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Analysis of genetic variability, heritability and genetic advance for yield and yield-associated traits for bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

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Abstract
The present investigation was conducted at Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.), the Main Experimental Station of the Department of Vegetable Science conducted the current study in Zaid, 2023. Using three replications of twenty-five genotypes, the experiment was run in a Randomised Complete Block Design to investigate genetic diversity, heritability, and genetic advancement in mean percentage among nineteen distinct traits. The experiment's design analysis of variance revealed highly significant variations in each character's genotype. The most promising genotypes for fruit were found to be NDBG-22-10 (426.76 q), NDBG-22-19 (413.45 q), and NDBG-22-6 (408.87 q), based on the average performance of fruit output per hectare and the number of seeds per fruit component.

Keywords: Broad sense heritability, bottle gourd, genetic advance, variability

Introduction
A notable cucurbitaceous vegetable, bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) is widely grown in tropical and subtropical regions of the world. It is a member of the family Cucurbitaceae and contains 2n=22 chromosomes. It goes by several names, including ghia, lauki, calabash, and white flowered gourd. The Latin terms "*lagena*" (bottle) and "*sicera*" (drinking utensil) are the source of the names "*lagenaria*" and "*siceraria*." According to Clarke *et al.* (2006) [12], one of the earliest plant species grown for human consumption was the bottle gourd. Lagenaria relics in both the old and new worlds may be at least 12,000 years old, according to archaeological findings (Hazra and Som, 2015). Bottle gourds come in six related species: *Lagenaria siceraria, Lagenaria spherica, Lagenaria abyssinica, Lagenaria guineensis, Lagenaria rufa*, and *Lagenaria breviflora. Lagenaria siceraria* is commonly grown in the tropical regions of the world. It is monoecious and annual, whereas the other five *Lagenaria* species are dioecious, perennial, and wild. Bottle gourd is thought to have originated in South Africa and had been introduced to Asia and other parts of the world through human migration over 10,000 years ago.

Bottle gourd, a vegetable grown for its tender fruits, is used for sweets, pickles, and treating various ailments due to its cooling effect and easy digestibility. Its medicinal value extends to its use in treating pain, ulcers, fever, bronchial disorders, and reducing cholesterol, triglyceride, and low -density lipoproteins. The plant leaf decoction is used for jaundice treatment, while the pulp is used as a poultice for shaved head delirium. Bottle gourd seeds offer a good source of protein, lipids, and essential macronutrients, making them a tasty addition to the human diet. A 100-gram serving of the fruit contains approximately 96 grams of water, 0.2 grams of protein, 0.1 grams of fat, 2.5 grams of carbohydrates, 0.6 grams of fiber, 0.5 grams of minerals, 20 milligrams of calcium, 10 milligrams of phosphorus, 0.7 milligrams of iron, 0.3 milligrams of thiamine, 0.01 milligrams of riboflavin, 0.2 milligrams of niacin, and 1.2 calories of energy.

The main production regions for bottle gourds are China, Hong Kong, India, Philippines, Indonesia, Malaysia, Tropical Africa, Colombia, and Brazil. Because of its low irrigation requirements and high production potential, it is extensively produced in areas like Bihar, Uttar

Pradesh, Punjab, Gujrat, Assam, Meghalaya, Rajasthan, North Konkan, and semi-arid Maharashtra. Bottle gourd's resilience to pollution and heavy metals makes it a promising bioremediation tool for damaged soil and water. However, it suffers difficulties like pests and parasites, limited yield from fewer female blooms, and illnesses. Selection can be effectively conducted on the phenotypic and genotypic coefficients of variation (PCV and GCV), which separate the population's variability into heritable and non - heritable components. Despite being indigenous to India, not much has been done to improve the crop genetically or through breeding. Fewer improved varieties and hybrids have been made available for commercial cultivation in our nation thus far, with the majority of strains being local ones. This leads to low yields due to the weak genetic makeup of the local strains, as well as decreased production and productivity of the crop. In light of this, increasing the production of current bottle gourd cultivars is essential to achieving

Materials and Methods

Twenty-five bottle gourd germplasm stocks kept at the Department of Vegetable Science, CHF, ANDUAT, Kumarganj, Ayodhya, used as the experimental materials for this study. Three replications of a Randomised Block Design (RBD) were used to assess these lines. The experimental period ran from March to June of 2023. Plant to plant and row-to-row spacing was maintained at 3.0 and 0.5 meters, respectively. For every replication and genotype, eight plants were maintained. The Department of Vegetable Science at Acharya Narendra Deva University of Agriculture and Technology, located in Narendra Nagar, Kumarganj, Ayodhya (U.P.) India, in the Main Experiment Station (MES) to cultivate high-quality crops by adhering to all recommended agronomic practices and crop protection measures.

The data were collected on the days to first staminate flower anthesis, days to first pistillate flower anthesis, node number to first staminate flower appearance, node number to first pistillate flower appearance, days to first fruit harvest, vine length, fruit length, fruit breadth, average fruit weight, number of fruits per plant, fruit yield per plant, fruit yield per hectare, total soluble solids, ascorbic acid, reducing sugars, non-reducing sugars, total sugars, number of seeds per fruit and 100 seed weight. The data were analysed by windostat 9.2 data analysis software.

