



RESEARCH ARTICLE

Genetic evaluation and selection of F_4 brinjal (*Solanum melongena* L.) segregants derived from Odisha landraces for yield, quality and tolerance to bacterial wilt

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Abstract

A field experiment was conducted at the All India Coordinated Research Project (AICRP) on Vegetable Crops, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha, India, during the *rabi* season, 2023-2024, with broad objectives of developing superior, green round-fruited brinjal genotypes for higher fruit yield, fruit quality and tolerance to bacterial wilt from local landraces. Additional objectives included genetic analysis, including studies of genetic variability, character association and path analysis, along with genetic divergence analysis for future population improvement of brinjal using local landraces. A total of 41 genotypes of brinjal, including 9 local landraces of Odisha as parents, 31 F_4 segregants and one check (BB-67), were evaluated by using randomised block design (RBD) with 2 replications. The analysis of variance revealed significant differences among all traits, suggesting enormous scope for effective phenotypic selection in brinjal. The genetic variability study revealed a high broad-sense heritability (> 60 %) coupled with high genetic advance as % of the mean (> 20 %) for most of the traits except plant height (cm), days to 1st flowering and days to 50 % flowering respectively, hence suitable for phenotypic selection. Similarly, study on character association revealed that total fruit yield per plant in brinjal was significantly and positively associated with average fruit weight and number of fruits per plant at both genotypic and phenotypic level whereas the path analysis showed direct positive effects on total fruit yield per plant with traits viz., number of fruits per plant, average fruit weight, plant height at final harvest, days required to 50 % flowering, fruit length, fruit breadth, plant spread (NS) and fruit length breadth ratio, indicating that the direct selection for these traits would be effective in brinjal improvement. Principal Component Analysis (PCA) revealed 3 principal components with eigenvalues greater than unity (1.0), accounting for 78.647 % of the total variance. Principal Component 1 (PC1) contributed the highest proportion of total variance (42.282 %) with an eigenvalue of 4.228. PC2 and PC3 explained 24.045 % and 12.32 % of the variance with the eigenvalues of 2.404 and 1.232 respectively.

Keywords: brinjal; correlation; F_4 segregants; genetic diversity; genetic variability; local landraces; path analysis

Introduction

Brinjal (*Solanum melongena* L.) belongs to the non-tuberiferous species within the genus *Solanum*, with chromosome number $2n=2x=24$. Botanically, it is a day neutral perennial crop around 29–40 % (1, 2) but grown as an annual crop on a commercial scale. Brinjal has significant nutritional and health human benefits viz., good source of vitamins (A, B complex and C), minerals, high dietary fibres (1.39 g) and considered a low calorie food (3). It is also rich in potassium and magnesium, which help neutralise the effects of sodium in the body (4). It contains a powerful antioxidant compound, chlorogenic acid prevents various chronic diseases and has cholesterol lowering action due to the presence of unsaturated fatty acids such as linoleic (65 %) and linolenic acids

(5). It is also used to treat bronchitis, asthma, dysuria, dysentery, cholera (6) and colon cancer (7).

There are 3 dominant colours of brinjal fruits: purple, green and white. The white brinjal is good for diabetic patients (8). Purple coloured fruits are reported to have a higher amount of copper, amino acids, polyphenol oxidase enzymes, whereas green ones are rich in iron and catalase activity (9) along with a good shelf life. Brinjal can be cooked and used in preparations of stuffed curry, bhaji, pakoras, bharta pickles and also for dehydration processes etc., while the green round fruits are resistant to high temperature, where there is no loss of colour and glossiness and primarily used for bharta (mashed eggplant) preparation, hence accepted by consumers (10).

India is considered as the primary centre of origin of brinjal (11), producing 12765000 tonnes of fruits from an area of 747000 ha. Among the states, West Bengal ranked first, followed by Odisha and Gujarat (12).

Being of Indian origin, brinjal shows substantial genetic divergence in our country, offering much scope for improvement through selection. The dominance of local landraces in India reduces productivity significantly because farmers are reluctant to adopt hybrids at the expense of quality. Hence, despite significant production, the supply often falls off the region specific, diverse consumer preferences for brinjal varieties. Another problem associated with the cultivation of this crop is susceptibility to the wilt complex in general and bacterial wilt in particular, caused by the bacteria, *Ralstonia solanacearum* (13). This disease is quite prevalent in hot, humid parts of the world, causing a loss of 4.82–86.14 % (14) and 100 % (15) in India; as Odisha has a similar climatic conditions, this disease is also prevalent there.

Besides, due to the strong local preferences for colour, shape and taste, many specific brinjal genotypes are grown in particular localities. It is not possible to have a single cultivar that suits different localities. It is therefore required to improve the yield potential of local brinjal types grown in various regions of Odisha through simultaneous selection without losing the original special characters of the local kind. Variability studies in plant breeding are key to harnessing genetic diversity, optimising selection processes and achieving sustainable crop productivity and quality improvements. Hence, understanding genetic variability and the relationship between yield and related traits, along with genetic divergence, is essential for selecting and developing superior varieties.

Material and Methods

The present investigation was conducted at All India Coordinated Research Project (AICRP) on Vegetable Crops, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha, India during *rabi*, 2023–24, situated at East and South Eastern coastal plains with 20.27° N latitude and 85.84° E longitude. A total of 40 local landraces of brinjal (9 parents and 31 F₄ segregants) and 1 local check (BB67) were used as treatments and laid out in a Randomised Block Design (RBD) with 2 replications. One month old seedlings were transplanted in the main field on 3rd January, 2024, with a spacing of 60 cm x 60 cm and were grown by following the standard package of practices. Observations were recorded on morphological parameters including plant height (cm), plant spread (NS) (EW) (cm), number of primary branches per plant, leaf area index (using leaf area meter); flowering behaviour viz.; days to 1st flowering, days to 50 % flowering, number of flowers per cluster; fruit yielding parameters viz.; fruit length (cm), fruit breadth (cm), number of fruits per plant, number of seeds per fruit, average fruit weight (g); fruit quality parameters including fruit TSS (° Brix), total sugar (%), ascorbic acid content, dry matter; incidence of bacterial wilt at 60 and 90 days after transplanting (DAT) and fruit yield per plant. The incidence of bacterial wilt for each genotype was recorded by following the scale (0–5) (16). Moreover, to introduce genetic diversity among selected parental lines, an extensive hybridisation scheme was implemented where targeted crosses were executed by employing standard emasculation and controlled hand pollination techniques, ensuring the precision and

fidelity of each hybrid combination. The choice of parent genotypes was guided by desirable agronomic characteristics and broad genetic backgrounds. A structured set of biparental combinations formed the foundation of the crossing programme, with each hybrid assigned a unique code (C₁–C₄₁) presented in Table 1.

Following pollination, all flowers were labelled and monitored for fruit and seed set. Harvested seeds were collected at maturity and stored under optimal conditions followed by subsequent evaluation. These hybrid seeds formed the basis for advancing segregating populations, which were subjected to further selection and assessment in accordance with best practice crop breeding protocols (17). In the present study, only F₄ segregants along with parents and one local check were grown for genetic studies.

The estimates of variability phenotypic and genotypic coefficient of variation (PCV and GCV) were estimated (18) and the heritability (h²) and genetic advance (GA) as % of mean were estimated by using the standard formulae (19). The correlation and path analysis among traits were analysed by following standard procedure (20). To reduce dimensionality of the datasets while preserving critical information, Principal Component Analysis (PCA) was performed.

Statistical analysis

All the statistical analysis were conducted by using R studio and the significance of the results was assessed using the statistical F test. The mean values, SE(m) ±, along with analysis of variance, test of significance is presented in Table 2.

Results and Discussion

Mean performance of 41 genotypes of brinjal

The analysis of variance (ANOVA) was used to study the genetic variability in the present investigation for 23 distinct traits which revealed significant differences between the nine parents, 31 F₄ segregants and a check. During the present investigation, the degrees of experimental precision were found 10 % for all traits except fruit dry matter.

Vegetative parameters

The per se performance of 41 genotypes of brinjal showed a wide range of variations for vegetative plant characters (Table 1). The plant height varied significantly from 48.87 cm (Selection from BBSR-192-1 × Selection from 145-1) to 115.50 cm (BBJ-20-1) among the F₄ segregants, BBSR-08-2 × BBSR-10-26 (111.75), BBSR-08-2 × BBSR-192-1 (111.75), BBSR-08-02 × BBSR-10-25 (105.00), showed statistical parity with the highest value of BBJ-20-1 (115.50 cm). The plant spread (EW) varied significantly from 78.40 cm (BBSR-10-26 × BBSR 195-3) to 137.50 cm (BBJR-20-2), where F₄ segregant BBSR-195-3 × BBSR-09-5 was observed statistical parity with the higher value of BBJR-20-2. The results for plant spread (NS) also varied significantly from 63.57 cm (BBV-77-23) to 118 cm (BBSR-10-25 × BBSR-09-5). The number of primary branches per plant also varied significantly from 5.50 (BBSR-08 × BBSR-10-26, B2) to 9.75 (BBJR-20-2). However, the F₄ segregant, BBSR-10-26 × Selection from BBSR-145-1, showed statistical parity with the highest value of BBJR-20-2 for the number of primary per branches plant. The results on leaf area

Table 1. Crossing details and mean performance on vegetative parameters of the 41 genotypes of brinjal at F₄ generation

