Original Research Article

Genetic variability, correlation and path analysis in F_3 and F_4 generation of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

ABSTRACT

The bottle gourd is an important summer vegetable in India, but its productivity is hindered by biotic and abiotic stresses, challenging growing conditions and the lack of high-yielding varieties. Therefore, it is essential to understand its genetics to develop high-yielding cultivars. A thorough understanding of genotypic and phenotypic variability, heritability and genetic advance is necessary for a successful crop improvement program. Research conducted during the spring-summer and rainy seasons of 2021–22 at CCS HAU, Hisar, on the F_3 and F_4 generations of the bottle gourd cross GH-28 × Pusa Santushti, showed variability in various yield and yield-contributing traits. The fruit yield per hectare showed high values for genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance in both generations, with progeny 4 performing best in yield-related traits. The observed changes in genetic variability across generations suggested heterozygosity, which may stabilize once homozygosity is achieved in later generations. Additionally, correlation and path analysis indicated that the number of primary branches, days to first harvest, average fruit weight and fruit length directly affected fruit yield per hectare. Thus, selecting for these traits could significantly enhance a breeding program's success.

Keywords: bottle gourd, heritability, progenies, segregating generation, variability

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1. INTRODUCTION

Bottle gourd, an important vegetable in the Cucurbitaceae family, is extensively grown in India during the summer for its nutritious fruits. With a water content of 96.3 percent (Thamburaj and Singh, 2015), it has a cooling effect, enhancing its popularity in the country. Beyond its culinary uses, the pulp of the fruit provides therapeutic benefits for issues like constipation, biliousness, and indigestion. The monoecious nature of plant, which encourages cross-pollination while avoiding inbreeding depression, can be exploited to achieve stable homozygosity for desired traits. Sirohi and Sivakami (1991) have documented the variation in bottle gourd fruit characteristics, and utilizing this diversity is essential for developing cultivars that offer early fruiting, a higher number of female flowers, more primary branches, greater yields, and improved fruit shape and size. The main goal of any breeding program is to enhance crop yield and productivity.

Direct selection may not be effective for complex traits like fruit yield, which are controlled by multiple genes and influenced by environmental factors. Therefore, analyzing variability parameters is crucial for understanding the inheritance of traits and enabling effective selection. Burton (1952) suggested that genetic variation combined with heritability estimates can predict genetic advance through selection, a concept supported by Johnson *et al*. (1955). Heritability and genetic advance help determine the potential for improvement post-selection and the environmental influence on trait expression (Robinson *et al*., 1949).

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Moreover, examining correlation coefficients and the magnitude of directional influence among various fruit yield and yield-contributing traits is important for selecting specific traits. Genetic studies in segregating generations offer insights into traits valuable for breeding programs. These generations introduce variation due to random allele recombination, promoting heterozygosity for these traits. With this in mind, the current study aims to investigate genetic variability parameters, correlation coefficients, and path analysis within the F_3 and F_4 generations of bottle gourd.

2. MATERIALS AND METHODS

2.1 Experimental details and observations recorded

The research took place in the Department of Vegetable Science at CCS Haryana Agricultural University, Hisar. The experimental materials included bottle gourd cross between GH-28 and Pusa Santushti, set up in a Randomized Block Design with three replications. Five progenies from each of the F_3 and F_4 generations of the cross were cultivated during the rainy season of 2021 and the spring-summer season of 2022, respectively. Each progeny consisted of ten plants, amounting to a total of 200 plants per generation per replication. Standard agronomic practices were maintained throughout the crop period. Observations on 17 quantitative traits were made on five randomly selected plants in each generation and analyzed statistically.

2.2 Statistical Analysis

The observed data for various traits were statistically analyzed to determine the genetic variability parameters as proposed by Panse and Sukhatme (1985). The phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) were estimated according to Burton and Devane (1952). Heritability was calculated based on the method by Lush (1940), and genetic advance was determined as described by Johnson *et al*. (1955). Correlation coefficients were calculated using the approach by Al-Jibouri *et al*. (1958), and path coefficients were computed as explained by Dewey and Lu (1959).

2.3 Categorization of variability parameters

GCV and PCV was classified as low (0 -10%), moderate (10 - 20%) and high (>20%) as suggested by Shivasubramanian and Madhavamenonenon (1973). Johnson *et al*. (1955) categorized heritability in broad sense values as low (Less than 50 %), moderate (50 - 75 %) and high (More than 75 %). Johnson *et al*. (1955) categorized the range of genetic advance as per cent of mean values as low (Less than 10 %), moderate (10 -20%) and high (More than 20 %).

3. RESULTS AND DISCUSSION

The examination of variability indices, such as the genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, and genetic advance as a percent of the mean, revealed the presence of variability in the F_3 and F_4 generations of the GH-28 × Pusa Santushti cross. Comparable mean and range values for corresponding traits were observed in these generations (Table 1). However, there was a decline in traits contributing to fruit yield, such as average fruit weight, number of fruits per vine, fruit yield per plot, and fruit yield per hectare from the F_3 to F_4 generation. This decline can be attributed to seasonal fluctuations, with higher summer temperatures adversely affecting flowering and fruit behaviour in the F_4 generation. Similar ranges for several traits in bottle gourd segregating generations were reported by Vaidya (2018) and Chandramouli *et al*. (2021).