Results and Discussion

Variance analysis to determine the significance of the genotype differences, analysis of variance was applied to the data on 19 quantitative and quality variables. Table 1 analysis of variance revealed that, for each of the nineteen characters the mean squares resulting from genotypes were determined to be significant and validating additional statistical and biometrical investigation. The findings supported the conclusions made by Sultana *et al.*_(2018) [11], Gupta *et al.* (2020) [6], Singh *et al.* (2021) [10], Panigrahi and Duhan (2018) [9], and Dhuan *et al.* (2022) [5], showing a notable degree of variety within the bottle gourd germplasm.

Table 1: Analyss of variance for 19 quantitative and quality characters in bottle gourd

S. No.	Characters	Source of variation		
		Replications	Treatments	Error
	d.f.	2	24	48
1.	Days to first staminate flower anthesis	15.33	13.23**	2.78
2.	Days to first pistillate flower anthesis	0.88	20.11**	3.95
3.	Node number to first staminate flower appearance	6.05	6.93**	0.99
4.	Node number to first pistillate flower appearance	1.16	3.00**	0.41
5.	Days to first fruit harvest	13.08	23.38*	11.12
6.	Vine length(m)	0.74	0.65**	0.11
7.	Fruit length (cm)	4.67	31.55*	14.38
8.	Fruit equatorial circumference (cm)	8.24	39.75**	2.89
9.	Average fruit weight (kg)	20.76	7208.11**	808.33
10.	Number of fruits per plant	0.52	1.73**	0.05
11.	Fruit yield per plant (kg)	0.52	1.51**	0.08
12.	Fruit yield per hectare (q)	1607.99	4667.59**	252.17
13.	Total soluble solids (%)	0.001	0.39**	0.004
14.	Ascorbic acid (mg/100g fresh fruit)	0.09	0.82**	0.05
15.	Reducing sugars (%)	0.03	0.36**	0.006
16.	Non-reducing sugars (%)	0.00	0.01**	0.0006
17.	Total sugars (%)	0.00	0.33**	0.006
18.	Number of seeds per fruit	3.38	6834.78**	34.08
19.	100 seed weight (g)	0.15	2.16**	0.11

*,** Significant at 5% and 1% percent probability level, respectively

For every trait, the estimations of the coefficient of variation demonstrated that the phenotypic coefficient of variation (PCV) was greater than the genotypic coefficient of variation (GCV), underscoring the environment's substantial influence. The phenotypic coefficient of variation (PCV) ranged from 5.51% to 19.24% for the various characters studied. Highest phenotypic coefficient of variation was recorded for the character number of seeds per fruit (19.24%), fruit equatorial circumference (14.62%), number of fruits per plant (11.85%), average fruit length (11.77%), fruit yield per hectare (11.76%), fruit yield per plant (11.75%), number of nodes at which female flowers appear (11.27%), number of nodes at which male flowers appear (10.52%), vine length (9.24), 100 seed weight (7.16%), days to first fruit harvesting (6.65%), days to first female flower anthesis(6.09%), average fruit weight (5.64%) and days to first male flower anthesis(5.51%). Singh and Kumar (2002) [10], Ahmad *et al.* (2019) [1-2], Gupta *et al.* (2020) [6], Chandramouli *et al.* (2021) [4] and Dhuan *et al.* (2022) [5] likewise documented comparable results.

Genotypic coefficient of variation (GCV) It is revealed in Table 2 that, the genotypic coefficient of variation (GCV) ranged from 3.44% to 19.10% for various characters studied. Highest genotypic coefficient of variation was recorded for the character number of seeds per fruit (19.10%), fruit equatorial circumference (13.15%), number of fruits per plant (11.31%), fruit yield per hectare (10.87%), fruit yield per plant (10.86%), number of nodes at which female flowers appear (9.19%), number of nodes at which male flowers appear (8.63%), vine length (7.16%), 100 seed weight (6.63%), average fruit length (6.28%), average fruit weight (4.80%), days to first female flower anthesis (4.64%), days to first male flower anthesis (4.10%) and days to first fruit harvesting. Pandit *et al.* (2009), Ahmad *et al.* (2019) [1-2], Gupta *et al.* (2020) [6], Chandramouli *et al.* (2021) [4], and Dhuan *et al.* (2022) [5] also obtained similar results.

Heritability and Genetic Advance

For breeders, a trait's broad heritability is important since it indicates the potential for improvement through selective breeding. Because it measures the connection between parents and offspring, it also aids in determining the proper path for the pressure of selection. As a consequence, it is widely employed to evaluate the possibility of a trait being passed on from parents to their offspring. However, unless it is combined with a substantial genetic development, high heritability alone is not adequate for effective selection in advanced generations (Burton, 1952) [3]. When significant genetic progress is combined with high heritability, it presents encouraging prospects for additional improvement in future generations. Estimates of genetic progress and heritability for nineteen traits are given in Table 2. The heritability estimates in this study were elevated.