Crosses	Crossing Details	Plant height (cm)	Plant spread (EW) (cm)	Plant spread (NS) (cm)	Primary Branches per plant	Leaf area (cm ²)
C1	B2	101.25	134.325	94.45	5.5	163.425
C2	BBSR-08 × BBSR10-26	96.5	99.95	100	5.5	159.35
C3	BBSR-10-26 × BBSR-95-23	97.5	88.95	68.55	6.25	174.8
C4	BBSR-08-2	100.1	82.4	90.45	7	175.79
C5	BBJ-20-1	115.5	82.4	80.4	8.75	186.3
C6	BBJR-20-2	99	137.5	102.25	9.75	173.3
C7	BBV-77-23	76.575	81.075	63.575	6.5	168.275
C8	BBSR-08-2 × BBSR-10-25	105	98.2	100.25	6.75	174.075
C9	BBSR-08-2 × BBSR-10-26	111.75	94.325	89.55	8.25	172.15
C10	BBSR08-2 × BBSR195-3	80.625	88.4	77.125	7	167.525
C11	BBSR-08-2 × BBSR-195-1	111.75	84.95	101.375	8.25	168.775
C12	BBSR-08-2 × Selection from BBSR-192-1	101.525	94.55	87.625	7.25	177.375
C13	BBSR-08-2 × Selection from BBSR-145-1	98.75	100.25	100.25	5.75	168.325
C14	BBSR-08-2 × BBSR-09-5	94.725	96.125	95.125	5.75	170.25
C15	BBSR-10-25 × BBSR-10-26	89.925	90.5	79.2	6.25	165.15
C16	BBSR-10-25 × BBSR-195-3	100.875	125	94.625	7	172.9
C17	BBSR-10-25 × BBSR-192-1	85.625	79	85.875	7.75	165.9
C18	BBSR-10-25 × Selection from BBSR-192-1	95.375	93.675	99.9	6.75	171.85
C19	BBSR-10-25 × Selection from BBSR-145-1	87.8	86.45	78.65	6.75	173.225
C20	BBSR-10-25 × BBSR-09-5	95.625	96.888	118	6.5	172.475
C21	Jammusahi Local × BBSR-192-1	99.175	101.5	85.375	7.5	176.9
C22	Jammusahi Local × Selection from BBSR-192-1	98	95.75	95.4	7	170.6
C23	BBSR-10-26 × BBSR-195-3	100.75	78.4	97.075	6.75	169.35
C24	BBSR-10-26 × BBSR-192-1	109	105.125	102.625	8.75	174.325
C25	BBSR-10-26 × Selection from BBSR-192-1	98	89.25	89.25	9	166.875
C26	BBSR-10-26 × Selection from BBSR-145-1	99.5	99.7	95.775	8.5	173.1
C27	BBSR-10-26 × BBSR-09-5	91.65	96.875	94.55	8.5	168.975
C28	BBSR-195-3 × BBSR-192-1	106.25	94.625	88.85	6.5	172.975
C29	BBSR-195-3 × BBSR-09-5	102.4	136.75	102.375	5.75	172.7
C30	BBSR-192-1 × Selection from BBSR-145-1	90.375	84.75	72.65	7.5	165.45
C31	BBSR-192-1 × BBSR-09-5	89.875	83.875	76.9	7.25	178.425
C32	Selection from BBSR-192-1 × Selection from BBSR-145-1	48.875	96.25	101.7	8.25	171.325
C33	Selection from BBSR-192-1 × BBSR-09-5	99.5	109	96.4	7.75	168.45
C34	Selection from BBSR-145-1 × BBSR-09-5	99.05	97.625	92.3	9.25	166.075
C35	Bhadrak local	84.75	86.75	80.9	7	171.1
C36	Chhatia local selection	91.85	82.125	85.65	8	175.275
C37	Jammusahi local	94	87.125	94.65	9.25	176.875
C38	Salepur local selection	92.125	90.5	103	7.75	167.625
C39	Selection from BBSR-192-1	91.375	96.25	91.125	6.75	175.725
C40	Selection from BBSR-145-1	91.125	95.75	96.375	8.75	170.9
C41	BB-67 (Andharua local selection)	94.375	110.75	98.75	7.5	157.225
Mean		95.56	96.43	91.44	7.38	171.01
CV (%)		5.49	5.79	5.59	5.99	2.98
SE(m)±		3.71	3.95	3.61	0.31	3.61
CD at 5 %		10.6	11.28	10.33	0.89	10.3

Table 2. Analysis of variance for different traits of 41 genotypes of brinjal

Sl. No.	Source	Mean Sum of Squares (MSS)		
		Replication	Treatment	Error
	Degrees of freedom	1	40	40
1	Plant height (cm)	11.380	240.179**	27.52
2	Plant spread (EW) (cm)	0.637	425.133**	31.173
3	Plant spread (NS) (cm)	24.695	233.747**	26.125
4	Primary Branches/plant	0.780	2.457**	0.195
5	Leaf area (cm ²)	52.057	54.964**	25.997
6	Days to first flowering	3.524	14.422**	4.513
7	Days to 50 % flowering	5.902	30.336**	7.307
8	Flowers/cluster	0.000	0.421**	0.054
9	Fruit length (cm)	0.598	16.132**	0.712
10	Fruit breadth (cm)	2.061	25.335**	1.948
11	Fruit length to breadth ratio	0.003	0.228**	0.002
12	Average Fruit weight (g)	6.507	2558.106**	97.808
13	Fruits/plant	0.027	14.071**	1.306
14	Number of seeds/fruit	2928.049	63021.002**	7202.015
15	TSS (°Brix)	0.149	0.824**	0.162
16	Reducing Sugar (%)	0.000	0.197**	0.002
17	Total Sugar content (%)	0.000	0.342**	0.002
18	Ascorbic acid (mg 100 g ⁻¹)	0.001	2.545**	0.001
19	Leaf chlorophyll content	7.024	40.597**	4.345
20	Fruit dry matter (%)	0.176	15.832**	0.966
21	Bacterial wilt at 60 DAT (%)	0.009	1.500**	0.004
22	Bacterial wilt at 90 DAT (%)	0.022	2.177**	0.011
23	Total fruit yield plant (kg)	0.002	0.255**	0.021

revealed significant variations from 157.22 cm² (BB-67) to 186.30 cm² (BBJ-20-1). However, the other F₄ segregants viz.; BBSR-08-2 × Selection from BBSR-192-1, Jammusahi local × BBSR 192-1, BBSR 192-1 × BBSR-09-5 and the parent, Jammusahi local were statistically at par with the highest value of BBJ-20-1 for leaf area. Similarly, leaf chlorophyll content also varies significantly from 18.35 (BBSR-08 × BBSR-10-26) to 37.22 (Salepur local selection). The F₄ segregants viz.; BBSR-10-25 × Selection from BBSR-145-1, Jammusahi Local × BBSR-192-1 and among parents Bhadrak local, Selection from BBSR-192-1, Selection from BBSR-145-1 Chhatia local selection showed statistical parity with the high value (37.22) for leaf chlorophyll content.

Overall, superior performance of F₄ segregants with respect to vegetative growth parameters were viz.; BBSR-08-2, BBSR-10-25, BBSR -08-2 × BBSR-10-26, BBSR-08-2 × BBSR1951, BBSR-08-2 × Selection from BBSR-192-1, BBSR-195-3 × BBSR-09-5, BBSR-192-1 × Selection from BBSR-145-1, BBSR-192-1 × BBSR-09-5, Selection from BBSR-145-1 × BBSR-09-5. Simultaneous consideration of vegetative growth parameters indicated that relatively superior vegetative growth is expected to contribute towards yield and yield-attributing traits. The results of the present investigation showed wide variations in vegetative growth parameters in brinjal have also been reported by various workers (21–28).

Flowering parameters

In the present study, the results on flowering behaviour showed significant variations (Table 3) where the days to 1st flowering varied from 33.5 to 45.5 days, the days to 50 % flowering also showed variations from 40.5 to 55 days. The F₄ segregant, BBSR-08-2 × BBSR-19-53, exhibited earliness for both days to 1st flowering and days to 50 % flowering, whereas Bhadrak Local revealed maximum days to 1st and days to 50 % flowering. The genotype, Salepur Local selection was also found to be the earliest flowering one along with the F₄ segregant BBSR-08-2 × BBSR-195-3. Among F₄ segregants, BBSR-08 × BBSR-10-26, BBSR 10-26 × BBSR -95-23, BBSR-08-2 × Selection from BBSR -192-1, BBSR-08-2 × Selection from BBSR-145-1, BBSR-10-25 × BBSR-10-26, BBSR-10-25 × BBSR 195-3, Jammusahi Local × BBSR 192-1, Jammusahi Local × Selection from BBSR 192-1, BBSR-10-26 × BBSR 195-3, BBSR-10-26 × BBSR -192-1 where statistical parity was observed with the earliest of days to 1st flowering (33.5). Whereas, BBSR-08 × BBSR10-26, BBSR-08-2 × BBSR -102-6, BBSR-08-2 × Selection from BBSR -192-1, BBSR-08-2 × Selection from BBSR-145-1, BBSR-10-25 × BBSR-10-26, BBSR-10-25 × BBSR 195-3, BBSR-10-25 × Selection from BBSR-192-1, Jammusahi Local × BBSR 192-1, Jammusahi Local × Selection from BBSR 192-1, BBSR-10-26 × BBSR 195-3, BBSR-10-26 × BBSR-192-1, BBSR-10-26 × BBSR-09-5 showed

Table 3. Mean performance on flowering parameters of the 41 genotypes of brinjal at F₄ generation

Sl. No.	Crossing Details	Days to 1 st flowering	Days to 50 % flowering	Flowers per cluster
1	B2	37	44.5	3.25
2	BBSR-08x BBSR-10-26	37.5	44.5	4.25
3	BBSR-10-26 × BBSR-95-23	35.5	40.5	3.5
4	BBSR-08-2	36.5	40.5	3.25
5	BBJ-20-1	39	48.5	3.75
6	BBJR-20-2	39	50.5	4.5
7	BBV-77-23	45	53	4.25
8	BBSR-08-2x BBSR-10-25	39.5	46	4
9	BBSR-08-2 × BBSR-10-26	38.5	45	4
10	BBSR-08-2 × BBSR-195-3	33.5	40.5	3.5
11	BBSR-08-2 × BBSR-195-1	39.5	51.5	3.5
12	BBSR-08-2 × Selection from BBSR-192-1	37	44	3.5
13	BBSR-08-2 × Selection from BBSR-145-1	37	45.5	4.25
14	BBSR-08-2 × BBSR-09-5	41	47.5	3.75
15	BBSR-10-25 × BBSR-10-26	34	41.5	3.5
16	BBSR-10-25 × BBSR-195-3	37.5	44	3.25
17	BBSR-10-25 × BBSR-192-1	38	47	4
18	BBSR-10-25 × Selection from BBSR-192-1	36	43	3.75
19	BBSR-10-25 × Selection from BBSR-145-1	38.5	51	4
20	BBSR-10-25 × BBSR-09-5	39	46	3.5
21	Jammusahi Local × BBSR192-1	37	44	3.75
22	Jammusahi Local × Selection from BBSR-192-1	37.5	45	3.5
23	BBSR-10-26 × BBSR-195-3	36	45	3.25
24	BBSR-10-26 × BBSR-192-1	37.5	45	4.25
25	BBSR-10-26 × Selection from BBSR-192-1	41	48	4
26	BBSR-10-26 × Selection from BBSR-145-1	38	46	4.25
27	BBSR-10-26 × BBSR-09-5	38	45	3
28	BBSR-195-3 × BBSR-192-1	41.5	51.5	3.25
29	BBSR-195-3 × BBSR-09-5	41	51.5	4
30	BBSR-192-1 × Selection from BBSR-145-1	38.5	54	3.75
31	BBSR-192-1 × BBSR-09-5	44.5	51.5	3.75
32	Selection from BBSR-192-1 × Selection from BBSR145-1	38	52	3.75
33	Selection from BBSR-192-1 × BBSR-09-5	40.5	51.5	2.5
34	Selection from BBSR-145-1 × BBSR-09-5	41.5	51.5	3
35	Bhadrak local	45.5	55	4
36	Chhatia local selection	40.5	50	4.5
37	Jammusahi local	40.5	49	4.75
38	Salepur local selection	33.5	45.5	3.5
39	Selection from BBSR-192-1	39	46	3.5
40	Slection from BBSR-145-1	39.5	52.5	3.5
41	BB67 (Andharua local selection)	39	47	4
Mean		38.7	47.34	3.73
CV (%)		5.49	5.71	6.21
SE (m)±		1.5	1.91	0.16
CD at 5 %		4.29	5.46	0.47

statistical parity with the lowest value days to 50 % flowering (40.5 days). In commercial cultivation of brinjal, development of earliness is considered as an important biometrical trait which helps the growers not only to secure early market placement to attain premium prices but also to increase the staggered harvesting for a long time to avoid market glut. With respect to the number of flowers per cluster which varied significantly from 2.50 (Selection from BBSR-192-1 × BBSR-09-5) to 4.75 (Jammusahi Local). The parent, Jammusahi local recorded significantly highest number of flowers per cluster (4.75) than other genotypes and was statistically at par with Chhatia Local selection (4.50) and BBJR-20-2 (4.50) and among the F_4 segregants, showing ≥ 4.00 values viz.; BBSR-08-2 × BBSR-10-25, BBSR-08-2 × BBSR-10-26, BBSR-08-2 × Selection from BBSR-145-1, BBSR-10-25 × BBSR-192-1, BBSR-10-25 × Selection from BBSR-145-1, BBSR-10-26 × BBSR-192-1, BBSR-10-26 × Selection from BBSR-192-1, BBSR-10-26 × Selection from BBSR-145-1 and BBSR-195-3 × BBSR-09-5 may be considered for the production of higher number of flowers per cluster in future crop improvement. The results on the number of flowers per cluster showed a direct association with fruit yield. This result on flowering behaviour provided enormous scope for crop improvement with respect to flowering parameters, which has also been confirmed earlier (8, 22–31) in brinjal respectively.