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3.1 Phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV)

For ease of understanding, coefficients of variation are categorized as genotypic and phenotypic. The minor discrepancy between phenotypic and genotypic coefficients of variation in this study is due to a minimal environmental impact, indicating that the phenotype closely represents the genotype. Higher GCV and PCV values (Figure 1) were observed for fruit length (22.53% and 23.23%, respectively), average fruit weight (20.09% and 22.79%, respectively), fruit yield per plot (28.75% and 33.45%, respectively), and fruit yield per hectare (28.75% and 33.45%, respectively) in the F_3 generation. In the F_4 generation, higher values were reported for fruit yield per plot (24.63% and 29.42%, respectively) and fruit yield per hectare (24.63% and 29.42%, respectively). These findings align with results from Alekar *et al*. (2019) in the F_4 population of bitter gourd and Kanimozhi *et al*. (2015) in wax gourd. Due to the significant variability caused by heterozygosity, these traits can be directly exploited in improvement programs through simple selection. The presence of moderate variability indicates that selection for these traits is feasible to some extent for enhancement. Similar findings were reported by Chandramouli *et al*. (2021) in the F_2 generation of bottle gourd and Kumar *et al*. (2011) in the F_2 generation of cucumber.

3.2 Heritability and genetic advance as per cent of mean

Understanding heritability is crucial to determine whether phenotypic differences among individuals are due to genetic differences or environmental factors. In the F_3 and F_4 generations (Figure 2), the average fruit weight demonstrated high heritability estimates of 77.67% and 74.02%, respectively, with substantial genetic advance as a percentage of the mean (36.47% and 32.09%, respectively). For fruit length, heritability estimates were exceptionally high at 94.06% and 90.51%, respectively, with significant genetic advances of 45.00% and 31.53% in the F_3 and F_4 generations. Fruit yield per hectare also showed high heritability estimates of 73.89% and 70.10%, along with considerable genetic advance percentages of 50.91% and 42.49% in F_3 and F_4 generations, respectively. Vine length had heritability values of 84.13% and 94.91%, with high genetic advances (34.34% and 32.51%) in the respective generations. Comparable results were reported by Alekar *et al*. (2019) in the F_4 generation of bitter gourd and by Chinthalapudi *et al.* (2021) in the F_3 generation of ridge gourd. Kumar *et al.* (2011) also observed similar findings in the F_2 population of cucumber regarding flowering traits. Direct selection for these traits is feasible due to their control by additive genes with minimal environmental influence. Traits such as fruit diameter, which exhibit high heritability but moderate genetic advance, suggest limited potential for further improvement due to the presence of both additive and non-additive gene activity. Pradhan *et al*. (2021) reported similar findings for fruit traits in the F_4 generation of bitter gourd, while Sravani *et al*. (2021) and Kannan *et al*. (2019) found comparable heritability values in the F_2 and F_4 generations of ridge gourd, respectively.

Table 1 Estimation of mean values (GH-28 × Pusa Santushti, F_3 and F_4 generations)

Trait	Mean		Minimum		Maximum	
	F_3	F_4	F_3	F_4	F_3	F_4
DFG	8.40	8.53	7.33	6.67	9.67	9.67
NPB	15.38	14.30	13.00	11.27	17.57	17.13
DMF	43.12	43.43	41.00	41.00	46.00	46.00
DFF	46.96	46.87	43.00	42.00	50.00	50.00
NMF	7.62	6.91	6.83	5.61	8.78	8.11
NFF	11.54	11.15	9.94	9.33	12.79	12.55
LL	20.35	20.33	18.15	18.03	22.96	22.50
LW	25.18	27.06	22.85	24.11	28.85	29.55
DFH	58.67	56.33	56.00	52.00	61.00	60.00
FL	31.98	34.58	25.73	28.33	44.33	41.17
FD	7.28	6.75	5.93	5.48	8.63	8.13
VL	6.38	7.11	5.04	5.65	7.91	8.43
AFW	653.87	628.47	531.33	514.33	882.00	832.67
SW	18.26	17.87	16.57	15.74	21.52	21.36
FPV	6.46	5.81	5.67	4.83	7.20	7.07
FYP	42.91	36.71	32.11	29.02	63.65	50.37
FYH	257.47	220.28	192.68	174.14	381.90	302.20

DFG: Days to 50% germination; NPB: Number of primary branches ; DMF: Days to first male flower opening; DFF: Days to first female flower opening; NMF: Node to first male flower; NFF: Node to first female flower; LL: Leaf length (cm); LW: Leaf width (cm); DFH: Days to first harvest; FL: Fruit length (cm); FD: Fruit diameter (cm): VL: Vine length at the time of final harvest (m); AFW: average fruit weight (g); SW: 100 seed weight (g); FPV: Number of fruits per vine; FYP: Fruit yield per plot (kg); FYH: fruit yield per hectare (q/ha).

