Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(5): 3189-3193
Received: 04-07-2018
Accepted: 06-08-2018

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Genetic variability, heritability and genetic advance for yield and its contributing traits in brinjal (*Solanum melongena* L.)

Sandeep Yadav, VB Singh, Rohit Maurya, Vivek Thapliyal and Kuwar Anurag Pratap Singh

Abstract
Experimental material for the study was consisted of 32 genotypes of two groups (long purple and round purple) including three checks (Punjab Sadabahar, Navina and Swarna Mani). The experiment was conducted in Randomized Complete Block Design with three replications. Each treatment consisted of 20 plants in two rows, having spacing of 60x45cm with net plot size of 4.5x1.2m. The experiment was executed at Main Experimental, Station of Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, during Kharif2015-2016. Observations were recorded on 10 quantitative characters viz.,), primary branches per plant, secondary branches per plant, days to 50% flowering, days to first fruit harvest, plant height (cm), fruit length (cm), fruit circumference (cm),, fruits per plant, average fruit weight (g) and total fruit yield per plant (kg). The analysis of variance for the design of experiment indicated highly significant differences among the genotypes for all the traits. Based on mean performance of genotypes NDB-12-9, NDB-12-18 and NDB-12-3 for long purple and NDB-11-10, NDB-11-17, NDB-11-15 and NDB-11-6 for round purple fruit were found as most promising genotypes for total fruit yield per plant. High magnitude of variability was observed in case of fruits per plant followed by average fruit weight, fruit circumference, fruit length, total fruit yield per plant, secondary branches per plant, primary branches per plant, plant height and Days to 50% flowering. Days to first fruit harvest exhibited low value of variability. High heritability coupled with high genetic advance in per cent of mean were recorded for most of the traits except days to first fruit harvest, days to 50% flowering, plant height indicating opportunity for selection response.

Keywords: Brinjal (*Solanum melongena* L.), Genetic variability, GCV, PCV, Heritability, Genetic advance

Introduction
Brinjal or eggplant (*Solanum melongena* L. 2n=2x=24) is one of the most popular and principal Solanaceous vegetable crops. It is worldwide known as aubergine or guinea squash which is one of the most popular and major vegetable crop in India and other parts of the world. It is probably originated in India and showed secondary diversity in South East Asia. It is being grown extensively in India, Bangladesh, Pakistan, China, Japan, Philippines, France, Italy and U.S.A. In Southern Europe, brinjal is a staple vegetable and it is a favourite dish in South East of France. Brinjal has got much potential as raw material in pickle making and dehydration industries. It is highly productive and usually finds its place as the poorman's vegetable. In India, it is being consumed as a cooked vegetable in many ways and is liked by both poor and rich. Year round availability, easy culture, moderate to high yield and consumption in varieties of ways like *salad*, *bhaji*, stuffed brinjal, *bhartha*, *chatni*, pickles etc., has made brinjal the king of vegetables in India. Further, in recent years brinjal is being exported in the form of products like *baingan bhartha*, *chatni*, *pickles* etc. *Solanum incanum*, a wild species and having wide distribution in atleast 10 habitats in India is the progenitor of the cultivated species, *Solanum melongena*. The first record of brinjal in India was during 300 B.C. to 300 A.D. Atleast 33 Sanskrit names for brinjal have been mentioned in the ancient literetures of India and the most common being Varttaka, Bhantaki and Vattingan. It is cultivated in Africa around 9th century A.D. It was known in Italy at the end of 14th century and introduced into southern Europe in the 15th century and the name "eggplant" was probably derived from the white egg like fruits. Brinjal is being cultivated in India over an area of 0.68 million ha with an average annual production of 12.70 million tonnes and productivity of 18.26 mt/ha. It is distributed in Orissa, Bihar, Karnataka, West Bangal, Andhra Pradesh, Maharashtra and Utter Pradesh.