Fruit yield attributing parameters

In the present investigation, emphasis was placed on identifying round fruited genotypes with relatively lower fruit length, lower fruit length to breadth ratio and higher fruit breadth. The study showed that fruit yield attributing traits varied significantly (Table 4) ranging from average fruit length from 6 cm (BBSR-08-2) to 16.30 cm (BBSR-195-3 × BBSR-192-1). The genotype, BBV-77-23 (6.45), showed statistically at par with the lowest value (6.00). However, several segregants recorded fruit length ≤ 10 cm, indicating suitability for round fruit types (Table 4).

Average fruit breadth showed wide variations from 8.50 cm (BBSR-10-25 × BBSR-102-6) to 30.40 cm (BB-67). The check genotype, BB-67 recorded the highest fruit breadth (30.40) while among F_4 segregants, BBSR-08-2 × BBSR-10-26 (28.55) and among parents, BBJR-20-2 (27.8) was statistically at par with the highest value (30.40 cm). The results on fruit length-breadth ratio varied significantly from 0.22 (BBSR-08-2) to 2.54 (BBSR-10-25 × BBSR-10-26). However, the genotype, BBSR-08-2 showed lowest fruit length to breadth ratio (0.22) among genotypes, followed by BBV-77-23 which were statistically at par with the lowest value. The results of the present investigation with respect to producing round fruits in brinjal were well similar to earlier works (10, 17, 32–34).

In brinjal, the popularity of a variety primarily depends on consumer preference to colour, shape, average fruit weight etc. In the present scenario, due to an increased trend towards nuclear families, most of the preference is given to fruit weighing from 100 to 150 g. In general, consumers do not prefer too small or too large fruits of brinjal. Therefore, in the present investigation, emphasis has been made to isolate F_4 segregants having an average fruit weight (g) of 100.00 to 150.00 g, which also showed a variation significantly from 77.50 g (BBJR-20-2) to 209.50 g (BBSR-10-26 × BBSR-195-3). The heaviest fruits were recorded in F_4 segregant, BBSR-10-26 × BBSR-195-3 (209.50 g), followed by Jammusahi Local × BBSR-192-1 (202.5), Salepur local selection (208.50), which were statistically at par. The results suggested that Jammusahi Local may contribute to increased fruit weight in segregating populations. Similar reports are on the transmission of traits from

parents to progeny (24, 26, 31, 34, 35–37).

Regarding the number of fruit per plant, another important fruit yield attributing traits varied significantly not only among parents but also among F_4 segregants, ranging from 10.30 (BBSR-10-25 × BBSR-09-5) to 20.00 (Selection from BBSR-192-1 × BBSR-09-5). Among F_4 segregants, BBSR-08-2 × BBSR-195-1, Jammusahi Local × Selection from BBSR-192-1, Selection from BBSR-192-1 × Selection from BBSR-145-1 were found to be statistically at par with the highest value (20.00). On a commercial scale, it has been reported that any genotype producing ≥ 15.00 numbers of fruit per plant is considered a high-yielding genotype which may be selected for cultivation or to develop superior genotypes with relatively high fruit yield per plant in brinjal. Similar trends have also been reported earlier (22–26) and (10, 34). The trait, number of seeds per fruit, the results showed significant variations that varied from 685.00 (BBSR-10-25 × BBSR-195-3) to 1570.00 (BBSR-10-25 × BBSR-10-26) and among F_4 segregants, BBSR-10-25 × BBSR-195-3 recorded the lowest value (685.00) which was closely followed by BBSR-08-2 × BBSR-10-26, BBSR-08-2 × Selection from BBSR-192-1, BBSR-08-2 × Selection from BBSR-145-1, BBSR-10-26 × BBSR-192-1, BBSR-10-26 × selection from BBSR-145-1, BBSR-195-3 × BBSR-09-5 and BBSR-08-2 × BBSR-09-5 which were statistically at par with the lowest value (685.00) and was well correlated with the earlier work (23).

Fruit quality parameters

The fruit quality plays a significant role in crop improvement programmes aimed at enhancing market acceptance and consumer preference. The fruit quality parameters revealed significant variations presented in Table 5. The result on the fruit TSS content (°Brix) varied significantly from 3.5 (BBSR-10-25 × BBSR-10-26, BBSR-10-25 × BBSR-192-1, Selection from BBSR-192-1) to 5.75 (Selection from BBSR-192-1 × BBSR-09-5). However, BBSR-08-2 × BBSR-10-25, BBSR-10-25 × BBSR-09-5, Jammusahi Local × BBSR-192-1, BBSR-10-26 × BBSR-195-3, BBSR-10-26 × Selection from BBSR-145-1, BBSR-10-26 × BBSR-09-5, BBSR-195-3 × BBSR-09-5, BBSR-192-1 × Selection from BBSR-145-1, Selection from BBSR-192-1 × Selection from BBSR-145-1, Selection from BBSR-145-1 and BB-67 were statistically at par with the highest value of TSS. The results on fruit reducing sugar content (%) ranged from 0.90 (BBV-77-23) to 1.99 (BBSR-10-25 × BBSR-192-1). The F_4 segregants, BBSR-08-2 × Selection from BBSR-145-1, BBSR-195-3 × BBSR-09-5 and Selection from BBSR-192-1 × BBSR-09-5 were statistically at par with the high value (1.99). Regarding, total sugar content (%) varied significantly from 0.98 (BBJ-20-1) to 2.57 (BBSR-10-25 × BBSR-192-1 with an average value of 1.80). The results on ascorbic acid content of brinjal fruits ($\text{mg } 100\text{g}^{-1}$) also varied significantly from 3.40 (BBSR-08-2 × BBSR-10-26) to 7.93 (B2) with an average value of 5.84. The dry matter (%) of the brinjal fruit varied from 4.18 (BBSR-10-26 × BBSR-09-5) to 17.66 (BBSR-10-25 × BBSR-09-5). Similar qualitative findings of brinjal have also been reported (1, 36, 37) for fruit dry matter content, (22, 23, 27) for fruit ascorbic acid content; (1, 38, 39) for fruit TSS. However, among F_4 segregants, BBSR-08-2 × Selection from BBSR-192-1, BBSR-10-25 × BBSR-192-1, BBSR-10-25 × BBSR-09-5, Jammusahi local × BBSR-192-1, Jammusahi Local × Selection from BBSR-192-1 and BBSR-192-1 × Selection from BBSR-145-1, Selection from BBSR-192-1 × Selection from BBSR-145-1 were identified to record fair good amount of fruit quality parameters.

Table 4. Mean performance on fruit yielding parameters and reaction to bacterial wilt of the 41 genotypes of brinjal in F₄ generation

Sl. No.	Crossing details	Fruit length (cm)	Fruit breadth (cm)	Fruit length to breadth ratio	Average Fruit weight (g)	Fruits per plant	Number of seeds per fruit	Bacterial wilt at 60 DAT (%)	Bacterial wilt at 90 DAT (%)	Total fruit yield per plant (kg)
1	B2	11	24.75	0.444	108.3	14.51	1022.5	0.50	0.50	1.285
2	BBSR-08×BBSR-10-26	9	22.25	0.404	131.5	12.1	995	0.50	8.33	1.285
3	BBSR-10-26 × BBSR-95-23	9.75	25	0.391	141	11.2	1012.5	0.50	0.50	1.305
4	BBSR-08-2	6	26.75	0.224	97	19.5	880	2.78	12.50	1.536
5	BBJ-20-1	11	23.5	0.47	127.5	12.2	995	6.94	0.50	1.265
6	BBJR-20-2	12.25	27.8	0.441	77.5	12.4	1010	5.56	8.33	0.781
7	BBV-77-23	6.45	22.75	0.29	95	12.3	1102.5	0.50	0.50	0.95
8	BBSR-08-2×BBSR-10-25	12.5	23.5	0.533	148.15	17.6	950	5.56	0.50	1.75
9	BBSR-08-2 × BBSR-10-26	12.9	28.55	0.452	94.8	11.3	835	5.56	4.42	1.82
10	BBSR-08-2 × BBSR-195-3	11.3	20.5	0.559	184.5	10.5	940	0.50	0.50	1.574
11	BBSR-08-2 × BBSR-195-1	15.5	24.5	0.636	120	17.8	1275	5.56	0.50	1.907
12	BBSR-08-2 × Selection from BBSR-192-1	8.75	21.25	0.411	157.15	17.5	1160	5.56	8.58	1.925
13	BBSR-08-2 × Selection from BBSR-145-1	11.5	26.3	0.437	154.95	11.4	810	0.50	4.42	1.8
14	BBSR-08-2 × BBSR-09-5	11.75	23.5	0.502	147.5	11.9	710.5	0.50	0.50	1.425
15	BBSR-10-25 × BBSR-10-26	21.5	8.5	2.542	93.5	15.85	1570	0.50	8.33	1.477
16	BBSR-10-25 × BBSR-195-3	13.8	21.5	0.644	95.75	14.2	685	0.50	4.42	1.655
17	BBSR-10-25 × BBSR1-92-1	10.5	24	0.439	99.45	14.4	1012.5	5.56	4.42	1.515
18	BBSR-10-25 × Selection from BBSR-192-1	12.95	23.5	0.554	159	15.1	1020	0.50	0.50	1.951
19	BBSR-10-25 × Selection from BBSR-145-1	15.1	21.25	0.71	102.65	16.2	1115	0.50	4.42	1.965
20	BBSR-10-25 × BBSR-09-5	10.15	24.15	0.42	147	10.3	1312.5	0.50	4.42	1.6
21	Jammusahi Local × BBSR192-1	11	25	0.443	202.5	15.6	1127.5	0.50	0.50	1.925
22	Jammusahi Local × Selection from BBSR192-1	11	26.5	0.415	98.9	17.9	1070	0.50	0.50	1.84
23	BBSR-10-26 × BBSR-195-3	13.75	27.25	0.505	209.5	12.3	1007.5	0.50	4.42	1.7
24	BBSR-10-26 × BBSR-192-1	10.5	26.5	0.397	169	13.4	698.5	0.50	0.50	1.841
25	BBSR-10-26 × Selection from BBSR192-1	14.65	23.5	0.623	110	11.6	705	0.50	0.50	1.45
26	BBSR-10-26 × Selection from BBSR-145-1	11.75	24.5	0.48	157.5	12.4	1017.5	0.50	0.25	1.555
27	BBSR-10-26 × BBSR-09-5	15.9	24.25	0.655	94	14.9	1007.5	0.50	4.42	1.138
28	BBSR-195-3 × BBSR-192-1	16.3	24	0.684	125	16.4	987.5	4.42	4.42	1.667
29	BBSR-195-3 × BBSR-09-5	13.3	20.75	0.646	100	13.3	705	0.50	0.50	1.081
30	BBSR-192-1 × Selection from BBSR-145-1	7.75	21.9	0.354	133.65	14.4	875	4.42	8.33	1.895
31	BBSR-192-1 × BBSR-09-5	10.3	26.25	0.393	119.25	12	927.5	0.50	0.50	1.163
32	Selection from BBSR-192-1 × Selection from BBSR-145-1	9.9	25.3	0.392	182.05	18.85	912.5	0.50	0.50	1.79
33	Selection from BBSR-192-1 × BBSR-09-5	12.05	23.45	0.514	98.15	20	892.5	8.33	12.50	1.593
34	Selection from BBSR-145-1 × BBSR-09-5	10.2	24.75	0.413	88.65	16.05	1237.5	12.50	12.50	1.274
35	Bhadrak local	11.4	22.4	0.509	106.5	11.6	1217.5	0.50	0.50	1.004
36	Chhatia local selection	9.1	17.4	0.533	83.5	12.1	996.5	0.50	0.50	0.821
37	Jammusahi local	9.9	18.25	0.54	110.8	11.7	1005	0.50	12.50	1.053
38	Salepur local selection	13.8	27.3	0.506	208.5	12.1	992.5	0.50	0.50	2.05
39	Selection from BBSR-192-1	14.8	24.25	0.61	107.5	13.9	1015	0.50	16.67	1.215
40	Sction from BBSR-145-1	13.7	25.4	0.541	91.5	11.5	885	8.33	8.33	0.855
41	BB-67 (Andharua local selection)	12.6	30.4	0.415	126.5	11.1	1047.5	6.95	4.42	1.141
Mean		11.89	23.73	0.54	126.95	13.94	993.73	1.28	1.56	1.48
CV (%)		7.1	5.88	7.38	7.79	8.2	8.54	5.23	6.78	9.8
SE (m) ±		0.6	0.99	0.03	6.99	0.81	60.01	0.05	0.07	0.1
CD at 5 %		1.71	2.82	0.08	19.99	2.31	171.52	0.14	0.21	0.29