The variations in GCV, PCV, and heritability from the F_3 to F_4 generations showed no clear pattern. The increase in GCV, PCV, and heritability values from F_3 to F_4 suggests increasing homozygosity, whereas selection in later generations is necessary to establish homozygosity in traits with decreasing values. Similar trends were observed in faba beans by Ahmad (2016) and in ridge gourd by Suresh and Balamohan (2018).

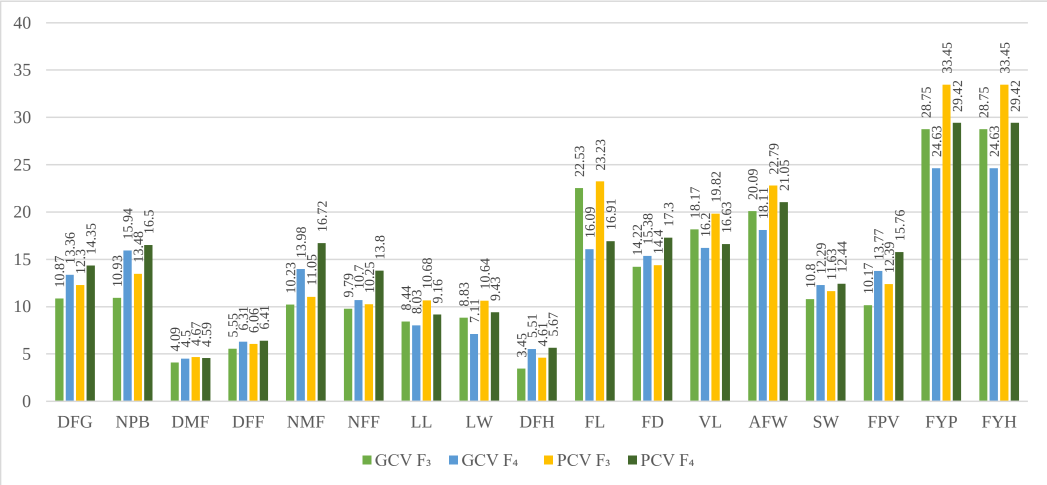

Figure 1. Estimation of GCV and PCV, (GH-28 × Pusa Santushti, F_3 and F_4 generations) : DFG: Days to 50% germination; NPB: Number of primary branches ; DMF: Days to first male flower opening; DFF: Days to first female flower opening; NMF: Node to first male flower; NFF: Node to first female flower; LL: Leaf length (cm); LW: Leaf width (cm); DFH: Days to first harvest; FL: Fruit length (cm); FD: Fruit diameter (cm): VL: Vine length at the time of final harvest (m); AFW: average fruit weight (g); SW: 100 seed weight (g); FPV: Number of fruits per vine; FYP: Fruit yield per plot (kg); FYH: fruit yield per hectare (q/ha).

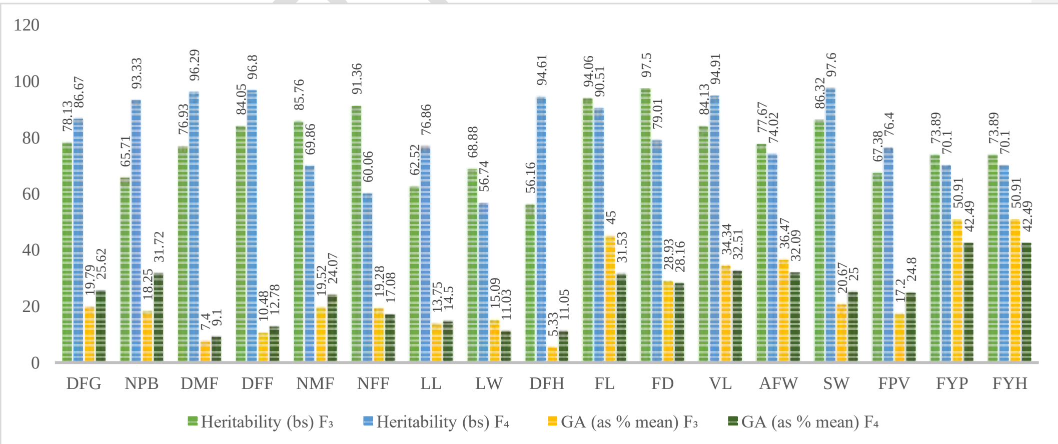

Figure 2. Estimation of heritability (b.s.) and genetic advance (GH-28 × Pusa Santushti, F_3 and F_4 generations) : DFG: Days to 50% germination; NPB: Number of primary branches ; DMF: Days to first male flower

opening; DFF: Days to first female flower opening; NMF: Node to first male flower; NFF: Node to first female flower; LL: Leaf length (cm); LW: Leaf width (cm); DFH: Days to first harvest; FL: Fruit length (cm); FD: Fruit diameter (cm): VL: Vine length at the time of final harvest (m); AFW: average fruit weight (g); SW: 100 seed weight (g); FPV: Number of fruits per vine; FYP: Fruit yield per plot (kg); FYH: fruit yield per hectare (q/ha).

3.2 Correlation coefficients and path coefficient analysis

The analysis of correlation values revealed that, for most traits, the genotypic correlation coefficients were generally higher than the phenotypic correlation coefficients. This indicates that the environmental factors tend to diminish the phenotypic expression of traits even when there is a strong inherent association between them.

