breeders to achieve greater productivity and meet food demands more effectively. Analogous results were reported for SCA effects of all the observed traits in the earlier studies of Saikiran *et al.* (2021), Kavya *et al.* (2022) and Pattanashetti *et al.* (2025).

Heterosis and overall heterotic status of hybrids: By assessing mid-parent heterosis, breeders can evaluate the synergistic effects of specific parent combinations and select those that maximise advantageous traits, thereby optimising hybrid performance and maximising agricultural productivity whereas, better parent heterosis provides critical insights into the potential performance of hybrids, allowing breeders to make informed decisions that can lead to the development of high-yielding and quality crops. The measure of standard heterosis enables breeders to compare new hybrids against established ones, facilitating the selection of commendable crosses for cultivation. Furthermore, standard heterosis aids in breeding programmes focused on developing hybrids with enhanced agronomic traits that meet market demands.

The results revealed that, for the trait grain yield/plant, the hybrids displaying standard heterosis in a positive direction over both checks were 456 A × SOR 3570 (57.8% and 61.45%), 463 A × SOR 3570 (43.16% and 46.47%), 463 A × SOR 4346 (38.95% and 42.17%) 463 A × SOR 4346 (36), 456 A × SOR 6852 (34.58% and 37.69%) and 463 A × SOR 11942 (24.66 % and 27.54%) (Table 3, Supplementary Table 7a and b) (Fig. 2 and 3). These results underscore the potential of these hybrids to contribute to enhanced yield performance in sorghum breeding programmes. The outcomes of the present investigation were similar to the prior reports of Ingle *et al.* (2018), Kalpande *et al.* (2019), Saikiran *et al.* (2021) and Pattanashetti *et al.* (2025). The hybrid 456 A × SOR 3570 displayed an H × H combination, while the remaining four had H × L/L × H combinations (Supplementary Table 8). This highlights the advantage of selecting female parents with high GCA, or at least one parent with superior GCA, to boost heterotic hybrid production. These results emphasise the value of

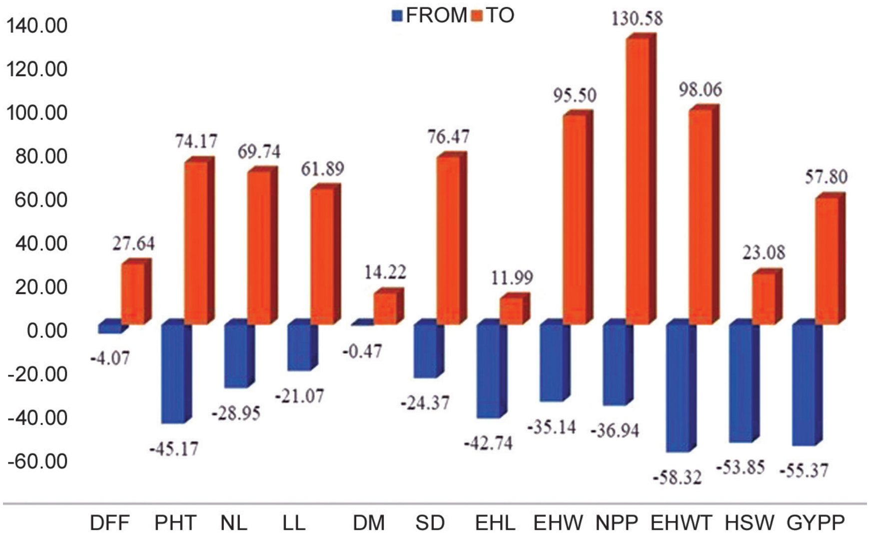

Fig. 2 Range of standard heterosis of sorghum hybrids over CSH-30.
DFF, Days to fifty per cent flowering; PHT, Plant height (cm); NL, No. of leaves/plant; LL, Leaf length (cm); DM, Days to maturity; SD, Stem diameter (mm); EHL, Ear head length (cm); EHW, Ear head width (cm); EHWT, Ear head weight (g); NPP, Number of primary branches/panicle; HSW, 100-seed weight (g); GYPP, Grain yield/plant (g).

