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ASSESSMENT OF HETEROSIS FOR GRAIN YIELD AND YIELD-CONTRIBUTING TRAITS IN CMS-BASED WHEAT (*Triticum aestivum* L.) HYBRIDS

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ABSTRACT

Exploitation of heterosis offers significant potential for improving yield in hybrid wheat. The present study was conducted to evaluate the magnitude of heterosis for grain yield per plant in cytoplasmic male sterile (CMS) based wheat hybrids. A total of 64 hybrids were evaluated and heterosis was estimated over mid-parent, better-parent and the standard check MP 3336. Significant variation was observed among the hybrids for grain yield per plant. Among the evaluated crosses, eight hybrids exhibited significant and desirable positive heterosis across all three measures, namely mid-parent heterosis, heterobeltiosis and economic heterosis. The hybrid 95A × MP3382 recorded the highest heterotic response, surpassing both its parental lines and the standard check, indicating the involvement of additive and non-additive gene effects for yield improvement. Other promising crosses such as 89A × MP3382, 82A × MP3382, 91A × VL3022, 86A × MP3382, 95A × VL3022, 86A × VL3022 and 91A × MP3465 also showed significant positive heterosis. The continuous expression of heterosis in these hybrids highlights their potential utility in hybrid wheat breeding programs aimed at enhancing grain yield. The superior hybrids identified in the present investigation may serve as valuable genetic resources for future wheat improvement projects.

Key words : Hybrid wheat, CMS lines, Heterosis, Grain yield, Hybrid breeding.

Introduction

Wheat (*Triticum aestivum* L.), a polyploid member of the Poaceae family, is one of the most essential and genetically diverse cereal crops cultivated globally. It contributes significantly to food security by providing carbohydrates, proteins, and essential nutrients. Increasing wheat yield has become a significant problem for plant breeders due to a growing population and the scarcity of cultivable land. Therefore, one of the main goals of contemporary wheat breeding projects continues to be the creation of high-yielding cultivars through genetic enhancement.

Wheat occupies a pivotal position in global agriculture owing to its adaptability across diverse agro-climatic conditions and its substantial contribution to human nutrition. It provides approximately 20% of the calories and protein consumed worldwide and serves as a staple

food for a large proportion of the global population. In India, wheat is the second most important cereal crop after rice and plays a vital role in ensuring national food security. Although remarkable progress has been achieved through conventional breeding and improved agronomic practices, the annual rate of yield improvement is becoming insufficient to meet the increasing food demand associated with rapid population growth, climate change, and shrinking cultivable land. Consequently, innovative breeding approaches capable of accelerating genetic gain are essential for sustaining future wheat productivity.

One of the promising approaches for yield improvement is the exploitation of Heterosis, which refers to the superior performance of hybrid offspring compared to their parental lines. In many crops, heterosis has been used extensively to provide notable yield increases. In wheat, evaluation of heterosis for yield and related traits helps in identifying superior hybrid combinations that can

be utilized in breeding programs. The use of Cytoplasmic Male Sterility (CMS) systems has facilitated hybrid seed production by eliminating the need for manual emasculation. CMS-based hybrid breeding enables effective exploitation of heterosis and provides an efficient approach for developing high-yielding hybrids.

Heterosis, commonly referred to as hybrid vigour, is the phenomenon in which F_1 hybrids exhibit superior performance over their parents for one or more economically important traits. This superiority may be expressed through increased grain yield, enhanced biomass production, improved stress tolerance, early maturity, or greater adaptation to diverse environmental conditions. Since the pioneering work of Shull (1908) and East (1908), heterosis has become one of the most important genetic phenomena exploited in crop improvement. Commercial utilization of heterosis has revolutionized the production of crops such as maize, rice, sunflower, pearl millet and several vegetable crops. Although exploitation of heterosis in self-pollinated crops like wheat has been comparatively limited, considerable research has demonstrated the existence of substantial hybrid vigour for yield and its component traits, indicating significant potential for hybrid wheat breeding.

