Estimation of genetic diversity using D^2 and PCA in Brinjal (*Solanum melongena* L.)

Abstract

The current investigation was carried out on brinjal (*Solanum melongena* L.) during autumn winter season 2021 -2022 with the aims to study the genetic diversity with the help of D^2 and principle component analysis.The experimental material for study consisted of 38 genotypes including one check (NDB-2) and laid out in Completely Randomized-Block Design with three replications.Based on $D^2$the genotypes were grouped into seven different non-overlapping clusters. Cluster I had highest number of genotypes (23) followed by cluster II (10) and cluster III, IV, V, VI and VII (1).The maximum inter-cluster distance was observed between cluster III and VII. Maximum percent contribution in genetic divergence was showed by fruit circumference, TSS, numbero. of primary branches per plant and minimum contribution by fruit yield per plant. Based on the PCA with 13 traits, it formed 6 principal components (PCs) with more than 1 Eigen value apart from PC6 (0.80). These components indicated maximum variation among the variables with a diversity percentage of 79.30 per cent. The first PC showed 23.43 per cent variation, while the second, third, fourth, fifth and sixth PCs showed the variation of 16.89 per cent, 14.11 per cent, 10.37 per cent, 8.31 per cent and 6.17, respectively. Therefore, the traits coming under the 6 PCs manifest a high degree of genetic variation and they add up the genetic diversity between the genotypes which could be exploited in crop improvement programmes.Thus, there is a great potential for effective crop modification for improved yield and yield-attributing traits in present brinjal germplasm.

Key word: Brinjal or (*Solanum melongena* L.) ; genetic diversity; D^2 analysis, PCA

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Introduction

Brinjal (*Solanum melongena* L.), 2n=2x=24, is a member of the family Solanaceae. It is classified as a subgenus Leptospermum section Melongena. It is also referred to as aubergine or guinea zucchini and is one of the most widely grown vegetables in India and other countries. It is most likely evolved in India, with South East Asia exhibiting secondary diversity.In India, it is cultivated over an area of 7.49 million hectarea with an average annual

production of 128.74 million tonnes. It is widely distributed in Orissa, Bihar, Karnataka, West Bengal, Andhra Pradesh, Maharashtra, Gujrat and Utter Pradesh. In Uttar Pradesh, brinjal is being cultivated on an area of 4.10 lakh hectare~~a~~ with annual production of 136.16 lakh tonnes (Anon., 2020-2021).

The brinjal, also known as the eggplant, is an annual crop but is perennial in nature. Despite occasionally consisting of a cluster of 2–5 blooms, inflorescences are frequently solitary. A varietal characteristic of an inflorescence is its solitary or clustering form. Flower is complete and hermaphrodite. Heterostyly is a very common feature, and fruit setting flower consist of long styled (70-85%) and medium styled (12-55%) flower.Except for higher altitudes, brinjal can be grown easily almost all part of India. Successful brinjal output requires a long and warm growing season. Although spring and summer are also used to produce some brinjal, winter and autumn are the seasons when most of the crop is grown. However, because the fruit does not set properly in high temperatures (above 350C) during the spring and summer, brinjal output is drastically reduced. A temperature of 15.5-21.10C is ideal for development and fruit set. Many of the round-varieties usually produce fruit at a slightly lower temperature and are vulnerable to frost, while long-fruited varieties demonstrate tolerance to frost and set fruit at a higher temperature. Brinjal extracts are known to significantly lower liver and blood lipid levels. According to Hanur *et al.* (2006), the peel of brinjal contains large amounts of anthocyanin, an antioxidant with anti-cancer, anti-aging, anti-inflammatory and neuroprotective properties.In terms of plant type, stem colour, leaf size, leaf tip, midrib colour, fruit size, fruit shape, fruit colour, fruit production, fruit quality, cooking quality, and insect and disease tolerance, egg plant has a significant indigenous biodiversity (Ullah *et al.*, 2014).

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Genetic diversity can be worked out with the help of D^2 analysis which has given by Mahalanobis (1936). For the first time, use of this technique for assessing the genetic variability in plants was suggested by Rao (1952). It is very potent assessment technique ~~of assessment of~~for estimating genetic diversity among the genotypes and the contribution of each character to the total diversity. Greater the genetic distance better are the chances of obtaining desirable hybrids or segregates after hybridization between diverse groups. ~~Now~~ In the recent years,it is reliably and extensively used in plants for measuring genetic divergence (Shinde*et al.*, 2012; Vidhya and Kumar, 2014).

