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Estimation of Combining Ability Effect for Hybrid Breeding in Bottle Gourd [*Lagenaria siceraria* (Molina) Standl.] Using Diallel Mating Design

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A half diallel mating design was employed to cross eight parental lines of bottle gourd, resulting in 28 F_1 hybrids (excluding reciprocals). These F_1 hybrids, along with the parental lines and a commercial check (Pant Lauki-3), were evaluated during the summer of 2024 at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The study aimed to assess the combining ability for yield and yield-related traits using a randomized complete block design with three replications. The genetic variance ratio being less than unity suggested that non-additive gene action was dominant for all the characters. The analysis indicated that none of the parents

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consistently exhibited good general combining ability across all traits. However, the cross combination NDBG-104 × Pusa Sandesh followed by Pant Lauki-4 × Kashi Kirti emerged as the best for most of the traits analyzed. The results suggest that it may be possible to further enhance fruit yield and earliness through hybridization and selection in transgressive segregants.

Keywords: Combining ability; gene action; half diallel; bottle gourd; fruit yield.

1. INTRODUCTION

Bottle gourd (*Lagenaria siceraria* (Molina) Standl.), is a versatile crop within the Cucurbitaceae familywith a chromosome number of 2n = 2x = 22. It plays a crucial role in food security, particularly in Asia and Africa [1]. The tender young fruits are harvested according to consumer preference, while mature seeds from dried fruits are processed for animal feed. Bottle gourd fruits are rich in essential macro and micronutrients, including vitamins B, C, and E, minerals such as iron, phosphorus, potassium, calcium, and magnesium, as well as carbohydrates and dietary fiber [2]. The leaves provide important nutrients like zinc, nitrogen, manganese, and copper [3], and the seeds are rich in crude protein, crude lipids, crude fiber, and carbohydrates [4]. Additionally, the seeds contain vital amino acids such as aspartic acid, glutamic acid, leucine, arginine, and lysine (Ogunbusola et al., 2010).

Bottle gourd is a monoecious species, with both male and female flowers developing in the leaf axils of the same plant [5,6]. Although it predominantly exhibits monoecious sex expression, research has shown that andro-monoecious genetic stock is recessive to monoecious, controlled by a single gene [7]. Despite being monoecious, bottle gourd is a highly cross-pollinated crop [8].

Recently, there has been a growing focus on breeding superior bottle gourd cultivars, particularly through the development of hybrid seeds [9]. The identification and selection of the best parental lines for producing genetically superior germplasm through hybridization must be based on comprehensive genetic potential information [10]. Understanding combining ability is essential for identifying the best combiners for hybridization, whether to exploit heterosis or to accumulate fixable genes through selection. The development of improved varieties with high yield potential is an ongoing process that relies heavily on the choice of parents. In this context, the experiment was designed to provide information on general and specific combining ability estimates in bottle gourd through a diallel mating design. General combining ability (GCA) effects aid in selecting superior parents, while specific combining ability (SCA) effects assist in choosing the best parental cross combinations (hybrids).

2. MATERIALS AND METHODS

The experimental material comprised eight parental lines: Pant Lauki-3, Pant Lauki-4, NDBG-104, Pusa Samridhi, Kashi Kirti, Kashi Kiran, Pusa Sandesh, and Narendra Rashmi. These parental lines were crossed using a half diallel mating design (excluding reciprocals) during the summer season of 2023 and subsequently evaluated in 2024. The resulting 28 F_1 hybrids, along with their parents, were assessed in a randomized complete block design (RCBD) with three replications, each containing 10 plants, at the Vegetable Research Centre, Department of Vegetable Science, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. Seeds were sown with a spacing of 3 meters between rows and 1 meter between plants. The Observations were recorded from five randomly selected plants for various traits, including days to anthesis of the first male flower, days to anthesis of the first female flower, days to first fruit harvest, average fruit weight, number of fruits per plant, fruit yield per plant, fruit yield per hectare, number of primary branches per plant, and vine length at harvest.

