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

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Abstract
The present investigation was carried out to study genetic parameters for fifteen yield and its contributing characters in 64 (48 F_1s, 12 lines and 4 testers) genotypes with two check varieties during *Kharif* 2017-18 to 2018-19. Analysis of variance revealed that the differences among treatments were highly significant for majority of the characters studied in both the years. Further partitioning of treatment variances into parents, crosses, lines and testers revealed highly significant differences among parents as well as crosses for majority of the characters. The pooled analysis of variance also divided the source of variance into environments found highly significant for all the traits under study except for specific gravity. In the year Y_1, high estimate of heritability in narrow-sense was recorded for fruit length (84.40%) and fruit circumference (80.30%).In the year Y_2, high estimate of heritability in narrow-sense was recorded for fruit length (84.50%) followed by fruit circumference (85.00%), leaf width (33.90%) and dry matter content (30.60%). In case of over pooled, high estimate of heritability in narrow-sense was recorded for fruit length (84.60%) and fruit circumference (80.30%). In Y_1, high estimate of genetic advance in per cent of mean (>20%) was observed for average fruit weight (89.58%). In Y_2, high estimate of genetic advance in per cent of mean (>20%) was observed for average fruit weight (88.38%). In over pooled, high estimate of genetic advance in per cent of mean (>20%) was observed for average fruit weight (88.46%), this suggest that these traits can be taken as selection parameters to select elite genotypes.

Keywords: Genetic variability, heritability, genetic advance and brinjal (*Solanum melongena* L.)

Introduction
Eggplant (*Solanum melongena* L.) or brinjal is a solanaceous vegetable, which is worldwide known as aubergine or guinea squash, is one of the most popular and major vegetable crop in India and other parts of the world. It is a self-pollinated and annual herbaceous plant, probably originated in India and shows 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 favorite dish in South East of France. Brinjal has got much potential as raw material in pickle making and dehydration industries (Singh *et al*., 1963). It is highly productive and usually finds its place as the poor man'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. to Middle East countries.

Brinjal is being cultivated in India over an area of 0.733 million ha. With an average annual production of 12.510 million tonnes and productivity of 17.06 mt/ha. In Uttar Pradesh, brinjal is being cultivated on an area of 3.0 lakh ha. With annual production of 90.9 lakh tonnes. In Uttar Pradesh, Agra, Meerut, Lucknow, Kanpur, Aligarh, Chitrakoot and Gorakhpur districts contribute more area and production to the state pool (Anon., 2016-17).

Brinjal fruits are rich source of minerals like calcium, magnesium, potassium, iron, zinc and copper. It is also a fair source of fatty acids and it is used for medicinal purposes in curing diabetes, asthma, cholera, bronchitis and diarrhea. It is reported to stimulate the intrapeptic metabolism of blood cholesterol. Leaf and fruit, fresh or dry produce marked drop in blood cholesterol level. The de-cholestrolizing action is Sattributed to the presence of polyunsaturated fatty acids (lionleic and linolenic) which are present in flesh and seeds of the fruit in higher amount (65.1%). The presence of magnesium and potassium salts also helps in de-cholestrolizing action. Aqueous extracts of fruit inhibit choline esterase activity of human plasma. Dry fruit is reported to contain goitrogenic principles.

Therefore, efforts must be put to exploit regional genetic resources without tossing consumers preferences. Thus under such circumstances, it is necessary to improve these genotypes or to develop hybrids superior to these types of qualitative and quantitative characters.