Fruit yield per hectare exhibited significant positive genotypic correlations with the number of primary branches (0.778 and 0.904), leaf width (0.943 and 0.836), number of fruits per vine (0.995 and 0.682), and average fruit weight (0.974 and 0.856). Conversely, there were negative genotypic correlations with days to first harvest (-0.624 and -0.784), days to first female flower opening (-0.926 and -0.661), node to first female flower (-0.524 and -0.650), and days to first male flower opening (-0.858 and -0.510) in both the F_3 and F_4 generations (Tables 2 and 3). This pattern suggests that earlier blooming, indicated by fewer nodes and fewer days until the first flower opens, leads to higher yields. Similar findings were reported by Rani *et al*. (2014) in the F_6 generation of ridge gourd for flowering traits. The observed correlations among fruit traits align with the results of Kannan *et al*. (2019) and Muttur *et al*. (2016) in the F_4 generation of pumpkin. Additionally, Vaidya (2018) noted a significant positive genotypic correlation between fruit yield and traits such as the number of primary branches, fruit length, fruit diameter, number of fruits per vine, and average fruit weight. The data suggest that fruit size, influenced by fruit length and diameter, positively correlates with average fruit weight.

To evaluate the direct and indirect effects of contributing traits on yield per hectare, path coefficient analysis was conducted using the genotypic correlation coefficients, with yield per hectare as the dependent variable and other traits as independent variables. The results of the path coefficient analysis are presented in Table 4. The findings indicate that in the F_3 generation, fruit yield per plot (1.078) had the highest direct positive effect on yield per hectare, while average fruit weight (-0.133) and node to first female flower (-0.063) had direct negative effects. Similarly, in the F_4 generation, fruit yield per plot (0.581) had the highest direct positive effect, whereas vine length (-0.6617) had a direct negative effect on fruit yield per hectare.

The results for the F_3 generation were consistent with the findings of Bhoomika *et al.* (2021). Similarly, in the F_2 generation of pumpkin, Gupta *et al.* (2018) identified a direct effect of average fruit weight and the number of fruits per vine on fruit yield. Kannan *et al.* (2019) observed a direct positive effect on fruit yield from fruit length, fruit diameter, average fruit weight, and the number of fruits per vine in the F_4 generation of ridge gourd. In the F_3 generation of pumpkin, Krishnamoorthy and Avinashgupta (2021) found a negative direct effect on fruit yield per hectare from the days to the first female bloom and the length of the fruit. Additionally, Das (2017) recorded a positive indirect effect on fruit yield via fruit length through average fruit weight in the F_3 generation of bottle gourd.

Table 2. Genotypic and phenotypic correlation co-efficient for yield and yield contributing characters (GH-28 × P. Santushti, F_3 generation)

	DFG	NPB	DMF	DFF	NMF	NFF	LL	LW	DFH	FL	FD	VL	AFW	SW	FPV	FYP	FYH
DFG	1.000	-0.135	-0.340	-0.548*	-0.429	0.520*	0.549*	0.259	0.030	-0.274	0.252	-0.445	-0.028	-0.075	0.474	0.149	0.149
NPB	-0.186	1.000	-0.671**	-0.178	-0.532*	-0.417	0.096	0.392	0.093	0.541*	0.601*	0.743**	0.476	0.447	0.409	0.431	0.431
DMF	-0.364	-0.889**	1.000	0.375	0.928**	0.081	-0.485*	-0.467	0.036	-0.463	-0.490*	-0.332	-0.595*	-0.170	-0.655**	-0.639**	-0.639**
DFF	-0.647**	-0.308	0.572*	1.000	0.550*	0.197	0.005	-0.797**	0.553*	-0.530*	-0.214	0.274	-0.547*	-0.628**	-0.738**	-0.618**	-0.618**
NMF	-0.453	-0.743**	0.990**	0.632**	1.000	0.054	-0.483*	-0.507*	0.188	-0.501*	-0.311	-0.154	-0.680**	-0.190	-0.772**	-0.732**	-0.732**
NFF	0.654**	-0.412	-0.017	0.301	0.005	1.000	0.606**	-0.246	0.581*	-0.807**	0.070	-0.296	-0.613**	-0.794**	-0.006	-0.462	-0.462
LL	0.552*	0.034	-0.579*	0.087	-0.621**	0.857**	1.000	-0.162	0.547*	-0.329	0.092	-0.042	-0.175	-0.529*	0.352	-0.073	-0.073
LW	0.421	0.896**	-0.815**	-0.876**	-0.730**	-0.495*	-0.109	1.000	-0.367	0.656**	0.546*	0.179	0.593*	0.597*	0.512*	0.612**	0.612**
DFH	-0.158	-0.074	0.010	0.903**	0.171	0.760**	0.521*	-0.637**	1.000	-0.577*	0.237	0.328	-0.685**	-0.624**	-0.327	-0.678**	-0.678**
FL	-0.296	0.788**	-0.522*	-0.539*	-0.521*	-0.902**	-0.412	0.698**	-0.747**	1.000	0.107	0.312	0.845**	0.734**	0.379	0.737**	0.737**
FD	0.230	0.726**	-0.541*	-0.240	-0.328	0.090	0.078	0.707**	0.304	0.123	1.000	0.577*	0.114	0.252	0.202	0.156	0.156
VL	-0.570*	0.883**	-0.470	0.317	-0.218	-0.293	-0.052	0.283	0.465	0.384	0.650**	1.000	0.225	0.178	-0.176	0.106	0.106
AFW	0.024	0.836**	-0.772**	-0.778**	-0.801**	-0.692**	-0.022	0.857**	-0.634**	0.998**	0.146	0.231	1.000	0.590*	0.527*	0.972**	0.972**
SW	-0.110	0.415	-0.175	-0.716**	-0.165	-0.820**	-0.810**	0.904**	-0.933**	0.833**	0.283	0.098	0.743**	1.000	0.326	0.528*	0.528*
FPV	0.849**	0.397	-0.910**	-0.940**	-0.989**	0.017	0.489*	0.894**	-0.524*	0.487*	0.282	-0.154	0.836**	0.324	1.000	0.648**	0.648**
FYP	0.289	0.778**	-0.858**	-0.926**	-0.911**	-0.524*	0.145	0.943**	-0.624**	0.915**	0.202	0.105	0.974**	0.703**	0.995**	1.000	1.000**
FYH	0.289	0.778**	-0.858**	-0.926**	-0.911**	-0.524*	0.146	0.943**	-0.624**	0.915**	0.201	0.105	0.974**	0.703**	0.995**	1.000**	1.000