In Uttar Pradesh, brinjal is being cultivated on an area of 4.10 lakh ha with annual production of 136.16 lakh tonnes. (Anon., 2016) [3]. Brinjal or eggplant is a perennial but grown commercially as annual crop. Inflorescence is often solitary but some time it constitutes a cluster of 2-5 flowers. Solitary or clustering nature of inflorescence is a varietal character. Flower is complete and hermaphrodite. Heterostyly is a common feature, and fruit setting flower consist of long (70-86.7%) and medium styled (12-55.6%) flower. The non-fruit setting flowers consist of short styled and pseudo styled. Eggplant is usually self-pollinated but the extent of cross-pollination has been reported as high as 29% and hence it is classified as often cross-pollinated or facultative cross-pollinated. Flower generally emerges 40-45 days after transplanting. Anthesis occurs at about 6-8 a.m. in August-September and usually between 9.30-11.15 a.m. during winter (December-January). Stigma receptivity is highest during anthesis *i.e.* flower opening. Anthers usually dehisce 15-20 minutes after the anthesis. Brinjal contain certain medicinal properties like white brinjal is said to be good for diabetic patients (Choudhary, 1976) [5]. It has also been recommended as an excellent remedy for those suffering from liver complaint. One hundred gram edible portion of brinjal fruit contains 92.7% moisture, 24.0% calories, 4.0% carbohydrates, 1.4 g protein, 0.3 g fats, 1.3 g fibers, 124.0 (I.U.) Vitamin A and 12.0 mg Vitamin C (Chen and Li, 1996). It also contains 52.0 mg chlorine, 47.0 mg phosphorus, 44.0 mg sulphur and other minerals (Aykroyd, 1963) [1]. It is easily cultivated in almost all parts of India except higher altitudes. It is a warm season crop and highly susceptible to frost. A long and warm growing season is desirable for successful brinjal production. The main crop of brinjal is raised during autumn- winter season however; some production is obtained during spring-summer season also. But during spring-summer season high temperature (above 35 ^{0}C) causes drastic reduction in brinjal production due to poor fruit set. The optimum temperature for growth and fruit set is 15.5-21.1 ºC. Many of the round varieties usually set fruit at slightly lower temperature and are susceptible to frost and long-fruited varieties set fruits at higher temperature and show tolerance to frost. Brinjal being most important to growers and consumer, there is pressing need to increase its productivity to fulfill the increasing demands throughout the year. The information usually needed for developing high yielding varieties in a particular species pertains to the extent of genetic variability for desirable traits in the available germplasm.

Evaluation of germplasm is the basic tool for identification of important genotypes. The great extent of natural variation present in various characters among the genotypes suggests good scope of improvement in economic traits. Large variability ensures better chance of producing new forms. Variability parameters like genotypic and phenotypic coefficient of variations, heritability and genetic advance, along with degree of association between the various characters and direct effect of yield contributing characters on total yield, is of paramount significance in formulating an appropriate breeding strategy aimed at exploiting the inherent variability of the original population. Phenotypic variability changes under different environmental conditions while genetic variability remains unchanged and more useful to a plant breeder for exploitation in selection or hybridization. Yield is very complex characteristics controlled by several yield contributing components and it is highly influenced by environmental factors, consequently estimates of heritability and genetic advance are useful for selection.

Materials and methods

The field experiment under present investigation was conducted during autumn-winter season 2015-2016, at the Main Experiment Station, Department of Vegetable Science, N.D. University of Agriculture and Technology Narendra Nagar (Kumarganj), Faizabad (U.P.). The experimental field had sandy loam soil, low in organic carbon, nitrogen, medium in phosphorus, potash, and slightly alkaline in nature with pH 8.5.The mechanical composition of soil was 60.9 per cent, 27.8 per cent silt and 11.3 per cent clay. The experimental material for the present investigation comprised of 32 genotypes of brinjal collected from different places in India and being maintained at Main Experiment Station in the Department of Vegetable Science, N.D. University of Agriculture & Technology, (Narendra Nagar) Kumarganj, Faizabad (U.P). The experiment was conducted in Randomized Complete Block Design with three replications during autumn-winter season in 2015-2016 to assess the performance of 32 genotypes. Each treatment consisted of two rows. Ten plants were maintained in each row and replicated thrice. Transplanting was done at a spacing of 60 cm between row to row and 45 cm plant to plant having net plot size of 4.5x1.2 m^2.The seed were sown in nursery bed on 03-08-2015 and transplanted on 04-09-2015. All the recommended agronomic package of practices and plant protection measures were followed to raise a good crop. Observations recorded Days to 50 per cent flowering,Plant height(cm),Number of primary branches per plant,Number of secondary branches per plant, Days to first fruit harvest, Fruit length (cm), Fruit circumference (cm), Number of fruits per plant, Average fruit weight (g), Total fruit yield per plant (kg).