Table 5. Mean performance on fruit quality parameters of the 41 genotypes of brinjal in F₄ generation

Sl. No.	Treatments	Fruit TSS (0 Brix)	Fruit reducing sugar (%)	Fruit total sugar (%)	Fruit ascorbic acid content (mg/100 g)	Leaf chlorophyll content	Fruit dry matter (%)
1	B2	4.75	0.975	1.04	7.936	22.975	7.775
2	BBSR-08x BBSR-10-26	3.75	1.8	2.291	7.266	18.35	9.975
3	BBSR-10-26 × BBSR-95-23	4	1.51	1.733	6.078	28.175	7.815
4	BBSR-08-2	5.25	1.505	1.855	5.237	27.2	7.575
5	BBJ-20-1	4	0.95	0.98	5.308	31.6	6.775
6	BBJR-20-2	4.25	1.3	2.222	3.749	23.275	7.175
7	BBV-77-23	3.75	0.895	1.067	5.934	30.05	10.385
8	BBSR-08-2×BBSR-10-25	5.5	1	1.295	4.768	32.675	6.985
9	BBSR-08-2 × BBSR-10-26	4.5	1	1.136	3.407	29.125	9.975
10	BBSR-08-2 × BBSR-195-3	4	1.01	1.225	4.86	21.775	9.975
11	BBSR-08-2 × BBSR-195-1	4	1.2	1.302	4.389	31.15	7.975
12	BBSR-08-2 × Selection from BBSR-192-1	4	1.74	1.945	5.233	23.75	8.665
13	BBSR-08-2 × Selection from BBSR-145-1	3.75	1.91	2.296	6.472	26.875	11.545
14	BBSR-08-2 × BBSR-09-5	4	1.225	1.501	4.86	21.675	9.975
15	BBSR-10-25 × BBSR-10-26	3.5	0.995	1.225	4.221	25.775	7.475
16	BBSR-10-25 × BBSR-195-3	4.75	1.825	2.475	5.806	28.8	4.625
17	BBSR-10-25 × BBSR-192-1	3.5	1.99	2.575	4.691	25.675	10.315
18	BBSR-10-25 × Selection from BBSR-192-1	3.75	1.825	2.326	7.165	22.075	7.815
19	BBSR-10-25 × Selection from BBSR-145-1	4	1.06	1.379	5.581	33.225	11.725
20	BBSR-10-25 × BBSR-09-5	5.25	1.225	1.537	5.743	30.925	17.665
21	Jammusahi Local × BBSR192-1	5.5	1.715	1.904	7.818	33.625	10.125
22	Jammusahi Local × Selection from BBSR192-1	4.75	1.525	1.909	5.095	31.525	11.135
23	BBSR-10-26 × BBSR-195-3	5.5	1.59	1.882	5.005	31.975	5.025
24	BBSR-10-26 × BBSR-192-1	4	1.375	2.018	4.439	25.2	12.525
25	BBSR-10-26 × Selection from BBSR-192-1	4.5	1.465	1.831	3.229	29.375	8.025
26	BBSR-10-26 × Selection from BBSR-145-1	5	1.425	1.994	6.055	26.75	9.025
27	BBSR-10-26 × BBSR-09-5	5	1.44	1.831	4.652	31.1	4.185
28	BBSR-195-3 × BBSR-192-1	4.25	1.4	1.882	4.307	23.9	7.315
29	BBSR-195-3 × BBSR-09-5	5	1.97	2.346	4.919	32.75	12.925
30	BBSR-192-1 × Selection from BBSR-145-1	5	1.18	1.438	5.984	29.6	7.919
31	BBSR-192-1 × BBSR-09-5	4	1.515	1.736	5.718	28.6	7.167
32	Selection from BBSR-192-1 × Selection from BBSR-145-1	5.25	1.765	1.977	5.185	25.35	9.115
33	Selection from BBSR-192-1 × BBSR-09-5	5.75	1.975	2.266	6.074	25.925	14.465
34	Selection from BBSR-145-1 × BBSR-09-5	4.5	1.61	1.831	5.005	27.725	11.645
35	Bhadrak local	4.5	1.665	1.937	5.847	34.95	14.655
36	Chhatia local selection	4.25	1.525	1.692	3.976	34.475	8.595
37	Jammusahi local	4.25	1.55	2.122	6.02	31.625	6.185
38	Salepur local selection	3.75	1.615	1.793	6.733	37.225	11.025
39	Selection from BBSR-192-1	3.5	1.59	2.122	7.306	32.45	10.025
40	Slection from BBSR-145-1	5	1.7	1.995	6.694	36.7	13.655
41	BB67 (Andharua local selection)	5.25	1.49	1.831	5.984	34.95	8.25
Mean		4.46	1.46	1.8	5.48	28.8	9.39
CV (%)		9.03	2.77	2.18	0.64	7.24	10.46
SE (m) ±		0.28	0.03	0.03	0.02	1.47	0.7
CD at 5 %		0.81	0.08	0.08	0.07	4.21	1.99

Reaction to bacterial wilt

Brinjal is highly vulnerable to wilt complexes caused by bacterial, fungal and nematode pathogens. Among the wilt complex, brinjal crop is highly susceptible to bacterial wilt that causes damage from 4.82–86.14 % (20) and 100 % loss (21), leading to huge economic loss to the growers. Keeping this in view, developing a tolerant variety was also one of our objectives and 40 genotypes were screened of brinjal along with one check against bacterial wilt at 60 and 90 DAT (%) in the sick plot of AICRP on Vegetable crops, OUAT, Bhubaneswar, Odisha. The results showed that the incidence of bacterial wilt at 60 DAT (%) and 90 DAT (%) showed significant variations (Table 4), ranging from 0.50 to 12.50 and 0.50 to 16.67 respectively. Considering the bacterial wilt at 60 and 90 DAT, F_4 segregants showing resistance (0.50) were viz.; BBSR-08-2 × BBSR-195-3, BBSR-08-2 × BBSR-09-5, BBSR-10-25 × Selection from BBSR-192-1, Jammusahi local × BBSR-192-1, Jammusahi local × Selection from BBSR192-1, BBSR-10-25 × BBSR-192-1, BBSR-10-25 × Selection from BBSR-192-1, BBSR-195-3 × BBSR-09-5, BBSR-192-1 × BBSR-09-5 and Selection from BBSR-192-1 × Selection from BBSR-145-1 under sick plot condition which can be used as parents for future brinjal improvement programme in backcross breeding. These findings are consistent with earlier reports in brinjal (10, 24, 26, 38).

Fruit yield per plant

In general, total fruit yield per plant (kg) in brinjal is a very complex trait controlled by polygenes, hence always strongly influenced by several environmental factors. The performance of brinjal genotypes primarily depends on the vegetative growth parameters, flowering behaviours, fruit yielding attributes and resistance to various stresses. In the present investigation, the genotypes showed significant variations (Table 4) for fruit yield per plant (kg), which varied significantly from 0.78 (BBJ202) to 2.05 (Salepur local selection). However, among the F_4 segregants, BBSR-08-2 × BBSR-10-26, BBSR-08-2 × BBSR-195-1, BBSR-08-2 × Selection from BBSR-192-1, BBSR-08-2 × Selection from BBSR-145-1, BBSR-10-25 × Selection from BBSR-192-1, BBSR-10-25 × Selection from BBSR-145-1, Jammusahi Local × BBSR 192-1,

Jammusahi Local × Selection from BBSR-192-1, BBSR-10-26 × BBSR-192-1, BBSR-192-1 × Selection from BBSR-145-1 and Selection from BBSR-192-1 × Selection from BBSR-145-1 was statistically at par with the high value (2.05). The results of the present investigation are in agreement with the earlier reports (17, 28, 31).

Genetic variability of 41 genotypes of brinjal

In any crop improvement programme, including brinjal, the presence of wide genetic variations is essential for subsequent selection of desirable genotypes as per the breeding objectives. It has already been established that both wide genetic variations followed by effective selection are considered as 2 pillars of any crop improvement programme. Therefore, it is highly essential to study the genetic variations in terms of range, general mean, PCV, GCV, heritability and GA as % of mean to study the nature and extent of variations for further selection (Table 6, Fig. 1).

Results on the coefficient of variations, both at the phenotypic and genotypic level recorded significant variations for all traits studied. The present investigation also revealed that PCV (%) values were higher than corresponding GCV (%) values of a trait, which indicated the presence of an environmental effect on expression of the trait. Similar results were also reported by several scientists in brinjal viz.; (24, 26, 35, 40–43). The traits viz.; plant spread (EW) (14.56 and 15.66), number of primary branches per plant (14.41 and 15.61), fruit length (23.36 and 24.42), fruit breadth (14.41 and 15.56), fruit length to breadth ratio (62.57 and 63.00), average fruit weight (27.63 and 28.70), number of fruits per plant (18.13 and 19.90), fruit reducing sugar (21.36 and 21.53), fruit total sugar (22.94 and 23.04), ascorbic acid content (20.58 and 20.59), fruit dry matter (29.02 and 30.85), incidence of bacterial wilt at 60 DAT (67.52 and 67.72) and 90 DAT (66.85 and 67.19) and total fruit yield per plant (23.06 and 25.06) showed < 10.00 % difference between PCV and GCV clearly implied the least influence of environment on the expression of these traits. Therefore, simple phenotypic selection of these traits will be very effective in the brinjal crop improvement programme. Similar reports in brinjal have also been reported previously (41–44).

