Journal of Crop and Weed, 14(2): 51-60 (2018)

Morpho-biochemical characterization and trait inter-relationship in brinjal germplasm

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Received : 08-09-2017 ; Revised : 03-08-2018 ; Accepted : 14-08-2018

ABSTRACT

Thirty one genotypes of brinjal were evaluated for bioactive compounds and their association with yield attributing traits. Total anthocyanin content, chlorophyll content, total phenolics content, radical scavenging activity (DPPH assay), total antioxidant capacity, fruit weight and fruit girth were found to vary significantly among all the genotypes. BRBL-1 was the best genotype on the basis of both yield and quality characters. It had the highest yield potential (2.58 kg plant^{-1}) and considerable amount of ascorbic acid (3.39 mg100^{-1}g), total chlorophyll content (2.25 mg100^{-1}g) and total antioxidant capacity (4.81 µ moltrolox equivalent/g fresh weight). Yield per plant had positive correlation with number of fruits plant^{-1} and fruit length. Total antioxidant capacity had strong but negative association with fruit length and girth, whereas, a strong positive correlation of total antioxidant capacity with chlorophyll content, total phenolics content and radical scavenging activity was observed. The results indicated that the green genotypes BRBL-1 and BRBL-8 could be used in further breeding programme to develop new varieties with improved yield and elevated antioxidant status.

***Keywords*:** Biochemical compounds, characterization, correlation, morphology, path analysis

Brinjal (*Solanum melongena* L.), commonly known as eggplant or aubergine, is ranked amongst the top ten vegetables in terms of antioxidant capacity due to the phenolics and flavonoid components (Cao *et al*., 1996), which are related to innumerable health aids (Ames *et al*., 1993; Huang *et al*., 2004). Therefore, it can play a vital role in achieving the nutritional security (Sarker *et al*., 2006). The purple color of brinjal peel is due to anthocyanins. Nasunin [delphinidin-3-(p-coumaroylrutino side)-5-glucoside] is the major anthocyanin in brinjal peels (Noda *et al*., 2000). Varieties of purple, green or white fruit colour with an extensive range of colour intensities are common. These pigments help to provide natural protection against the harmful effect of UV irradiation, as well as providing anti-viral and anti-microbial activities (Wrolstad, 2006). Hence, targeting improvement of these traits in brinjal may lead to nutritional security of increasing population.

Brinjal, being an economical source of plant-derived nutrients, the identification of genotypes with higher nutrients, yield potential and better consumer liking could be favorable for society, mostly for poor buyers. The agronomical traits like fruit shape, size, taste and colour vary significantly with the type of brinjal cultivar and the demand varies according to the locality. Brinjal has been widely studied for physico-morphological characteristics, but the information on bioactive molecules and their bioactivity is scarcely available. Moreover, information about inter-relationship between morpho-biochemical characters and their direct and indirect effect on yield is limited. It is, therefore, necessary to identify cultivars having higher amount of health promoting bioactive compounds along high yield potential to meet the increasing demand of health conscious consumers of world.

This investigation was aimed to evaluate thirty one diverse genotypes of cultivated brinjal (*Solanum melongena* L.) of Asian origin in terms of the bioactive compounds present in them and yield attributing agronomic traits in order to assess the genetic variability and genetic inter-relationship among different antioxidant, quality and agronomic traits, determine the direct and indirect effects of different attributes towards yield potential, identify appropriate selection indices for the improvement of brinjal and isolate the outstanding accessions for utilization in future breeding programs to develop new varieties of health and economic importance.

MATERIALS AND METHODS

Thirty one genotypes of brinjal differing in colour, shape and size comprising of cultivated varieties, breeding lines and land races maintained in in the Department of Horticulture (Vegetable and Floriculture), Bihar Agricultural University, Sabour, Bhagalpur, Bihar were used for the present study. One month-old brinjal seedling was transplanted in open field maintaining a spacing of 60 cm from plant to plant and 75 cm between

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rows with twenty four plants per plot. The experiment was laid out in randomized complete block design with three replications. Standard agro-techniques were followed for effective raising of the crop. The fruits were randomly harvested at commercial maturity stage (selected on the basis of tenderness, glossiness and free from attack of diseases and pests) for estimation of biochemical compounds and agronomic traits. Morphological observations included days to 50% flowering, fruit length, fruit girth, average fruit weight, number of fruits plant^{-1} and fruit yield plant^{-1}.

At the second picking, fourth picking and sixth picking 5 randomly selected fruits were taken from the harvested fruits, composited and used for the biochemical observations. Total sugar was analyzed by Lane-Eynon method (AOAC, 2000) using Fehling solutions as a reagent. Ascorbic acid content in the fresh fruits was estimated by volumetric method as per AOAC (2001). Total chlorophyll was estimated as per Arnon (1949) using spectrophotometric method. Total anthocyanin was estimated as per Ranganna (1977).

For extraction of total phenolics, total antioxidant activity (CUPRAC assay) and free radical scavenging activity (DPPH assay), composited fruits were cut into small pieces and homogenized from which 2 g of samples were extracted twice with 20 ml of ethanol (80%) and kept in dark for 30 minutes. The homogenate was then centrifuged for 20 minutes at 10,000 rpm at 4°C. The supernatant was used for further estimation. Total phenolics were estimated using Folin-Ciocalteu reagent (FCR) as per Singleton *et al*. (1999). Radical scavenging activity (DPPH assay) was estimated using DPPH (2, 2-diphenylpicrylhydrazyl) (Brand-Williams *et al*., 1995). Total Antioxidant Capacity was estimated by CUPRAC assay (Apak *et al*., 2004).

Analysis of variance for Randomised Block Design was adopted as suggested by Panse and Sukhatme (1967). Fisher's least significant difference test was used to determine whether the mean of the different traits differed significantly between the genotypes. The inter-relationship between the traits was determined by single correlation coefficients 'r' computed at genotypic and phenotypic levels between pair of characters as per Johnson *et al*.(1955) and Al-Jibouri *et al*. (1958).The direct and indirect effects of different traits (independent variables) on the yield (dependent variable) were done by path coefficient analysis according to Dewey and Lu (1959).