Results and discussion

The analysis of variance for different characters is presented in table 1. The mean squares due to genotypes were highly significant for all the characters. In other words, the performances of the genotypes with respect of these characters were statistically different; suggesting that, there exists ample scope for selection in different traits for brinjal improvement. In order to evaluate the listed genotypes the mean of thirty two genotypes including check for ten characters has been presented in table 2. A very wide range of variations in mean performance of genotypes were observed for all the characters under study. The comparison of mean performance of 32 genotypes for ten traits using critical differences revealed existence of very high level of variability in the used genotypes. The genotypes NDB-12-11 (3.20 kg), NDB-12-1 (2.51 kg) significantly out yielded in respect of all genotypes as well as check in case of long purple and also showed high mean performance for fruits per plant 47.98 and 44.06. This genotype also showed high mean performance for some other characters as well genotypes NDB-11-6 (3.05 kg), NDB-11-2 (2.97 kg), NDB-11-11 (2.82 kg), NDB-11-10 (2.78) and NDB-11-15 (2.35) genotypes produced higher yield per plant than the check Swarna Mani (1.25 kg) in case of round purple group.

Table 1: Analysis of variance (mean squares) for ten quantitative characters in brinjal germplasm

S. No	Characters	Source of variation		
		Replication	Treatments	Error
	d.f.	2	31	62
1.	Number of primary branches per plant	0.8016	6.61**	0.4410
2.	Number of secondary branches per plant	0.5563	34.9389**	1.5348
3.	Days to 50% flowering	8.0000	29.3679**	2.8064
4.	Days to first fruit harvest	0.8750	70.2093**	5.6922
5.	Plant height (cm)	3.7593	279.1772**	14.5913
6.	Fruit length (cm)	1.7444	49.9837**	0.9833
7.	Fruit circumference (cm)	0.3804	52.3945**	1.2592
8.	No. of fruits per plant	6.5531	292.9246**	3.8003
9.	Average fruit weight (gm)	7.9032	1430.7078**	7.9194
10.	Total fruit yield per plant (kg)	0.0123	0.8163**	0.0145

