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Genetic variability studies in brinjal (*Solanum melongena* L.)

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Abstract
The present study was conducted during the Kharif season of 2023 at the ICAR-NIASM, Malegaon, Baramati to assess genetic variability in 26 local brinjal genotypes using a randomized block design with three replications. The ANOVA revealed significant variability among the genotypes for all studied traits, indicating a broad genetic base for selection. Results showed that the phenotypic coefficients of variance were higher than genotypic coefficients for most of the traits. High GCV and PCV were observed for polar diameter, equatorial diameter, fruit shape index, fruit firmness, fruit dry matter, ascorbic acid, total phenolics content, total flavonoid content, antioxidant capacity measured by DPPH, average fruit weight, number of fruits per plant, yield per plant, yield per plot, and yield per hectare. High heritability estimates coupled with a high genetic advance as a percentage of the mean were observed for plant height, stem girth, plant spread (E-W, N-S), polar diameter, equatorial diameter, FSI, TSS, fruit firmness, FDM, AA, TPC, TFC, antioxidant capacity measured by DPPH and yield parameters, suggesting that selection for these traits would be effective in breeding programs due to their additive gene effects.

Keywords: Brinjal, variability, heritability, genetic advance, PCV and GCV

Introduction

Brinjal (*Solanum melongena* L.), with a chromosome number of 2n = 24, holds significant importance as a solanaceous vegetable crop in subtropical and tropical regions. India is recognized as the center of origin and diversity for brinjal. It is known by various names like eggplant, garden egg, baingan, badane, vangi, and aubergine (Rai *et al.*, 1993) [24]. Brinjal is a staple vegetable crop in India, thriving across diverse agro-climatic zones and adaptable to year-round cultivation except at high altitudes.

India is the world's second-largest producer of eggplant, following China. Brinjal is a nutrient-rich vegetable. On an average, 100g of brinjal fruit contains 92.70% moisture, 0.1g of fat, 5.7g of carbohydrates, and 1.0g of protein. (Kumar *et al.*, 2018) [12]. It is widely recognized as a healthy vegetable due to its low caloric content and the rich array of vitamins, minerals, and bioactive compounds that promote human health. (Prohens *et al.*, 2007) [22].

It is among the top 10 vegetables in terms of its ability to absorb oxygen radicals, highlighting its strong antioxidant properties (Raigón *et al.*, 2008) [25]. The fruit's flesh contains chlorogenic acid, a phenolic acid, and its skin contains anthocyanins (Mennella *et al.*, 2012) [18], which contribute significantly to brinjal's bioactive attributes. These compounds have numerous health benefits to humans (Stommel *et al.*, 2015) [28]. Brinjal ranks among the top ten vegetables out of 120 analyzed for antioxidant capacity (Nisha *et al.*, 2009) [21]. This vegetable is rich in potent antioxidants, including ascorbic acid and phenolics. The antioxidant properties of brinjal are associated with its phenolic content, skin colour, and fruit size, with smaller purple varieties exhibiting the highest levels of antioxidant activity (Nisha *et al.*, 2009) [21].

A notable trait of brinjal is that it displays a wide range of fruit shapes, colours, and location-specific demands throughout India. The fruit shapes range from oval or egg-shaped to long club-shaped, while the colours range from white, green, purple, and variegated combinations of these three hues.

Purple is more prevalent than green, while green is more prevalent than white. Different regions and locations exhibit various shades of purple, green, and white. Consumer preferences for colour, size, and shape are significant factors in determining the cultivars grown in India. Due to the high local preference for specific fruit characteristics, it is challenging to develop a single cultivar that satisfies the demands of different regions. To address this issue, it is crucial to improve locally preferred cultivars for high yield potential and adapt or develop new hybrid combinations from local cultivars following desired selections (Sharma and Katoch, 2022) [33].

Materials and Methods

Experimental Site: The experiment was executed at ICAR-National Institute of Abiotic Stress Management, Baramati in the Pune district of Maharashtra, India. The area under investigation lies within the Deccan Plateau, identified as an agro-ecological region with a hot and semi-arid climate (AER-6) and categorized in the agro-climatic zone AZ-95, which is noted as Maharashtra's scarcity zone, averaging about 560 mm of annual precipitation primarily in rainfall form.