Materials and Methods

The present investigation was carried out at the Vegetable Research Farm Department of Vegetable Science, Kalyanpur, C. S. Azad University of Agriculture and Technology, Kanpur. The experimental materials for the present investigation consisted of 64 (48 F1s, 12 lines and 4 testers) genotypes with two check varieties of brinjal viz., Azad Brinjal-1, Pusa purple long. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Each replication consisted of 64 genotypes and two check varieties. 30 days old seedlings were transplanted 60cm apart between rows and 60 cm within the row. All the recommended cultural practices were followed to raise a good crop. Observations were recorded randomly on five competitive normal looking plants from each treatment in each replication to record the observations *viz*., days to 50 % flowering, number of flowers per inflorescence, leaf length(cm),leaf width (cm),number of primary branches per plant, plant height (cm), number of fruits per cluster, fruit length (cm), fruit circumference (cm), number of fruits per plant, average fruit weight (g), specific gravity, dry matter content, total soluble solids (TSS), and total fruit yield per plant (kg). The mean values of recorded data were used for analysis of variance (Panse and Sukhatme, 1967) [13], heritability in narrow sense (Kempthorne, 1957) [9] and (Johnson *et al*., 1955) [6].

Results and Discussion

Analysis of variance for line × tester mating design for both the years (Y_1 and Y_2) had been presented in Table 1. Analysis of variance revealed that the differences among treatments were highly significant for majority of the characters studied in both the years. Further partitioning of treatment variances into parents, crosses, lines and testers revealed highly significant differences among parents as well as crosses for majority of the characters. Variances due to parents were highly significant for almost all the characters in both the years and significant for number of primary branches per plant in second year except number of fruits per cluster. Variances due to parents *vs.* crosses were highly significant for majority of the characters except number of fruits per cluster in second year and for fruit length in both the years. Variances due to lines *vs*. testers were highly significant for almost all the characters except number of fruits per cluster in first year, for number of fruits per plant in second year and for leaf width as well as for specific gravity in both the years.

The pooled analysis of variance given in Table 2 also divided the source of variance into environments found highly significant for all the traits under study except for specific gravity. Variances due to parents, crosses, parent vs crosses, line vs tester and treatments were found highly significant for all the traits under study except number of fruits per cluster.

The estimates of heritability and genetic advance in per cent of mean are given in Table 3. Estimates of heritability in narrow-sense (h^2_{ns}) have been classified by Kempthorne and Curnow (1961) [8] into three categories *viz*., high (> 30%), medium (10-30%) and low (<10%). In the year Y_1,high estimate of heritability in narrow-sense was recorded for fruit length (84.40%) and fruit circumference (80.30%) while, moderate estimate of heritability in narrow sense was observed for dry matter content (24.90%), plant height (12.30%) and total soluble solids (11.20%) while, remaining characters showed low estimate of heritability in narrow-sense (h^2_{ns}).

In the year Y_2, high estimate of heritability in narrow-sense was recorded for fruit length (84.50%) followed by fruit circumference (85.00%), leaf width (33.90%) and dry matter content (30.60%) while, moderate estimate of heritability in narrow sense was observed for plant height (16.20%) followed by total soluble solids (27.58%),and number of flowers per inflorescence (10.30%) while, remaining characters showed low estimate of heritability in narrow-sense (h^2_{ns}).

In case of over pooled, high estimate of heritability in narrow-sense was recorded for fruit length (84.60%) and fruit circumference (80.30%) while, moderate estimate of heritability in narrow sense was observed for dry matter content (28.30%), plant height (13.20%) and leaf width (12.70%)while, remaining characters showed low estimate of heritability in narrow-sense (h^2_{ns}).

In Y_1, high estimate of genetic advance in per cent of mean (>20%) was observed for average fruit weight (89.58%). Moderate estimate of genetic advance in percent of mean (10-20%) was observed for plant height (13.23%) followed by days to 50% flowering (11.84%),fruit length (10.92%) and fruit circumference (10.38%),while, remaining characters showed low estimate of genetic advance in per cent of mean.

In Y_2, high estimate of genetic advance in per cent of mean (>20%) was observed for average fruit weight (88.38%). Moderate estimate of genetic advance in percent of mean (10-20%) was observed for plant height (16.43%) followed by days to 50% flowering (11.73%),fruit length (11.10%) and fruit circumference (10.41%),while, remaining characters showed low estimate of genetic advance in per cent of mean.