Table 2: Mean performance of thirty two genotypes for ten characters in brinja

S. No	Characters / Genotypes	No. of primary branches per plant	No. of secondary branches per plant	Days to 50% flowering	Days to first fruit harvest	Plant height (cm)	Fruit length (cm)	Fruit circumference (cm)	No. of fruits per plant	Average fruit weight(gm)	Total fruit yield per plant (kg)
1.	NDB-12-1	6.2333	12.7333	28.6667	55.3333	91.6667	20.6633	9.5767	44.0667	56.9667	2.5100
2.	NDB-12-2	5.5000	10.8333	33.3333	70.6667	94.5000	21.4333	11.3867	34.2800	53.3333	1.8237
3.	NDB-12-3	7.1000	22.1667	28.6667	60.3333	95.0000	21.3300	12.5567	39.6500	51.0000	2.0207
4.	NDB-12-5	9.4000	15.8333	35.6667	70.3333	94.4033	14.5700	15.3333	44.4467	53.6667	2.3850
5.	NDB-12-6	6.7333	14.0000	30.3333	67.6667	92.4433	24.6667	11.4167	37.0667	42.3333	1.5653
6.	NDB-12-8	5.9333	14.8000	34.0000	67.6667	95.1667	15.5533	11.4467	39.7700	54.6667	2.1680
7.	NDB-12-9	7.8333	12.4333	31.6667	61.0000	106.0000	15.5367	13.4433	47.2333	62.0000	2.9267
8.	NDB-12-11	7.5000	13.8333	37.0000	69.0000	90.0980	17.4100	11.4667	47.9833	66.7200	3.1990
9.	NDB-12-12	8.0000	15.0000	27.3333	60.0000	104.2967	20.5533	8.4667	28.9167	70.0000	2.0233
10.	NDB-12-14	6.8000	11.5000	28.6667	59.3333	97.3900	20.5667	10.4667	19.7867	69.0000	1.3643
11.	NDB-12-15	6.0000	13.1667	35.0000	65.0000	90.5233	12.4333	14.5433	29.4333	51.3333	1.5087
12.	NDB-12-16	6.0000	12.2333	35.3333	67.3333	83.2067	20.5933	11.4800	31.6533	54.6667	1.7293
13.	NDB-12-18	10.5000	20.6000	30.6667	60.3333	113.5567	18.3933	12.6000	44.6367	49.0000	2.1847
14.	NDB-12-19	6.9333	13.1333	33.3333	65.0000	97.9000	16.4167	14.5000	25.5667	61.1467	1.5620
15.	NDB-12-20	5.3667	10.8333	31.3333	58.0000	90.9067	18.7500	10.5333	29.4333	81.6500	2.3987
16.	NDB-12-21	8.9333	17.7333	33.0000	65.3333	75.5500	22.3700	10.4767	30.0167	61.3333	1.8410
17.	NDB-11-1	7.8333	16.6000	35.0000	68.0000	98.0000	12.3167	18.5267	17.3667	99.0000	1.7153
18.	NDB-11-2	6.6667	13.5000	35.3333	68.3333	74.9267	11.4167	17.6000	36.1500	82.4167	2.9790
19.	NDB-11-3	9.5000	21.2667	34.6667	67.3333	92.9200	12.3700	21.5000	29.3200	78.6667	2.3067
20.	NDB-11-4	5.9333	10.5000	37.3333	71.3333	93.3333	16.4100	19.7500	20.5333	89.6667	1.8413
21.	NDB-11-6	9.0000	19.6667	34.6667	67.3333	71.7033	9.3333	22.5100	38.6533	79.0000	3.0553
22.	NDB-11-7	7.1000	13.8333	34.0000	67.3333	98.3733	11.4500	16.3167	26.9167	79.3333	2.1327
23.	NDB-11-8	5.0000	11.0000	34.0000	64.6667	70.7767	13.4167	22.5000	25.6900	91.3333	2.3463
24.	NDB-11-10	7.0000	15.3333	35.0000	65.0000	85.5433	12.2500	17.4167	34.4167	81.0000	2.7867
25.	NDB-11-11	6.4000	12.0667	36.0000	70.6667	82.1733	12.2333	18.5000	31.3333	90.0000	2.8200
26.	NDB-11-12	5.9000	13.4000	33.6667	69.6667	103.2800	12.4433	21.5000	24.4000	95.3333	2.3250
27.	NDB-11-14	7.0667	14.1000	35.6667	74.0000	95.5567	10.5267	22.0000	18.1833	82.3333	1.4967
28.	NDB-11-15	6.5000	13.4667	28.0000	58.6667	98.3333	15.5100	13.5667	36.9500	64.3333	2.3547
29.	NDB-11-17	11.3333	22.9000	40.0000	73.3333	95.6667	14.6200	12.5000	21.8667	91.3333	1.9970
30.	Navina	8.0000	17.5000	28.6667	60.0000	91.1667	21.8667	16.6000	13.6433	117.6667	1.6017
31.	Pb. Sadabahar	7.0000	14.0000	30.6667	61.3333	99.8333	17.6000	15.4000	28.7833	80.3333	2.3107
32.	Swarna Mani	6.8333	12.0000	36.3333	69.6667	93.2500	15.4333	11.5833	8.6333	145.6667	1.2557
Mean		7.2448	14.7490	33.2188	65.5938	92.4201	16.2636	14.9207	30.8369	74.5698	2.1417
C.V.		9.1665	8.3998	5.0431	3.6373	4.1332	6.0972	7.5209	6.3218	3.7738	5.6364
S.E.		0.3834	0.7153	0.9672	1.3775	2.2054	0.5725	0.6479	1.1255	1.6247	0.0697
CD 5 %		1.0839	2.0221	2.7343	3.8940	6.2346	1.6185	1.8315	3.1818	4.5931	0.1970
Range lowest		5.0000	10.5000	27.3333	55.3333	70.7767	9.3333	8.4667	8.6333	42.3333	1.2557
Range Highest		11.3333	22.9000	40.0000	74.0000	113.5567	24.6667	22.5100	47.9833	145.6667	3.1990

The estimate of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for the all traits. High magnitudes of variability was observed in case of no. of fruits per plant (32.45%) followed by average fruit weight (29.44%), fruit circumference (28.67%), fruit length (25.58%), total fruit yield per plant (24.78%), secondary branches per plant (24.13%), primary branches per plant (21.82%), plant height (10.97%) and Days to 50% flowering (10.27). While, low variability was recorded in case of days to first fruit harvest (7.95).

Estimates of heritability and genetic advance for different characters are presented in (Table-3).The heritability in broad sense ranged from 75.93 per cent in case of days to 50% flowering to 98.36 per cent for average fruit weight. High estimates of heritability >75% were recorded for all the characters. Highest value of genetic advance in per cent of mean was shown by no. of fruits per plant (64.32%) while

days to first fruit harvest exhibited lowest value (12.95%) for this parameter. The characters showing very high estimate of genetic advance were fruits per plant (64.32%), average fruit weight (59.66%), fruit circumference (55.00%), fruit length (49.71%), total fruit yield per plant (48.42%), secondary branches per plant (43.69%), and primary branches per plant (37.02%). Low genetic advance in per cent of mean were recorded for days to first fruit harvest (12.95%) days to 50% flowering (16.07%) and plant height (19.39%).High heritability coupled with high genetic advance was observed for most of the traits except days to first fruit harvest, days to 50% flowering, plant height which indicated opportunity for selection response in available germplasm of brinjal.