Combining ability was calculated following Griffing's Method II Model I [11]. Data related to combining ability were compiled and analyzed using INDOSTAT and SPAR software to test the significance of differences for general combining ability (GCA) and specific combining ability (SCA) among the parents and F_1 hybrids, respectively.

3. RESULTS AND DISCUSSION

The study revealed highly significant variances for nearly all traits in terms of general and specific combining abilities. The results showed a significant difference between the general and specific combining abilities of the parents and their crosses. The ratio of GCA to SCA variance for each trait was less than unity, indicating the dominance of non-additive gene action (Table 1). Specifically, traits such as the number of primary branches per plant (0.02), days to anthesis of the first male flower (0.09), days to anthesis of the first female flower (0.18), days to first fruit harvest (0.17), average fruit weight (0.09), number of fruits per plant (0.06), fruit yield per plant (0.05), fruit yield per hectare (0.03), and vine length at harvest (0.004) all showed SCA variances greater than GCA variances, further indicating the predominance of non-additive gene action. Therefore, heterosis breeding is recommended for the improvement of these traits. As GCA is primarily a function of additive gene action whereas higher SCA denote non additive gene action. GCA variance is higher the breeding methods involving selection, intermating of selects and reselection in segregating generations followed by pedigree method of breeding may help to improve the characters whereas when SCA variance is higher the breeding method should be shift towards heterosis breeding. Patel et al*.* [12] in bottle gourd noted higher SCA variance for all characters studied except day to first female flower openingwhich indicate that these traits predominantly governed by non- additive type of gene action.Similar findings in bottle gourd have been reported by Mahawar et al. [13], Mishra et al. [14], Khot et al*.* [15] Masud et al. [16] and Patel and Mehta [17] who found that the presence of both additive and non-additive gene action for almost all characters studied.

3.1 GCA Estimates of Parents

Earliness, which is crucial for favouring hybrids over pure line varieties, was evident in traits such as the number of days until the first male flower anthesis, first female flower anthesis, and days to first fruit harvest. The GCA effect for days to anthesis of the first male flower ranged from -1.34 (Pusa Samridhi) to 1.02 (Kashi Kiran). Kashi Kirti (-0.72), Pusa Sandesh (-0.69), and Narendra Rashmi (-0.38) were identified as significant negative general combiners. For days to anthesis of the first female flower, the GCA ranged from -1.54 (Pusa Sandesh) to 1.81 (NDBG-104), with Kashi Kirti (-1.36) and Pusa Samridhi (-1.24) also showing significant negative GCA values. The GCA effect for days to first fruit harvest ranged from -1.97 (Pusa Sandesh) to 1.81 (NDBG-104), with Kashi Kirti (-1.22) and Pusa Samridhi (-0.91) demonstrating the earliest harvest times. Similar findings in bottle gourd were reported by Janaranjani et al. [18].

The number of fruits per vine and average fruit weight are directly related to yield. The GCA effect for average fruit weight ranged from -123.23 (Pusa Samridhi) to 150.33 (Kashi Kirti), with Kashi Kirti showing a highly significant positive GCA effect, making it an excellent general combiner for this trait. The GCA value for the number of fruits per plant ranged from -0.54 (NDBG-104) to 0.59 (Pusa Samridhi), with Narendra Rashmi (0.49) and Pant Lauki-4 (0.23) also showing significant positive values. Similar results were reported by Khot et al. [19].

Since high yield per vine is a key factor in the acceptance of a variety or hybrid by farmers, it is a primary goal in breeding programs. The GCA effect for yield per vine ranged from -0.44 (Pusa Samridhi) to 0.49 (Kashi Kirti), with Pant Lauki-4 (0.37), Pant Lauki-3 (0.27), and NDBG-104 (0.10) identified as the best general combiners due to their significant positive GCA effects. For fruit yield per hectare, the GCA effect ranged from -13.08 (Pusa Sandesh) to 22.58 (Pant Lauki-4), with Narendra Rashmi (11.68) also showing a significant positive GCA effect. Mishra et al. [20] reported similar results in bottle gourd.