RESULTS AND DISCUSSION

The mean sum of squares due to genotypes was significant for all the characters under study (Table 1) which indicated that the genotypes included in the study were genetically diverse and considerable amount of variability were present. Hence, there is ample scope for inclusion of promising genotypes in breeding programme for yield and quality characters.

Morphological characterization

The agronomic traits of the thirty one genotypes *viz*., days to 50% flowering, fruit length, fruit girth, average fruit weight, number of fruits plant^{-1} and total yield plant^{-1} have been presented in the table 2. Significant variation between the genotypes for every trait has been observed. The genotype IC-215020 took 46 ± 2.25 days after transplanting (DAT) to flower and could be referred as the earliest genotype. This was statistically at par with another nine genotypes (*viz.*, IC-89933, IBH-2, IBL-1-116-135, Aruna, IC-89888, IC-90087, EC-382524, EC-169084 and IC-261802). The genotype Swarna Mani was the last to flower (69 DAT). Babu and Patil (2005) also observed sufficient variation for days to 50% flowering and it ranged from 36 days to 61 days. The green coloured long genotype Rajendra Baigan-2 produced significantly the highest fruit length (22.91 ± 0.73 cm) which was followed by BRBL-7 (19.17 cm), whereas, the lowest fruit length (8.83 cm) was recorded in round genotype EC-169084. Maximum fruit girth (26.15 cm) was noted in round genotype Swarna Mani. However, the long genotype Arka Neelkanth gave the lowest fruit girth (10.71 cm). Dhruve *et al*. (2014) found similar trend for fruit length (8.77-29.30 cm) and fruit girth (8.30-27.40 cm) in eggplant.

Concerning fruit weight it is evident that the genotype Muktakeshi produced significantly the heaviest fruit weight (169.18 ± 2.92 g), while the minimum fruit weight (54.42 ± 2.92 g) was observed in genotype IIHR-562. Variation in fruit weight is a genotypic characteristic. Singh and Kumar (2005) also observed large variation in fruit weight that ranged between 29.98g to 177.00 g. Nayak and Nagre (2013) reported that fruit weight varied from 134.26 to 609.0g.

The maximum number of fruits plant^{-1} (31.39± 0.89) was obtained in the oblong genotype BRBL-1. However the genotype Swarna Mani produced least number of fruits per plant (7.96 ± 0.89) and it was at par with Muktakeshi (8.31 ± 0.89), BRBL-7 (9.83 ± 0.89), BSB-31 (9.83 ± 0.89), BSB-464 (9.84 ± 0.89), IIHR-636 (9.80 ± 0.89) whose average fruit weight was high (Table 2).It was apparent that the genotype BRBL-1 produced significantly the highest yield plant^{-1} (2.58 ± 0.09kg) while, the lowest yield plant^{-1} was obtained in genotype EC-467268 (0.75 ± 0.09 kg). Singh and Kumar (2005) previously reported that number of fruits plant^{-1}t varied from 9.54 to 32.83 and yield plant^{-1} from 0.737 kg to 2.982 kg.

Table 1: Analysis of variance for 6 morphological and 9 biochemical characters under study

Characters	Mean sum of square		
	Replication (df=2)	**Genotypes (df=30)**	**Error (df=60)**
Morphological characters			
Days to 50% flowering	44.204	63.830**	15.238
Fruit length (cm)	0.135	31.621**	1.594
Fruit girth (cm)	1.779	40.489**	0.877
Fruit weight (g)	20.347	2323.774**	25.631
Number of fruits plant^{-1}	5.902	97.758**	2.368
Yield plant^{-1} (kg)	0.011	0.619**	0.022
Biochemical characters			
Total sugar content	0.005	1.129**	0.055
Total ascorbic acid content	0.054	1.607**	0.057
Chlorophyll a content	0.002	0.458**	0.001
Chlorophyll b content	0.000	0.168**	0.001
Total chlorophyll content	0.002	1.218**	0.003
Total anthocyanin content	0.916	312.436**	0.556
Total phenol content	0.164	4.808**	0.123
Radical scavenging activity	2.378	75.757**	0.788
Total antioxidant capacity	0.283	3.558**	0.091

*Note: *, ** are significant at 1% and 5% levels of significance respectively.*

Biochemical characterization

The biochemical traits, *viz*., total sugar, ascorbic acid, chlorophylls, anthocyanin, total phenolics, total antioxidants and radical scavenging activity have been depicted in the table 3. The total sugar content ranged between 1.25-4.17per cent of fresh weight in the genotypes under study. Kandoliya *et al*. (2015) also observed that total soluble sugar content varied significantly in the brinjal varieties ranging between 3.02 to 3.64 per cent on fresh weight basis. Ghadsingh *et al*. (2012) also reported that the value of soluble sugar ranged from 2.7 to 5.0g 100^{-1} g. The green oblong genotype BRBL-8 yielded maximum amount of total sugar (4.17 ± 0.14 %). Bajaj *et al*. (1979) also reported that on an average the oblong fruited brinjal cultivars are rich in total soluble sugars.

The concentration of ascorbic acid ranged between 1.04 ± 0.14mg 100^{-1} g FW for IBH-2 and 3.75 ± 0.14mg 100^{-1} g FW for IC-261802 (Table 3). These findings were in line with the results of Prohens *et al*. (2007) for ascorbic acid content in brinjal (1.0-2.26 mg 100^{-1} g). Ascorbic acid content in brinjal flesh ranged from 33.62 to 92.75 mg kg^{-1} and in brinjal peel from 1.245 to 11.101 mg 100g^{-1} as observed by Kadivec *et al*. (2015).