DFG: Days to 50% germination; NPB: Number of primary branches ; DMF: Days to first male flower opening; DFF: Days to first female flower opening; NMF: Node to first male flower; NFF: Node to first female flower; LL: Leaf length (cm); LW: Leaf width (cm); DFH: Days to first harvest; FL: Fruit length (cm); FD: Fruit diameter (cm): VL: Vine length at the time of final harvest (m); AFW: average fruit weight (g); SW: 100 seed weight (g); FPV: Number of fruits per vine; FYP: Fruit yield per plot (kg); FYH: fruit yield per hectare (q/ha), *significant at 5 % level of significance, **significant at 1 % level of significance.

Table 3. Genotypic and phenotypic correlation co-efficient for yield and yield contributing characters (GH-28 × P. Santushti, F_4 generation)

	DFG	NPB	DMF	DFF	NMF	NFF	LL	LW	DFH	FL	FD	VL	AFW	SW	FPV	FYP	FYH
DFG	1.000	0.090	0.346	-0.152	-0.202	-0.632**	0.563*	0.032	-0.017	0.566*	0.618**	0.434	0.322	0.288	0.360	0.415	0.415
NPB	0.118	1.000	-0.754**	-0.753**	0.780**	-0.147	0.365	0.494*	-0.895**	0.465	0.681**	0.817**	0.791**	-0.728**	0.402	0.791**	0.791**
DMF	0.363	-0.804**	1.000	0.316	-0.773**	-0.312	-0.205	-0.258	0.660**	-0.027	-0.226	-0.647**	-0.348	0.923**	-0.243	-0.379	-0.379
DFF	-0.132	-0.764**	0.338	1.000	-0.332	0.472	-0.291	-0.324	0.900**	-0.703**	-0.641**	-0.419	-0.879**	0.445	0.081	-0.600*	-0.600*
NMF	-0.117	0.874**	-0.871**	-0.422	1.000	0.198	0.058	0.603*	-0.571*	0.013	0.291	0.676**	0.423	-0.540*	0.515*	0.573*	0.573*
NFF	-0.923**	-0.356	-0.397	0.715**	0.089	1.000	-0.363	-0.136	0.274	-0.657**	-0.616**	-0.211	-0.458	-0.201	-0.037	-0.360	-0.360
LL	0.752**	0.423	-0.177	-0.316	-0.07	-0.632**	1.000	-0.136	-0.285	0.745**	0.726**	0.654**	0.383	-0.311	0.120	0.332	0.332
LW	0.172	0.653**	-0.334	-0.444	0.914**	-0.293	-0.347	1.000	-0.358	-0.071	0.157	0.397	0.616**	-0.055	0.598*	0.752**	0.752**
DFH	0.021	-0.952**	0.675**	0.932**	-0.718**	0.407	-0.358	-0.527*	1.000	-0.557*	-0.601*	-0.612**	-0.823**	0.725**	-0.015	-0.610**	-0.610**
FL	0.637**	0.478	-0.005	-0.750**	-0.128	-0.946**	0.833**	-0.090	-0.604*	1.000	0.779**	0.454	0.640**	-0.233	-0.130	0.399	0.399
FD	0.793**	0.746**	-0.282	-0.702**	0.362	-0.880**	0.875**	0.405	-0.699**	0.910**	1.000	0.757**	0.660**	-0.275	0.342	0.674**	0.674**
VL	0.499*	0.856**	-0.645**	-0.430	0.739**	-0.387	0.669**	0.527*	-0.633**	0.466	0.864**	1.000	0.594*	-0.561*	0.601*	0.737**	0.737**
AFW	0.348	0.912**	-0.413	-0.982**	0.649**	-0.833**	0.405	0.568*	-0.968**	0.758**	0.927**	0.701**	1.000	-0.401	0.246	0.856**	0.856**
SW	0.347	-0.781**	0.948**	0.463	-0.695**	-0.270	-0.391	-0.055	0.743**	-0.259	-0.385	-0.592*	-0.453	1.000	-0.021	-0.304	-0.304
FPV	0.463	0.412	-0.357	0.134	0.747**	-0.074	0.161	0.756**	-0.108	-0.164	0.375	0.764**	0.201	-0.054	1.000	0.707**	0.707**
FYP	0.507*	0.904**	-0.510*	-0.661**	0.894**	-0.650**	0.397	0.836**	-0.784**	0.477	0.884**	0.943**	0.856**	-0.377	0.682**	1.000	1.000**
FYH	0.507*	0.904**	-0.510*	-0.661**	0.894**	-0.650**	0.397	0.836**	-0.784**	0.477	0.884**	0.943**	0.856**	-0.377	0.682**	1.000**	1.000

