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Study on the estimation of magnitude and direction of heterosis and combining ability of nutritional quality traits in bottle gourd [*Lagenaria siceraria* (Molina) Standl]

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Abstract

Bottle gourd (*Lagenaria siceraria* (Molina) Standl.) is a highly adaptable, nutritional rich, culinary versatility and affordability vegetable crop. In the present study a field experiment was conducted at Research Farm of Department of Vegetable Science, CCS Haryana Agricultural University, Hisar to estimate the heterosis and combining ability in bottle gourd in half-diallel mating design involving eight diverse genotypes. Observations were recorded for different nutritional quality traits, with special emphasis on total soluble solids (TSS), ascorbic acid content and titratable acidity. Results revealed that several hybrids exhibited significant positive heterosis for nutritional parameters. Based on the performance of hybrids for relative heterosis, heterobeltiosis and standard heterosis, the cross GH-63 × GH-74 emerged as the most promising combination. Combining ability analysis revealed significant general combining ability (GCA) and specific combining ability (SCA) effects for the traits under study. Among the parents, GH-60 was identified as a good general combiner for all quality traits except titratable acidity. The crosses GH-63 × GH-71, GH-71 × GH-74 and GH-60 × GH-72 showed significant potential specific combining ability for all the nutritional quality traits among the 28 evaluated hybrids. So, these parents can be used for further recombination breeding programme. The magnitude of σ^2 SCA was higher than σ^2 GCA for all traits, indicating the predominance of non-additive gene action, particularly dominance effects, in their inheritance. These findings highlight the effectiveness of heterosis breeding for the genetic enhancement of nutritional quality traits in bottle gourd. Overall, the study underscores the importance of improving nutrient composition and identifies promising parental lines and hybrid combinations for future breeding programs.

Keywords: Half-diallel, bottle gourd, GCA, SCA and genotypes

Introduction

Bottle gourd (*Lagenaria siceraria* (Molina) Standl.) is a highly adaptable vegetable crop belonging to the family Cucurbitaceae, possessing a somatic chromosome number of $2n = 2x = 22$ (Bevy and Kuriachan, 1996) [3]. Among cucurbitaceous vegetables, it is increasingly valued for its palatability, nutritional richness, culinary versatility, affordability, year-round market availability, high productivity and export potential. According to data from the U.S. Department of Agriculture, 100 g of raw bottle gourd contains 96.10% moisture, 0.62 g protein, 0.02 g fat, 0.50 g fibre, 3.39 g carbohydrates and provides 14.00 kcal of energy. It also supplies essential minerals and vitamins, including calcium (26.00 mg), phosphorus (13.00 mg), potassium (150.00 mg), iron (0.20 mg), magnesium (11.00 mg), sodium (0.20 mg), niacin (0.20 mg) and vitamin C (10.00 mg) (Martin *et al.*, 2012).

Tropical Africa is recognized as the primary centre of origin of bottle gourd (Singh, 1990) [20], and it is the only species of its genus that has achieved global distribution since prehistoric times. The crop had already spread widely across continents prior to Columbus's arrival in America, likely through natural dispersal via ocean currents (Whitaker and Carter, 1961) [26]. Although it performs best under warm and humid climatic conditions, it can also be cultivated successfully under relatively cooler environments (Maurya *et al.*, 1993; Singh *et al.*, 1996) [14, 21]. In North Indian agro-climatic conditions, bottle gourd is mainly cultivated during

the *spring-summer* and *rainy seasons*, with fruits available in the market from March to November (Anonymous, 2015b) [2].

Bottle gourd is an important cucurbitaceous vegetable valued for its high yield potential, stable market demand and export opportunities. Traditionally, its pulp has been used to relieve constipation, cough and night blindness and is considered an antidote to certain toxins. The crop is also reported to possess several pharmacological properties, including antioxidant, cardioprotective, hepatoprotective, antihypertensive and immunomodulatory effects (Minocha, 2015) [15]. Nutritionally, bottle gourd is a potential source of valuable nutrients such as oil, protein, choline, essential vitamins, minerals and amino acids required for neurotransmitter synthesis. It also holds promise as a raw material for agro-based industries (Hassan *et al.*, 2008). Owing to its rich nutrient profile, it has been traditionally regarded as a supportive food for overall health and mental well-being, with natural foods like bottle gourd suggested as alternatives to synthetic vitamin supplements (Rahman, 2003) [18].

India maintains an intensive reservoir of bottle gourd germplasm, encompassing both wild and cultivated forms that exhibit substantial morphological and genetic diversity. In the current context, there is a pressing need to develop nutritionally superior varieties and hybrids. Moreover, assessing the combining ability and pre-potency of parental lines in hybridization programmes is essential for effective hybrid development. Exploitation of heterosis offers considerable scope for improving quality attributes in bottle gourd. A thorough understanding of the crop's genetic architecture is fundamental to breeding high-quality hybrids. In view of this, an experiment was undertaken to evaluate the nutritional characteristics of various bottle gourd genotypes and their corresponding hybrids. Till now, production and productivity of bottle gourd is hampered by narrow genetic base and lack stable cultivar, so there is need to increase the production and productivity of bottle gourd by choosing better parent and crosses. So present study is planned for identification of better parent and crosses for nutritional quality.

Materials and Methods

Experimental Material

The experiment was conducted during *Spring-summer season* (2024) and *Rainy season* (2024) at Vegetable Research Farm of the CCS Haryana Agricultural University, Hisar, Haryana. Based on the diversity and eliteness for different economically important traits, eight promising genotypes namely GH-58, GH-60, GH-63, GH-69, GH-71, GH-72, GH-73 and GH-74 were selected to use in crossing programme. Crosses were made in half diallel fashion in all possible combinations excluding reciprocals during *spring-summer* season of 2024 and 28 hybrids and that of parents (obtained by selfing) were harvested separately, raised in randomized complete block design with 3 replications during *rainy season* (2024). All recommended packages of practices were followed.

Methodology and Statistical Analysis

Total soluble solid fresh fruit juice of bottle gourd was determined with the help of hand refractometer (Erma, Japan) of 0-32% range (Tigist *et al.*, 2013) [24]. The estimation of Ascorbic acid content (mg/100g) and Acidity (%) was done by using the method given in AOAC (1990). Further, half-diallel analysis was done through OPSTAT software (Sheoran *et al.*, 2010) [19]. The degree of heterosis was evaluated based on three reference points: the mid-parent (MP), better parent (BP) and standard parent (SP). The formulas used for estimating heterosis were derived from the works of Turner (1953) [25], Hayes *et al.*, (1956) [9] and Fonseca and Patterson (1968) [7]. The additive and dominance genetic variance were calculated as per Singh and Chaudhary (1997) [22].

Results and Discussion

Per se performance and heterosis: Results showed that significant and desirable variations in all the nutritional quality traits examined and mean value range between all the traits, viz. ascorbic acid (mg/100 g) (parents = 5.80-8.50 and hybrids = 5.80-8.70), total soluble solids (%) (parents = 2.66-5.02 and hybrids = 2.44-5.06) and titratable acidity (%) (parents = 1.26-2.82 and hybrids = 1.32-2.76). On the basis of mean value top 3 parents (Table 1) i.e. GH-73, GH-74, GH-58 for total soluble solids, GH-69, GH-72, GH-60 for ascorbic acid content and GH-71, GH-74, GH-72 for titratable acidity were observed whereas, top 3 hybrids (Table 1) i.e. GH-63 × GH-71, GH-72 × GH-73, GH-60 × GH-69 for total soluble solids, GH-60 × GH-73, GH-71 × GH-74, GH-60 × GH-71 for ascorbic acid, GH-63 × GH-74, GH-58 × GH-71, GH-63 × GH-71 for titratable acidity were observed. Similar results for the nutritional composition in cucumber was observed by Bisht *et al.*, (2023) [4] and in pumpkin by Nagar *et al.*, (2018) [16]. According to Allard (1960) [1] choosing parents based on average performance does not provide desirable outcomes. Therefore, we have identified heterosis, combining ability and gene action for all the traits under study in order to choose the best performing parents.

In the present investigation, mean performance data (Table 2) revealed varying degree of heterosis for total soluble solids among different hybrid combinations when evaluated against the mid-parent, better parent and the standard check variety (Pusa Naveen). Among the 28 crosses studied, 25 hybrids exhibited significant positive relative heterosis, 23 showed significant heterobeltiosis and 8 demonstrated significant standard heterosis for dry matter content. With respect to ascorbic acid content, 21 hybrids recorded significant relative heterosis, 17 showed significant heterobeltiosis and 11 exhibited significant standard heterosis compared to the check variety Pusa Naveen. For titratable acidity, 12 hybrids showed significant relative heterosis, 20 demonstrated significant heterobeltiosis and 14 showed significant standard heterosis over the standard check, Pusa Naveen. These findings are in the alignment with the results reported by Dhakne *et al.* (2021) [5] and Masud *et al.* (2021) [13].

Table 1: Mean value of parents, hybrids and standard checks for quality traits

	Total soluble solids (%)	Ascorbic acid (mg/100g)	Titrateable acidity (%)
Range (parents)	2.66-5.02	5.80-8.50	1.26-2.82
Mean	3.84	7.15	2.04
Best (parents)	GH-73, GH-74, GH-58	GH-69, GH-72, GH-60	GH-71, GH-74, GH-72
Range (hybrids)	2.44-5.06	5.80-8.70	1.32-2.76
Mean	3.75	7.25	2.04
Best (hybrids)	GH-63×GH-71, GH-72×GH-73, GH-60×GH-69	GH-60×GH-73, GH-71×GH-74, GH-60×GH-71	GH-63×GH-74, GH-58×GH-71, GH-63×GH-71
Mean Checks	3.56	5.9	2.46
C.D. at 5%	0.428	0.665	0.009
SE(m)	0.152	0.236	0.003

The ranking of the hybrids based on their relative heterosis, heterobeltiosis and standard heterosis for the studied traits is listed in Table 2. In terms of total soluble solids, notable relative and heterobeltiosis effects were observed in top hybrids GH-63 × GH-71 (51.76%), GH-69 × GH-71 (21.40%), GH-58 × GH-72 (12.16%), while significant standard heterosis was seen in GH-63 × GH-71 (42.13%), GH-72 × GH-73 (41.57%), GH-60 × GH-69 (41.01%). As for ascorbic acid, significant relative heterosis were found in top hybrids GH-71 × GH-74 (37.63%), GH-63 × GH-74 (32.26%), GH-60 × GH-71 (26.95%), heterobeltiosis and standard heterosis were found in top hybrids GH-71 × GH-74 (33.33%), GH-63 × GH-74 (28.13%), GH-60 × GH-73 (20.93%) and GH-60 × GH-73 (47.46%), GH-71 × GH-74 (44.07%), GH-60 × GH-71 (42.37%), respectively. Regarding titrateable acidity, notable relative and heterobeltiosis effects were seen in GH-69 × GH-71 (-40.81%), GH-71 × GH-74 (-38.91%), GH-60 × GH-71 (-36.12%) and GH-69 × GH-71 (-53.19%), GH-63 × GH-74 (-41.04%), GH-71 × GH-74 (-40.43%), whereas significant standard heterosis occurred in GH-69 × GH-71 (-46.34%), GH-58 × GH-63 (-39.84%), GH-63 × GH-74 (-35.77%).

Combining ability: Combining ability analysis is considered a highly effective method for identifying superior parents for hybridization, whether the objective is to exploit heterosis or to accumulate desirable genes, as suggested by Sprague and Tatum (1942) [23]. In the present study, all parents exhibited strong general combining ability (GCA) for different quality traits across both seasons as well as in the pooled analysis. The results indicated that five parents were good general combiners for total soluble solids (Table 2). In addition, four parents showed significant GCA effects for ascorbic acid, while three parents were identified as good general combiners for titrateable acidity.

A low GCA effect, whether positive or negative, reflects minimal deviation between the parental mean and the overall mean of crosses. In contrast, a high GCA effect (positive or negative) suggests that the parental mean is either superior or inferior to the general mean of hybrids. This pattern indicates the transmission of genetic potential from parents to their progeny, as reported by Fasahat *et al.* (2016) [6].

The most promising cross combinations for different traits (Table 2) exhibited high specific combining ability (SCA)

effects along with superior per se performance in the pooled analysis. For example, the hybrids GH-63 × GH-71, GH-69 × GH-71 and GH-72 × GH-73 recorded desirable SCA effects and superior performance for total soluble solids content. Likewise, GH-71 × GH-74, GH-63 × GH-74 and GH-58 × GH-69 were identified as the best hybrids for ascorbic acid, while GH-60 × GH-72, GH-69 × GH-72 and GH-63 × GH-72 performed exceptionally well for titrateable acidity, all exhibiting significant SCA effects in the pooled analysis.

The occurrence of strong specific combining ability (SCA) effects, particularly when associated with parents exhibiting good general combining ability (GCA), indicates a high likelihood of generating valuable transgressive segregants in subsequent generations, as suggested by Jinks and Jones (1958) [11]. The findings presented in (Table 2) further reveal that superior hybrids can also be obtained from parents with poor GCA effects. This observation highlights that the most promising crosses are not exclusively derived from combinations of high GCA parents.

Crosses governed predominantly by additive gene action, which is heritable and fixable, are especially advantageous for heterosis breeding as well as for the selection of superior segregants in advanced generations. Similar observations have been reported in earlier studies by Masud *et al.* (2021) [13] and Patel and Mehta (2021) [17].

Gene action: For effective crop improvement, it is essential to assess both additive and non-additive components of genetic variance. In the present study (Table 3), the estimates of σ^2 SCA were considerably higher than those of σ^2 GCA, indicating the predominance of non-additive gene effects, particularly dominance, in the inheritance of these traits. This finding highlights the importance of heterosis breeding for improving nutritional attributes.

Furthermore, the average degree of dominance was less than unity for all the traits studied, reinforcing the conclusion that non-additive gene action plays a major role in controlling these nutritional characteristics (Table 3). Overall, the analysis of gene action emphasizes the significant contribution of non-additive effects in trait expression, suggesting that heterosis breeding is an effective strategy for enhancing the nutritional quality of bottle gourd.

Table 2: Heterosis (relative heterosis, heterobeltiosis and standard heterosis) and top performing general and specific combiner for quality traits

		Total soluble solids (⁰ brix)	Ascorbic acid (mg/100 g)	Titrateable acidity (%)
Relative Heterosis	Relative heterosis (No.)	25	21	12
	Best (Hybrids)	GH-63× GH-71 (51.76%)	GH-71×GH-74 (37.63%)	GH-69×GH-71(40.81%)
		GH-69× GH-71 (21.40%)	GH-63×GH-74 (32.26%)	GH-71×GH-74 (-38.91%)
Heterobeltiosis	Heterobeltiosis (No.)	23	17	20
	Best (hybrids)	GH-63 × GH-71 (25.83%)	GH-71×GH-74 (33.33%)	GH-69×GH-71 (-53.19%)
			GH-63×GH-74 (28.13%)	GH-63×GH-74 (-41.04%)
Standard Heterosis	Standard heterosis (No.)	8	11	14
	Best (hybrids)	GH-63× GH-71 (42.13%)	GH-60×GH-73 (47.46%)	GH-69×GH-71 (-46.34%)
		GH-72× GH-73 (41.57%)	GH-71×GH-74 (44.07%)	GH-58×GH-63 (-39.84%)
GCA effects	Parents (No.)	5	4	3
	Parents (Best)	GH-60 (0.27)	GH-60 (0.40)	GH-72 (0.10)
		GH-72 (0.20)	GH-73 (0.29)	GH-63 (0.02)
SCA effects	Hybrids (No.)	9	12	7
	Hybrids (Best)	GH-63 × GH-71(1.89)	GH-71 × GH-74 (1.54)	GH-60 × GH-72 (0.37)
		GH-69 × GH-71(1.14)	GH-63 × GH-74 (1.36)	GH-69 × GH-72 (0.34)
		GH-72 × GH-73(0.82)	GH-58 × GH-69 (1.26)	GH-63 × GH-72 (0.28)

Table 3: Estimation of genetic component of variance for nutritional traits

Traits	σ^2_{gca}	σ^2_{sca}	$\sigma^2_{gca}/\sigma^2_{sca}$
Total soluble solids (%)	0.07	0.65*	0.11
Ascorbic acid (mg/100g)	0.09	0.68*	0.13
Acidity (%)	0.00	0.03	0.14

Conclusion

In the fight against malnutrition, evaluating the nutritional quality of crops is of great importance. The present investigation assessed key nutritional traits of bottle gourd in both parental lines and their respective hybrids to determine their nutrient potential. Among the parents, GH-72 and GH-60 exhibited superior performance for most of the traits studied. Among the hybrids, GH-60 × GH-69 showed outstanding per se performance across the majority of nutritional parameters. Based on relative heterosis, heterobeltiosis, and standard heterosis, the cross GH-63 × GH-74 proved to be the most promising combination. Parent GH-60 emerged as a good general combiner, performing well for all quality traits except titrateable acidity. With regard to specific combining ability, the crosses GH-63 × GH-71, GH-71 × GH-74 and GH-60 × GH-72 demonstrated significant potential for multiple traits among the 28 evaluated combinations. The higher magnitude of σ^2_{SCA} compared to σ^2_{GCA} further confirmed the predominant role of dominance gene action in the inheritance of these traits, highlighting the effectiveness of hybrid breeding for their genetic improvement. Overall, the findings emphasize the importance of enhancing nutritional quality and identify promising hybrid combinations for future breeding programs aimed at improving these traits.

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Conflict of Interest. None.

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