Experimental details: The experimental material consists of 26 local genotypes including one check (Manjari Gota), acquired from various sources, were evaluated during Kharif 2023. Initially, brinjal genotypes were grown in pro-trays filled with sterile coco-peat media. Following one month of growth, the seedlings were transplanted using a randomized block design (RBD) with three replications and a spacing of 90 cm x 60 cm. Observations on 21 quantitative traits were recorded from three randomly selected, competitive plants per plot across all three replications. Growth parameters included plant height (PH), number of primary branches per plant (NOPBPP), stem girth (SG), days to 50% flowering (DTFPF), and the normalized difference vegetation index (NDVI).Fruit physical and biochemical parameters such as polar diameter (PD), equatorial diameter (ED), fruit shape index (FSI), total soluble solids (TSS), fruit firmness (FF), fruit dry matter (FDM), ascorbic acid (AA), total phenolic content (TPC), total flavonoid content (TFC), and antioxidant capacities (DPPH and FRAP) were recorded. Yield contributing traits included average fruit weight (AFW), number of fruits per plant (NOFPP), yield per plant, yield per plot, and yield per hectare.

Statistical analysis: The experimental data were analyzed using R statistical software, version 4.2.3 (R Core Team, 2022). Analysis of variance (ANOVA) was carried out in RCBD, through the “Doebioresearch" package. Genotypic and phenotypic coefficients of variation (GCV and PCV) were estimated using the formula given by Lush (1940) [14] and Burton and Devane (1952) [4]. Broad-sense heritability was estimated to determine the proportion of genetic variance and genetic advance was calculated using the approach suggested by Johnson *et al.* (1955) [9] to assess the potential for selection gain.

Results and Discussion

Genetic variability studies provide essential insights into the genetic parameters of genotypes, forming the basis for designing effective breeding methods for crop improvement. The statistical analysis of the numerical data collected for 21 quantitative traits revealed highly significant differences among the genotypes. Table 1. Indicates substantial genetic variability, aligned with the findings of Shilpa *et al.* (2018) [27], Tirkey *et al.* (2018) [29] and Akhtar *et al.* (2021) [1] who also reported a wide range of variability in traits studied.

The study revealed that among the 21 quantitative characters analysed, 14 characters showed high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values, all exceeding 20% (Table 2). These characters included polar diameter (GCV: 29.45%, PCV: 29.77%), equatorial diameter (GCV: 26.60%, PCV: 26.70%), FSI (GCV: 58.78%, PCV: 59.11%), fruit firmness (GCV: 23.72%, PCV: 23.72%), FDM (GCV: 31.74%, PCV: 31.75%), ascorbic acid content (GCV: 23.78%, PCV: 23.90%), TPC (GCV: 48.90%, PCV: 48.91%), TFC (GCV: 33.45%, PCV: 33.76%), antioxidant capacity measured by DPPH (GCV: 27.16%, PCV: 29.07%), AFW (GCV: 28.94%, PCV: 29.06%), number of fruits per plant (GCV: 33.05%, PCV: 34.49%), yield per plant (GCV: 23.74%, PCV: 24.45%), yield per plot (GCV: 23.74%, PCV: 24.46%), and yield per hectare (GCV: 23.74%, PCV: 24.46%). Although, PCV was more than GCV but the difference was very narrow suggesting that, there was less influence of environment on alteration and expression of these characters. Similar findings were documented by Koundinya *et al.* (2017) [11], Shilpa *et al.* (2018) [27], Tirkey *et al.* (2018) [29], and Akhtar *et al.* (2021) [1] for the above traits in brinjal. However, other traits in the study registered a medium range of variability, indicating the importance of their significance could be considered in breeding strategies based on the objective of brinjal crop improvement programme. The five characters displayed moderate genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) values, between 10-20%. These characters were plant height (GCV: 13.08%, PCV: 13.22%), stem girth (GCV: 15.57%, PCV: 17.24%), plant spread east-west (GCV: 15.23%, PCV: 15.38%), plant spread north-south (GCV: 17.74%, PCV: 17.93%), and TSS (GCV: 11.63%, PCV: 11.95%). Additionally, moderate PCV values were observed in the traits such as number of primary branches per plant (PCV: 16.96%), days to 50% flowering (PCV: 13.94%) and antioxidant capacity measured by FRAP (PCV: 10.45%). Similar results were noted by Khapte and Jansirani (2014) [10], Vidhya and Kumar (2015) [30], and Mahmoud and El-Mansy (2018) [16] in different solanaceous crops. Whereas the study found that low genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) values were found for the character NDVI (GCV: 5.68%, PCV: 8.03%). Furthermore, low GCV values were observed for the number of primary branches per plant (GCV: 8.21%), days to 50% flowering (GCV: 9.78%), and antioxidant capacity measured by FRAP (GCV: 9.48%). The findings are consistent with those reported by Ridzuan *et al.* (2018) [32] and Datta *et al.* (2021) [7].