Table 6. Estimation of genetic parameters of 41 genotypes of brinjal (31 F_4 segregants including 9 parents and check)

Sl.No.	Genetic Parameters	Mean	Range	GCV	PCV	h^2 (Broad Sense)	GAM
1	Plant height (cm)	95.56	48.88–15.50	10.79	12.11	79.439	19.81
2	Plant spread (EW) (cm)	96.43	78.40–137.50	14.56	15.66	86.337	27.86
3	Plant spread (NS) (cm)	91.44	63.58–118.00	11.14	12.47	79.894	20.52
4	Primary Branches/plant	7.38	5.50–9.75	14.41	15.61	85.272	27.42
5	Leaf area (cm ²)	171.01	157.23–186.30	2.23	3.72	35.779	2.74
6	Days to first flowering	38.70	33.50–45.50	5.75	7.95	52.332	8.57
7	Days to 50 % flowering	47.34	40.50–55.00	7.17	9.16	61.176	11.55
8	Flowers per cluster	3.73	2.50–4.75	11.49	13.06	77.383	20.82
9	Fruit length (cm)	11.89	6.00–21.50	23.36	24.42	91.545	46.05
10	Fruit breadth (cm)	23.73	8.50–30.40	14.41	15.56	85.723	27.48
11	Fruit length to breadth ratio	0.54	0.22–2.54	62.57	63.00	98.627	128.00
12	Average fruit weight (g)	126.73	77.50–209.50	27.63	28.70	92.635	54.78
13	Fruits per plant	13.94	10.30–20.00	18.13	19.90	83.016	34.03
14	No. of seeds/fruit	993.73	685.00–1570.00	16.81	18.86	79.488	30.88
15	TSS (° Brix)	4.46	3.50–5.75	12.91	15.76	67.172	21.80
16	Fruit Reducing Sugar (%)	1.46	0.90–1.99	21.36	21.53	98.346	43.63
17	Fruit total sugar (%)	1.80	0.98–2.58	22.94	23.04	99.105	47.04
18	Ascorbic acid content (mg 100g ⁻¹)	5.48	3.23–7.94	20.58	20.59	99.902	42.36
19	Chlorophyll content	28.80	18.35–37.23	14.78	16.46	80.664	27.35
20	Fruit dry matter (%)	9.39	4.19–17.67	29.02	30.85	88.496	56.24
21	Bacterial wilt at 60 DAT (%)	1.28	0.71–3.48	67.52	67.72	99.404	138.68
22	Bacterial wilt at 90 DAT (%)	1.56	0.35–4.08	66.85	67.19	98.981	137.00
23	Total fruit yield per plant (kg)	1.48	0.78–2.05	23.06	25.06	84.706	43.73

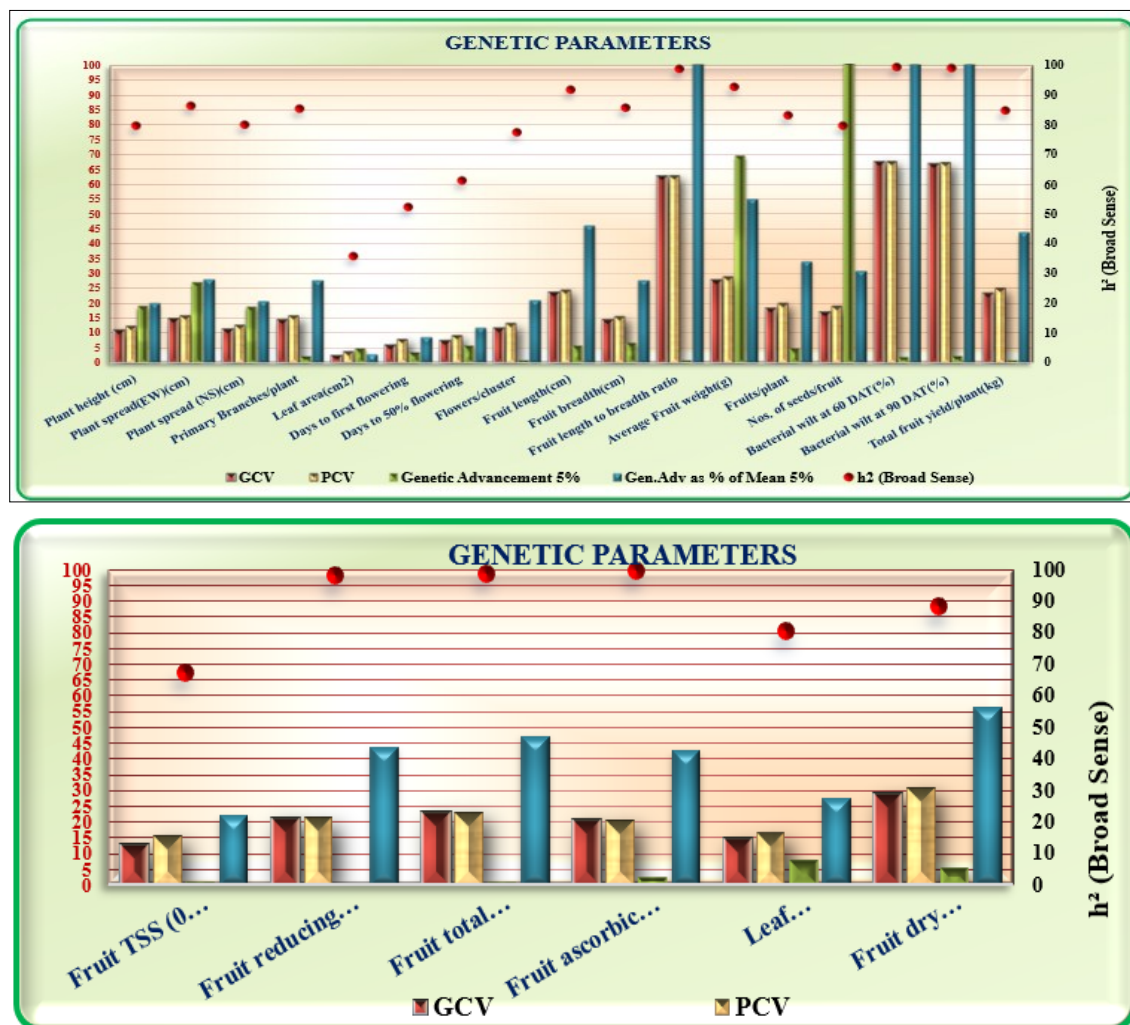


Fig. 1. Graphical presentation on analysis of genetic variability of various parameters in 41 genotypes (31 F_4 segregants, 9 parents and one check) of brinjal.

In any crop improvement programme, it was reported that for effective phenotypic selection neither high broad sense heritability nor high GA as % of mean was effective rather simultaneous consideration of high heritability (> 60.00 %) coupled with high GA as % of mean (> 20.00 %) (45). Hence, the results of the present investigation showed the combined effect of high heritability and high genetic advance as % of mean was seen for most of the traits under study, except for plant height (79.44 and 19.81) and days to 50 % flowering (61.18 and 11.55) having high heritability of traits with genetic advance as % of mean. Therefore, it may be concluded that the above traits can be considered for simple, effective selection in the brinjal improvement programme primarily due to strong additive gene action. These findings are consistent with earlier reports in brinjal (13, 24, 26, 37, 45, 46).

Correlation and path analysis

In a crop improvement programme, the study of character association or correlation coefficient provides insight about the interrelationship among various traits, which will be very effective for further phenotypic selection. In the present investigation, both phenotypic and genotypic character association were studied among 41 genotypes of brinjal (9 local landraces of Odisha as parents, 31 F_4 segregants and 1 check variety) (Table 7, Fig. 2, 3).

The study revealed that total fruit yield per plant showed a significant positive association with average fruit weight and number of fruits per plant while a significant but negative association was observed with days to 1st flowering, days to 50 %

flowering, number of flowers per cluster at genotypic and phenotypic level respectively. The results of the present study are in agreement with findings of previous studies in brinjal (47–52).

Considering both genotypic and phenotypic correlation simultaneously significant positive correlation were observed in days to 50 % flowering with days to 1st flowering, fruit breadth with plant spread (NS), fruit length to breadth ratio with fruit length, number of seeds per fruit with fruit length to breadth ratio, incidence of bacterial wilt at 60 DAT with plant height as well as incidence of bacterial wilt at 60 DAT with fruit breadth at genotypic and phenotypic level respectively. Similar results of positive association with other fruit yielding attributes in brinjal have also been reported (50, 53, 54).

Similarly, the study also revealed significant but negative correlation with traits viz.; days to 50 % flowering with plant height at final harvest, fruit length to breadth ratio with fruit breadth, average fruit weight with days to 1st flowering as well as days to 50 % flowering, number of fruits per plant with number of flowers per cluster, number of seeds per fruit with plant spread (EW) and fruit breadth, incidence of bacterial wilt at 60 DAT with average fruit weight and incidence of bacterial wilt at 90 DAT with average fruit weight. Similar results of significant negative association with different traits in brinjal have also been reported (49, 50, 53, 55). Besides, the above traits all other traits showed a non-significant effect on total fruit yield per plant and ancillary traits in brinjal.

The overall results on path analysis (Table 8, Fig. 4) showed

Table 7. Correlation coefficient among 17 characters in 41 genotypes (31F₆ segregants, 9 parents and 1 check) of brinjal at genotypic and phenotypic level

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	G	1	0.1943	0.1793	0.0743	0.1467	0.0959	0.222*	0.1719	0.1802	0.0239	0.0896	0.0085	0.0905	0.298*	0.0225	0.1149
	P	1	0.1946	0.1781	0.0719	0.1521	0.0984	0.225*	0.1711	0.1819	0.0245	0.0899	0.0087	0.0895	0.297*	0.022	0.1154
2	G	1	0.454**	0.0837	0.0900	0.0376	0.0105	0.0296	0.1364	0.1298	0.0094	0.1684	0.008	0.249*	0.0438	0.031	0.1754
	P	1	0.453**	0.0835	0.0915	0.0373	0.0102	0.0297	0.1367	0.1297	0.0093	0.1683	0.009	0.248*	0.0437	0.0311	0.1755
3	G	1	1	0.077	0.1243	0.1441	0.0521	0.0352	0.1526	0.274*	0.1082	0.1779	0.0517	0.1344	0.0536	0.0627	0.145
	P	1	1	0.073	0.1192	0.148	0.0553	0.0353	0.1514	0.273*	0.1092	0.1777	0.0515	0.133	0.0543	0.0621	0.1458
4	G	1	1	1	0.1898	0.1046	0.266*	0.1599	0.0047	0.1932	0.1405	0.1439	0.0083	0.0096	0.431**	0.0353	0.1552
	P	1	1	1	0.2027	0.0994	0.262	0.1604	0.0072	0.1978	0.1426	0.1451	0.0088	0.007	0.430**	0.0342	0.1548
5	G	1	1	1	1	0.1067	0.0112	0.0400	0.1502	0.0062	0.132	0.0212	0.0343	0.0463	0.0361	0.0628	0.0025
	P	1	1	1	1	0.1165	0.0034	0.0405	0.1477	0.0118	0.1308	0.02223	0.0354	0.0508	0.038	0.0614	0.001
6	G	1	1	1	1	0.724**	0.1548	0.1555	0.1996	0.0205	0.225*	0.424**	0.101	0.0547	0.1466	0.098	0.439**
	P	1	1	1	1	0.723**	0.1551	0.1557	0.2022	0.0236	0.227*	0.423**	0.1017	0.0527	0.1478	0.0993	0.438**
7	G	1	1	1	1	1	1	0.1555	0.0729	0.0057	0.171	0.298*	0.0269	0.015	0.282*	0.0363	0.267*
	P	1	1	1	1	1	1	0.1557	0.0750	0.0084	0.1725	0.297*	0.0266	0.013	0.281*	0.0373	0.266**
8	G	1	1	1	1	1	1	1	0.2081	0.068	0.1014	0.0008	0.434**	0.1234	0.2108	0.1126	0.241*
	P	1	1	1	1	1	1	1	0.2082	0.0681	0.1015	0.0009	0.433**	0.1234	0.2108	0.1127	0.240*
9	G	1	1	1	1	1	1	1	1	0.258*	0.734**	0.0769	0.0558	0.1914	0.016	0.0676	0.1068
	P	1	1	1	1	1	1	1	1	0.257*	0.733	0.0771	0.0557	0.1926	0.0157	0.0672	0.1072
10	G	1	1	1	1	1	1	1	1	1	0.714**	0.2101	0.0751	0.347*	0.233*	0.1447	0.1134
	P	1	1	1	1	1	1	1	1	1	0.713**	0.2107	0.0749	0.349*	0.232*	0.1442	0.1129
11	G	1	1	1	1	1	1	1	1	1	1	0.1703	0.1054	0.441**	0.1273	0.1816	0.0045
	P	1	1	1	1	1	1	1	1	1	1	0.1705	0.1053	0.442	0.1271	0.1813	0.0047
12	G	1	1	1	1	1	1	1	1	1	1	1	0.0807	0.069	0.286*	0.319*	0.575**
	P	1	1	1	1	1	1	1	1	1	1	1	0.0808	0.0688	0.285*	0.318*	0.574**
13	G	1	1	1	1	1	1	1	1	1	1	1	1	0.1344	0.239*	0.1512	0.443**
	P	1	1	1	1	1	1	1	1	1	1	1	1	0.1347	0.238*	0.1511	0.442**
14	G	1	1	1	1	1	1	1	1	1	1	1	1	1	0.0966	0.0571	0.0301
	P	1	1	1	1	1	1	1	1	1	1	1	1	1	0.0962	0.0576	0.0305
15	G	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2143	0.0615
	P	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2145	0.0617
16	G	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.133
	P	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.1328
17	G	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	P	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