The heritability in broad sense ranged from 28.5% (average fruit length) to 98.5% (number of seeds per fruit). High heritability was calculated for the characters number of seeds per fruit (98.5%), number of fruits per plant (91.1%), 100 seed weight (85.8%), fruit yield per plant (85.4%), fruit yield per hectare (85.4%), fruit equatorial circumference (81%), average fruit weight (72.5%), number of nodes at which male flowers appear (67.3%), number of nodes at which female flowers appear (66.5%). Moderate heritability was calculated for vine length (60%), days to first female flower anthesis (57.7%) and days to first male flower anthesis (55.5%). Low heritability was calculated for average fruit length (28.5%) and days to first fruit harvesting (26.9%). Kumar and Pal (2007) [8], Gupta *et al.* (2020) [6], and Chandramouli *et al.* (2021) [4] have likewise observed comparable finding.

The genetic advance in percent of mean varied from 3.68% (days to first fruit harvesting) to 39.05% (number of seeds per fruit). The high genetic advance in percent of mean (>20%) were calculated for number of seeds per fruit (39.05%), fruit equatorial circumference (24.38%), number of fruits per plant (22.24%), fruit yield per hectare (20.69%) and fruit yield per plant (20.67%). Moderate genetic advance as percent of mean was calculated for number of nodes at which female flowers appear (15.43%), number of nodes at which male flowers appear (14.58%), 100 seed weight (12.66%) and vine length (11.43%). Low values of genetic advance in percent of mean (0-10%) was calculated for days to first fruit harvesting (3.68%), days to first male flower anthesis (6.30%), average fruit length (6.90%), days to first female flower anthesis (7.24%) and average fruit weight (8.42%). results reported by Gupta *et al.* (2020) [6], Chandramouli *et al.* (2021) [4]. The traits like number of seeds per fruit, seed weight per fruit and seed yield per fruit showed comparatively higher value of PCV, GCV, heritability (broad sense), genetic advance and genetic advance in percent of mean through additive gene effect and they can be improved by selection, similar results were also reported by Gupta *et al.* (2020) [6] Chandramouli *et al.* (2021) [4] and Dhuan *et al.* (2022) [5].

Table 2: A summary illustrating the phenotypic and genotypic coefficients of variability (PCV and GCV), along with heritability (h2 b) and genetic advance for various traits in bottle gourd

	Range		PCV	GCV	h² (Broad Sense)	Gen. Adv as % of Mean 5%	General Mean
	Lowest	Highest					
Days to 1st male Flowering	41.33	49.67	5.513	4.108	55.5	6.308	45.426
Days to 1st Female Flowering	43.33	54.33	6.092	4.627	57.7	7.24	50.162
No of Nodes at which Male	8.80	13.23	10.524	8.631	67.3	14.582	10.754
No of Nodes at which Female	12.31	17.95	11.271	9.19	66.5	15.434	15.306
Days to 1st fruit harvesting	52.00	63.67	6.651	3.448	26.9	3.683	58.64
Vine Length(m)	5.07	6.63	9.244	7.162	60	11.432	5.881
Average Fruit length(cm)	32.00	46.17	11.775	6.283	28.5	6.906	38.083
Fruit equatorial circumference	22.52	36.48	14.624	13.158	81	24.389	26.641
Average Fruit Weight(g)	810.00	1020.76	5.64	4.803	72.5	8.425	961.704
No. of fruits per plant	5.10	7.73	11.854	11.315	91.1	22.248	6.619
Total Soluble solid (%)	2.07	3.37	13.248	13.007	96.4	26.308	2.77
Ascorbic Acid (mg/100gm)	7.73	9.74	6.27	5.66	81.5	10.525	8.916
Reducing Sugar (in %)	1.08	2.27	20.801	20.28	95.1	40.732	1.711
No- Reducing Sugar (in %)	0.70	0.96	8.822	8.277	88	15.997	0.805
Total Sugar (%)	2.02	3.01	13.585	13.201	94.4	26.426	2.518
Number of seeds per fruit	169.33	326.33	19.246	19.103	98.5	39.059	249.24
100 seed weight(g)	10.77	14.14	7.164	6.638	85.8	12.669	12.451
Fruit yield per plant(kg)	5.16	7.68	11.756	10.862	85.4	20.672	6.353
Fruit yield per hectare(q)	286.30	426.76	11.764	10.87	85.4	20.69	352.94

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Conclusion

Based on the results of the current study it can be said that among other characteristics NDBG-22-10, NDBG-22-06 and NDBG-22-23 were identified as the most significant and promising genotypes for fruit produce per plant. Taking into account the phenotypic and genotypic coefficient of variability, heritability and genetic advancement of several commercially significant qualities in this crop our analysis clearly indicates that there is plenty of space for improvement through selective breeding. By applying the knowledge gleaned from these genetic characteristics bottle gourds numerous economic qualities could be greatly improved.

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