DFG: Days to 50% germination; NPB: Number of primary branches ; DMF: Days to first male flower opening; DFF: Days to first female flower opening; NMF: Node to first male flower; NFF: Node to first female flower; LL: Leaf length (cm); LW: Leaf width (cm); DFH: Days to first harvest; FL: Fruit length (cm); FD: Fruit diameter (cm): VL: Vine length at the time of final harvest (m); AFW: average fruit weight (g); SW: 100 seed weight (g); FPV: Number of fruits per vine; FYP: Fruit yield per plot (kg); FYH: fruit yield per hectare (q/ha), *significant at 5 % level of significance, **significant at 1 % level of significance

		DFG	**NPB**	**DMF**	**DFF**	**NMF**	**NFF**	**LL**	**LW**	**DFH**	**FL**	**FD**	**VL**	**AFW**	**SW**	**FPV**	**FYP**
DFG	F_3	**0.027**	0.001	-0.014	-0.034	0.019	-0.041	0.003	0.016	0.004	-0.003	-0.004	-0.020	-0.003	0.003	0.013	0.311
	F_4	**0.377**	-0.012	-0.035	0.011	-0.025	-0.041	0.012	0.038	0.005	-0.084	0.318	-0.308	0.060	-0.142	0.029	0.295
NPB	F_3	-0.005	**-0.005**	-0.033	-0.016	0.031	0.026	0.0001	0.033	0.002	0.009	-0.012	0.031	-0.111	-0.012	0.006	0.839
	F_4	0.045	**-0.105**	0.077	0.066	0.184	-0.016	0.007	0.143	-0.246	-0.063	0.299	-0.528	0.157	0.320	0.026	0.526
DMF	F_3	-0.010	0.004	**0.037**	0.030	-0.042	0.001	-0.003	-0.030	0.0001	-0.006	0.009	-0.017	0.103	0.005	-0.014	-0.925
	F_4	0.137	0.085	**-0.096**	-0.029	-0.184	-0.018	-0.003	-0.073	0.175	0.001	-0.113	0.398	-0.071	-0.389	-0.023	-0.297
DFF	F_3	-0.018	0.002	0.021	**0.053**	-0.027	-0.019	0.0001	-0.033	-0.020	-0.006	0.004	0.011	0.103	0.021	-0.015	-0.999
	F_4	-0.050	0.081	-0.032	**-0.086**	-0.089	0.032	-0.005	-0.097	0.241	0.099	-0.281	0.266	-0.169	-0.190	0.009	-0.384
NMF	F_3	-0.012	0.004	0.037	0.033	**-0.042**	0.0001	-0.003	-0.027	-0.004	-0.006	0.005	-0.008	0.106	0.005	-0.015	-0.982
	F_4	-0.044	-0.092	0.084	0.036	**0.211**	0.004	-0.001	0.200	-0.186	0.017	0.145	-0.456	0.112	0.285	0.047	0.520
NFF	F_3	0.018	0.002	-0.001	0.016	0.0001	**-0.063**	0.004	-0.018	-0.017	-0.011	-0.001	-0.010	0.092	0.024	0.0001	-0.565
	F_4	-0.348	0.038	0.038	-0.061	0.019	**0.045**	-0.010	-0.064	0.105	0.125	-0.352	0.239	-0.143	0.111	-0.005	-0.378
LL	F_3	0.015	0.0001	-0.021	0.005	0.026	-0.054	**0.005**	-0.004	-0.012	-0.005	-0.001	-0.002	0.003	0.024	0.008	0.157
	F_4	0.283	-0.045	0.017	0.027	-0.015	-0.028	**0.016**	-0.076	-0.093	-0.110	0.350	-0.413	0.070	0.160	0.010	0.231
LW	F_3	0.012	-0.004	-0.030	-0.046	0.031	0.031	-0.001	**0.037**	0.014	0.008	-0.012	0.010	-0.114	-0.026	0.014	1.017
	F_4	0.065	-0.069	0.032	0.038	0.193	-0.013	-0.005	**0.219**	-0.136	0.012	0.162	-0.325	0.098	0.023	0.048	0.486
DFH	F_3	-0.004	0.0001	0.0001	0.048	-0.007	-0.047	0.003	-0.024	**-0.022**	-0.009	-0.005	0.016	0.084	0.027	-0.008	-0.673
	F_4	0.008	0.100	-0.065	-0.080	-0.151	0.018	-0.006	-0.115	**0.259**	0.080	-0.280	0.391	-0.166	-0.305	-0.007	-0.455
FL	F_3	-0.008	-0.004	-0.019	-0.028	0.022	0.056	-0.002	0.026	0.017	**0.012**	-0.002	0.013	-0.133	-0.024	0.008	0.987
	F_4	0.240	-0.050	0.0001	0.064	-0.027	-0.042	0.013	-0.020	-0.156	**-0.132**	0.365	-0.288	0.130	0.106	-0.010	0.277
FD	F_3	0.006	-0.004	-0.020	-0.013	0.014	-0.006	0.000	0.026	-0.007	0.001	**-0.017**	0.023	-0.019	-0.008	0.004	0.217
	F_4	0.299	-0.079	0.027	0.060	0.076	-0.040	0.014	0.089	-0.181	-0.120	**0.400**	-0.533	0.159	0.158	0.024	0.513
VL	F_3	-0.016	-0.004	-0.017	0.017	0.009	0.018	0.0001	0.011	-0.010	0.005	-0.011	**0.035**	-0.031	-0.003	-0.002	0.113
	F_4	0.188	-0.090	0.062	0.037	0.156	-0.017	0.010	0.115	-0.164	-0.061	0.346	-0.617	0.121	0.243	0.048	0.548