In over pooled, high estimate of genetic advance in per cent of mean (>20%) was observed for average fruit weight (88.46%). Moderate estimate of genetic advance in percent of mean (10-20%) was observed for plant height (15.33%) followed by days to 50% flowering (11.82%),fruit length (11.03%) and fruit circumference (10.41%),while, remaining characters showed low estimate of genetic advance in per cent of mean.

The knowledge of heritability of a character is important to the breeder since it indicates the possibility and extent to which improvement is possible through selection (Robinson *et al.*, 1949) [14]. Heritability, which denotes the proportion of additive genetic variance to the total variability, is a measure of genetic relationship between parents and progeny and has been widely used in determining the degree to which character may be transmitted from parent to offspring. Singh *et al.* (2005) [17] pointed out that the heritability in combination with intensity of selection and amount of variability present in the population influences the gains to be obtained from selection. Since the genetic gain is yet another important selection parameter which is although independent and represents the expected genetic gain under selection. It measures the differences between the mean genotypic values of the selected lines and means genotypic value of base population from which these lines were selected. Thus, it is necessary to utilize the heritability in conjunction with selection differential, which would indicate the expected genetic gain. The estimate of heritability with genetic advance as per cent of mean provides a better picture to the breeders during the process of selection.

Table 1: Analysis of variance (RBD) for 15 characters of line × tester set of crosses and their parents in brinjal (Y_1=2017-18 and Y_2=2018-19)

Sources of variation	Years	*Df*	Days to 50 % flowering	Number of flowers per inflorescence	Leaf length (cm)	Leaf width (cm)	Number of primary branches per plant	Plant height (cm)	Number of fruits percluster	Fruit length (cm)
Replications	Y_1	2	1.60	1.66	29.22	0.85	0.60	289.75	0.056	0.13
	Y_2	2	1.33	0.032	1.19	0.42	0.015	4.06	0.023	0.40
Parents	Y_1	15	108.98**	1.16**	19.41**	3.53**	0.20**	186.19**	0.024	99.26**
	Y_2	15	106.35**	1.14**	19.17**	2.96**	0.19*	192.82**	0.035	104.50**
Parents (Line)	Y_1	11	110.47**	0.50	20.17**	2.79**	0.11	227.84**	0.029	91.26**
	Y_2	11	107.89**	0.63**	20.24**	2.54**	0.091	236.16**	0.040**	89.33**
Parents (Testers)	Y_1	3	68.97**	0.22	18.41**	7.31**	0.38**	79.71**	0.0044	153.77**
	Y_2	3	62.77**	0.85**	17.21**	5.38**	0.50**	79.82**	0.0099	184.44**
Lines *vs* Testers	Y_1	1	212.67**	11.22**	13.98**	0.30	0.66**	47.43**	0.027	23.83**
	Y_2	1	220.03**	7.70**	13.28**	0.24	0.39**	55.09**	0.062**	31.35**
Crosses	Y_1	47	105.61**	0.57	7.11**	2.42**	0.31**	128.11**	0.055**	84.19**
	Y_2	47	105.24**	0.66*	7.70**	4.10**	0.34**	129.91**	0.053**	87.82**
Parents vs Crosses	Y_1	1	154.17**	10.78**	36.86**	2.95**	0.22**	4324.09**	0.25**	0.28
	Y_2	1	113.79**	6.76**	8.77**	22.19**	0.78**	4126.21**	0.022	0.084
Error	Y_1	126	1.24	0.57	4.78	0.80	0.12	26.44	0.034	0.38
	Y_2	126	1.35	0.019	0.44	0.15	0.011	2.32	0.010	0.31