Significant variation was observed for chlorophyll and total anthocyanin content. This was due to diversity in colour of genotypes. Muktakeshi, the blackish purple coloured genotype, contained the highest amount (28.86 ± 0.43mg 100^{-1} g FW) of total anthocyanin which was followed by BRBL-2 (27.42 ± 0.43 mg 100^{-1} g FW) which was dark purple in colour. The minimum amount of total anthocyanin was extracted from greenish white genotype VR-2 (0.63 ± 0.43 mg 100^{-1} g FW). Sadilova *et al*. (2006) reported a greater anthocyanin content of 45.01 mg 100^{-1} g fresh weight for brinjal compared to violet pepper yielding 32.15 mg 100g^{-1} fresh weight.

The green genotype BRBL-8 exhibited maximum amount (2.35 ± 0.03 mg 100^{-1} g FW) of total chlorophyll content which was followed by BRBL-1 (2.25 ± 0.03 mg 100^{-1} g FW), another green genotype. The minimum amount of total chlorophyll was observed in purple colour genotype BSB-31 (0.15 ± 0.03 mg 100^{-1} g FW).

Muktakeshi, IBL-1-116-135 and IC-90121 had significant amount of both anthocyanin and chlorophyll pigment. The inner side of the peel of these cultivars remained green in colour. Besides, the blackish purple colour of these fruits is a resultant of the combination of high anthocyanin and high chlorophyll content.

It was observed that the light weighted purple genotype Arka Neelkanth had maximum amount of total phenol content (12.03 ± 0.20mg 100g^{-1} FW) which had statistical parity with EC-467268 (11.72 ± 0.20mg 100^{-1} g FW). However, the lowest amount of total phenolic content was noticed in higher weighing

Table 2: Morphological characteristics of 31 genotypes

Genotype	D50F	FrL	FrG	FrW	FrP	YP
Arka Neelkanth	54.33 bcd	14.68 def	10.71 q	83.29 op	11.47 ghij	0.90 mno
Aruna	50.67 de	11.56 ghijkl	16.30 hijkl	107.27 fg	11.50 ghij	1.21 hijk
BRBL-1	54.67 bcd	13.55 fg	16.60 ghijk	86.00 mnop	31.39 a	2.58 a
BRBL-2	59.00 bc	15.84 cde	10.99 q	95.60 ijklm	22.56 bcd	1.95 bc
BRBL-7	61.00 b	19.17 b	17.98 efgh	165.87 a	9.83 ijkl	1.61 def
BRBL-8	52.33 cde	13.68 efg	14.91 klmno	89.94 klmno	12.17 fghi	1.09 ijklmn
BRBR-1	58.67 bcd	11.11 hijklm	16.74 ghij	118.37 de	10.31 ijkl	1.19 hijkl
BSB-31	61.00 b	13.20 fgh	15.47 jklmn	125.83 cd	9.83 ijkl	1.17 hijklm
BSB-464	58.00 bcd	12.57 fghij	12.31 pq	95.31 ijklmn	9.83 ijkl	0.93 lmno
DRNKV-03-26	56.00 bcd	9.08 m	18.33 efg	88.82 klmno	11.14 hijk	0.93 klmno
EC-169084	50.67 de	8.83 m	13.83 nop	97.32 hijk	9.75 ijkl	0.95 klmno
EC-354689	56.33 bcd	10.95 hijklm	14.81 lmno	105.82 gh	16.40 e	1.59 efg
EC-382524	50.67 de	11.83 ghijk	14.29 mno	87.52 lmno	9.64 ijkl	0.83 no
EC-467268	56.33 bcd	11.80 ghijk	10.98 q	87.95 klmno	8.83 jkl	0.74 o
IBH-2	51.33 cde	11.74 ghijk	17.49 fghi	127.92 c	14.78 ef	1.87 cd
IBL-1-116-135	51.67 cde	17.85 bc	11.00 q	100.00 ghij	12.56 fghi	1.18 hijkl
IC-107769	56.00 bcd	12.65 fghij	14.44 mno	77.30 p	14.03 efgh	1.08 ijklmn
IC-215020	46.00 e	13.78 efg	13.93 nop	95.04 ijklmn	16.11 e	1.54 fg
IC-261802	50.67 de	9.25 lm	20.17 cd	166.99 a	11.39 hij	1.86 cde
IC-89888	51.67 cde	17.15 bc	15.77 ijklm	101.44 ghi	21.44 cd	2.16 b
IC-89933	52.00 cde	11.58 ghijkl	16.64 ghijk	96.58 hijkl	20.67 d	1.98 bc
IC-90087	46.33 e	16.27 cd	11.66 q	104.05 ghi	13.56 efgh	1.39 fgh
IC-90121	55.67 bcd	13.17 fghi	13.98 nop	108.80 fg	12.50 fghi	1.36 fghi
IIHR-322	52.33 cde	16.97 bc	13.40 op	67.86 q	23.69 bc	1.60 def
IIHR-562	56.33 bcd	11.87 ghijk	13.493 op	54.41 r	24.42 b	1.32 ghij
IIHR-636	52.33 cde	12.68 fghij	19.340 de	85.72 nop	9.81 ijkl	0.76 o
Muktakeshi	59.000 bc	17.283 bc	22.257 b	169.18 a	8.31 kl	1.40 fgh
Pant Rituraj	53.00 cde	9.91 klm	19.16 def	115.21 ef	15.06 ef	1.61 def
Rajendra Baigan-2	58.00 bcd	22.91 a	12.32 pq	90.70 jklmno	20.36 d	1.84 cde
Swarna Mani	69.00 a	10.44 jklm	26.15 a	148.71 b	7.96 l	1.06 jklmn
VR-2	54.67 bcd	10.75 ijklm	21.50 bc	132.69 c	14.42 efg	1.84 cde
LSD(0.05)	**6.56**	**2.03**	**1.55**	**8.24**	**2.57**	**0.24**

Note: D50F: Days to 50% flowering, FrL: Fruit length (cm), FrG: Fruit girth (cm), FrW: Average fruit weight (g), Number of fruit plant^{-1} (FrP) and YP: Yield/plant (kg).Means with different alphabets are significantly different.

Muktakeshi (7.28 ± 0.20mg 100^{-1} g FW) which was statistically similar to IC-89888 (7.49 ± 0.20mg 100^{-1} g FW). Nisha *et al*. (2009) also reported that the total phenolic content (TPC) was markedly higher in purple coloured small varieties. Sultana *et al*. (2013) observed that total phenol content (TPC) of methanolic extracts of different parts of selected varieties of aubergine, ranged from 16.72- 25.00 mg GAE 100^{-1} g on dry weight basis.

Brinjal fruit is a good source of free radical scavengers and possesses high antioxidant capacity. Present study revealed radical scavenging activity (DPPH assay) ranged between 40.34 ± 0.51 % for EC-169084 and 18.25 ± 0.51 % for Rajendra Baigan-2. This was in agreement with the findings of Kandoliya *et al*. (2015). They observed 25.17-40.35 per cent radical scavenging activity (DPPH assay) among different genotypes of brinjal.

Total antioxidant activity was the highest in IC-90121 (5.95 ± 0.17 µ moltrolox equivalent g^{-1} FW) which had statistical parity with green genotype BRBL-1 (4.81 ± 0.17 µ mol trolox equivalent g^{-1} FW) and Arka Neelkanth (4.62± 0.17µ mol trolox equivalent g^{-1} FW). However, least total antioxidant activity was noticed in IC-89888 (1.23 ± 0.17 µ mol trolox equivalent g^{-1} FW) having statistical parity with Aruna (1.72± 0.17 µ mol

Table 3: Biochemical characteristics of 31 genotypes

Genotype	TS	AA	Chl a	Chl b	TChl	TAnth	TPC	RSA	TAox
Arka Neelkanth	2.03 ^{ijk}	1.35 ^{mn}	0.79 ^{g}	0.39 ^{f}	1.23 ^{g}	23.01 ^{f}	12.03 ^{a}	26.10 ^{fghi}	4.62 ^{bc}
Aruna	2.92 ^{cde}	2.29 ^{jk}	0.33 ^{o}	0.25 ^{jk}	0.61 ^{m}	23.97 ^{def}	11.02 ^{b}	25.11 ^{ghij}	1.72 ^{no}
BRBL-1	2.29 ^{ghij}	3.39 ^{abc}	1.47 ^{b}	0.72 ^{c}	2.25 ^{b}	5.34 ^{mn}	8.90 ^{defg}	22.63 ^{kl}	4.81 ^{b}
BRBL-2	1.97 ^{ijkl}	2.75 ^{efghi}	0.18 ^{q}	0.09 ^{rs}	0.29 ^{pq}	27.42 ^{b}	8.37 ^{ghi}	23.00 ^{k}	2.98 ^{hij}
BRBL-7	2.35 ^{ghij}	2.32 ^{ijk}	0.46 ^{kl}	0.31 ^{hi}	0.78 ^{jk}	24.01 ^{def}	9.22 ^{de}	24.82 ^{ij}	2.52 ^{jklm}
BRBL-8	4.17 ^{a}	2.65 ^{fghij}	1.54 ^{a}	0.77 ^{b}	2.35 ^{a}	2.79 ^{o}	10.86 ^{b}	35.05 ^{b}	4.26 ^{bcdef}
BRBR-1	2.39 ^{fghij}	1.05 ^{n}	0.50 ^{jk}	0.23 ^{kl}	0.77 ^{jk}	21.70 ^{g}	10.53 ^{b}	26.61 ^{efgh}	3.82 ^{efg}
BSB-31	1.25 ^{n}	3.27 ^{bcd}	0.09 ^{s}	0.05 ^{t}	0.15 ^{r}	4.45 ^{n}	7.91 ^{ijk}	25.90 ^{fghij}	1.95 ^{mn}
BSB-464	1.76 ^{klm}	1.65 ^{lm}	0.53 ^{j}	0.37 ^{fg}	0.95 ^{i}	24.22 ^{def}	11.07 ^{b}	25.50 ^{ghij}	4.55 ^{bcd}
DRNKV-03-26	3.04 ^{c}	2.29 ^{jk}	0.18 ^{q}	0.14 ^{pq}	0.34 ^{op}	11.30 ^{i}	8.18 ^{hi}	34.88 ^{b}	3.95 ^{efg}