AFW	F_3	0.001	-0.004	-0.029	-0.041	0.034	0.043	0.0001	0.032	0.014	0.012	-0.002	0.008	**-0.133**	-0.022	0.013	1.050
	F_4	0.131	-0.096	0.040	0.084	0.137	-0.037	0.006	0.124	-0.250	-0.100	0.371	-0.433	**0.172**	0.186	0.013	0.497
SW	F_3	-0.003	-0.002	-0.007	-0.038	0.007	0.051	-0.004	0.034	0.021	0.010	-0.005	0.003	-0.099	**-0.029**	0.005	0.758
	F_4	0.131	0.082	-0.091	-0.040	-0.147	-0.012	-0.006	-0.012	0.192	0.034	-0.154	0.365	-0.078	-0.410	-0.003	-0.219
FPV	F_3	0.023	-0.002	-0.034	-0.050	0.042	-0.001	0.003	0.033	0.012	0.006	-0.005	-0.005	-0.111	-0.009	**0.016**	1.073
	F_4	0.174	-0.044	0.034	-0.012	0.157	-0.003	0.003	0.165	-0.028	0.022	0.150	-0.471	0.034	0.022	**0.063**	0.396
FYP	F_3	0.008	-0.004	-0.032	-0.049	0.038	0.033	0.001	0.035	0.014	0.011	-0.003	0.004	-0.129	-0.021	0.016	**1.078**
	F_4	0.191	-0.095	0.049	0.057	0.189	-0.029	0.006	0.183	-0.203	-0.063	0.354	-0.582	0.147	0.154	0.043	**0.581**

Table 4. Estimates of direct (diagonal values) and indirect effects of various characters over yield per hectare cross (GH-28 × P. Santushti)

Residual are 0.00184 in F_3 and 0.03534 in F_4: DFG: Days to 50% germination; NPB: Number of primary branches ; DMF: Days to first male flower opening; DFF: Days to first female flower opening; NMF: Node to first male flower; NFF: Node to first female flower; LL: Leaf length (cm); LW: Leaf width (cm); DFH: Days to first harvest; FL: Fruit length (cm); FD: Fruit diameter (cm): VL: Vine length at the time of final harvest (m); AFW: average fruit weight (g); SW: 100 seed weight (g); FPV: Number of fruits per vine; FYP: Fruit yield per plot (kg)

4. CONCLUSION

Although greater amount of variability is present in bottle gourd, this is not utilized in crop improvement program efficiently. Therefore, there is a need of hybrid development keeping in mind the results of genetic parameters studied. The variability analysis indicated that the traits, number of primary branches, fruit length and average fruit weight showed considerable variabilities in both the generations. Correlation and path analysis studies revealed that number of primary branches, average fruit weight, days to first harvest and days to first female flower opening had significant effect on fruit yield per hectare. And therefore, these characteristics can be successfully employed in breeding program as their contribution to fruit yield per hectare is significant. Along with the abovementioned information, emphasis on the traits with stabilized homozygosity will make the selection efficient. Further, the traits in heterozygous condition can be improved in subsequent generations.

Commented [LC5]: Give specific results

Reference:

Ahmad MSH. Studies on genetic variability, heritability and genetic advance in segregating generations of faba bean [*Vicia faba* L.]. Middle East j agric res. 2016; 5(1): 82-89.

Alekar AN, Shinde KG, Khamkar MB. Studies on genetic variability, heritability, genetic advance and correlation in bitter gourd [*Momordica charantia* L.]. Int J Chem Stud. 2019; 7(3): 1155-1159.