Materials and Methods

The present research work was carried out during autumn-winter season 2021-22 at the Main Experiment Station, Department of Vegetable Science, A.N.D. University of Agriculture and Technology Narendra Nagar, (Kumarganj), Ayodhya (U.P.).The experimental material for study consisted of 38 genotypes of brinjal including one check (NDB-2), and laid out in Completely Randomized-Block Design with three replications. Each treatment consisted of threerows. Eighteen plants were maintained in one row ~~each~~ and each treatment replicated thrice. Transplanting was done at a spacing of 60 cm between row to row and 50 cm between plant to plant having net plot size of 3 x 1.8 m^2. The seed were sown in nursery bed on 01-08-2021 and transplanted on 30-08-2021. All the recommended agronomic package of practices and plant protection measures were followed to raise a good crop. Observations were recorded on 13 quantitative characters *viz.*, days to 50% flowering, days to first fruit harvest, plant height (cm), number of primary branches per plant, fruit circumference (cm), length of fruit (cm), length of pedicel (cm), average fruit weight (g), number of fruits per plant, total phenol content (mg/100g), dry matter content (%), TSS (˚Brix) and total fruit yield per plant (kg). Genetic divergence using D^2 analysis was carried out using Mahalanobis (1936) while PCA was performed following Harman (1976).

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Result and Discussion

The study of genetic divergence among the thirty-eight genotypes of brinjal was carried out using Mahalanobis D^2 statistics. The genotypes were grouped into seven different non-overlapping clusters (Table-1). Cluster I had highest number of genotypes (23) followed by cluster II (10) and cluster III, IV, V, VI and VII (1). Arti *et al.* (2018), Gurve *et al.* (2019) and Mohanty *et al.* (2021) also classified the genotypes into different groups. The estimates of inter-and intra-cluster distances represented by D^2 values are given in Table-2. The intra cluster D^2 values ranged from 38.02 (cluster I) to 49.90 (cluster II) suggesting therefore the minimum and maximum divergence among the genotypes. The largest intra-cluster distance was observed in cluster II (49.90), and cluster I (38.02). The highest inter-cluster distance was observed between cluster III and VII (270.80), followed by cluster III and V (224.13) cluster I and VII (215.06**).** The minimum inter-cluster distance was observed between cluster I and IV (52.52).The higher inter-cluster distance indicated greater genetic divergence between the genotypes of these clusters while, lower inter-cluster values between the clusters suggested that the genotypes of the clusters were not much genetically diverse from each other. Sindhuja *et al.* (2019), Dash *et al.* (2020) and Mohanty *et al.* (2021) studies also support the current findings.~~found similar result~~.

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The cluster means for thirteen characters in brinjal are given Table-3. Perusal of Table 3 showed that cluster means for different traits indicated considerable differences between the clusters. Cluster V was found for earliest mean values for days to 50% flowering (50.67 days). Cluster VI showed earliest mean values for the days to first harvesting (69.00), Cluster III showed maximum mean value for plant height (85.52 cm). Cluster VII showed maximum mean values for the number of primary branches per plant (3.15). Cluster III exhibited maximum fruit length (19.47 cm). Cluster VII showed maximum mean values for the fruit circumference (17.99). Cluster II showed maximum mean values for the length of pedicle (5.18 cm). Cluster VII showed maximum mean values for the average fruit weight (113.07) and cluster V showed maximum mean values for the numbero. of fruit per plant (25.02), Cluster I showed maximum mean values for the phenol content (2.62), cluster VII showed maximum values for total dry matter content (7.89%). Cluster III and IV showed maximum mean values for TSS (5.03%). Cluster III showed maximum mean values for fruit yield per plant (2.20 kg). Similar findings were also recorded by Nand *et al.* (2018); Pandey *et al.* (2019) and Silambarasan*et al.* (2020) for genetic divergence in brinjal.

The analysis of percent contribution towards total genetic divergence was made among thirty-eight genotypes of brinjal had been given in Ttable 4. The maximum contribution in manifestation of total genetic divergence was made by number of fruit circumference (11.10%), TSS (10.53%), number ofo. primary branches per plant (9.39), dry matter content (8.25) and plant height (7.82). The minimum contribution was noticed in case of total fruit yield per plant (5.69%) and fruit length (5.97%) towards genetic divergence. Similar results were also noticed by Arti *et al.* (2018), Gurve *et al.* (2019), Dash *et al.* (2020) and Begum *et al.* (2022).