Estimation of heterosis provides valuable information regarding the magnitude of hybrid vigour and the breeding potential of different parental combinations. Mid-parent heterosis reflects the superiority of a hybrid over the average performance of its parents and provides an estimate of the overall genetic advantage achieved through hybridization. Better-parent heterosis, also referred to as heterobeltiosis, measures the superiority of a hybrid over the better-performing parent and is particularly useful for identifying hybrids capable of surpassing elite parental lines. Standard or economic heterosis compares hybrid performance with a commercially cultivated check variety and is considered the most practical criterion for evaluating the commercial potential of newly developed hybrids. Together, these parameters provide a comprehensive assessment of hybrid performance and facilitate the identification of promising cross combinations for future breeding programmes.

In order to access the degree of heterosis for grain yield per plant in CMS-based wheat hybrids relative to their parental lines and the standard check MP 3336, the current study was conducted. The goal of the study was to find viable hybrid combinations that may be used in upcoming wheat hybrid breeding initiatives due to their higher yield performance.

Materials and Methods

The experimental material comprised a total of 88 genotypes, including 16 cytoplasmic male sterile (CMS) lines and 4 restorer lines used as parents. These parental lines were obtained from the Indian Institute of Wheat and Barley Research (IIWBR), Karnal, and the Division of Genetics, Indian Agricultural Research Institute (IARI). In addition, 64 CMS-based F_1 hybrids along with 4 standard check varieties were sourced from the Seed Breeding Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, under the CRP on Hybrid Wheat programme. The field trial was conducted during the Rabi season of 2024–25 at the Seed Breeding Farm, Department of Genetics and Plant Breeding, College of Agriculture, JNKVV, Jabalpur (Madhya Pradesh), India. The experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications. Each experimental unit consisted of two rows of 3 m length, with a row-to-row spacing of 20 cm. The experimental field had medium black soil with a uniform topography and was well-drained, free from waterlogging conditions.

The data were recorded on five randomly selected plants of each genotype for all characters. Observations were recorded on fifteen quantitative traits including days to heading, days to maturity, plant height, number of tillers per plant, spike length, peduncle length, awn length, spike weight, number of spikelets per spike, sterility percentage, thousand grain weight, number of grains per spike, biological yield per plant, harvest index and grain yield per plant.

All recorded observations were analysed using suitable statistical procedures, and heterosis was computed according to the methodology described by Fonseca and Patterson (1968).

Methodology for estimation of Heterosis

Estimation of Heterosis

Heterosis was estimated by comparing the performance of each F_1 hybrid with its respective parental lines and the standard commercial check. Three types of heterosis were calculated: average (mid-parent) heterosis, better parent heterosis, and standard (economic) heterosis. The estimates were expressed as percentages using the following formulae:

Average (Mid-parent) Heterosis

Mid-parent heterosis measures the superiority or inferiority of the F_1 hybrid over the average performance of its two parents. It provides an estimate of the overall genetic gain obtained through hybridization and reflects the combined contribution of both parents.

Table 1 : Types of heterosis, their calculation formulas, and breeding significance.

Type of Heterosis	Formula	Significance in Breeding
Mid-Parent Heterosis	$(F_1 - MP) / MP \times 100$	Measures superiority over the parental average
Better-Parent Heterosis	$(F_1 - BP) / BP \times 100$	Indicates superiority over the best parent
Standard Heterosis	$(F_1 - SC) / SC \times 100$	Assesses commercial breeding value

$$\text{Average Heterosis (\%)} = \frac{F_1 - MP}{MP} \times 100$$

where,

F_1 = Mean performance of hybrid

MP = Mean performance of the two parents

$$MP = \frac{P_1 + P_2}{2}$$

where,

P_1 = Mean performance of parent 1

P_2 = Mean performance of parent 2

Better-Parent Heterosis (Heterobeltiosis)

Better-parent heterosis compares the performance of the F_1 hybrid with that of the superior parent. This estimate is particularly useful in breeding programmes because it identifies hybrids capable of exceeding the performance of the best available parent, thereby indicating the possibility of obtaining superior hybrid combinations.