Table 1: Contd…

Sources of variation	Years	*Df*	Fruit circumference (cm)	Number of fruits per plant	Average fruit weight (g)	Specific gravity	Dry matter content	TSS (%)	Fruit yield per plant (kg)
Replications	Y_1	2	2.09	3.54	2.75	0.0004	0.063	0.083	0.050
	Y_2	2	0.21	0.065	6.08	0.0043	0.33	0.11	0.0075
Parents	Y_1	15	81.44**	13.17**	5938.45**	0.046**	1.74**	0.78**	1.01**
	Y_2	15	82.14**	13.69**	5963.33**	0.045**	1.75**	0.79**	1.00**
Parents (Line)	Y_1	11	80.20**	17.21**	3229.36**	0.051**	1.61**	0.77**	0.81**
	Y_2	11	80.18**	17.99**	3250.44**	0.050**	1.65**	0.78**	0.81**
Parents (Testers)	Y_1	3	112.31**	0.31	8019.55**	0.041**	2.01**	1.00**	1.10**
	Y_2	3	115.66**	0.28**	7938.87**	0.041**	1.95**	1.02**	1.05**
Lines *vs* Testers	Y_1	1	2.37**	7.33**	29495.16**	0.0002	2.35**	0.28**	2.97**
	Y_2	1	3.23**	6.63	29885.66**	0.0001	2.28**	0.18**	3.01**
Crosses	Y_1	47	77.81**	27.02**	5962.89**	0.040**	2.64**	1.51**	1.82**
	Y_2	47	77.59**	27.88**	5731.75**	0.038**	3.17**	1.49**	1.88**
Parents vs Crosses	Y_1	1	13.92**	95.22**	1107.43**	0.023**	3.45**	3.42**	4.20**
	Y_2	1	18.02**	101.07**	1728.81**	0.024**	4.58**	3.70**	4.67**
Error	Y_1	126	0.38	0.92	4.05	0.0012	0.041	0.036	0.040
	Y_2	126	0.11	0.15	6.67	0.00089	0.21	0.045	0.0028

*, ** Significant at 5% and 1% probability levels, respectively.

Table 2: Analysis of variance (Pooled) for 15 characters of line × tester set of crosses and their parents in brinjal

Sources of variation	*df*	Days to 50 % flowering	Number of flowers per inflorescence	Leaf length (cm)	Leaf width (cm)	Number of primary branches per plant	Plant height (cm)	Number of fruits percluster	Fruit length (cm)
Locations	1	290.50**	1.21**	56.58**	52.61**	1.05**	335.25**	0.23**	6.18**
Replicates	4	1.46	0.85	15.20	0.63	0.31	146.87	0.039	0.27
Parents	15	214.84**	2.25**	38.54**	6.36**	0.35**	379.12**	0.057	203.45**
Female	11	217.78**	1.13**	40.38**	5.32**	0.14**	464.19**	0.067	180.50**
Male	3	131.48**	0.87**	35.56**	12.31**	0.88**	159.42**	0.013	337.05**
Female vs Male	1	432.66**	18.75**	27.27**	0.00073**	1.03**	102.45**	0.086	55.11**
Crosses	47	210.04**	1.23**	14.34**	6.09**	0.48**	257.44**	0.10	171.96**
Parent vs Crosses	1	266.40**	17.30**	40.80**	20.66**	0.92**	8449.25**	0.21	0.033
Parents× Locations	15	0.48	0.059	0.045	0.13	0.051	-0.088**	0.0023	0.31
Female × Locations	11	0.59	0.010	0.045	0.025	0.066	-0.16	0.0027	0.092
Male × Locations	3	0.26	0.20	0.059	0.39	0.0048	0.10	0.00055	1.16**
(FvsM) × Locations	1	0.037	0.16	0.0098	0.55	0.018	0.16	0.0034	0.27
Crosses× Locations	47	0.81	0.015	0.48	0.43	0.17	0.56	0.0029	0.060
(PARvsCRO) × Locations	1	1.59	0.23	4.79**	4.45**	0.084	1.25	0.065	0.31
ERROR	252	1.30	0.29	2.61	0.48	0.070	14.38	0.022	0.35

Table 2: Contd….