The eigen values, variability proportion (per cent) and cumulative proportion (per cent) are displayed in Table 5. Based on the PCA with thirteen parameters of cent percent diversity, it formed 6 principal components (PCs) with more than 1 eigen value apart from PC6 (0.80). These components indicated maximum variation among the variables 77 with a diversity percentage of 79.30 per cent. The first PC showed 23.43 per cent variation,while the second, third, fourth, fifth and sixth PCs showed the variation of 16.89 per cent, 14.11 per cent, 10.37 per cent, 8.31 per cent, and 6.17 per cent, respectively. Therefore, the traits coming under the 6 PCs manifest a high degree of genetic variation and they add up the genetic diversity between the genotypes which could be exploited in crop improvement programs.

The contribution of morphological and quality (biochemical) traits was furnished in Table 6. In PC 1, maximum positive factor loadings were observed in average fruit length (0.364), followed by phenol content (0.336), numbero. of fruit per plant (0.307), plant height (0.250) and days to 50 per cent flowering (0.124). The rest of the traits showed negative factor loadings. In PC2, maximum factor loadings were reflected in total fruit yield per plant (0.485), days to 50 per cent flowering (0.436) and average fruit weight (0.408), fruit length (0.336). Negative factor loadings were noted in TSS, days to first fruit harvest, number of primary branches per plant and phenol content. In PC 3, TSS (0.521), plant height (0.448) and days to total fruit yield per plant (0.098). Few parameters namely phenol content, days to first fruit harvest, dry matter content, no. of primary branches per plant, no. of fruit per plant, fruit length and average fruit weight revealed negative factor loadings.In PC 4, maximum factor loadings were appeared in number of primary branches per plant (0.460), total fruit per plant (0.205) and days to 50 per cent flowering (0.151). The plant traits namely pedicel length, days to first fruit harvest, total phenol content, fruit circumference, no. of fruit per plant, plant height and TSS. In PC 5, the highest factor loadings were noticed in no. of primary branches per plant (0.450), fruit circumference (0.369), no. of fruit per plant (0.294). The negative factor loading was recorded in dry matter content, fruit length, total fruit yield per plant, pedicel length. In PC 6, maximum factor loadings were noted in days to 50 per cent flowering (0.577), pedicel length (0.294) and the TSS (0.216). The plant parameters namely no. of fruit per plant, plant height, total fruit yield per plant, dry matter content, average fruit weight and a day to first fruit harvest showed negative factor loadings.

The study of contribution for diverse trait in principal component analysis among the thirty-eight genotypes of brinjal was carried out using Harman statistics. The thirty eight genotype were group into six different groups.Table-6shows positive maximum variable loaded component PC I for fruit length (0.364), PC II total fruit yield per plant (0.485), PC III for TSS (0.521), PC IV primary branches per plant (0.460), PC V for primary branches per plant (0.450) and PC VI days to 50 per cent flowering (0.577). Similar results were also noticed by Ahmed *et al.* (2014), Caguiat *et al.* (2014), Patel *et al.* (2018), Santhiya *et al.* (2019) and Uddin *et al.* (2021).

Table-1: Clustering pattern of thirty-eight genotypes of brinjal based on Mahalanobis D^2 statistics

Cluster Number	Number of Genotypes	Genotypes
I	23	2019/BRLVAR-8, NDB-55, 2019/BRLVAR-7, NDB-59, 2019/BRLVAR-4, 2019/BRLVAR-5, 2021/BRLVAR-3, 2021/BRLVAR-10, 2019/BRLVAR-6, 2020/BRLVAR-6, 2021/BRLVAR-4, NDB-52, 2020/BRLVAR-5, NDB-54, 2020/BRLVAR-8, 2021/BRLVAR-9, 2020/BRLVAR-1, NDB-53, 2020/ BRLVAR-11, 2019/BRLVAR-9, NDB-2(C), NDB-51, 2020/BRLVAR-2
II	10	2021/BRLVAR-2, NDB-57, NDB-58, NDB-56, 2019/BRLVAR-3, 2021/BRLVAR-7, 2019/BRLVAR-1, 2021/BRLVAR-8, 2019/BRLVAR-2, 2020/BRLVAR-4,
III	1	2020/BRLVAR-7
IV	1	2021/BRLVAR-1
V	1	2021/BRLVAR-5
VI	1	2020/BRLVAR-3
VII	1	2020/BRLVAR-9

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Table2: Average intra and inter cluster D^2 value for seven clusters in brinjal genotypes

Clusters	I	II	III	IV	V	VI	VII
I	38.02	79.72	71.28	52.52	151.59	174.54	215.06
II		49.90	99.29	66.49	87.05	86.61	147.57
III			0.00	112.41	224.13	178.33	270.80
IV				0.00	82.11	89.25	120.73
V					0.00	61.91	106.17
VI						0.00	145.65
VII							0.00

Table-3:Cluster meanforthirteencharactersingenotypesofbrinjal

Cluster	Days to 50% flowering	Days to first fruit harvest	Plant height	No. of primary branches per plant	Fruit length	Fruit circumference	Pedicel length	Average fruit weight	No. of fruit per plant	Phenol content	Dry matter content	TSS	Total fruit yield per plant
I	53.88	73.39	66.42	2.72	14.68	10.19	4.90	69.11	23.15	2.62	6.94	4.85	1.59
II	54.77	74.60	65.67	2.75	14.66	10.74	5.18	73.48	21.39	1.99	7.39	4.77	1.56
III	58.00	76.67	85.52	2.71	19.47	8.57	3.80	96.47	22.84	2.48	6.12	5.03	2.20
IV	54.00	75.67	68.21	2.77	9.49	13.10	4.97	61.72	24.02	2.46	6.52	5.03	1.59
V	51.67	71.00	54.76	2.92	5.40	11.31	2.79	47.70	25.02	1.68	7.72	4.60	1.19
VI	50.67	69.00	80.93	2.77	9.46	12.27	4.31	61.93	22.57	1.45	6.21	5.00	1.39
VII	53.67	73.33	54.79	3.15	10.29	17.99	4.77	113.07	17.44	2.13	7.89	4.80	1.96

Table4:Percentcontributionofthirteencharacterstowardstotalgeneticdivergenceinbrinjal

S.No.	Traits	Percent contribution
1.	Day to 50% flowering	6.83
2.	Days to first fruit harvest	7.40
3.	Plant height	7.82
4.	No. of primary branches per plant	9.39
5.	Fruit length	5.97
6.	Fruit circumference	11.10
7.	Pedicel length	7.25
8.	Average fruit weight	4.69
9.	No. of fruit per plant	7.40
10.	Phenol content	7.68
11.	Dry matter content	8.25
12.	TSS	10.53
13.	Total fruit yield per plant	5.69

Table-

5:Resultsofprincipalcomponentanalysis(PCA)forquantitativecharacterscontributingto divergenceinbrinjal

Principalcomponent	Eigen values (%)	Proportion (%)	Cumulative Proportion(%)
PC1	3.04	23.43	23.43
PC2	2.19	16.89	40.32
PC3	1.83	14.11	54.44
PC4	1.34	10.37	64.82
PC5	1.08	8.31	73.13
PC6	0.80	6.17	79.30

Table 6: Principal component analysis for thirteen characters in brinjal

Character	PC1	PC2	PC3	PC4	PC5	PC6
Day to 50% flowering	0.124	0.436	0.007	0.151	0.100	0.577
Days to first fruit harvest	-0.222	-0.197	-0.311	-0.336	0.059	-0.078
Plant height	0.250	0.161	0.448	-0.154	0.136	-0.299
No. of primary branches per plant	-0.193	-0.177	-0.291	0.460	0.450	0.078
Fruit length	0.364	0.366	-0.159	0.099	-0.097	0.062
Fruit circumference	-0.463	0.047	-0.005	-0.237	0.369	0.027
Pedicel length	-0.146	0.237	0.037	-0.647	-0.041	0.294
Average fruit weight	-0.314	0.408	-0.056	0.002	0.224	-0.110
No. of fruit per plant	0.307	0.163	-0.198	-0.203	0.294	-0.536
Phenol content	0.336	-0.086	-0.421	-0.244	0.124	0.296
Dry matter content	-0.248	0.055	-0.302	0.008	-0.678	-0.138
TSS	-0.071	-0.288	0.521	-0.048	0.003	0.216
Total fruit yield per plant	-0.308	0.485	0.098	0.205	-0.077	-0.147

Conclusion

Based on the above result of genetic diversity with the help of principle component analysis it could be concluded for all characteristics in this study, 38 genotypes were classified into 7 clusters, Cluster I had highest number of genotypes (23) followed by cluster II (10) and cluster III, IV, V, VI and VII (1). The maximum inter-cluster distance was observed between cluster III and VII. Maximum percent contribution in genetic divergence was showed by fruit circumference, TSS, no. of primary branches per plant and minimum

contribution by fruit yield per plant. Based on the PCA with 13 parameters of cent percent diversity, it formed 6 principal components (PCs) with more than 1 Eigen value apart from PC6 (0.80). These components indicate maximum variation among the variables with a diversity percentage of 79.30 per cent. The first PC showed 23.43 per cent variation, while the second, third, fourth, fifth and sixth PCs showed the variation of 16.89 per cent, 14.11 per cent, 10.37 per cent, 8.31 per cent and 6.17, respectively. Thus, this finding indicated that these traits could utilize in various breeding as well as improvement programmes. The information may further help the breeders in formulating appropriate strategy aimed at getting higher yield and character improvement in Brinjal.

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