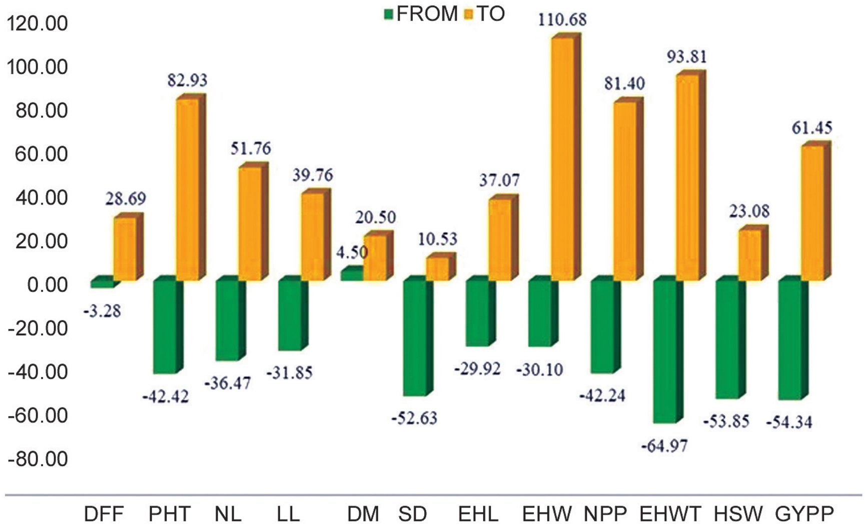

Fig. 3 Range of standard heterosis of sorghum hybrids over CSH-14.
DFF, Days to fifty per cent flowering; PHT, Plant height (cm); NL, No. of leaves/plant; LL, Leaf length (cm); DM, Days to maturity; SD, Stem diameter (mm); EHL, Ear head length (cm); EHW, Ear head width (cm); EHWT, Ear head weight (g); NPP, Number of primary branches/panicle; HSW, 100-seed weight (g); GYPP, Grain yield/plant (g).

using parental lines with contrasting GCA effects for the development of hybrids that not only exhibit strong hybrid vigour but also showed enhanced specific interactions between the parent lines.

The primary aim of the present investigation was to ascertain hybrid combinations that markedly surpassed the standard checks regarding grain productivity and associated yield-determining attributes, whilst simultaneously elucidating eminent general and specific combiners. Among the parental genotypes, SOR3570 R and 456 A were recognised as highly effective general combiners, thereby establishing their potential utility as elite progenitors in future hybridisation programmes. The cross combinations 463 A × SOR 4346, 456 A × SOR 6852, 415 A × SOR 3350, 456 A × SOR 3570, and 463 A × SOR 11942. manifested markedly higher SCA effects and standard heterosis relative to the superior check CSH-30, coupled with enhanced per se performance across the majority of yield-related traits. Accordingly, these potential cross combinations can be subjected to extensive multi-location and multi-environmental evaluations to ascertain the stability and consistency of their superiority. Moreover, systematic screening against biotic and abiotic stress factors is imperative to validate their adaptability and resilience under diverse agro-climatic conditions.

REFERENCES

ABD Elraheem O A Y, Hafeez H M and Ahmed Y M Y. 2023. Heterosis and combining ability in grain sorghum. *Egypt Journal of Plant Breeding* **27**(3): 327–42.

Arunachalam V and Bandyopadhyay A. 1979. Are "multiple cross-multiple pollen hybrids' an answer for productive populations in *Brassica campestris* var. 'brown sarson'? *Theory of Applied Genetics* **54**: 203–07.

Begna T. 2021. Combining ability and heterosis in plant improvement. *Open Journal of Plant Science*. 108–17.

Dehinwal A K, Kumar A, Pahuja S K, Shafiqurrahaman M and Kumar A. 2017. Studies on combining ability for yield and its component traits in forage sorghum. *International Journal of Pure and Applied Bioscience* **5**(5): 493–502.

Dhillon B S. 1975. The application of partial-diallel crosses in plant breeding-A review. *Crop Improvement* **2**(1): 01–08.

El-Sherbeny G A R, Khaled A G A, Hovney M R A and Bahaa A Z. 2019. Combining ability and gene action using line by tester analysis on some new hybrids of grain sorghum under drought conditions. *PKV Resource Journal* **49**(1): 118–29.

Fasahat P, Rajabi A, Rad J M and Derera J. 2016. Principles and utilisation of combining ability in plant breeding. *Biometrics and Biostatistics International Journal* **4**(1): 1–24.

Ingle K P, Gahukar S J, Khelurkar V C, Ghorade R B, Kalpande V V, Jadhav P V and Moharil M P. 2018. Heterosis and combining ability for grain yield trait in *rabi* sorghum (*Sorghum bicolor* L. Moench) using line × tester mating design. *International*

Journal of Current Microbiology and Applied Science **6**: 1925–34.

Jadhav R R and Deshmukh D T. 2017. Heterosis and combining ability studies in sorghum [*Sorghum bicolor* (L.) Moench] over the environments. *International Journal of Current Microbiology and Applied Sciences* **6**(10): 3058–64.

Kalpande H V, Tiwari R and Kalyankar S V. 2019. Heterosis studies for yield, its component and grain mould resistance in sorghum genotype. *Journal of Pharmacognosy and Phytochemistry* **8**(3): 2907–14.

Kavya P, Rao V S, Ramana J V, Sreekanth B, Radhakrishna Y and Umar S N. 2022. Combining ability studies through Line × Tester design in sweet sorghum (*Sorghum bicolor* L.) for bioethanol production. *Electronic Journal of Plant Breeding* **13**(3): 967–73.

Kumar S and Chand P. 2015. Combining ability and heterosis for grain yield, fodder yield and other agronomic traits in sorghum [*Sorghum bicolor* (L.) Moench]. *Journal of Applied and Natural Science* **7**(2): 1001.

Mohan Rao G, Reddy L, Kulkarni R S, Ramesh S and Reddy S L. 2004. Prediction of heterosis based on genetic divergence of parents through regression analysis in sunflower (*Helianthus annuus* L.). *Helia* **27**(41): 51–58.

Paterson A H, Bowers J E and Chapman B A. 2004. Ancient polyploidisation predating divergence of the cereals, and its consequences for comparative genomics. *Proceedings of the National Academy of Sciences* **101**(26): 9903–08.

Patil J V, Reddy P S, Prabhakar U A, Gomashe S and Ganapathy K N. 2014. History of post-rainy season sorghum research in India and strategies for breaking the yield plateau. *Indian Journal of Genetics and Plant Breeding* **74**(3): 271–85.

Patil V R and Kute N S. 2015. Combining ability studies in grain sorghum. *Journal of Global Biosciences* **4**(1): 1902–09.

Pattanashetti B M, Sajjanar G M, Maralappanavar M S, Swaroop K O and Soregaon C D. 2025. Heterosis and combining ability analysis using landrace-based hybrids for yield and yield components in *rabi* sorghum. *Electronic Journal of Plant Breeding* **16**(4): 489–95.

Rana B S, Singh B U, Rao M H, Indira S, Rao S S and Kaul S L. 1998. Sorghum (*Sorghum bicolor*) research in India. *The Indian Journal of Agricultural Sciences* **68**(8): 405–22.

Saikiran V, Shivani D, Maheswaramma S, Sujatha K, Sravanthi K, Ramesh S, Yamini K N and Kumar C S. 2021. Combining ability and heterosis studies in different crop sites for yield and yield contributing traits in sorghum (*Sorghum bicolor* L. Moench). *Electronic Journal of Plant Breeding* **12**(4): 1351–58.

Soumya H H, Gangappa E, Ramesh S, Showkath B M, Rakesh B, Neelavva K, Suneetha N C, Aruna K, Bharti M S and Mahesh G P. 2018. Overall GCA, SCA and heterotic status of maize (*Zea mays* L.) inbreds and hybrids. *International Journal of Pure and Applied Biosciences* **6**(6): 125–30.

Sprague G F and Tatum L A. 1942. General vs. specific combining ability in single crosses of corn. *Journal of American Society of Agronomy* **34**: 923–32.

Tanwar R, Panghal A, Chaudhary G, Kumari A and Chhikara N. 2023. Nutritional, phytochemical and functional potential of sorghum: A review. *Food Chemistry Advances* **3**: 100501.

Vinoth P, Selvi B, Senthil N, Iyanar K, Jeyarani S and Santhiya S. 2021. Estimation of gene action, combining ability and heterosis for yield and yield contributing traits in sorghum [*Sorghum bicolor* (L) Moench]. *Electronic Journal of Plant Breeding* **12**(4): 1387–97.

Zhang Y, Chen J, Gao Z, Wang H, Liang D, Guo Q, Zhang X, Fan X, Wu Y and Liu Q. 2024. Identification of heterosis and combining ability in the hybrids of male sterile and restorer sorghum [*Sorghum bicolor* (L.) Moench] lines. *PloS one* **19**(1): e0296416.