EC-169084	2.42 ^{fghi}	3.14 ^{cde}	0.92 ^{e}	0.51 ^{e}	1.49 ^{f}	23.66 ^{ef}	9.09 ^{def}	40.34 ^{a}	3.75 ^{fg}
EC-354689	2.80 ^{cdef}	3.39 ^{abc}	0.24 ^{p}	0.16 ^{nop}	0.41 ^{no}	1.05 ^{pq}	9.32 ^{cde}	28.611 ^{d}	4.13 ^{cdef}
EC-382524	2.39 ^{fghij}	2.94 ^{cdefgh}	0.76 ^{g}	0.38 ^{f}	1.18 ^{gh}	1.65 ^{opq}	7.94 ^{ij}	28.32 ^{de}	2.12 ^{lmn}
EC-467268	2.29 ^{ghij}	2.64 ^{fghij}	0.42 ^{lm}	0.17 ^{mnop}	0.63 ^{m}	8.51 ^{j}	11.72 ^{a}	28.06 ^{de}	4.38 ^{bcde}
IBH-2	1.95 ^{jkl}	1.04 ^{n}	1.13 ^{d}	0.94 ^{a}	2.15 ^{c}	5.60 ^{lmn}	9.32 ^{cde}	23.00 ^{k}	2.90 ^{ij}
IBL-1-116-135	3.78 ^{b}	3.33 ^{abcd}	1.11 ^{d}	0.68 ^{d}	1.95 ^{d}	25.70 ^{c}	8.10 ^{hij}	24.21 ^{jk}	2.77 ^{ijk}
IC-107769	1.73 ^{klm}	2.49 ^{hij}	0.25 ^{p}	0.15 ^{op}	0.41 ^{no}	0.91 ^{q}	9.35 ^{cd}	31.23 ^{c}	3.19 ^{hi}
IC-215020	1.93 ^{jkl}	2.55 ^{ghij}	1.19 ^{c}	0.68 ^{d}	1.93 ^{d}	2.29 ^{op}	9.17 ^{de}	26.70 ^{efg}	4.15 ^{cdef}
IC-261802	2.39 ^{fghij}	3.75 ^{a}	0.37 ^{n}	0.20 ^{lm}	0.63 ^{m}	23.97 ^{def}	9.91 ^{c}	27.38 ^{def}	4.00 ^{defg}
IC-89888	3.01 ^{cd}	3.08 ^{cdef}	0.40 ^{mn}	0.24 ^{jk}	0.66 ^{lm}	18.36 ^{h}	7.49 ^{jk}	25.57 ^{ghij}	1.23 ^{o}
IC-89933	2.60 ^{defg}	2.58 ^{ghij}	0.51 ^{j}	0.21 ^{klm}	0.75 ^{kl}	6.34 ^{lm}	8.65 ^{efgh}	21.33 ^{lm}	2.56 ^{jkl}
IC-90087	2.25 ^{ghij}	1.36 ^{mn}	0.11 ^{rs}	0.11 ^{qr}	0.24 ^{pqr}	6.88 ^{kl}	7.87 ^{ijk}	26.34 ^{fghi}	2.17 ^{lmn}
IC-90121	2.14 ^{hijk}	3.07 ^{cdef}	0.51 ^{j}	0.34 ^{gh}	0.86 ^{ij}	18.34 ^{h}	9.47 ^{cd}	27.48 ^{def}	5.95 ^{a}
IIHR-322	2.34 ^{ghij}	1.67 ^{lm}	0.58 ^{i}	0.38 ^{f}	1.12 ^{h}	7.91 ^{jk}	8.90 ^{defg}	24.94 ^{hij}	2.94 ^{hij}
IIHR-562	1.38 ^{mn}	2.54 ^{ghij}	0.40 ^{mn}	0.18 ^{mno}	0.60 ^{m}	23.26 ^{ef}	8.89 ^{defg}	39.14 ^{a}	3.49 ^{gh}
IIHR-636	2.57 ^{efgh}	2.00 ^{kl}	0.51 ^{j}	0.30 ^{hi}	0.82 ^{jk}	24.52 ^{cde}	10.74 ^{b}	26.24 ^{fghi}	2.27 ^{klmn}
Muktakeshi	2.66 ^{cdefg}	2.901 ^{defgh}	0.63 ^{h}	0.28 ^{ij}	0.94 ^{i}	28.86 ^{a}	7.29 ^{k}	20.35 ^{m}	2.40 ^{jklm}
Pant Rituraj	1.54 ^{lmn}	2.66 ^{fghij}	0.26 ^{p}	0.20 ^{lm}	0.47 ^{n}	23.01 ^{f}	10.85 ^{b}	26.82 ^{efg}	4.08 ^{cdef}
Rajendra Baigan-2	2.22 ^{ghij}	3.63 ^{ab}	0.86 ^{f}	0.75 ^{bc}	1.66 ^{e}	1.42 ^{pq}	9.15 ^{de}	18.25 ^{n}	2.53 ^{jklm}
Swarna Mani	2.30 ^{ghij}	2.97 ^{cdefg}	0.26 ^{p}	0.19 ^{lmn}	0.48 ^{n}	25.27 ^{cd}	8.45 ^{fghi}	24.70 ^{ij}	2.81 ^{ijk}
VR-2	2.08 ^{ijk}	2.64 ^{fghij}	0.14 ^{qr}	0.07 st	0.23 ^{qr}	0.64 ^{q}	10.52 ^{b}	20.19 ^{m}	2.00 ^{lmn}
LSD (0.05)	**0.38**	**0.39**	**0.05**	**0.04**	**0.09**	**1.23**	**0.58**	**1.50**	**0.51**