The GCA value for the number of primary branches ranged from -0.19 (Pusa Samridhi and Kashi Kirti) to 0.38 (Kashi Kiran), with Kashi Kiran identified as the best parental line for this trait. Vine length showed highly significant GCA values ranging from -0.09 (NDBG-104) to 0.11 (Narendra Rashmi), with Kashi Kirti (0.04) and Pusa Samridhi (0.01) also having positive significant values (Table 2). Adarsh et al. [21] reported similar findings in bottle gourd.

3.2 SCA Effect of Crosses

Out of the 28 cross combinations, 27 exhibited significant SCA effects, with 14 showing significant negative estimates for the number of days until the first male flower anthesis. The crosses NDBG-104 × Narendra Rashmi, NDBG-104 × Kashi Kiran, NDBG-104 × Pusa Sandesh, and Pant Lauki-4 × Pusa Samridhi showed negative SCA values, indicating earliness. Similarly, 27 crosses displayed significant SCA effects, and 14 crosses had significant negative estimates for the number of days until the first female flower anthesis. Among these, the

Table 1. Analysis of variance for combining ability in bottle gourd

Source of variation/Parameters	GCA (General Combining Ability)	SCA (Specific Combining Ability	Error	GCA variance	SCA variance	GCA/SCA ratio
D.F.	**7**	**28**	**70**			
Days to anthesis of first male flower	7.98**	8.51 **	0.05	0.79	8.46	0.09
Days to anthesis of first female flower	15.26 **	8.51 **	0.07	1.52	8.44	0.18
Days to first fruit harvest	15.97 **	9.33 **	0.06	1.59	9.27	0.17
Average fruit weight (g)	61788.84 **	67263.81 **	2854.35	5893.45	64409.46	0.09
No of fruits per plant	1.79 **	2.64 **	0.03	0.17	2.61	0.06
Fruit yield per plant (kg)	1.29 **	2.27 **	0.02	0.12	2.25	0.05
Fruit yield per hectare (q/ha)	1579.12 **	4341.78 **	144.06	143.51	4197.72	0.03
Number of primary branches per plant	0.30 **	0.83 **	0.01	0.02	1.34	0.02
Vine length (m) at harvest	0.03 **	0.83 **	0.00	0.004	0.83	0.004

**, ** : Significant at 0.05 and 0.01 probability level, respectively*

Table 2. General combing ability (GCA)effects for different metric characters in bottle gourd

Parents	Days to anthesis of first male flower	Days to anthesis of first female flower	Days to first fruit harvest	Average fruit weight (kg)	No of fruits per plant	Number of primary branches per plant	Vine length (m)	Fruit yield per plant (kg)	Fruit yield per hectare (q/ha)
Pant Lauki-3	0.51**	0.91	0.99**	11.77	-0.31**	-0.02	-0.01**	0.27**	0.52
Pant Lauki-4	0.88**	0.62 **	0.74 **	-14.89	0.23**	0.00	0.01**	0.37**	22.58**
NDBG-104	0.65**	1.81 **	1.81**	25.66	-0.54**	0.03	-0.09**	0.10**	-12.87**
Pusa Samridhi	-1.34**	-1.24 **	-0.91 **	-123.23**	0.59**	-0.19-**	0.01**	-0.44**	2.01
Kashi Kirti	-0.72**	-1.36	-1.22 **	150.33**	-0.48**	-0.19**	0.04**	0.49**	0.03
Kashi Kiran	1.09**	0.58 **	0.16**	30.66	-0.01	0.38**	-0.04**	-0.24**	-10.86**
Pusa Sandesh	-0.69**	-1.54 **	-1.97	-28.20	0.03	-0.02	-0.04**	-0.42**	-13.08**
Narendra Rashmi	-0.38**	0.21 **	-0.39	-52.11**	0.49**	0.01	0.11**	-0.14**	11.68**
S.E. (gi)	0.06	0.0.7	0.07	15.80	0.05	0.03	0.003	0.04	3.55
S.E. (gi-gj)	0.10	0.11	0.11	23.89	0.08	0.05	0.004	0.07	5.36