High heritability was observed in traits including fruit firmness (99.99%), FDM (99.99%), TPC (99.90%), equatorial diameter (99.30%), AFW (99.20%), ascorbic acid content (99.00%), FSI (98.90%), TFC (98.20%), plant spread east-west (98.00%), plant height (97.90%), plant spread north-south (97.80%), polar diameter (97.80%), TSS (94.60%), yield per plant (94.30%), yield per plot (94.20%), yield per hectare (94.20%), number of fruits per plant (91.80%), antioxidant capacity measured by DPPH

(87.30%), antioxidant capacity measured by FRAP (82.30%), stem girth (81.50%), and NDVI (65.00%). Similar outcomes for heritability in brinjal were documented by Pujer (2017) [23] and Mangi *et al.* (2020) [17]. In contrast, a moderate heritability level was found for days to 50% flowering (49.20%). These results align with those observed by Omar *et al.* (2016) [31] and Nagar *et al.* (2024) [20] while low heritability was recorded for the number of primary branches per plant (24.00%). These findings are consistent with those observed by Chithra *et al.* (2021) [6], Chaudhary *et al.* (2023) [5] and Kuswaha *et al.* (2023) [13].

The findings of this study demonstrated that the highest estimates of genetic advance were recorded for fruit firmness (427.95), TPC (186.03), AFW (47.26), plant spread north-south (29.39), plant spread east-west (26.41), and plant height (20.79). The results align with those previously documented by Mili *et al.* (2014) [19], Pujer (2017) [23], and Mangi *et al.* (2020) [17]. Moderate genetic advance was observed for the number of fruits per plant (15.91), yield per hectare (15.04), antioxidant capacity measured by DPPH (14.46), TFC (14.34), and antioxidant capacity measured by FRAP (12.57). Comparable findings were noted by Omar *et al.* (2016) [31], Tirkey *et al.* (2018) [29] and Sangam *et al.* (2020) [26]. The lowest magnitude of genetic advance was found for yield per plot (8.12), ascorbic acid (5.33), polar diameter (4.82), stem girth (4.26), days to 50% flowering (3.72), FDM (3.69), equatorial diameter (2.57), FSI (2.37), TSS (1.41), yield per plant (0.81), number of primary branches (0.44), and NDVI (0.06). Arunkumar *et al.* (2013) [2], Mili *et al.* (2014) [19] and Madhavi *et al.* (2015) [15], have reported similar findings.

The genetic advance as a percentage of the mean provides important information regarding the effectiveness of selection in enhancing specific traits. This measure indicates the improvement in the genotypic value of a new population relative to the original population. In this study, the range of genetic advance as a percentage of the mean varied from 8.22% to 120.43%. High estimates were noted for traits including FSI (120.43%), TPC (100.66%), TFC (68.29%), FDM (65.41%), number of fruits per plant (65.22%), polar diameter (59.98%), AFW (59.38%), equatorial diameter (54.62%), antioxidant capacity measured by DPPH (52.27%), fruit firmness (48.86%), ascorbic acid (48.75%), yield per plant (47.52%), yield per plot (47.47%), yield per hectare (47.46%), plant spread north-south (36.13%), plant spread east-west (31.06%), stem girth (28.95%), plant height (26.66%), and TSS (23.30%). Research by Mili *et al.* (2014) [19], Gupta *et al.* (2018) [8], Mangi *et al.* (2020) [17] and Sangam *et al.* (2020) [26] yielded similar findings. Moderate estimates of genetic advance as a percentage of the mean were observed for antioxidant capacity measured by FRAP (17.72%), days to 50% flowering (14.13%), and NDVI (10.77%). The current results are consistent with those documented by Sangam *et al.* (2020) [26], Balasubramaniyam *et al.* (2021) [3] and Nagar *et al.* (2024) [20]. While the lowest estimate was found for the number of primary branches per plant (8.22%). Similar findings have been observed in the studies conducted by Chaudhary *et al.* (2023) [5] and Kuswaha *et al.* (2023) [13]. Therefore, the characters that showed high heritability along with high GAM suggested that the heritability was probably caused by additive gene effects. To improve these traits in brinjal, simple selection or pure line selection followed by hybridization with selection from previous generations might be useful.