Note: TS:Total sugar content (%), AA: Ascorbic acid content (mg/100g FW), Chl a:Chlorophyll a content(mg/100g FW), Chl b:Chlorophyll b content(mg/100g FW), TChl:Total chlorophyll content(mg/100g FW), TAnth:Total anthocyanin content(mg/100g FW), TPC:Total phenolics content(mg/100g FW), RSA:Radical scavenging activity (%),TAox:Total antioxidant capacity(µ moltrolox equivalent/g FW). Means with different alphabets are significantly different.

Table 4: Genotypic and phenotypic correlation coefficient of morpho-biochemical characters

Character	D50F	FrL	FrG	FrW	FrP	YP	TS	AA	Chl a	Chl b	TChl	TAnth	TPC	RSA	TAox
D50F(r_g/r_p)	1.000	0.067	0.392**	0.364**	-0.188	-0.116	-0.239	0.16	-0.377**	-0.347**	-0.378**	0.298**	-0.059	-0.18	0.041
	1.000	0.062	0.316**	0.281**	-0.151	-0.099	-0.199	0.12	-0.268**	-0.251*	-0.272**	0.214*	-0.067	-0.129	0.003
FrL(r_g/r_p)		1.000	-0.364**	-0.022	0.275**	0.280**	0.149	0.062	0.217*	0.310**	0.264*	-0.013	-0.317**	-0.496**	**-0.322****
		1.000	-0.312**	-0.008	0.243*	0.246*	0.118	0.064	0.199	0.290**	0.247*	-0.013	-0.269**	-0.456**	**-0.290****
FrG(r_g/r_p)			1.000	0.671**	-0.245*	0.141	0.038	0.122	-0.210*	-0.208*	-0.220*	0.175	-0.117	-0.193	**-0.236***
			1.000	0.651**	-0.246*	0.128	0.014	0.123	-0.203	-0.199	-0.214*	0.173	-0.097	-0.179	**-0.221***
FrW(r_g/r_p)				1.000	-0.464**	0.193	0.024	0.166	-0.203	-0.152	-0.191	0.298**	-0.143	-0.391**	-0.204
				1.000	-0.456**	0.181	0.007	0.153	-0.201	-0.147	-0.185	0.295**	-0.128	-0.379**	-0.187
FrP(r_g/r_p)					1.000	0.770**	-0.136	0.16	0.209*	0.192	0.212*	-0.264*	-0.240*	-0.15	0.030
					1.000	0.716**	-0.109	0.154	0.201	0.187	0.199	-0.253*	-0.238*	-0.141	0.027
YP(r_g/r_p)						1.000	-0.084	0.272**	0.127	0.171	0.146	-0.185	-0.319**	-0.497**	-0.123
						1.000	-0.050	0.257*	0.120	0.16	0.136	-0.176	-0.279**	-0.460**	-0.099
TS(r_g/r_p)							1.000	0.166	0.391**	0.307**	0.372**	0.028	-0.067	0.070	-0.089
							1.000	0.147	0.365**	0.283**	0.346**	0.021	-0.054	0.080	-0.079
AA(r_g/r_p)								1.000	0.049	-0.014	0.024	-0.073	**-0.349****	-0.005	0.001
								1.000	0.043	-0.015	0.018	-0.063	**-0.328****	0.016	0.001
Chl a(r_g/r_p)									1.000	0.930**	0.988**	-0.176	0.080	0.033	**0.308****
									1.000	0.927**	0.985**	-0.176	0.077	0.032	**0.294****
Chl b(r_g/r_p)										1.000	0.975**	-0.196	0.054	-0.073	**0.215***
										1.000	0.970**	-0.195	0.051	-0.074	**0.205***
TChl(r_g/r_p)											1.000	-0.181	0.061	-0.014	**0.270****
											1.000	-0.180	0.064	-0.016	**0.257***
TAnth(r_g/r_p)												1.000	0.086	0.061	0.033
												1.000	0.083	0.060	0.031
TPC(r_g/r_p)													1.000	0.077	**0.444****
													1.000	0.074	**0.431****
RSA(r_g/r_p)														1.000	**0.344****
														1.000	**0.321****
TAox(r_g/r_p)															1.000
															1.000

Note: r_g: Genotypic correlation coefficient, r_p: Phenotypic correlation coefficient.D50F: Days to 50% flowering, FrL: Fruit length (cm), FrG: Fruit girth (cm), FrW: Average fruit weight (g), Number of fruit/plant (FrP) and YP: Yield/plant (kg), TS:Total sugar content, AA: Ascorbic acid content, Chl a: Chlorophyll a content, Chl b: Chlorophyll b content, TChl: Total chlorophyll content, TAnth: Total anthocyanin content, TPC: Total phenolics content, RSA: Radical scavenging activity,TAox: Total antioxidant capacity.

Table 5: Direct (diagonal) and indirect effects of component traits attributing to fruit yield per plant in brinjal at phenotypic level

Character	D50F	FrL	FrG	FrW	FrP	TS	AA	Chl a	Chl b	TAnth	TPC	RSA	TAox
D50F	**-0.048**	-0.003	-0.015	-0.013	0.007	0.009	-0.006	0.013	0.012	-0.010	0.003	0.006	0.000
FrL	-0.005	**-0.075**	0.023	0.001	-0.018	-0.009	-0.005	-0.015	-0.022	0.001	0.020	0.034	0.022
FrG	-0.021	0.020	**-0.065**	-0.043	0.016	-0.001	-0.008	0.013	0.013	-0.011	0.006	0.012	0.014
FrW	0.198	-0.006	0.460	**0.706**	-0.322	0.005	0.108	-0.142	-0.104	0.208	-0.090	-0.268	-0.132
FrP	-0.152	0.245	-0.248	-0.459	**1.008**	-0.110	0.156	0.203	0.189	-0.255	-0.240	-0.142	0.027
TS	-0.014	0.009	0.001	0.001	-0.008	**0.072**	0.011	0.026	0.020	0.002	-0.004	0.006	-0.006
AA	0.003	0.002	0.003	0.004	0.004	0.004	**0.026**	0.001	0.000	-0.002	-0.008	0.000	0.000
Chl a	0.034	-0.025	0.025	0.025	-0.025	-0.046	-0.005	**-0.125**	-0.116	0.022	-0.010	-0.004	-0.037
Chl b	-0.034	0.039	-0.027	-0.020	0.025	0.038	-0.002	0.125	**0.135**	-0.026	0.007	-0.010	0.028
TAnth	-0.022	0.001	-0.018	-0.030	0.026	-0.002	0.006	0.018	0.020	**-0.102**	-0.008	-0.006	-0.003
TPC	-0.002	-0.008	-0.003	-0.004	-0.007	-0.002	-0.010	0.002	0.002	0.003	**0.031**	0.002	0.013
RSA	0.010	0.034	0.013	0.028	0.010	-0.006	-0.001	-0.002	0.005	-0.004	-0.005	**-0.074**	-0.024
TAox	0.000	-0.009	-0.007	-0.006	0.001	-0.002	0.000	0.009	0.006	0.001	0.013	0.010	**0.030**
Phenotypic correlation with YP	-0.099	0.246	0.128	0.181	0.716	-0.050	0.257	0.120	0.160	-0.176	-0.279	-0.460	-0.099

R^2=0.888, Residual effect=0.335

Note: D50F: Days to 50% flowering, FrL: Fruit length (cm), FrG: Fruit girth (cm), FrW: Average fruit weight (g), Number of fruit/plant (FrP) and YP: Yield/plant (kg), TS:Total sugar content, AA: Ascorbic acid content, Chl a: Chlorophyll a content, Chl b: Chlorophyll b content, TChl: Total chlorophyll content, TAnth: Total anthocyanin content, TPC: Total phenolics content, RSA: Radical scavenging activity,TAox: Total antioxidant capacity.

trolox equivalent g^{-1} FW). Similar results were observed by Kaur *et al*. (2012).