Sources of variation	*Df*	Fruit circumference (cm)	Number of fruits per plant	Average fruit weight (g)	Specific gravity	Dry matter content	TSS (%)	Fruit yield per plant (kg)
Locations	1	12.31**	8.86**	1286.00**	0.0012	0.55**	0.43**	0.30**
Replicates	4	1.15	1.80	4.50	0.0023	0.19	0.097	0.028
Parents	15	163.52**	26.85**	11901.95**	0.091	3.50**	1.58**	2.01**
Female	11	160.31**	35.18**	6479.75**	0.10	3.26**	1.56**	1.62**
Male	3	227.95**	0.59	15957.15**	0.082	3.97**	2.03**	2.15**
Female vs Male	1	5.57**	13.95**	59380.56**	0.00029	4.64**	0.45**	5.98**
Crosses	47	155.34**	54.82**	11590.82**	0.078	5.69**	2.99**	3.70**
Parent vs Crosses	1	31.81**	196.25**	2801.87**	0.047	8.01**	7.12**	8.87**
Parents × Locations	15	0.063	0.017	0.40	0.000054	-0.0018	0.0022	0.00049
Female × Locations	11	0.076	0.019	0.13	0.000072	-0.0027	0.0020	0.00059
Male × Locations	3	0.029	0.012	1.29	0.0000019	0.00026	0.0016	0.00030
(FvsM) × Locations	1	0.028	0.0095	0.67	0.0000053	0.0015	0.0064	-0.000027
Crosses× Locations	47	0.064	0.081	103.76**	0.00046	0.13**	0.0011	0.0033
(PARvsCRO) × Locations	1	0.087	0.030	35.12**	-0.00027	0.036	0.00069	0.0056
ERROR	252	0.25	0.53	5.34	0.0010	0.081	0.040	0.021

*, ** Significant at 5% and 1% probability levels, respectively

Table 3: Components of genetic variance, average degree of dominance, predictability ratio and heritability in narrow sense for 15 characters in brinjal over two years and pooled

Parameters / Characters	gca variance (σ^2g)			sca variance (σ^2s)			Average degree of dominance $\sqrt{\sigma^2s/2\sigma^2g}$			Predictability ratio		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Days to 50% Flowering	0.97	1.28	1.12	27.35**	26.40**	26.99**	3.75	3.22	3.47	0.067	0.089	0.078
Number of Flower per Influrencence	0.0063	0.014	0.0098	0.00	0.24**	0.17	0.10	2.83	2.92	1.00	0.12	0.011
Leaf Length(cm)	0.13	0.030	0.11	1.10	2.34**	2.07	2.09	6.25	3.00	0.19	0.025	0.10
Leaf Width(cm)	0.036	0.19**	0.074	0.048	0.72**	0.66	0.83	1.38	2.09	0.60	0.35	0.19
Number of primary branches per plant	0.00	0.0021*	0.00071	0.06	0.11**	0.07	0.24	0.33	2.65	0.00	0.00	0.13
Plant Height(cm)	3.93	3.69	3.78	25.41**	36.11**	33.41**	1.80	2.22	2.10	0.24	0.17	0.19
Number of Fruit per Cluster	0.0018	0.0024	0.0021	0.01	0.01	0.01	0.10	0.10	0.10	0.00	0.00	0.00
Fruit length(cm)	20.66**	21.61**	21.13**	7.23**	7.53**	7.42**	0.42	0.42	0.42	0.86	0.86	0.86
Fruit Cercum ference	17.78**	17.56**	17.66**	8.39**	8.49**	8.47**	0.48	0.50	0.48	0.81	0.81	0.81
Number of Fruit per plant	0.24**	0.28**	0.27**	9.23**	9.42**	9.35**	4.46	4.04	4.25	0.049	0.058	0.053
Average fruit weight	28.65**	13.97**	23.31**	2020.21**	1942.03**	1963.48**	5.91	8.34	6.64	0.028	0.015	0.023
Specific gravity	0.00046	0.00040*	0.00044	0.01**	0.01**	0.01**	0.10	0.10	0.10	0.00	0.00	0.00
Dry matter content	0.10*	0.14**	0.12**	0.56**	0.66**	0.60**	1.68	1.49	1.55	0.27	0.32	0.30
total Soluble Solids	0.029	0.014**	0.030*	0.44**	0.44**	0.44**	2.71	2.71	6.27	0.12	0.12	0.12
Fruit Yield per plant (kg)	0.016**	0.018**	0.017**	0.60**	0.63**	0.61**	4.48	3.97	3.91	0.048	0.060	0.062

Table 3: Contd......

Parameters / Characters	Σ ²A			σ^2D			Heritability (h^2ns %)			Genetic advance in per cent of mean		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Days to 50% Flowering	1.95	2.56	2.25	27.35	26.40	26.99	6.37	8.37	7.33	11.84	11.73	11.82
Number of Flower per Influrencence	0.01	0.03	0.020	0.00	0.24	0.17	1.72	10.30	4.00	0.22	1.05	0.75
Leaf Length(cm)	0.25	0.06	0.23	1.10	2.34	2.07	4.5	2.47	5.18	1.55	3.49	2.81
Leaf Width(cm)	0.07	0.38	0.15	0.048	0.72	0.66	8.25	33.90	12.70	1.08	2.23	1.68
Number of primary branches per plant	0.00	0.00	0.01	0.06	0.11	0.07	0.00	0.00	6.67	0.26	0.61	0.31
Plant Height(cm)	7.85	7.38	7.57	25.41	36.11	33.41	12.30	16.20	13.20	13.23	16.43	15.33
Number of Fruit per Cluster	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.06	0.17	0.16
Fruit length(cm)	41.32	43.21	42.26	7.23	7.53	7.42	84.40	85.00	84.60	10.92	11.10	11.03
Fruit Cercumference	35.56	35.13	35.34	8.39	8.49	8.47	80.30	80.50	80.30	10.38	10.41	10.41
Number of Fruit per plant	0.47	0.58	0.52	9.23	9.42	9.35	4.65	5.79	5.16	5.44	5.79	5.68
Average fruit weight	57.30	27.93	44.61	2020.21	1942.03	1963.48	2.75	1.41	2.22	89.58	88.38	88.46
Specific gravity	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.23	0.23	0.23
Dry matter content	0.20	0.30	0.25	0.56	0.66	0.60	24.90	30.60	28.3	1.78	1.83	1.80
total Soluble Solids	0.06	0.06	0.06	0.44	0.44	0.44	11.20	12.00	11.60	1.30	1.28	1.31
Fruit Yield per plant (kg)	0.03	0.04	0.04	0.60	0.63	0.61	4.48	5.96	5.98	1.44	1.53	1.50

Y_1=2017-18 and Y_2=2018-19

In this study high estimate of heritability in narrow-sense was recorded for fruit length and fruit circumference in Y_1, fruit length followed by fruit circumference, leaf width, and dry matter content in Y_2 and fruit length and fruit circumference in over pooled (Table-4.10), suggested that selection would be highly effective and efficient. Similar finding for high estimate of narrow sense heritability for different brinjal traits have been also reported by Chaudhary, D. R. (2001) [3], Singh *et al*. (2011) [16], Sharma and Swaroop (2000) [15] and Das *et al*. (2002) [4]. Moderate estimate of heritability in narrow sense was observed for dry matter content, plant height and total soluble solidsin Y_1, plant height, total soluble solids and number of flowers per inflorescence in Y_2 and matter content, plant height and leaf width in over pooled. Similar finding for moderate estimate of narrow sense heritability for different brinjal traits have been also reported by previous workers (Prasad *et al*. (2004) [12] and Kaur and Thakur 2007) [7].

High estimate of genetic advance in per cent of mean (>20%) was observed for average fruit weight in both the years and over pooled. Moderate estimate of genetic advance in per cent of mean was observed for plant height, days to 50% flowering, fruit length, fruit circumference in both the years and over pooled. Similar results had also been reported by earlier workers (Lohakare *et al*. (2008) [10]; Mishra *et al.* (2008) [11]; Dhameliya and Dobariya (2008) [5] and Ansari *et al.* (2011) [2].

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