Table 3: Range, grand mean, phenotypic (PCV), genotypic (GCV), environmental (ECV) coefficient of variation, heritability in broad sense, genetic advance in per cent of mean (Ga) for ten characters in brinjal garmplasm

S. No.	Characters	Range		Grand measn	PCV (%)	GCV (%)	ECV (%)	Heritability broad sense (%) (h^2_{bs})	Genetic advance in per cent of mean (Ga)
		Lowest	Highest						
1.	Number of primary branches per plant	5.00	11.33	7.24	21.82	19.80	9.16	82.36	37.02
2.	Number of secondary branches per plant	10.50	22.90	14.74	24.13	22.62	8.40	87.89	43.69
3.	Days to 50% flowering	27.33	40.00	33.21	10.27	8.95	5.04	75.93	16.07
4.	Days to first fruit harvest	55.33	74.00	65.59	7.95	7.07	3.63	79.07	12.95
5.	Plant height (cm)	77.77	113.55	92.42	10.97	10.16	4.13	85.80	19.39
6.	Fruit length (cm)	9.33	24.66	16.26	25.58	24.85	6.09	94.32	49.71
7.	Fruit circumference (cm)	8.46	22.51	14.92	28.67	27.67	7.52	93.12	55.00
8.	No. of fruits per plant	8.63	47.98	30.83	32.45	31.83	6.32	96.21	64.32
9.	Average fruit weight (gm)	42.33	145.66	74.57	29.44	29.20	3.77	98.36	59.66
10.	Total fruit yield per plant (kg)	1.25	3.19	2.14	24.78	24.13	5.63	94.83	48.42

The estimate of genotypic coefficient of variation is of prime importance to breeder because genetic variance alone does not allow a decision as to which characters were showing the highest degree of variability. Therefore, accurate relative comparison can be made with the help of phenotypic and genotypic coefficients of variation. In general, the phenotypic coefficients of variability were higher than the genotypic coefficients of variability for all the characters under study which indicates that environment played very important role in the expression of the traits (table 4.3). High magnitudes of variability was observed in case of number of fruits per plant (32.45) followed by average fruit weight (29.44), fruit circumference (28.67%), fruit length (25.58%), total fruit yield per plant (24.78%) secondary branches per plant (24.13%), primary branches per plant plant (21.82%), plant height (10.97%) and days to 50% flowering(10.27%).While, low variability was recorded in case of days to first fruit harvest (7.95). Jadhav *et al.*(2009) [7], Ansdari *et al.*(2011) [2], Thangavel *et al*. (2011) [14]; Kumar *et al*. (2014) and Rajpoot *et al.*(2015) [10] also reported similar results in their studies. Moderate PCV and GCV were estimated for primary branches per plant and fruit length. The phenotypic and genotypic coefficients of variations were lower for days to first fruit harvest. It may be due to the fact that the environment influenced the observed variance. Such influences were also evident for genotypic coefficient of variation. Genotypic coefficient of variation ranged from 7.07 (days to first fruit harvest) to 31.83 (number of fruits per plant). Similar result was also reported by Ansari *et al.* (2011) [2].

Heritability in broad sense of a character is important to the breeder since it indicates the possibility and extent to which improvement is possible through selection. It also indicates direction of selection pressure to be applied for a trait during selection because it measures relationship between parents and their progeny, hence widely used in determining the degree to which a character may be transmitted from parents to offspring. However, high heritability alone is not enough to make efficient selection in advanced generation unless accompanied by substantial amount of genetic advance (Burton, 1952) [4]. High estimates of heritability along with high genetic advance provide good scope for further improvement in advance generations. The result on heritability and genetic advance in per cent of mean of present investigation has been presented in table-3. The heritability estimates for different characters ranged from 75.93 to 98.36 per cent. High heritability was recorded for all the characters. Similar finding was also reported by Tripathi *et al.* (2009) [15]. High heritability coupled with high genetic advance in per cent of mean were recorded for fruits per plant, average fruit weight, fruit circumference, fruit length and total fruit yield pel plant indicating that these traits were less influenced by environment. Thus, require low selection intensity for improvement, Similar results were also reported by Kumar *et al*. (2011) [9]; Neeraj *et al*. (2015); (Dhaka and Soni (2012) [6]. Kumar *et al.* (2012) observed high heritability coupled with high genetic advance for fruit length, fruits per plant, fruit weight and yield per plant, primary branches per plant. Shekar *et al* (2012) [13] reported highest genetic advance as per cent of mean for almost all the characters except for days to first flowering. Reshmika *et al*. (2015) [11] found high genetic advance coupled with high heritability for fruit length, days to first flowering, average fruit weight.

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