Table 1: Analysis of variance (ANOVA) for 21 characters in brinjal

<table>
<tr><th>Sr. No.</th><th colspan="2">Characters</th><th colspan="3">Mean sum of squares</th></tr>
<tr><td></td><td colspan="2">DF</td><td>Replications (2)</td><td>Treatment (25)</td><td>Error (25)</td></tr>
<tr><td>1.</td><td colspan="2">Plant height (cm)</td><td>7.11</td><td>314.48**</td><td>2.18</td></tr>
<tr><td>2.</td><td colspan="2">Number of primary branches per plant</td><td>2.20</td><td>1.19*</td><td>0.62</td></tr>
<tr><td>3.</td><td colspan="2">Stem girth (mm)</td><td>5.46</td><td>16.92**</td><td>1.19</td></tr>
<tr><td>4.</td><td colspan="2">Days to 50% flowering</td><td>20.40</td><td>26.73**</td><td>6.84</td></tr>
<tr><td rowspan="2">5.</td><td rowspan="2">Plant spread (cm)</td><td>East-West</td><td>21.20</td><td>506.45**</td><td>3.46</td></tr>
<tr><td>North-South</td><td>20.32</td><td>629.05**</td><td>4.65</td></tr>
<tr><td>6.</td><td colspan="2">NDVI</td><td>0.01</td><td>0.00**</td><td>0.00</td></tr>
<tr><td>7.</td><td colspan="2">Polar diameter (cm)</td><td>0.50</td><td>16.93**</td><td>0.12</td></tr>
<tr><td>8.</td><td colspan="2">Equatorial diameter (cm)</td><td>2.04</td><td>4.72**</td><td>0.01</td></tr>
<tr><td>9.</td><td colspan="2">Fruit shape index</td><td>0.27</td><td>4.03**</td><td>0.02</td></tr>
<tr><td>10.</td><td colspan="2">Total soluble solids (ºBrix)</td><td>0.27</td><td>1.52**</td><td>0.03</td></tr>
<tr><td>11.</td><td colspan="2">Fruit firmness (g)</td><td>14.00</td><td>129461.00**</td><td>4.00</td></tr>
<tr><td>12.</td><td colspan="2">Fruit dry matter (%)</td><td>0.34</td><td>9.61**</td><td>0.00</td></tr>
<tr><td>13.</td><td colspan="2">Ascorbic acid (mg 100 g^{-1} FW)</td><td>10.79</td><td>20.35**</td><td>0.07</td></tr>
<tr><td>14.</td><td colspan="2">Total Phenolic Content (mg 100 g^{-1} FW)</td><td>27.10</td><td>24501.20**</td><td>6.00</td></tr>
<tr><td>15.</td><td colspan="2">Total Flavonoid Content (mg 100 g^{-1} FW)</td><td>5.00</td><td>148.82**</td><td>0.92</td></tr>
<tr><td rowspan="2">16.</td><td rowspan="2">Antioxidant Capacity (%)</td><td>DPPH</td><td>11.29</td><td>177.54**</td><td>8.18</td></tr>
<tr><td>FRAP</td><td>61.57</td><td>145.35**</td><td>9.72</td></tr>
<tr><td>17.</td><td colspan="2">Average fruit weight (g)</td><td>14.02</td><td>1595.95**</td><td>4.29</td></tr>
<tr><td>18.</td><td colspan="2">Number of fruits per plant</td><td>19.95</td><td>200.82**</td><td>5.77</td></tr>
<tr><td>19.</td><td colspan="2">Yield per plant (kg)</td><td>0.06</td><td>0.51**</td><td>0.01</td></tr>
<tr><td>20.</td><td colspan="2">Yield per plot (kg)</td><td>5.93</td><td>50.52**</td><td>1.01</td></tr>
<tr><td>21.</td><td colspan="2">Yield per ha. (t/ha)</td><td>20.32</td><td>173.23**</td><td>3.46</td></tr>
</table>

*, ** significant at 5% and 1% levels respectively.

Figures inscribed in parentheses indicate degree of freedom.

Table 2: Genetic variability parameters in 26 genotypes of brinjal.