Al-Jibouri HA, Miller PA, and Robinson HF. Genotypic and environmental variances and co-variances in upland cotton crosses of inter specific origin. J Agron. 1958; 50: 633-637.

Bhoomika MR, Adivappar N, Thippesha D, Gangaprasad S. Study on correlation and path analysis of F_2 population of cucumber [*Cucumis sativus* L.]. EJPB. 2021; 12(3): 1029-1032.

Burton GW. Quantitative inheritance in grasses. Proceedings of 6th International Grassland Congress, 1952; 11: 277-283.

Burton GW and Devane EH. Estimating heritability in tall fescue (*Festuca arundinancea*) from replicated clonal materials. J Agron. 1952; 45: 478-481.

Chandramouli B, Reddy RVSK, Babu MR, Jyothi, K.U., Umakrishna, K. and Rao, M.P. Genetic variability studies for yield and yield attributing traits in F_2 generation of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. Pharma Innov. 2021; 10(5): 1484-1488.

Chinthalapudi PMD, Rekha GK, Kumari KU, Jyothi UK, Narasimharao S. Variability studies in F_3 population of ridge gourd [*Luffa acutangula*] for yield and yield attributing traits. Pharma Innovation. 2021; 10(7): 612-615.

Das SP. Genetic variability, heritability, correlation, path coefficient and divergence analysis in F_3 population of bottle gourd [*Lagenaria siceraria* (Molina) Standl.] 2017. Ph.D. (Agri.) Thesis, Department of Horticulture, Banaras Hindu University, Varanasi, Uttar Pradesh.

Dewey DR, Lu KH. A correlation and path coefficient analysis of yield components of the crested wheat grass seed production. J Agron. 1959; 51: 515-518.

Gupta TA, Krishnamoorthy V, Balasubramanian P, Thangaraj K and Arunachalam P. Research article correlation and path analysis in F_2 generation of pumpkin [*Cucurbita moschata* Duch. ex Poir]. EJPB. 2018; 9(3): 1170-1193.

Johnson HW, Robinson HF and Comstock RE. Estimates of genetic and environmental variability in soybean. J Agron. 1955; 47: 314-318.

Kanimozhi R, Yassin GM, Kumar SR, Kanthaswamy V, Thirumeni S. Genetic analysis in segregating generation of wax gourd. Int J Veg Sci. 2015; 21(3): 281-296.

Kannan A, Rajamanickam C, Krishnamoorthy V and Arunachalam P () Genetic variability, correlation and path analysis in F_4 generation of ridge gourd [*Luffa acutangula* (Roxb) L.]. Int J Chem Stud. 2019; 7(3): 208-213

Krishnamoorthy V, Avinashgupta TV. Genetic analysis in F_3 generation of pumpkin [*Cucurbita moschata* Duch Ex. Poir]. EJPB. 2021; 12(1): 122-128.

Kumar KA, Ramanjinappa V and Patil MG. Genetic variability studies in F_2 population of cucumber [*Cucumis sativus* L.]. Plant Arch. 2011; 11(1): 347-350

Lush JL. Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics. J Anim Sci.1940; (1): 293-301

Panse VG and Sukhatme PV. Statistical Methods for Agricultural Workers. New Delhi, Indian Council of Agricultural Research. 1985; 1-381

Pradhan P, Tripathy P, Sahu GS, Tripathy B and Sourabh S. Assessment of genetic variability in F_4 segregating population of bitter gourd [*Momordica charantia* L.]. J pharmacogn phytochem. 2021;10(2): 1452-1455.

Rani KR, Reddy KR and Raju CS. Association of fruit yield and component traits in segregating population of bitter gourd. Plant Arch. 2014; 14(1): 215-220

Robinson HF. Quantitative genetics in relation to breeding on centennial of Mendelism. Indian J Genet Plant Breed. 1966; 26: 171-187.

Robinson HF, Comstock, RE and Harvey PH. Estimates of heritability and degree of dominance in corn. J Agron. 1949; 41: 253-259.

Sivasubramanian J. and Madhavamenon P. Genotypic and phenotypic variability in rice. Madras Agric J. 1973; 12: 15-16.

Sirohi PS and Sivakami N. Genetic variability in cucurbits bottle gourd. Indian Horticulture. 1991; 36: 44-45.

Sravani Y, Rekha GK, Ramana CV, Naidu LN and Suneetha DS. Studies on genetic variability, heritability and genetic advance in F_2 generation of ridge gourd. Pharma Innov. 2021; 10(7): 927-930.

Suresh GSP and Balamohan TN. Genetic variability studies in F_2 and F_3 generations of ridge gourd for yield and yield components [*Luffa acutangula* (L.) Roxb.]. Annals of Plant Sciences. 2018; 7(8): 2385-2390.

Thamburaj S and Singh N. Vegetables, Tubercrops, and Spices. New Delhi, Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research. 2015; 271-272.

Vaidya AV. Genetic studies in F_3 and F_4 generations of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] M. Sc. 2018. (Agri.) Thesis, Department of Vegetable Science, University of Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra.