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Per se performance of different genotypes and their hybrids for qualitative traits in brinjal (*Solanum melongena* L.)

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Abstract

The present investigation was conducted during Kharif seasons 2022-23 (Y1) and 2023-24 (Y2) to per se performance using diallel mating design with ten diverse parents of brinjal. They were crossed in a diallel fashion (Excluding reciprocals) for generating experimental material. All ten parents and their 45 hybrids were grown in randomized block design with three replications. Observations were recorded for the seven traits characters. The evaluation of parents and hybrids for seven quality traits over two years revealed significant variations. Pant Samrat, NDB-2 and NDB Sel.16-1 consistently exhibited high values among parents for total phenol content, dry matter content and non-reducing sugar respectively. Among hybrids P1 × P9, P2 × P5 and P1 × P3 were top performers for total phenol content, dry matter content and reducing sugar respectively. The findings highlight the potential of genotypes and hybrids in improving quality traits through various breeding programs.

Keywords: Brinjal, quality traits, reducing sugar, phenol content

Introduction

Brinjal or eggplant (*Solanum melongena* L.) likely originated in India, with the domestication of large fruit varieties around 1886, De Candol C. It is native to Asia, and Vavilov (1928) [21] identified the Indo-Burma region as its center of origin. Zeaven and Zhukovsky (1975) [18] noted its spread to China by the 5th century B.C., becoming a secondary center of variation. Arabic traders introduced brinjal to Africa and Spain. As a crucial crop in tropical and subtropical regions, its name derives from Sanskrit and Arabic, while "eggplant" refers to the fruit's white, egg-like appearance. In Europe, it is called "aubergine," from the French word.

Brinjal belongs to the Solanaceae family, which includes 75 genera and about 2000 species. Nearly 150-200 species are tuber-bearing, while around 1800 are non-tuber bearing, with almost all having a chromosome number of 2n = 24. India ranks second globally in vegetable production, contributing significantly to global vegetable area and output. Brinjal is cultivated on 0.758 million hectares in India, producing 13.154 million tons annually, with a productivity rate of 17.5 tonnes per hectare. Uttar Pradesh alone produces 2.75 million tons annually on 0.080 million hectares, with a productivity of 34.40 tonnes per hectare (Anonymous, 2021) [2].

Brinjal exhibits diverse fruit shapes and colors, from round or egg-shaped to long club-shaped, and colors ranging from white, yellow, and green to deep purple and nearly black. It is versatile in cooking, used in dishes like bhaji, stuffed brinjal, bhartha, pickles, sambar, and fish curries (Hedges and Lister, 2007) [19]. Nutritionally, 100 g of brinjal contains 24 calories, 3 mg sodium, 92.7% moisture, 0.12 mg copper, 4% carbohydrates, 2 mg potassium, 1.4 g protein, 44 mg sulfur, 0.3 g fat, 52 mg chlorine, 1.3 g fiber, 124 I.U. vitamin A, 18 mg oxalic acid, 34 µg folic acid, 18 mg calcium, 0.04 mg thiamine, 15 mg magnesium, 0.11 mg riboflavin, 47 mg phosphorus, 0.74 µg B-carotene, 0.38 mg iron, 12 mg vitamin C, and 0.22 mg zinc (Sharma & Kaushik, 2021) [16].

Brinjal has ayurvedic medicinal properties, useful for treating diabetes, bronchitis, asthma, high blood pressure, osteoporosis, arthritis, Alzheimer's, various cancers, heart disease, and stroke (Matsubara *et al*, 2005, Sękara, *et al*, 2007) [9, 15]. Mature fruits treat stomach pains and abscesses; fruit stalks treat fistula and piles (Small, 2009 & Mak, 2013) [20, 8]. The juice, sometimes mixed with leaves, treats syphilitic eruptions, while leaves and roots are used for skin diseases, rheumatism, inflammation, and other ailments (Adachi, 2008, Mak, 2013) [1, 8].

The brinjal plant is semi-spreading with an erect habit, grown as an annual crop. It is mainly self-pollinating, but cross-pollination can occur in hot, humid climates. Its photo-insensitivity allows for biannual cultivation, aiding crop improvement. Breeding efforts focus on traits like earliness, yield, fruit quality, and pest and disease resistance. Hybridization has been explored since Bailey (1891) [3] and Munson (1892) [11], with hybrid vigor first noted by Nagai and Kida (1926). [12] However, regional preferences are often overlooked in hybrid development.

Effective breeding programs require understanding genetic characteristics and combining abilities. Diallel cross analysis helps estimate genetic components and combining abilities, crucial for identifying favorable traits for breeding. Non-additive gene activity is essential for exploiting heterosis, leading to higher productivity. Genetic factors like heritability and genetic progress aid breeders in selecting genotypes with desirable traits.

Overall, genetic improvement in brinjal involves crossing genetically diverse parents to produce heterotic F1 progeny. Half-diallel analysis is a valuable tool for identifying superior parents and understanding genetic variations, facilitating the development of high-yielding brinjal varieties.

Materials and methods

The investigation conducted during Kharif seasons 2022-23 (Y1) and 2023-24 (Y2) to study the heritability in narrow sense and genetic advance in percent of mean by using diallel (except reciprocal) mating design at the Main Experiment Station (MES) of Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Ayodhya (U.P.) India. The experimental site is geographically, falls under a humid, sub-tropical climate and is located between 24.470 and 26.560 N latitude and 82.120 and 83.980 E longitude at an altitude of 113 m above the mean sea stratum in the Gangetic alluvial plains of Eastern Uttar Pradesh. The soil of the experimental site was sandy loam with average fertility level with pH in the range of 7.5-8.5.The selected parental lines *i.e.;* Pant Samrat (P1), Pant Rituraj (P2), Pusa Ankur (P3), NDB Sel-19-1 (P4), NDB Sel-16-1 (P5), NDB - 3 (P6), Narendra Suyog (P7), KS-251 (P8), NDB - 2 (P9) and Co-2 (P10) were crossed in all possible cross combinations (excluding reciprocals) during year, 2021-22 to get 45 F1's for the study of heritability in narrow sense and genetic advance in percent of mean. The mean of five plants was calculated and used for statistical analysis. A spacing of 1.2 m × 3 m was adopted and recommended agronomic practices were followed to raise a successful experimental crop. Observations were recorded for seven quality characters namely total phenol content (%), total soluble solid (T.S.S.) (brix), reducing sugar (%), non-reducing sugar (%), total sugar (%), ascorbic acid (mg/100 g), dry matter content (%).

Results

Per se performance of parents and hybrids, ranges and grand mean for all the seven quality traits over two years (Y1, Y2) and pooled has been presented in Table1 the results are described below under the following heads:

Total Phenol Content (%)

In Y1, total Phenol Content (%) ranged from 0.78 to 1.22% for parents and 0.78 to 1.21% for hybrids. Pant Samrat (1.22%) found maximum for total Phenol Content (%) among the parents which was followed by NDB-2 (1.14%), NDB- 3 (1.13%), Pusa Ankur (1.11%). The best F1 hybrid for total Phenol Content (%) was recorded for cross $P_1 \times P_9$ (1.21%) followed by $P_6 \times P_9$ (1.16%), $P_1 \times P_3$ (1.16%) and $P_1 \times P_5$ (1.14%). Averages over the parental mean (1.00%) and averages over the F1 hybrid mean (0.97%) were more or less of the same order.

In Y2, total Phenol Content (%) ranged from 0.81 to 1.22% for parents and 0.81 to 1.21% for hybrids. Pant Samrat (1.22%) found maximum for total Phenol Content (%) among the parents which was followed by Pusa Ankur (1.13%), NDB- 3 (1.12%), NDB Sel.-16-1 (1.11%). The best F1 hybrid for total Phenol Content (%) was recorded for cross $P_1 \times P_5$ (1.21) followed by $P_1 \times P_9$ (1.14%), $P_1 \times P_3$ (1.14%) and $P_3 \times P_6$ (1.12%). Averages over the parental mean (0.99%) and averages over the F1 hybrid mean (0.96%) were more or less of the same order.

In Pooled, Total Phenol Content (%) ranged from 0.80 to 1.22 for parents and 0.80 to 1.18 for hybrids. Pant Samrat (1.22%) found maximum for Total Phenol Content (%) among the parents which was followed by NDB-3 (1.13%), Pusa Ankur (1.12%), NDB Sel.-16-1 (1.10%). The best F1 hybrid for Total Phenol Content (%) was recorded for cross $P_1 \times P_5$ (1.18%) followed by $P_1 \times P_9$ (1.17%), $P_1 \times P_3$ (1.15%) and $P_3 \times P_6$ (1.13%). Averages over the parental mean (0.99%) and averages over the F1 hybrid mean (0.97%) were more or less of the same order.

Dry matter content (%)

In Y1, dry matter content (%) ranged from 7.12 to 8.23% for parents and 7.12 to 8.64% for hybrids. NDB-2 (8.23%) found maximum for dry matter content (%) among the parents which was followed by Pusa Ankur (7.92%), Narendra Suyog (7.89%), CO-2 (7.69%). The best F1 hybrid for dry matter content (%) was recorded for cross $P_2 \times P_5$ (8.64) followed by $P_4 \times P_6$ (8.37%), $P_3 \times P_6$ (8.35%) and $P_1 \times P_6$ (8.31%). Averages over the parental mean (7.62%) and averages over the F1 hybrid mean (7.64%) were more or less of the same order.

In Y2, dry matter content (%) ranged from 7.21 to 8.30% for parents and 7.09 to 8.54% for hybrids. NDB-2 (8.30%) found maximum for dry matter content (%) among the parents which was followed by Narendra Suyog (7.91%), Pusa Ankur (7.85%), KS-251 (7.72%). The best F1 hybrid for dry matter content (%) was recorded for cross $P_2 \times P_5$ (8.54%) followed by $P_1 \times P_6$ (8.40%), $P_3 \times P_6$ (8.38%) and $P_6 \times P_7$ (8.35%). Averages over the parental mean (7.62%) and averages over the F1 hybrid mean (7.63%) were more or less of the same order.

In Pooled, dry matter content (%) ranged from 7.18 to 8.27% for parents and 7.11 to 8.59% for hybrids. NDB-2 (8.27%) found maximum for dry matter content (%) among the parents which was followed by Narendra Suyog (7.90%), Pusa Ankur (7.89%), KS-251 (7.70%). The best F1 hybrid for dry matter content (%) was recorded for cross $P_2 \times P_5$ (8.59%) followed by $P_3 \times P_6$ (8.37%), $P_1 \times P_6$ (8.36%) and $P_4 \times P_6$ (8.36%). Averages over the parental mean (7.63%) and averages over the F1 hybrid mean (7.63%) were more or less of the same order.

Reducing sugar (%)

In Y1, reducing sugar (%) ranged from 0.80 to 1.51% for parents and 0.49 to 1.37% for hybrids. NDB-2 (1.51%) found maximum for reducing sugar (%) among the parents which was followed by KS-251 (1.34%), Pant Rituraj (1.26%) and Pant Samrat (1.24%). The best F1 hybrid for reducing sugar (%) was recorded for cross $P_1 \times P_3$ (1.37%) followed by $P_4 \times P_6$ (1.36%), $P_4 \times P_{10}$ (1.34%) and $P_3 \times P_6$ (1.32%). Averages over the parental mean (1.18%) and averages over the F1 hybrid mean (1.01%) were more or less of the same order.

In Y2, reducing sugar (%) ranged from 0.86 to 1.30% for parents and 0.54 to 1.32% for hybrids. NDB-2 (1.30%) found maximum for reducing sugar (%) among the parents which was followed by Pant Rituraj (1.25%), Pusa Ankur (1.25%) and Narendra Suyog (1.24%). The best F1 hybrid for reducing sugar (%) was recorded for cross $P_1 \times P_3$ (1.32%) followed by $P_5 \times P_9$ (1.31%), $P_4 \times P_6$ (1.24%) and $P_3 \times P_6$ (1.21%). Averages over the parental mean (1.15%) and averages over the F1 hybrid mean (0.97%) were more or less of the same order.

In Pooled, reducing sugar (%) ranged from 0.86 to 1.41 for parents and 0.52 to 1.35 for hybrids. NDB-2 (1.41) found maximum for reducing sugar (%) among the parents which was followed by KS-251 (1.29), Pant Rituraj (1.26) and NDB-3 (1.24). The best F1 hybrid for reducing sugar (%) was recorded for cross $P_1 \times P_3$ (1.35) followed by $P_4 \times P_6$ (1.30), $P_5 \times P_9$ (1.29) and $P_3 \times P_6$ (1.27). Averages over the parental mean (1.17) and averages over the F1 hybrid mean (0.99) were more or less of the same order.

Non-reducing sugar (%)

In Y1, non-reducing sugar (%) ranged from 0.35 to 0.68% for parents and 0.31 to 0.68% for hybrids. NDB Sel.16-1 (0.68%) found maximum for non-reducing sugar (%) among the parents which was followed by Narendra Suyog (0.63%), NDB Sel-19-1 (0.62%) and Pant Samrat (0.56%). The best F1 hybrid for non-reducing sugar (%) was recorded for cross $P_1 \times P_2$ (0.68%) followed by $P_4 \times P_9$ (0.68%), $P_6 \times P_7$ (0.68%) and $P_6 \times P_8$ (0.66%). Averages over the parental mean (0.52%) and averages over the F1 hybrid mean (0.54%) were more or less of the same order.

In Y2, non-reducing sugar (%) ranged from 0.34 to 0.71% for parents and 0.30 to 0.71% for hybrids. NDB Sel.16-1 (0.71%) found maximum for non-reducing sugar (%) among the parents which was followed by CO-2 (0.68%), NDB Sel-19-1 (0.59%) and Narendra Suyog (0.54%). The best F1 hybrid for non-reducing sugar (%) was recorded for cross $P_8 \times P_9$ (0.71%) followed by $P_4 \times P_9$ (0.68%), $P_6 \times P_8$ (0.68%) and $P_6 \times P_7$ (0.65%). Averages over the parental mean (0.52%) and averages over the F1 hybrid mean (0.54%) were more or less of the same order.

In Pooled, non-reducing sugar (%) ranged from 0.35 to 0.70% for parents and 0.33 to 0.70% for hybrids. NDB Sel.16-1 (0.71%) found maximum for non-reducing sugar (%) among the parents which was followed by CO-2 (0.65%), NDB Sel-19-1 (0.61%) and Narendra Suyog (0.59%). The best F1 hybrid for non-reducing sugar (%) was recorded for cross $P_8 \times P_9$ (0.70%) followed by $P_4 \times P_9$ (0.68%), $P_6 \times P_8$ (0.68%) and $P_6 \times P_7$ (0.65%). Averages over the parental mean (0.52%) and averages over the F1 hybrid mean (0.54%) were more or less of the same order.

Total Sugar (%)

In Y1, total sugar (%) ranged from 1.44 to 1.86% for parents and 0.86 to 1.87% for hybrids. NDB-2 (1.86%) found maximum for total sugar (%) among the parents which was followed by NDB Sel.16-1 (1.83%), Pant Samrat (1.79%) and CO-2 (1.76%). The best F1 hybrid for total sugar (%) was recorded for cross $P_5 \times P_{10}$ (1.87%) followed by $P_4 \times P_{10}$ (1.86%), $P_1 \times P_3$ (1.85%) and $P_3 \times P_9$ (1.83%). Averages over the parental mean (1.70%) and averages over the F1 hybrid mean (1.57%) were more or less of the same order.

In Y2, total sugar (%) ranged from 1.45 to 1.88% for parents and 1.08 to 1.88% for hybrids. CO-2 (1.88%) found maximum for total sugar (%) among the parents which was followed by NDB Sel.16-1 (1.82%), NDB-3 (1.75%) and Narendra Suyog (1.75%). The best F1 hybrid for total sugar (%) was recorded for cross $P_5 \times P_9$ (1.88%) followed by $P_4 \times P_6$ (1.85%), $P_5 \times P_7$ (1.78%) and $P_3 \times P_9$ (1.83%). Averages over the parental mean (1.68%) and averages over the F1 hybrid mean (1.54%) were more or less of the same order.

In Pooled, total sugar (%) ranged from 1.45 to 1.83% for parents and 0.97 to 1.81% for hybrids. NDB Sel.16-1 (1.83%) found maximum for total sugar (%) among the parents which was followed by CO-2 (1.82%), KS-251 (1.79%) and NDB-2 (1.78%). The best F1 hybrid for total sugar (%) was recorded for cross $P_4 \times P_6$ (1.85%) followed by $P_5 \times P_9$ (1.80%), $P_3 \times P_9$ (1.78%) and $P_2 \times P_{10}$ (1.77%). Averages over the parental mean (1.69%) and averages over the F1 hybrid mean (1.56%) were more or less of the same order.

Total soluble solid (Brix)

In Y1, TSS (Brix) ranged from 4.40 to 5.97 Brix for parents and 4.94 to 6.22 Brix for hybrids. NDB Sel-19-1 (5.97 Brix) found maximum for TSS (Brix) among the parents which was followed by NDB Sel.-16-1 (5.74 Brix), Pant Rituraj (5.67 Brix) and Narendra Suyog (5.67 Brix). The best F1 hybrid for TSS (Brix) was recorded for cross $P_6 \times P_8$ (6.22 Brix) followed by $P_1 \times P_2$ (6.06 Brix), $P_1 \times P_6$ (6.05 Brix) and $P_1 \times P_4$ (5.97 Brix). Averages over the parental mean (5.32 Brix) and averages over the F1 hybrid mean (5.41 Brix) were more or less of the same order.

In Y2, TSS (Brix) ranged from 4.54 to 5.71 Brix for parents and 4.86 to 6.11 Brix for hybrids. NDB Sel.-16-1 (5.71 Brix) found maximum for TSS (Brix) among the parents which was followed by Narendra Suyog (5.70 Brix), NDB Sel-19-1 (5.56 Brix) and Pant Rituraj (5.53 Brix). The best F1 hybrid for TSS (Brix) was recorded for cross $P_6 \times P_8$ (6.11) followed by $P_1 \times P_4$ (6.01 Brix), $P_1 \times P_6$ (5.96 Brix) and $P_1 \times P_2$ (5.93). Averages over the parental mean (5.31 Brix) and averages over the F1 hybrid mean (5.40 Brix) were more or less of the same order.

In Pooled, TSS (Brix) ranged from 4.47 to 5.77 Brix for parents and 4.92 to 6.17 Brix for hybrids. NDB Sel-19-1 (5.77 Brix) found maximum for TSS (Brix) among the parents which was followed by NDB Sel.-16-1 (5.71), Narendra Suyog (5.69 Brix) and Pant Rituraj (5.69 Brix). The best F1 hybrid for TSS (Brix) was recorded for cross $P_6 \times P_8$ (6.17 Brix) followed by $P_1 \times P_6$ (6.01 Brix), $P_1 \times P_2$ (6.00 Brix) and $P_1 \times P_4$ (5.99 Brix). Averages over the parental mean (5.32 Brix) and averages over the F1 hybrid mean (5.41 Brix) were more or less of the same order.

Ascorbic acid (mg/100 g)

In Y1, ascorbic acid (mg/100 g) ranged from 8.79 to 14.35 mg/100 g for parents and 8.23 to 15.70 mg/100 g for hybrids. CO-2 (14.35 mg/100 g) found maximum for ascorbic acid (mg/100 g) among the parents which was followed by Narendra Suyog (14.25 mg/100 g), KS-251 (11.65 mg/100 g) and NDB Sel.-16-1 (11.54 mg/100 g). The best F1 hybrid for ascorbic acid (mg/100 g) was recorded for cross $P_1 \times P_6$ (15.70 mg/100 g) followed by $P_6 \times P_{10}$ (14.27 mg/100 g), $P_2 \times P_9$ (14.25 mg/100 g) and $P_4 \times P_9$ (14.25 mg/100 g). Averages over the parental mean (11.22 mg/100 g) and averages over the F1 hybrid mean (12.18 mg/100 g) were more or less of the same order.

In Y2, ascorbic acid (mg/100 g) ranged from 8.85 to 14.31 mg/100 g for parents and 8.41 to 14.82 mg/100 g for hybrids. Narendra Suyog (14.28 mg/100 g) found maximum for ascorbic acid (mg/100 g) among the parents which was followed by CO-2 (13.98 mg/100 g), KS-251 (12.21 mg/100 g) and NDB Sel.-16-1 (11.24 mg/100 g). The best F1 hybrid for ascorbic acid (mg/100 g) was recorded for cross $P_1 \times P_6$ (14.82 mg/100 g) followed by $P_1 \times P_4$ (14.61 mg/100 g), $P_6 \times P_7$ (14.38 mg/100 g) and $P_4 \times P_6$ (14.18 mg/100 g). Averages over the parental mean (11.10 mg/100 g) and averages over the F1 hybrid mean (11.93 mg/100 g) were more or less of the same order.

In Pooled, ascorbic acid (mg/100 g) ranged from 8.82 to 14.28 mg/100 g for parents and 8.32 to 15.26 mg/100 g for hybrids. Narendra Suyog (14.28 mg/100 g) found maximum for ascorbic acid (mg/100 g) among the parents which was followed by CO-2 (14.17 mg/100 g), NDB-3 (13.32 mg/100 g) and KS-251 (11.93 mg/100 g). The best F1 hybrid for ascorbic acid (mg/100 g) was recorded for cross $P_1 \times P_6$ (15.26 mg/100 g) followed by $P_1 \times P_4$ (14.43 mg/100 g), $P_6 \times P_7$ (14.32 mg/100 g) and $P_4 \times P_6$ (14.22 mg/100 g). Averages over the parental mean (11.16 mg/100 g) and averages over the F1 hybrid mean (12.06 mg/100 g) were more or less of the same order.

Table 1: Mean performance, general mean, range, coefficient of variation and critical difference for seven quality characters of diallel set of 45 F1's and their 10 parents in Y1 (2022-23), Y2 (2023-24) and pooled.

Sr. No.	Genotypes	Total phenol content (%)			Dry matter content (%)			Reducing sugar (%)		
		Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled
1	Pant Samrat	1.22	1.22	1.22	7.36	7.21	7.29	1.24	1.21	1.23
2	Pant Rituraj	1.09	0.99	1.04	7.58	7.42	7.50	1.26	1.25	1.26
3	Pusa Ankur	1.11	1.13	1.12	7.92	7.85	7.89	1.19	1.25	1.22
4	NDB Sel-19-1	0.79	0.85	0.82	7.56	7.57	7.57	0.94	0.86	0.90
5	NDB Sel.-16-1	1.08	1.11	1.10	7.12	7.24	7.18	1.15	1.10	1.13
6	NDB 3	1.13	1.12	1.13	7.23	7.31	7.28	1.23	1.23	1.24
7	Narendra Suyog	0.82	0.81	0.82	7.89	7.91	7.90	0.80	0.91	0.86
8	KS-251	0.89	0.91	0.90	7.67	7.72	7.70	1.34	1.24	1.29
9	NDB-2	1.14	0.95	1.05	8.23	8.30	8.27	1.51	1.30	1.41
10	CO-2	0.78	0.81	0.80	7.69	7.71	7.70	1.14	1.20	1.17
	Average	1.00	0.99	1.00	7.62	7.62	7.63	1.18	1.15	1.17
	Min	0.78	0.81	0.80	7.12	7.21	7.18	0.80	0.86	0.86
	Max	1.22	1.22	1.22	8.23	8.30	8.27	1.51	1.30	1.41
	Hybrids									
11	1×2	1.07	0.97	1.02	7.31	7.41	7.36	1.10	1.09	1.10
12	1×3	1.16	1.14	1.15	7.98	7.84	7.91	1.37	1.32	1.35
13	1×4	0.95	0.93	0.94	7.25	7.27	7.26	0.90	0.86	0.88
14	1×5	1.14	1.21	1.18	7.49	7.52	7.51	0.89	0.91	0.90
15	1×6	1.07	0.96	1.02	8.31	8.40	8.36	0.68	0.74	0.71
16	1x7	0.92	0.89	0.91	7.65	7.71	7.68	0.81	0.84	0.83
17	1x8	0.98	0.99	0.99	7.15	7.24	7.20	0.85	0.81	0.83
18	1x9	1.21	1.14	1.17	8.21	8.11	8.16	0.91	0.98	0.94
19	1x10	0.84	0.86	0.86	7.58	7.56	7.57	0.97	1.01	0.99
20	2x3	0.95	0.97	0.96	7.26	7.32	7.29	1.25	1.21	1.23
21	2×4	0.85	0.84	0.85	7.84	7.94	7.89	0.73	0.79	0.76
22	2x5	0.98	0.87	0.93	8.64	8.54	8.59	0.95	0.96	0.96
23	2×6	1.02	1.06	1.04	7.31	7.26	7.29	0.86	0.89	0.88
24	2×7	0.89	0.88	0.88	7.86	7.66	7.77	0.77	0.84	0.81
25	2×8	0.94	0.96	0.95	7.15	7.26	7.21	1.21	1.10	1.16
26	2×9	1.08	1.09	1.09	7.60	7.67	7.64	0.67	0.74	0.71
27	2x10	0.79	0.83	0.81	7.51	7.46	7.49	1.17	1.09	1.13
28	3×4	0.91	0.86	0.89	7.23	7.28	7.26	0.52	0.63	0.58
29	3x5	1.11	1.04	1.08	7.51	7.42	7.47	1.08	0.98	1.03
30	3x6	1.13	1.12	1.13	8.35	8.38	8.37	1.32	1.21	1.27
31	3x7	0.88	0.97	0.93	7.64	7.72	7.69	0.83	0.85	0.84
32	3×8	0.97	0.94	0.96	7.52	7.42	7.48	0.96	0.93	0.95
33	3×9	1.12	1.05	1.09	8.15	8.11	8.13	1.24	1.21	1.23
34	3×10	0.83	0.86	0.85	7.25	7.30	7.28	0.94	0.96	0.95
35	4x5	0.95	0.95	0.96	7.64	7.67	7.66	1.24	1.08	1.16
36	4×6	0.88	0.82	0.85	8.37	8.34	8.36	1.36	1.24	1.30
37	4×7	0.81	0.84	0.83	7.24	7.21	7.23	0.76	0.84	0.80

38	4x8	0.96	0.98	0.97	7.38	7.42	7.41	1.27	1.03	1.16
39	4×9	0.84	0.88	0.87	7.14	7.18	7.17	0.93	0.97	0.96
40	4x10	0.78	0.82	0.80	7.61	7.68	7.65	1.34	1.03	1.19
41	5×6	1.11	1.09	1.10	7.23	7.28	7.26	0.95	0.92	0.94
42	5×7	0.85	0.81	0.83	7.12	7.09	7.11	1.25	1.14	1.20
43	5x8	0.97	0.94	0.96	7.69	7.11	7.40	0.63	0.70	0.67
44	5×9	1.06	0.98	1.02	7.24	7.35	7.30	1.27	1.31	1.29
45	5x10	0.89	0.81	0.85	7.59	7.46	7.53	1.33	1.12	1.23
46	6×7	0.98	1.05	1.02	8.30	8.35	8.33	0.82	0.86	0.84
47	6x8	0.93	0.94	0.94	7.66	7.79	7.73	0.83	0.79	0.81
48	6x9	1.16	0.98	1.08	8.12	8.14	8.13	0.49	0.54	0.52
49	6×10	0.86	0.87	0.87	7.12	7.25	7.19	1.16	1.06	1.11
50	7x8	0.92	0.94	0.93	7.81	7.87	7.84	0.96	0.97	0.97
51	7x9	1.08	0.97	1.03	8.05	7.97	8.01	1.04	0.91	0.98
52	7×10	0.85	0.86	0.86	7.69	7.67	7.68	1.16	1.05	1.11
53	8×9	1.09	1.08	1.09	7.25	7.26	7.26	0.94	0.86	0.90
54	8x10	0.84	0.85	0.85	7.81	7.89	7.86	1.25	1.11	1.18
55	9x10	1.07	0.98	1.03	7.89	7.54	7.72	1.08	0.96	1.02
56	Shamli hybrid(Check)	1.03	1.06	1.05	7.45	7.39	7.42	1.17	1.06	1.09
Mean		0.97	0.96	0.97	7.64	7.63	7.63	1.01	0.97	0.99
CV		3.50	3.5	2.32	4.49	5.00	3.19	2.42	2.43	1.69
SEm		0.02	0.02	0.01	0.20	0.22	0.14	0.01	0.01	0.01
CD at 5%		0.06	0.05	0.04	0.55	0.62	0.39	0.04	0.04	0.03
CD at 1%		0.07	0.07	0.05	0.73	0.82	0.52	0.05	0.05	0.04
Minimum		0.78	0.81	0.80	7.12	7.09	7.11	0.49	0.54	0.52
Maximum		1.21	1.21	1.18	8.64	8.54	8.59	1.37	1.32	1.35

Sr. No.	Genotypes	Nonreducing sugar (%)			Total sugar (%)			TSS (%)		
		Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled
1	Pant Samrat	0.56	0.47	0.52	1.79	1.69	1.75	5.35	5.29	5.32
2	Pant Rituraj	0.47	0.49	0.48	1.74	1.74	1.74	5.67	5.53	5.61
3	Pusa Ankur	0.36	0.34	0.35	1.55	1.58	1.57	4.98	5.12	5.05
4	NDB Sel-19-1	0.62	0.59	0.61	1.56	1.45	1.51	5.97	5.56	5.77
5	NDB Sel.-16-1	0.68	0.71	0.70	1.83	1.82	1.83	5.74	5.71	5.73
6	NDB 3	0.46	0.51	0.49	1.70	1.75	1.73	5.31	5.32	5.32
7	Narendra Suyog	0.63	0.54	0.59	1.44	1.45	1.45	5.67	5.70	5.69
8	KS-251	0.49	0.51	0.50	1.83	1.75	1.79	4.40	4.54	4.47
9	NDB-2	0.35	0.38	0.37	1.86	1.68	1.78	4.89	4.98	4.94
10	CO-2	0.62	0.68	0.65	1.76	1.88	1.82	5.24	5.35	5.30
	Average	0.52	0.52	0.52	1.70	1.68	1.69	5.32	5.31	5.32
	Min	0.35	0.34	0.35	1.44	1.45	1.45	4.40	4.54	4.47
	Max	0.68	0.71	0.70	1.86	1.88	1.83	5.97	5.71	5.77
	Hybrids									
11	1×2	0.68	0.51	0.60	1.78	1.59	1.69	6.06	5.93	6.00
12	1×3	0.48	0.33	0.41	1.85	1.65	1.75	5.56	5.48	5.52
13	1×4	0.54	0.56	0.55	1.44	1.42	1.43	5.97	6.01	5.99
14	1×5	0.36	0.30	0.33	1.25	1.22	1.24	5.13	5.23	5.19
15	1×6	0.52	0.57	0.55	1.19	1.30	1.25	6.05	5.96	6.01
16	1x7	0.31	0.41	0.36	1.12	1.24	1.18	5.73	5.68	5.71
17	1x8	0.56	0.50	0.54	1.41	1.32	1.37	5.97	5.74	5.86
18	1x9	0.61	0.64	0.63	1.52	1.61	1.57	5.21	5.34	5.28
19	1x10	0.59	0.56	0.58	1.57	1.56	1.57	5.31	5.12	5.21
20	2x3	0.45	0.39	0.42	1.70	1.60	1.65	5.13	5.24	5.19
21	2×4	0.67	0.48	0.58	1.40	1.27	1.34	5.29	5.61	5.45
22	2x5	0.64	0.64	0.64	1.58	1.60	1.60	5.13	5.08	5.11
23	2×6	0.42	0.45	0.44	1.28	1.34	1.31	5.27	4.98	5.13
24	2×7	0.61	0.54	0.58	1.39	1.38	1.39	5.46	5.36	5.41
25	2×8	0.52	0.60	0.57	1.73	1.70	1.72	5.79	5.61	5.70
26	2×9	0.49	0.40	0.45	1.16	1.15	1.16	5.37	5.51	5.44
27	2x10	0.61	0.67	0.64	1.78	1.76	1.77	4.94	5.09	5.02
28	3×4	0.62	0.59	0.61	1.15	1.23	1.19	5.27	5.11	5.19
29	3x5	0.53	0.48	0.51	1.61	1.46	1.54	5.06	5.12	5.09
30	3x6	0.46	0.51	0.49	1.79	1.71	1.75	5.09	4.90	5.00
31	3x7	0.58	0.56	0.57	1.41	1.41	1.41	5.41	5.36	5.39
32	3×8	0.53	0.48	0.51	1.49	1.42	1.46	5.17	5.17	5.17
33	3×9	0.58	0.51	0.55	1.83	1.72	1.78	5.69	5.64	5.66
34	3×10	0.49	0.47	0.49	1.43	1.45	1.44	5.24	5.29	5.27
35	4x5	0.36	0.37	0.37	1.60	1.46	1.53	5.80	5.45	5.63

36	4×6	0.41	0.60	0.51	1.77	1.85	1.81	4.98	4.86	4.92
37	4×7	0.65	0.55	0.60	1.41	1.39	1.40	5.34	5.28	5.31
38	4x8	0.48	0.48	0.48	1.75	1.52	1.64	5.17	5.61	5.39
39	4×9	0.68	0.68	0.68	1.62	1.66	1.64	5.27	5.32	5.30
40	4x10	0.51	0.64	0.58	1.86	1.67	1.77	5.68	5.71	5.70
41	5×6	0.39	0.64	0.52	1.34	1.57	1.46	5.37	5.38	5.38
42	5×7	0.51	0.64	0.58	1.76	1.78	1.77	5.17	5.18	5.17
43	5x8	0.63	0.54	0.59	1.26	1.25	1.26	5.29	5.31	5.30
44	5×9	0.45	0.57	0.51	1.72	1.88	1.80	5.21	5.18	5.20
45	5x10	0.53	0.48	0.51	1.87	1.60	1.74	5.38	5.40	5.39
46	6×7	0.68	0.61	0.65	1.5	1.47	1.49	5.47	5.56	5.52
47	6x8	0.66	0.68	0.68	1.49	1.47	1.48	6.22	6.11	6.17
48	6x9	0.37	0.53	0.45	0.86	1.08	0.97	4.99	5.23	5.11
49	6×10	0.45	0.56	0.51	1.61	1.62	1.62	5.27	5.31	5.29
50	7x8	0.59	0.62	0.61	1.55	1.59	1.57	5.24	5.28	5.27
51	7x9	0.63	0.67	0.66	1.68	1.59	1.64	5.61	5.67	5.64
52	7×10	0.55	0.61	0.58	1.71	1.66	1.69	5.36	5.54	5.45
53	8×9	0.68	0.71	0.70	1.61	1.57	1.60	5.78	5.70	5.74
54	8x10	0.47	0.52	0.50	1.71	1.64	1.68	5.14	5.19	5.17
55	9x10	0.58	0.62	0.60	1.66	1.58	1.62	5.67	5.38	5.53
56	Shamli hybrid(Check)	0.46	0.45	0.46	1.58	1.51	1.55	5.19`	5.24	5.22
Mean		0.54	0.54	0.54	1.54	1.51	1.53	5.41	5.40	5.41
CV		2.74	2.66	1.99	2.79	2.80	2.08	4.79	4.8	3.23
SEm		0.01	0.01	0.01	0.03	0.02	0.02	0.15	0.15	0.1
CD at 5%		0.02	0.02	0.02	0.07	0.07	0.05	0.42	0.42	0.28
CD at 1%		0.03	0.03	0.02	0.09	0.09	0.07	0.55	0.55	0.37
Minimum		0.31	0.30	0.33	0.86	1.08	0.97	4.94	4.86	4.92
Maximum		0.68	0.71	0.70	1.87	1.88	1.81	6.22	6.11	6.17

Sr. No.	Genotypes	Ascorbic acid (mg/100 g)		
		Y1	**Y2**	**Pooled**
1	Pant Samrat	9.14	9.27	9.21
2	Pant Rituraj	9.35	9.15	9.25
3	Pusa Ankur	9.75	9.66	9.71
4	NDB Sel-19-1	8.79	8.85	8.82
5	NDB Sel.-16-1	11.54	11.24	11.39
6	NDB 3	13.85	12.78	13.32
7	Narendra Suyog	14.25	14.31	14.28
8	KS-251	11.65	12.21	11.93
9	NDB-2	9.54	9.62	9.58
10	CO-2	14.35	13.98	14.17
	Average	11.22	11.10	11.16
	Min	8.79	8.85	8.82
	Max	14.35	14.31	14.28
	Hybrids			
11	1×2	12.57	11.87	12.22
12	1×3	13.69	12.95	13.32
13	1×4	14.25	14.61	14.43
14	1×5	11.54	12.35	11.95
15	1×6	15.70	14.82	15.26
16	1x7	11.35	12.23	11.79
17	1x8	12.65	11.36	12.01
18	1x9	9.44	8.973	9.21
19	1x10	12.56	11.64	12.10
20	2x3	13.98	12.82	13.40
21	2×4	9.25	9.18	9.22
22	2x5	11.25	12.18	11.72
23	2×6	12.36	11.61	11.99
24	2×7	10.25	10.33	10.29
25	2×8	9.35	9.28	9.32
26	2×9	14.25	13.68	13.97
27	2x10	12.40	12.61	12.51
28	3×4	13.67	13.71	13.69
29	3x5	10.65	11.24	10.95
30	3x6	11.24	10.64	10.94
31	3x7	13.45	12.82	13.14
32	3×8	10.25	10.37	10.31
33	3×9	12.36	11.18	11.77

34	3×10	9.36	9.51	9.44
35	4x5	10.86	9.67	10.27
36	4×6	14.25	14.18	14.22
37	4×7	12.25	11.28	11.77
38	4x8	13.65	13.34	13.50
39	4×9	14.25	13.51	13.88
40	4x10	11.02	10.67	10.84
41	5×6	13.67	12.64	13.16
42	5×7	10.35	10.46	10.41
43	5x8	9.35	9.34	9.35
44	5×9	8.23	8.41	8.32
45	5x10	13.54	12.57	13.06
46	6×7	14.25	14.38	14.32
47	6x8	13.69	13.55	13.62
48	6x9	11.65	12.09	11.87
49	6×10	14.27	14.15	14.22
50	7x8	10.89	10.76	10.83
51	7x9	13.54	12.91	13.23
52	7×10	11.29	12.08	11.69
53	8×9	13.67	12.74	13.21
54	8x10	14.25	13.85	14.05
55	9x10	13.41	13.67	13.54
56	Shamli hybrid (Check)	10.24	10.52	10.38
Mean		12.18	11.93	12.06
CV		4.5	4.5	3.23
SEm		0.31	0.31	0.22
CD at 5%		0.87	0.86	0.62
CD at 1%		1.16	1.14	0.82
Minimum		8.23	8.41	8.32
Maximum		15.7	14.82	15.26

Conclusion

In conclusion, for total phenol content (%), in Y1 and Y2, the highest values among parents were recorded by Pant Samrat (1.22%), with hybrids P1 × P5 and P1 × P9 showing the best results (1.21% and 1.18% respectively). The pooled data reflected similar trends, with Pant Samrat maintaining the highest value among parents. For dry matter content (%), NDB-2 consistently showed the highest values among parents across Y1 (8.23%), Y2 (8.30%), and pooled (8.27%). Among hybrids, P2 × P5 consistently performed best across, particularly in pooled (8.59%). For reducing sugar (%), NDB-2 had the highest values among parents, with 1.51% in Y1, 1.30% in Y2, and 1.41% in pooled. The hybrid P1 × P3 was the top performer among hybrids across all datasets, with values of 1.37%, 1.32%, and 1.35% respectively. For non-reducing sugar (%), NDB Sel.16-1 had the highest values among parents in Y1 (0.68%), Y2 (0.71%), and pooled (0.71%). Hybrids P1 × P2, P8 × P9, and P6 × P8 were the best. For total sugar (%), NDB-2, NDB Sel.16-1, and CO-2 were consistently high among parents, while hybrid P5 × P10 was notable in Y1 (1.87%) and P4 × P6 in pooled (1.85%). For TSS (%), NDB Sel-19-1 had the highest values among parents in Y1 (5.97%) and pooled (5.77%), with the hybrid P6 × P8 consistently performing best across all datasets, reaching 6.22% in Y1 and 6.17% in pooled data. Similar finding was also reported by Nirmala *et al.* (2013) [13], Kanchana *et al.* (2021) [7], Gadhiya *et al.* (2016) [5], Timmareddygari *et al.* (2021) [17], Praneetha *et al.* (2018) [14] and Maurya *et al.* (2022) [10].

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