$$\text{Better-Parent Heterosis (\%)} = \frac{F_1 - BP}{BP} \times 100$$

where,

BP = Mean performance of the better-performing parent

Standard (economic) Heterosis

Standard heterosis evaluates the performance of the hybrid relative to a standard commercial cultivar. Since newly developed hybrids are ultimately intended to replace

existing cultivars, this parameter is considered the most important criterion for assessing the practical utility and commercial value of hybrid combinations. In the present investigation, the wheat variety MP 3336 was used as the standard check for estimating economic heterosis.

$$\text{Standard Heterosis (\%)} = \frac{F_1 - SC}{SC} \times 100$$

where,

SC = Mean performance of the standard commercial check or check variety

Results and Discussion

In this study, heterosis was assessed to evaluate hybrid vigour in CMS-based wheat hybrids for grain yield per plant. A total of 64 hybrids were analysed in relation to mid-parent, better parent (heterobeltiosis) and the standard check variety MP 3336 and the results are presented in Table 2.

Among these, eight hybrids exhibited significant and desirable positive heterosis across all three measures, indicating their strong genetic potential for yield improvement. The cross 95A $\times$ MP3382 showed the highest heterotic response over all three comparisons, suggesting the involvement of both additive and non-additive gene actions and highlighting its potential for commercial utilization. Other promising hybrids, including 89A $\times$ MP3382, 82A $\times$ MP3382, 91A $\times$ VL3022, 86A $\times$ MP3382, 95A $\times$ VL3022, 86A $\times$ VL3022 and 91A $\times$ MP3465, also demonstrated significant positive heterosis, though to a lesser extent.

Table 2 : Heterosis Analysis in CMS Wheat Hybrids.

Hybrids	Economic Heterosis (%)	Commercial Check	Mid-parent Heterosis (%)	Heterobeltiosis (%)	Better Parent
95A $\times$ MP3382	30.15	MP3336	31.38	91.47	MP3382
89A $\times$ MP3382	25.08	MP3336	29.58	84.00	MP3382
82A $\times$ MP3382	17.56	MP3336	26.72	72.94	MP3382
91A $\times$ VL3022	14.92	MP3336	8.29	18.08	VL3022
86A $\times$ MP3382	5.34	MP3336	21.56	54.97	MP3382
95A $\times$ VL3022	9.54	MP3336	5.90	12.55	VL3022
86A $\times$ VL3022	6.49	MP3336	4.49	9.41	VL3022
91A $\times$ MP3465	4.96	MP3336	6.80	14.58	MP3465

The magnitude of heterosis observed was considerable, with heterobeltiosis up to 91%, mid-parent heterosis up to 31%, and economic heterosis up to 30%. These findings confirm the role of both additive and non-additive gene effects and support the effectiveness of heterosis breeding for enhancing grain yield in wheat.

Overall, the significant and positive heterotic responses observed in selected CMS-based hybrids underscore their potential utility in developing high-yielding wheat hybrids and support the application of heterosis breeding as a viable strategy for yield enhancement.

Conclusion

The present study revealed considerable heterosis among the CMS-based wheat hybrids evaluated for grain yield and related traits, indicating substantial scope for the exploitation of hybrid vigour in wheat improvement. The estimation of average (mid-parent), better-parent, and standard (economic) heterosis enabled the identification of superior hybrid combinations with enhanced yield potential.

Among the evaluated hybrids, 95A × MP3382, 89A × MP3382 and 82A × MP3382 consistently exhibited desirable heterotic responses for grain yield and several yield-contributing traits, demonstrating their potential as promising candidates for future hybrid wheat breeding programmes. These findings highlight the effectiveness of the CMS-based breeding system in identifying productive hybrid combinations. However, further evaluation of these promising hybrids across different locations and seasons is necessary to assess the stability of their performance and adaptability. The superior hybrids identified in the present investigation may serve as valuable genetic resources for developing high-yielding wheat hybrids and enhancing wheat productivity.

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