Sr. No.	Traits		Range	General mean	GCV (%)	PCV (%)	ECV (%)	Heritability (Broad sense) (%)	Genetic Advance	GA as % of Mean
1.	Plant height (cm)		61.23-96.90	77.98	13.08	13.22	1.89	97.90	20.79	26.66
2.	Number of primary branches per plant		4.10-7.00	5.29	8.21	16.96	14.84	24.00	0.44	8.22
3.	Stem girth (mm)		9.90-19.10	14.71	15.57	17.24	7.42	81.50	4.26	28.95
4.	Days to 50% flowering		20.33-32.33	26.32	9.78	13.94	9.93	49.20	3.72	14.13
5.	Plant spread (cm)	East-West	62.96-100.96	85.03	15.23	15.38	2.19	98.00	26.41	31.06
		North-South	56.20-107.03	81.34	17.74	17.93	2.65	97.80	29.39	36.13
6.	NDVI		0.50-0.65	0.56	5.68	8.03	4.75	65.00	0.06	10.77
7.	Polar diameter (cm)		5.03-12.94	8.04	29.45	29.77	4.37	97.80	4.82	59.98
8.	Equatorial diameter (cm)		2.77-7.06	4.71	26.60	26.70	2.28	99.30	2.57	54.62
9.	Fruit shape index		0.92-4.66	1.97	58.78	59.11	6.39	98.90	2.37	120.43
10.	Total soluble solids (ºBrix)		4.33-7.30	6.06	11.63	11.95	2.79	94.60	1.41	23.30
11.	Fruit firmness (g)		456.46-1292.94	875.87	23.72	23.72	0.24	99.99	427.95	48.86
12.	Fruit dry matter (%)		3.32-9.58	5.64	31.74	31.75	0.66	99.99	3.69	65.41
13.	Ascorbic acid (mg 100 g^{-1} FW)		6.90-16.43	10.93	23.78	23.90	2.39	99.00	5.33	48.75
14.	Total Phenolic Content (mg 100 g^{-1} FW)		22.58-335.35	184.80	48.90	48.91	1.32	99.90	186.03	100.66
15.	Total Flavonoid Content (mg 100 g^{-1} FW)		7.98-30.90	20.99	33.45	33.76	4.58	98.20	14.34	68.29
16.	Antioxidant Capacity (%)	DPPH	9.87-48.15	27.66	27.16	29.07	10.34	87.30	14.46	52.27
		FRAP	59.47-82.35	70.92	9.48	10.45	4.40	82.30	12.57	17.72
17.	Average fruit weight (g)		29.16-131.66	79.59	28.94	29.06	2.60	99.20	47.26	59.38
18.	Number of fruits per plant		12.33-42.00	24.40	33.05	34.49	9.85	91.80	15.91	65.22
19.	Yield per plant (kg)		0.88-2.74	1.71	23.74	24.45	5.87	94.30	0.81	47.52
20.	Yield per plot (kg)		8.86-27.46	17.11	23.74	24.46	5.87	94.20	8.12	47.47
21.	Yield per ha. (t/ha)		16.42-50.86	31.68	23.74	24.46	5.87	94.20	15.04	47.46

GCV = Genotypic coefficient of variation,
PCV = Phenotypic coefficient of variation,
ECV= Environmental coefficient of variation,
GA =Genetic advance

Conclusion

The analysis of variance revealed highly significant differences among the twenty-six brinjal genotypes for all the traits studied, indicating sufficient variability among the genotypes for these traits. High GCV and PCV were recorded for polar diameter, equatorial diameter, fruit shape index (FSI), fruit firmness, fruit dry matter (FDM), ascorbic acid, total phenolic content, total flavonoid content, antioxidant capacity measured by DPPH, average fruit weight, number of fruits per plant, yield per plant, yield per plot and yield per hectare. Hence these traits are to be considered as important quantitative traits in brinjal improvement program and direct selection for these traits would be fruitful. High heritability estimates coupled with a high genetic advance as a percentage of the mean were observed for plant height, stem girth/diameter, plant spread (E-W, N-S), fruit polar diameter, fruit equatorial diameter, fruit shape index (FSI), TSS, fruit firmness, fruit dry matter (FDM), ascorbic acid, total phenolic content, total flavonoid content, antioxidant capacity measured by DPPH, average fruit weight, number of fruits per plant, yield per plant, yield per plot and yield per hectare. High heritability accompanied with a high genetic advance as a percentage of the mean indicates that most likely the heritability is due to additive gene effects and selection may be effective. Therefore, collection and evaluation of local genotypes helps in the improvement of brinjal, which is a vital strategy for addressing the challenges and meeting the increasing demand for local varieties.

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