**, **: Significant at 0.05 and 0.01 probability level, respectively*

Table 3. Specific combining ability (SCA) effects for different metric characters in bottle gourd

S. No.	Hybrids	DFMF	DFFF	DFH	AFW	NFPP	NPB	VL	FYP	FY
1.	Pant Lauki-3 × Pant Lauki-4	0.96 **	1.50 **	1.95 **	-165.90 **	2.00 **	1.21 **	0.67 **	0.71 **	86.33 **
2.	Pant Lauki-3 × NDBG-104	-0.25 **	-4.24 **	-5.34 **	232.44 **	-0.57 **	2.84 **	0.48 **	1.04 **	11.79 *
3.	Pant Lauki-3 × Pusa Samridhi	-1.59 **	-3.52 **	-3.74 **	120.21 **	-1.37 **	-1.11 **	0.48 **	0.35 **	-37.09 **
4.	Pant Lauki-3 × Kashi Kirti	1.12 **	2.04 **	0.35 **	-142.23 **	0.70 **	-0.11 *	0.47 **	-0.27 **	4.64
5.	Pant Lauki-3 ×Kashi Kiran	2.08 **	0.88 **	1.31 **	60.77 **	0.23 **	-0.68 **	0.67 **	2.16 **	66.22 **
6.	Pant Lauki-3 × Pusa Sandesh	0.87 **	3.67 **	5.11 **	202.96 **	-1.13 **	0.72 **	0.27 **	0.14 *	-24.00 **
7.	Pant Lauki-3 × Narendra Rashmi	-2.10 **	-1.64 **	-0.59 **	-278.68 **	1.73 **	-0.31 **	0.29 **	-0.78 **	21.24 **
8.	Pant Lauki-4 × NDBG-104	-0.18 *	-0.51 **	-0.75 **	-202.01 **	1.23 **	-0.34 **	0.42 **	-1.12 **	0.72
9.	Pant Lauki-4 × Pusa Samridhi	-2.75 **	-2.45 **	-2.15 **	-53.12 *	-1.90 **	-1.13 **	0.49 **	2.42 **	-0.16
10.	Pant Lauki-4 × Kashi Kirti	2.63 **	4.22 **	3.94 **	362.21 **	3.17 **	-0.13 **	0.73 **	1.49 **	161.26 **
11.	Pant Lauki-4 × Kashi Kiran	1.59 **	3.95 **	3.56 **	-190.34 **	0.70 **	0.31 **	0.07 **	-2.61 **	-64.01 **
12.	Pant Lauki-4 × Pusa Sandesh	-2.28 **	-1.26 **	0.03	-220.37 **	-1.67 **	-0.29 **	0.12 **	-0.66 **	-64.07 **
13.	Pant Lauki-4 × Narendra Rashmi	2.18 **	-0.57 **	-1.22 **	170.21 **	0.20 *	0.67 **	0.35 **	0.12	7.39
14.	NDBG-104 × Pusa Samridhi	-1.63 **	0.91 **	1.90 **	39.66	-1.47 **	1.84 **	0.27 **	-1.14 **	-61.71 **
15.	NDBG-104 × Kashi Kirti	4.64 **	3.59 **	4.10 **	-322.79 **	-0.07	-1.16 **	0.03 **	-1.33 **	-52.73 **
16.	NDBG-104 × Kashi Kiran	-3.73 **	-2.58 **	-0.84 **	-64.23 **	-0.87 **	-1.73 **	0.15 **	0.19 **	-12.84 **
17.	NDBG-104 × Pusa Sandesh	-2.49 **	-3.12 **	-3.04 **	50.19 *	2.43 **	0.67 **	0.84 **	0.74 **	97.39 **
18.	NDBG-104 × Narendra Rashmi	-4.47 **	2.90 **	1.60 **	151.88 **	-0.03	0.64 **	0.59 **	1.99 **	57.07 **
19.	Pusa Samridhi × Kashi Kirti	0.96 **	0.09	1.25 **	-51.68 *	-0.20 *	-0.94 **	0.33 **	-0.58 **	-21.50 **
20.	Pusa Samridhi × Kashi Kiran	2.04 **	2.37 **	2.54 **	123.55 **	3.33 **	-0.51 **	0.75 **	1.57 **	166.72 **
21.	Pusa Samridhi × Pusa Sandesh	-1.84 **	-0.73 **	-2.66 **	54.63 *	-0.70 **	-0.11 *	0.30 **	-0.52 **	-33.49 **

S. No.	Hybrids	DFMF	DFFF	DFH	AFW	NFPP	NPB	VL	FYP	FY
22.	Pusa Samridhi × Narendra Rashmi	-0.37 **	-1.71 **	-2.36 **	0.77	0.83 **	1.86 **	0.45 **	-0.07	19.74 **
23.	Kashi Kirti × Kashi Kiran	-0.03	0.82 **	0.52 **	738.88 **	-1.93 **	1.49 **	0.31 **	3.11 **	9.15
24.	Kashi Kirti × Pusa Sandesh	-1.79 **	-1.61 **	-2.24 **	-113.37 **	0.37 **	-0.11 *	0.41 **	0.16 *	18.71 **
25.	Kashi Kirti × Narendra Rashmi	-0.21 *	-1.81 **	-2.38 **	-78.34 **	-1.10 **	0.86 **	0.42 **	-0.46 **	-46.27 **
26.	Kashi Kiran × Pusa Sandesh	3.29 **	1.89 **	2.61 **	261.85 **	-1.43 **	-0.68 **	0.55 **	1.62 **	5.37
27.	Kashi Kiran × Narendra Rashmi	5.97 **	4.47 **	3.57 **	274.66 **	-1.90 **	-0.71 **	0.20 **	0.57 **	-22.57 **
28.	Pusa Sandesh × Narendra Rashmi	1.21 **	-0.85 **	0.04	-222.04 **	2.40 **	-0.31 **	0.60 **	-0.62 **	48.95 **
	SCA (ii)	0.208	0.239	0.215	48.445	0.177	0.110	0.008	0.146	10.883
	SCA (ij)	0.091	0.104	0.094	21.072	0.077	0.048	0.003	0.063	4.734
	SE (sij-ik)	0.308	0.353	0.319	71.679	0.262	0.162	0.013	0.215	16.103

**, **: Significant at 0.05 and 0.01 probability level, respectively*

*Where, **DFMF**: days to first male flower, **DFFF**: days to first female flower, **DFH**: days to first fruit harvest, **AFW:** Average fruit weight, **NFPP**: Number of fruits per plant, **NPB**: Number of primary branches, **VL**: Vine length, **FYP**: Fruit yield per plant (kg), **FY**: fruit yield (q/ha)* crosses Pant Lauki-3 × NDBG-104, Pant Lauki-3 × Pusa Samridhi, NDBG-104 × Pusa Sandesh, and NDBG-104 × Kashi Kiran showed negative values. For days to first fruit harvest, 12 cross combinations displayed negative SCA values, with the top-performing crosses being Pant Lauki-3 × NDBG-104, closely followed by Pant Lauki-3 × Pusa Samridhi, Pusa Samridhi × Pusa Sandesh, and Kashi Kirti ×Narendra Rashmi. The combinations involved good × poor, good × good, and poor × poor general combiners for these traits. Similar results were reported by Maurya et al. [22] in bottle gourd and pumpkin, where most crosses with significant SCA effects involved at least one good general combiner, indicating additive × dominance or additive × additive gene action.

For average fruit weight, 13 crosses exhibited significantly positive values, with Kashi Kirti × Kashi Kiran (738.88), Pant Lauki-4 × Kashi Kirti (362.21), Kashi Kiran × Narendra Rashmi (274.66), and Kashi Kiran × Pusa Sandesh (261.85) showing positive estimates. The SCA estimates for the number of fruits per plant ranged from -1.93 (Kashi Kirti × Kashi Kiran) to 3.33 (Pusa Samridhi × Kashi Kiran). For this trait, 13 crosses, including Pusa Samridhi × Kashi Kiran (3.33), Pant Lauki-4 × Kashi Kirti (3.17), NDBG-104 × Pusa Sandesh (2.43), and Pusa Sandesh × Narendra Rashmi (2.40), exhibited positive significant values. The crosses for these traits involved good × poor, poor × poor, and good × good general combiners, respectively. Similar findings in bottle gourd were reported by Patel and Mehta [17].

The SCA estimate for fruit yield per plant ranged from -2.61 (Pant Lauki-4 × Kashi Kiran) to 3.11 (Kashi Kirti × Kashi Kiran). Fifteen of the 28 crosses had a positive, statistically significant yield value per vine, with Kashi Kirti × Kashi Kiran (3.11), Pant Lauki-4 × Pusa Samridhi (2.42), Pant Lauki-3 × Kashi Kiran (2.16), NDBG-104 × Narendra Rashmi (1.99), and Kashi Kiran × Pusa Sandesh (1.62) among the crosses that displayed positive estimates. For fruit yield per hectare, the SCA estimates ranged from -64.07 (Pant Lauki-4 × Pusa Sandesh) to 166.72 (Pusa Samridhi × Kashi Kiran). The top-performing cross combinations were Pusa Samridhi × Kashi Kiran, closely followed by Pant Lauki-4 × Kashi Kirti, NDBG-104 × Pusa Sandesh, and Pant Lauki-3 × Pant Lauki-4. Similar findings in bottle gourd were reported by Niva et al. (2017) (Table 3).

Eleven crosses exhibited significant positive SCA values for the number of primary branches. Among these, the top-performing crosses were Pant Lauki-3 × NDBG-104 (2.84), Pusa Samridhi × Narendra Rashmi (1.86), NDBG-104 × Pusa Samridhi (1.84), and Kashi Kirti × Kashi Kiran (1.49). Regarding vine length, the SCA estimates ranged from 0.07 (Pant Lauki-4 × Kashi Kiran) to 0.84 (NDBG-104 × Pusa Samridhi). Significant positive SCA values were observed in 28 crosses, with NDBG-104 × Pusa Samridhi (0.84), Pusa Samridhi × Kashi Kiran (0.75), Pant Lauki-3 × Pant Lauki-4, and Pant Lauki-3 × Kashi Kiran (0.67 each) showing the highest values. Similar findings in bottle gourd were reported by Usha and Reddy [23], [24-26].

4. CONCLUSION

After thorough evaluation, the hybrids Pant Lauki-4 × Kashi Kirti and NDBG-104 × Pusa Sandesh shows strong potential for commercial use. Additionally, the superior segregates of these heterotic hybrids are likely to produce desirable progenies in subsequent generations. Based on the results, it can be concluded that heterosis breeding would effectively enhance early maturity and yield traits in bottle gourd.The cross NDBG-104 × Pusa Sandesh and Pant Lauki-4 × Kashi Kirti which exhibited significant positive SCA effects for most traits, can be considered for future breeding programs. GCA variance is higher the breeding methods involving selection, intermating of selects and reselection in segregating generations followed by pedigree method of breeding may help to improve the characters whereas when SCA variance is higher the breeding method should be shift towards heterosis breeding.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. ChatGPT 4.0

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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