1. Plant height at final harvest (cm), 2. Plant spread (EW) (cm), 3. Plant spread (NS) (cm), 4. Number of primary branches per plant, 5. Leaf area (cm²), 6. Days to 1st flowering, 7. Days to 50 % flowering, 8. Number of flowers per cluster, 9. Fruit length (cm), 10. Fruit breadth (cm), 11. Fruit length to breadth ratio, 12. Average fruit weight, 13. Number of fruit per plant, 14. Number of per seed fruit, 15. Bacterial wilt incidence at 60 DAT, 16. Bacterial wilt incidence at 90 DAT, 17. Fruit yield plant⁻¹ (kg) G - Genotypic correlation; P - Phenotypic correlation.

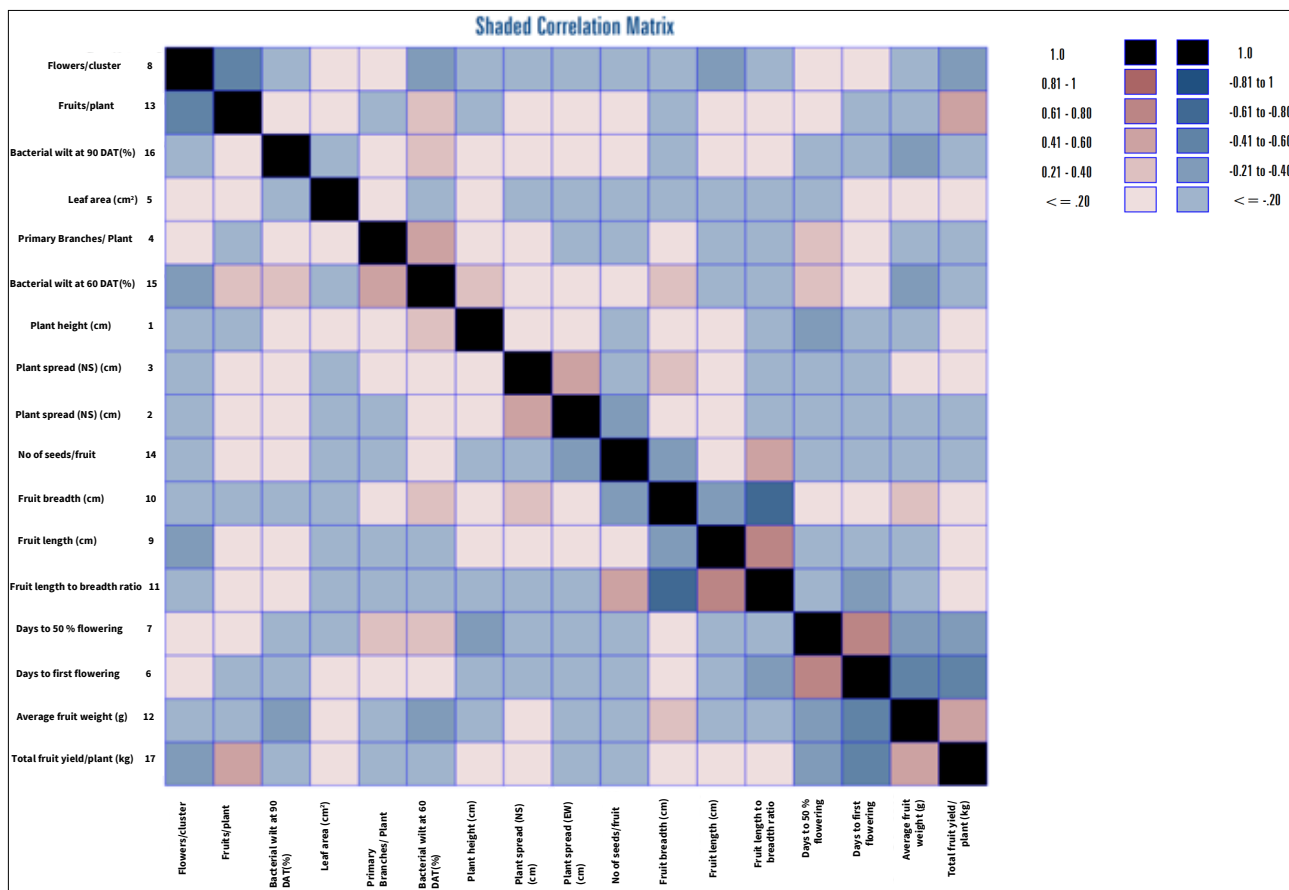


Fig. 2. Graphical presentation of correlation coefficient on various parameters at genotypic level in 41 brinjal genotypes (31 F₄ segregants and 9 parents).

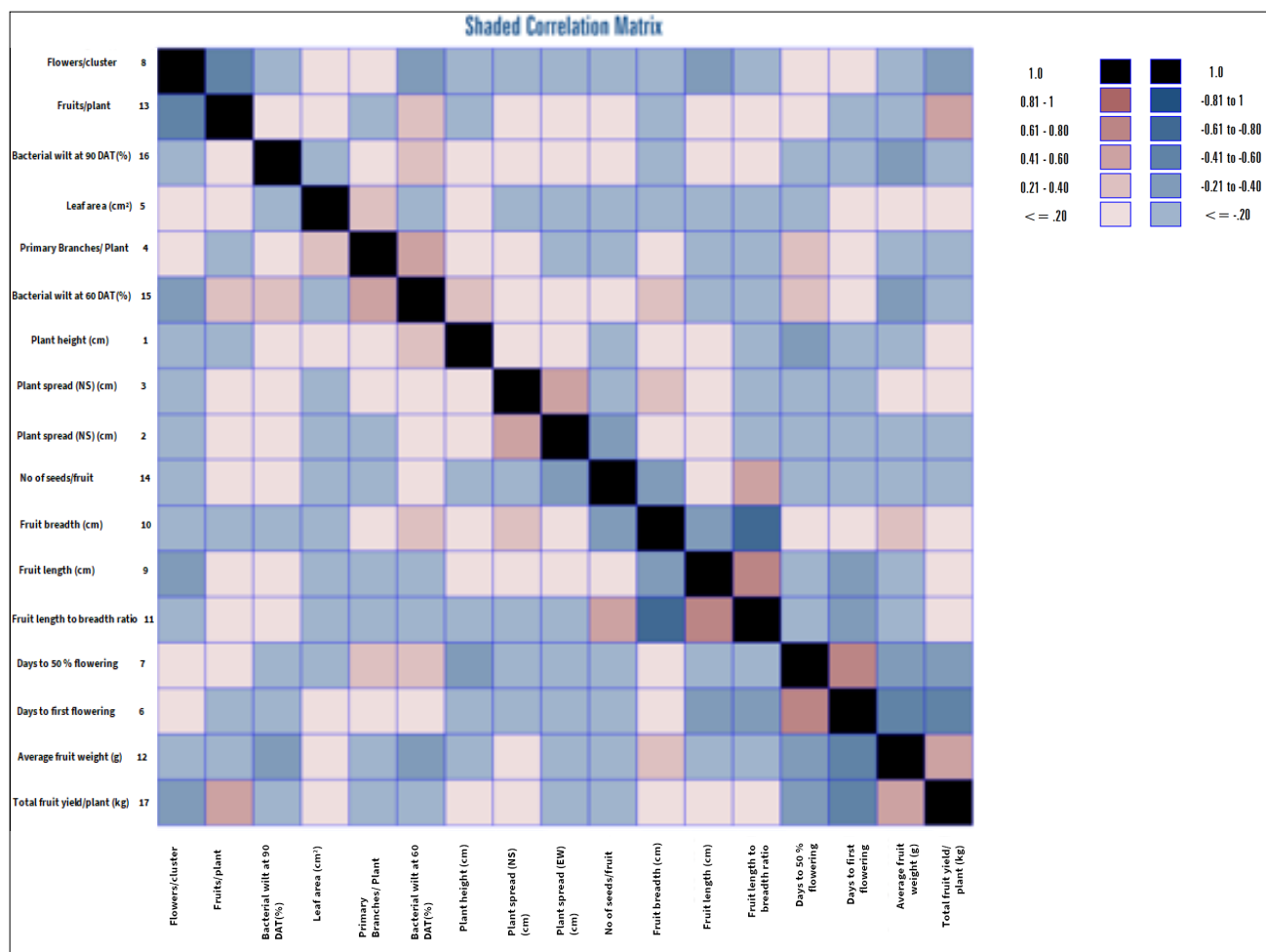


Fig. 3. Graphical presentation of correlation coefficient on various parameters at phenotypic level in 41 brinjal genotypes (31 F₄ segregants and 9 parents).

that number of fruits per plant (0.4855), average fruit weight (0.4657), plant height final harvest (0.1756), days to 50 % flowering (0.1043), fruit length (0.1028), fruit breadth (0.0579), plant spread (NS) (0.0469) and fruit length to breadth ratio (0.011) as positive direct effect on total fruit yield plant¹ in a decreasing trend. The results of the present study of positive direct effect on total fruit yield per plant are in agreement with the findings earlier (24, 49, 53–57) in brinjal. On the other hand, negative direct effect was observed in traits viz.; days to 1st flowering (0.230), plant spread (EW) (0.2194), number of primary branches per plant (0.1262), number of seeds per plant (0.1054), incidence of bacterial wilt at 90 DAT (0.0621) and 60 DAT (0.0145) as well as leaf area (0.0069) in an decreasing trend on total fruit yield per plant. The results are well corroborated with the findings (26, 57, 58) respectively.

The path analysis study also revealed that the residual effect was 0.278. Thus, the results indicated that some other fruit yielding attributing traits were not included. Similar reports of residual effect in path analysis of brinjal have been reported earlier (24, 50, 58) respectively.

Assessing genetic divergence of brinjal genotypes through principal component analysis (PCA)

Multivariate statistical methods such as Principal Component Analysis (PCA) are used to analyse and simplify complex datasets. The goal of PCA is to maximise data variance by transforming a set of correlated traits into independent composite factors (59). In this analysis, PCA was utilised to evaluate the genetic diversity among F₄ crosses while establishing relationships with observed traits,

leveraging correlations and patterns of variation across crosses. The scree plot presented in Fig. 5 depicts the proportion of total variance accounted for by each principal component. Eigenvalues derived from the correlation matrix were plotted in descending order, as per standard procedure (60).

In the present investigation, the results on Principal Component Analysis (PCA) showed 7 principal components with eigenvalues that account for 76.603 % of variance (Table 9). Among the 7 PCs, the first 3 PCs viz.; PC1, PC2 and PC3 contributed a high proportion of total variance (40.208 %) with eigenvalues 3.029, 2.652 and 2.174 respectively. The remaining components (PC4–PC7) explained variance ranging from 9.956 % to 6.112 %, with eigenvalues of 1.6931, 1.316, 1.126 and 1.039 respectively, which were consistent with earlier findings (61). The eigenvalue of the 7 PCs have been shown in the scree plot (Fig. 5). Among main PCs (PC1, PC2, PC3), the PC1 characters viz.; plant spread (EW) (0.019), number of primary branches per plant (0.242), leaf area (0.114), days to 1st flowering (0.448), days to 50 % flowering (0.395), number of flowers per cluster (0.226), fruit breadth (0.21), incidence of bacterial wilt at 60 DAT % (0.174) contributed positively where as in the traits viz.; number of primary branches per plant (0.021), days to 1st flowering (0.205), days to 50 % flowering (0.21), number of flowers per cluster (0.004), fruit length (0.243), fruit length to breadth ratio (0.423), number of fruits per plant (0.314), incidence of bacterial wilt at 60 DAT 90 DAT (0.07 and 0.199) showed positive contribution in PC2 component. In PC3, most of the traits contributed positively except leaf area (0.049), days to 1st flowering (0.022), number of flowers per cluster (0.327),

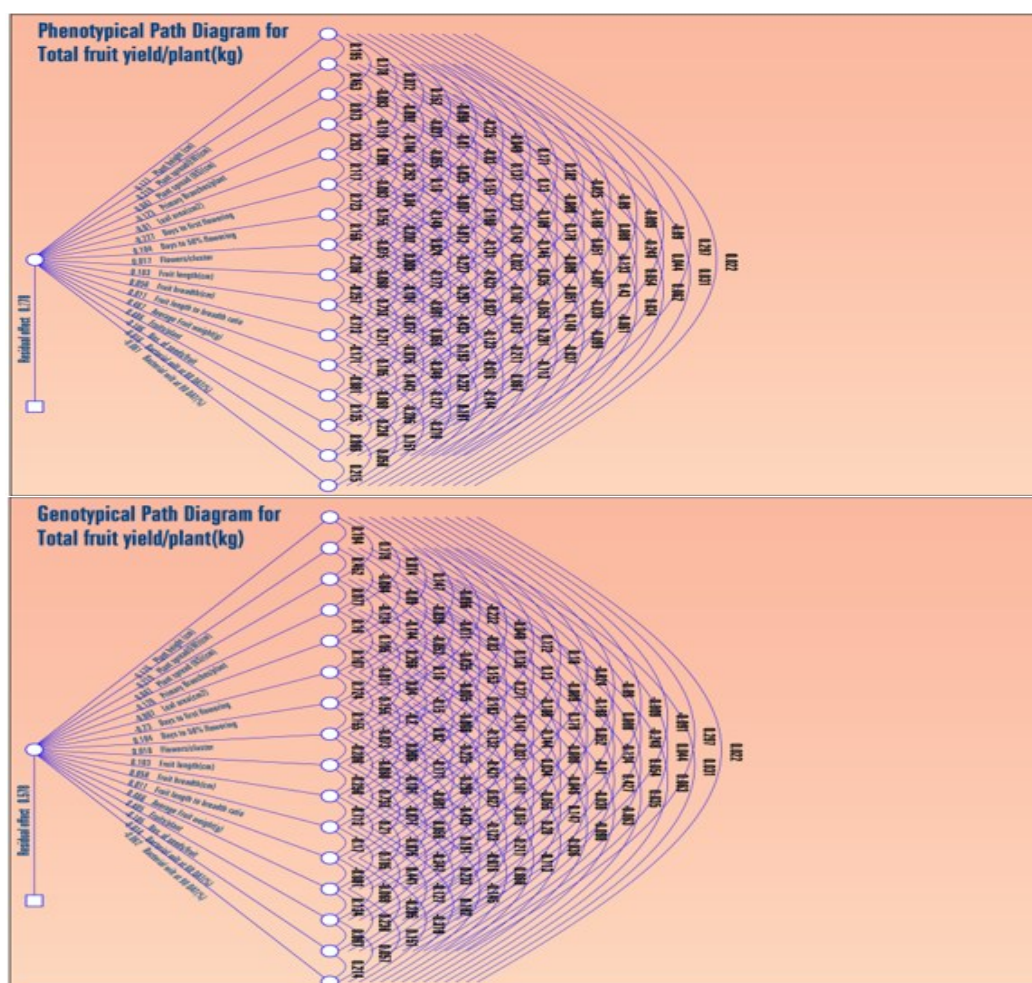


Fig. 4. Graphical presentation of path analysis on various parameters at phenotypic and genotypic level in 41 brinjal genotypes (31 F₄ segregants and 9 parents).

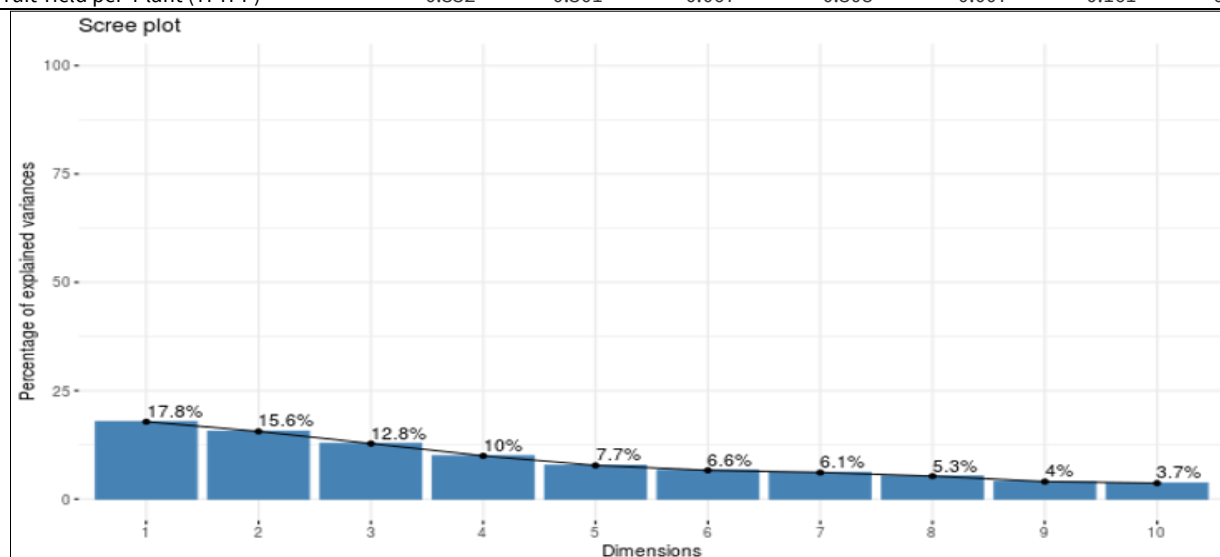
Table 8. Direct and indirect effects of component traits on yield in 41 genotypes (31 F₄ segregants, 9 parents and 1 check) of brinjal at phenotypic level for 17 characters

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.1756	0.0341	0.0315	0.0131	0.0258	0.0168	0.039	0.0085	0.0302	0.0317	0.0042	0.0157	0.0015	0.0159	0.0521	0.0039	0.1149
2		0.2194	0.0992	0.0184	0.0198	0.0082	0.0023	0.0065	0.0299	0.0285	0.0021	0.0369	0.0018	0.0544	0.0096	0.0068	0.1754
3			0.0469	0.0036	0.0058	0.0068	0.0024	0.0017	0.0072	0.0127	0.0051	0.0083	0.0024	0.0063	0.0025	0.0029	0.145
4				0.1262	0.0240	0.0132	0.0335	0.0202	0.0006	0.0244	0.0177	0.0182	0.0010	0.0012	0.0539	0.0045	0.1552
5					0.0069	0.0007	0.0001	0.0003	0.0010	0	0.0009	0.0001	0.0002	0.0003	0.0002	0.0004	0.0025
6						0.230	0.1666	0.0356	0.0459	0.0047	0.0517	0.0968	0.0232	0.0126	0.0337	0.0225	0.438**
7							0.1043	0.0162	0.0076	0.0006	0.0178	0.0308	0.0028	.0016	0.0292	0.0038	0.266**
8								0.0176	0.0037	0.0012	0.0018	0	0.0076	0.0022	0.0037	0.002	0.240*
9									0.1028	0.0265	0.0753	0.0079	0.0057	0.0197	0.0016	0.0069	0.1068
10										0.0579	0.0413	0.0122	0.0043	0.0201	0.0135	0.0084	0.1134
11											0.011	0.0019	0.0012	0.0049	0.0014	0.0020	0.0045
12												0.4657	0.0376	0.0321	0.1328	0.1486	0.574**
13													0.4855	0.0652	0.1157	0.0734	0.442**
14														0.1054	0.0102	0.006	0.0301
15															0.0145	0.0031	0.0615
16																0.0621	0.133

** Significant at 5 % R SQUARE= 0.2171(RESIDUAL EFFECT= 0.278) Bold values shows direct and normal values shows indirect effects : 1. Plant height at final harvest (cm), 2. Plant spread (EW) (cm), 3. Plant spread (NS)(cm), 4. Number of primary per branches plant, 5. Leaf area (cm²), 6. Days to 1st flowering, 7. Days to 50 % flowering, 8. Number of flowers per cluster, 9. Fruit Length (cm), 10. Fruit breadth (cm), 11. Fruit length to breadth ratio, 12. Average fruit weight, 13. Number of fruit per plant, 14. Number of seed per fruit, 15. Bacterial wilt incidence at 60 DAT, 16. Bacterial wilt incidence at 90 DAT, 17. Yield per plant (kg).

Table 9. Plant characteristic extracted Eigenvalues and latent vectors connected to the first 7 main components

Principal Components							
Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalue	3.029	2.652	2.174	1.693	1.316	1.126	1.039
Variance %	17.818	15.599	12.791	9.956	7.741	6.626	6.112
Cumulative variance %	17.818	33.416	46.207	56.163	63.905	70.531	76.644
Traits				Latent vectors			
Plant Height (PH)	0.027	0.116	0.334	0.118	0.515	0.141	0.21
Plant Spread (EW) (PSEW)	0.019	0.077	0.289	0.528	0.136	0.041	0.256
Plant Spread (NS) (PSNS)	0.059	0.244	0.323	0.323	0.062	0.279	0.071
Primary Branches per Plant (PBP)	0.242	0.024	0.225	0.161	0.344	0.314	0.403
Leaf Area (LA)	0.114	0.059	0.049	0.243	0.598	0.178	0.328
Days to 1 st Flowering (FF)	0.448	0.205	0.022	0.045	0.095	0.121	0.351
Days to 50 % Flowering (FPF)	0.395	0.21	0.065	0.121	0.203	0.351	0.175
Flowers per Cluster (FPC)	0.226	0.004	0.327	0.251	0.262	0.134	0.216
Fruit Length (FL)	0.297	0.243	0.196	0.207	0.163	0.4	0.132
Fruit Breadth (FB)	0.21	0.439	0.199	0.013	0.12	0.084	0.116
Fruit Length to Breadth Ratio (FLBR)	0.36	0.423	0.003	0.12	0.139	0.157	0.031
Average Fruit Weight (AFW)	0.222	0.406	0.218	0.128	0.014	0.279	0.094
Fruits per Plant (FPP)	0.159	0.042	0.327	0.407	0.227	0.097	0.295
Number of Seeds per Fruit (NSPF)	0.192	0.314	0.013	0.227	0.021	0.216	0.202
Bacterial wilt at 60 DAT % (BW60)	0.174	0.07	0.487	0.224	0.042	0.059	0.234
Bacterial Wilt at 90 DAT % (BW90)	0.047	0.199	0.249	0.044	0.06	0.509	0.423
Total Fruit Yield per Plant (TFYPP)	0.332	0.301	0.067	0.308	0.007	0.161	0.114

**Fig. 5.** Screen plot for principal components of 41 crosses of brinjal.

average fruit weight (0.218) and number of seeds per fruit (0.013) showed a negative contribution respectively. These results are in good agreement with an earlier work (62).

The principal component biplot (Fig. 6, 7) illustrates the distribution of 41 brinjal genotypes based on the first 2 principal components, which together explain 33.4 % of the total variability among the genotypes. Most crosses are clustered centrally, indicating moderate diversity within this group. In contrast, certain cross viz.; C15 is distinctly separated from the others, suggesting a high degree of divergence along the principal component axes. The colour intensity reflects the squared cosine ($\cos^2$) values, indicating the relative quality of representation of each cross on the biplot. Thus, this plot effectively visualises the genetic diversity among the brinjal crosses and highlights individuals with extreme or unique trait combinations respectively (Fig. 7). According to one report, critical traits such as fruit width, fruit weight and fruit yield per plant were key contributors to the genetic divergence observed among genotypes (63).

Conclusion

The present study revealed substantial genetic variability among F_4 brinjal segregants derived from Odisha landraces, indicating significant scope for selection and genetic improvement. High heritability coupled with high genetic advance for most traits suggested the predominance of additive gene action. Correlation and path analyses identified average fruit weight and number of fruits per plant as the most important contributors to fruit yield. Principal component analysis further confirmed the presence of wide genetic divergence among genotypes. Based on overall performance, F_4 segregants viz.; BBSR08-2 × Selection from BBSR192-1, BBSR10-25 × BBSR192-1, BBSR10-25 × BBSR09-5, Jammusahi local × BBSR192-1, Jammusahi Local × Selection from BBSR192-1 and BBSR192-1 × Selection from BBSR145-1, Selection from BBSR192-1 × Selection from BBSR145-1 were identified as promising for yield, quality traits and bacterial wilt tolerance under Bhubaneswar condition, Odisha and may be advanced for multilocation trials and future breeding programmes.

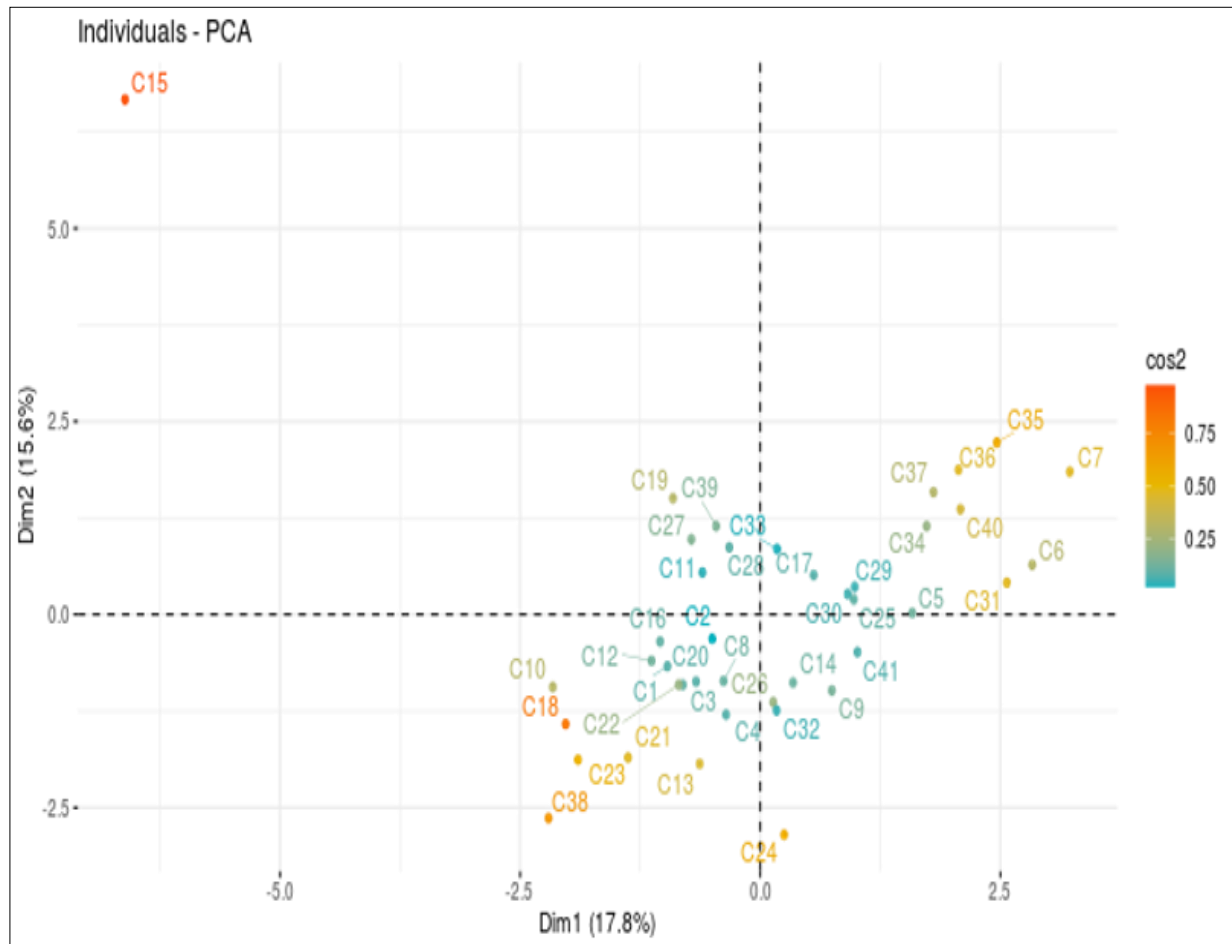


Fig. 6. Principal component biplot showing distribution of 41 crosses of brinjal.

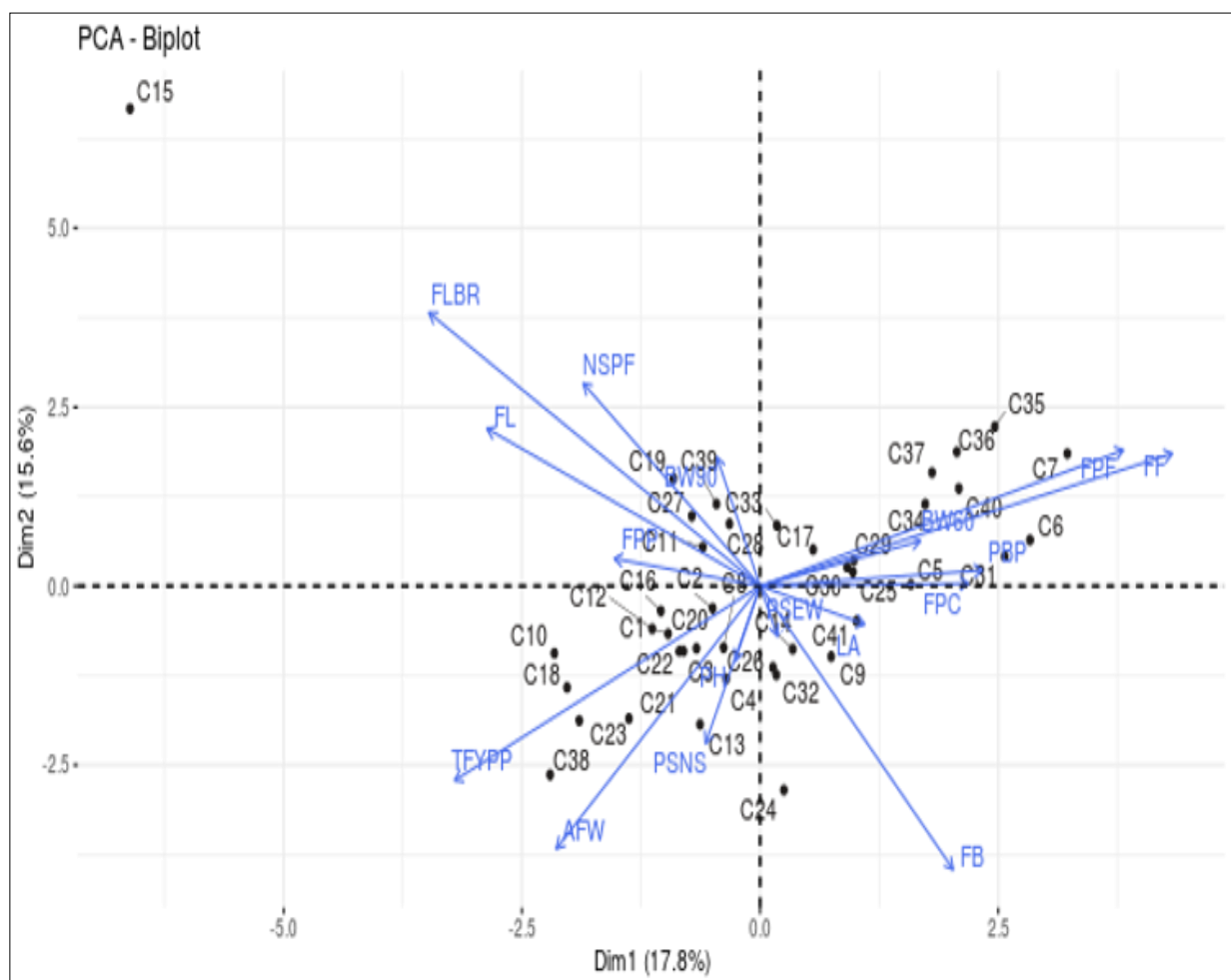


Fig. 7. Biplot of 41 crosses of brinjal based on different quantitative traits.

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Authors' contributions

KM contributed for investigation, formal analysis, writing of the original manuscript. PT carried out conceptualisation, methodology, supervision, validation, data curation, formal analysis, writing and editing the final Manuscript. AM, SD and SS¹ collected resources, validation, visualisation, writing review and editing. BT contributed for methodology, writing, editing, data analysis and validation. SS², AB, AK carried out collection of data and writing editing. NM and SKP performed validation, writing review and editing. All authors read and approved the final manuscript. [SS¹- Subrata Sarkar and SS²- Shrawama Sarma]

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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