Inter-relationship studies

The present study revealed that in general, genotypic correlation coefficients were higher than their phenotypic ones (Table 4). This could be recognized as the concealing effect of environment which alters the manifestation of a character thereby reducing the phenotypic expression (Nandpuri *et al*., 1977). At genotypic and phenotypic level, the correlation coefficient studies revealed that yield plant^{-1} had significant positive correlation with number of fruits plant^{-1}, fruit length and total ascorbic acid content. Similar significant positive association with fruit yield was previously documented by Singh and Khanna (1978) for number of fruits plant^{-1}, Shinde *et al*. (2012) for fruit length and yield plant^{-1}, Thangamani and Jansirani (2012) for yield plant^{-1} and total ascorbic acid content. Fruit weight showed significant and negative association with number of fruits plant^{-1} and positive correlation with fruit girth, while, fruit length had significant positive correlation with number of fruits plant^{-1} specifying that the restricted number of fruits plant^{-1} acquire larger portion of the metabolites more efficiently and thus increase the fruit girth. These results were also confirmed by the findings of Devi and Sankar (1990) as well as Thangamani and Jansirani (2012).

A strong positive correlation was observed between the phenolic bioactive properties and antioxidant activities and as reported earlier (Nisha *et al*., 2009; Kaur *et al*., 2012; Kandoliya *et al*., 2015). Total antioxidant capacity had strong positive correlation with radical scavenging activity and chlorophyll content. Significant negative correlation was observed between total phenol content and ascorbic acid content. This is in agreement with the findings of Dhruve *et al*. (2014). In green brinjal fruit, there was remarkable positive correlation between chlorophyll content and total soluble sugar. Similar trend of results was obtained by Wang *et al*. (2010) for chlorophyll and sugar content. Total chlorophyll had significant positive association with fruit length and number of fruits plant^{-1}. Total phenol content had strong negative correlation with fruit length and yield plant^{-1}. It also had significant negative correlation with number of fruits plant^{-1}. These results were also in corroboration with the findings of Thangamani and Jansirani (2012) for association of total phenol with fruit length and number of fruits plant^{-1}. Radical scavenging activity had high significant negative association with number of fruit length, fruit weight and yield plant^{-1}. Total antioxidant capacity had high significant negative correlation with fruit length. This study revealed that the small sized fruits of brinjal were rich in quality parameters. These results are in accordance with the findings of Nisha *et al*. (2009).

Path coefficient analysis

Correlation studies in conjunction with path coefficient analysis revealed a better picture of the cause and effect relationship of different attributes. In the present study, the path coefficients analysis (Table 5) indicated that number of fruits plant^{-1} expressed high positive direct influences on yield. Highest direct positive effect of number of fruits plant^{-1} on yield followed by fruit weight was previously reported by Bansal and Mehta (2008), Lokhare *et al*. (2008) and Shinde *et al*. (2012). Number of fruits plant^{-1} gave high negative indirect effect via fruit weight, which is in agreement with the findings of Karak *et al*. (2012). From this study, number of fruits plant^{-1} and fruit weight appeared as the most important fruit yield contributing characters of brinjal and these characters may be used as important selection parameters because of their probable conditioning by additive gene action. Quality characters did not give significant direct or indirect effect on yield. It envisaged that 67per cent variation in fruit yield at phenotypic level had been determined. It further spoke about presence of some factors, which were not considered here and need to include identifying the disparity in fruit yield of brinjal.

From the present study it was found that considerable amount of variability was present among the genotypes under study for the different active biomolecules as well as agronomic traits. For development of brinjal ideotype, average fruit weight, fruit length, fruit girth and number of fruits plant^{-1} can be put to direct selection intensity that would lead to yield increase. The study also revealed that brinjal genotypes with small sized fruits were rich in quality aspects and having higher antioxidant property, which indicated that yield improvement might sacrifice fruit quality. This needs to be considered carefully at the time of outlining a breeding strategy for simultaneous improvement of yield and fruit quality.

Out of the thirty one genotypes under study, BRBL-1 was found to be the best genotype on the basis of both yield and quality characters. It had the highest yield potential (2.58 kg plant^{-1}) and considerable amount of ascorbic acid (3.39 mg 100^{-1}g), total chlorophyll content (2.25 mg 100^{-1}g) and total antioxidant capacity (4.81 µ moltrolox equivalent g^{-1} FW). This genotype may be effectively used in brinjal improvement programmes for enhancing yield as well as bioactive properties.

REFERENCES

Al-Jibouri, H.A., Miller, P.A. and Robinson, H.F. 1958. Genotypic and environmental variances in an upland cotton cross of inter specific origin. *J. Agron*., **50**:633-36.

Ames, B. N., Shigenaga, M. K. and Hagen, T. M. 1993. Oxidants, antioxidant, and the degenerative diseases of aging. *Proc. Nat. Acad. Sci.* USA, **90**: 7915-22.

AOAC 2000. *Official methods of analysis. Association of Official Analytical Chemists*, Washington DC, USA.

AOAC 2001. *Official methods of analysis. Association of Official Analytical Chemists*, Washington DC, USA.

Apak, R., Guclu, K., Ozyurek, M. and Karademir, S. E. 2004. Novel total antioxidant capacity index for dietary polyphenols and vitamins C and E using their cupric ion reducing capabilities in the presence of neocuproine: CUPRAC method. *J. Agric. Food Chem*., **52**:7970-81.

Arnon, D. I. 1949. Spectrophotometric determination of chlorophyll. *Pl. Physiol*., **24**: 1.

Babu, B. R. and Patil, R.V. 2005. Evaluation and variability studies of brinjal genotypes. *Madras Agric. J*., **92**: 578-84.

Bajaj, K. L., Kaur, G. and Chadha, M. L. 1979. Glycoalkloid content and other chemical constituent of the fruit of some eggplant (*Solanum melongena* L.) varieties. *J. Pl. Foods*, **3**:163-68.

Bansal, S. T. and Mehta, A. K. 2008. Genotypic correlation and path analysis in brinjal. *National J. Pl. Improv*., **10**: 34-36.

Brand-Williams, W., Cuvelier, M. E. and Berset, C. 1995. Use of free radical method to evaluate antioxidant activity. *LWT Food Sci. Technol*., **28**:25-30.

Cao, G., Sofic, E. and Prior, R. L. 1996. Antioxidant capacity of tea and common vegetables. *J. Agric. Food Chem.*, **44**: 3426-31.

Devi, Y. S. and Sankar, C. R. 1990. Genetic variability and correlation studies in egg plant. *J. Maharashtra Agric. Univ*., **15**: 305-307.

Dewey, D. and Lu, K. H. 1959. A correlation and path coefficient analysis in crested wheat grass seed production. *Agron. J*., **54**: 515-18.

Dhruve, J. J., Shah, R., Gandhi, S. and Talati, J. G. 2014. Biochemical and morphological traits of different cultivars of brinjal fruits growing in Anand (Gujarat). *Indian J. Agric. Biochem*., **27**: 211-14.

Fisher, R. A. 1935. *The Design of Experiments. Edinburgh*, Oliver and Boyd.

Ghadsingh, P.G. and Mandge, S.V. 2012. Nutritional spoilage of tomato and brinjal fruits due to postharvest fungi. *Curr. Bot*., **3**:10-12.

Huang, H. Y., Chang, C. K., Tso, T. K., Huang, J. J., Chang, W. W. and Tsai, Y. C. 2004. Antioxidant activities of various fruits and vegetables produced in Taiwan. *Int. J. Food Sci. Nutr.*, **55**:423-29.

Johnson, H. W., Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soybean. *J. Agron*., **47**:314-18.

Kadivec, M., Kopjar, M., Znidarcic, D. and Pozzrl, T. 2015. Potential of eggplant peel as by-product. *Acta Alimentaria*, **44**:126-31.

Kandoliya, U. K., Bajaniya, V. K., Bhadja, N. K., Bodar, N. P. and Golakiya, B. A. 2015. Antioxidant and nutritional components of eggplant (*Solanum melongena* L) fruit grown in Saurastra region. *Int. J. Curr. Microbiol. App. Sci*., **4**: 806-13.

Karak, C., Ray, U., Akhtar, S., Naik, A. and Hazra, P. 2012.Genetic variation and character association in fruit and yield components and quality characters in brinjal (*Solanum melongena* L.). *J. Crop and Weed*, **8**: 86-89.

Kaur, C., Nagal, S., Nishada, J., Kumar, R. and Sarika. 2012. Evaluating eggplant (*Solanum melongena* L) genotypes for bioactive properties: A chemometric approach. *Food Res. Int.*, **60**: 205-11.

Lokhare, A. S., Dod, V. N. and Deshawattiudar, P. D. 2008. Correlation and path analysis in green fruited brinjal (*Solanum melongena* L.) *Asian J. Hort.*, **3**:173-75.

Nagre, P. K. and Nayak, B. R. 2013. Genetic variability and correlation studies in brinjal (*Solanum melongena* L.). *Int. J. Appl. Bio. Pharma. Tech.*, **4**: 212-13.

Nandpuri, K. S., Kanwar, J. S. and Lal, R. 1977. Variability, path analysis and discriminant function selection in tomato (*Lycopersicon esculentum* Mill.). *Haryana J. Hort. Sci*., **6**:73-78.

Nisha, P., Nazar, P. A. and Jayamurthy, P. 2009. A comparative study on antioxidant activities of different varieties of *Solanum melongena*. *Food Chem. Toxi*., **47**:2640-44.

Noda, Y., Kneyuki, T., Igarashi, K., Mori, A. and Packer, L. 2000. Antioxidant activity of nasunin, an anthocyanin in eggplant peels. *Toxicol*., **148**:119-23.

Panse, V. G. and Sukhatme, P. V. 1967. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi, pp. 152-61.

Prohens, J., Rodriguez-Burruezo, A., Dolores-Raigon, M. and Nuez, F. 2007. Total phenolic concentration and browning susceptibility in a collection of different varietal types and hybrids of eggplant: implications for breeding for higher nutritional quality and reduced browning. *J. American Soc. Hort. Sci.*, **132**:638-46.

Ranganna, S. 1977. Plant pigments. In. *Manual of Analysis of Fruit and Vegetable Products*. Tata McGraw-Hill Publishing Co., Ltd. New Delhi, pp. 72-93.

Sadilova, E., Stintzing, F. C. and Carle, R. 2006. Anthocyanins, colour and antioxidant properties of eggplant (*Solanum melongena* L.) and violet Pepper (*Capsicum annuum* L.) peel extracts. *J. Biosci*., **61**:527-35.

Sarker, R. H., Yesmin, S. and Hoque, M. I. 2006. Multiple shoot formation in eggplant (*Solanum melongena* L.). *Pl. Tissue Cult. Biotech.*, **16** : 53-61.

Shinde, K. G., Birajdar, U. M., Bhalekar, M. N. and Patil, B. T. 2012. Correlation and path analysis in eggplant (*Solanum melongena* L.). *Veg Sci.*, **39**:108-10.

Singh, B. and Khanna, K. R. 1978. Correlation studies in eggplant. *Indian J. Hort*., **35**:39-42.

Singh, O. and Kumar, J. 2005. Variability, heritability and genetic advance in brinjal (*Solanum melongena* L.). *Indian J. Hort*., **62**:265-67.

Singleton, V. L., Orthofer, R. and Lamuela-Ranventos, R. M. 1999. Analysis of total phenols other oxidation substrates and antioxidants by means of Folin–Ciocalteu reagent. *Methods Enzymol*., **299**:152-78.

Sultana, B., Hussain, Z., Hameedi, M. and Mushtaqi, M. 2013. Antioxidant activity among different parts of aubergine (*Solanum melongena* L). *Pakistan J. Bot*., **45**:1443-48.

Thangamani, C. and Jansirani, P. 2012. Correlation and path coefficient analysis studies on yield and attributing characters in brinjal (*Solanum melongena* L.). *Electron. J. Pl. Breed*., **3**:939-44.

Wang, L. P., Dai, D. L. and Hu, H. J. 2010. Relationship between contents of pigments and soluble sugars during development of eggplant fruits with different genotypes. *China Veg*., **22**:41-46.

Wrolstad, R. E. 2004. Anthocyanin pigments-Bioactivity and colouring properties. *J. Food Sci.*, **69**:419-25.