

Genetic analysis of biparental progenies in eggplant, *Solanum melongena* L

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ABSTRACT

Genetic analysis was performed on progenies developed in F_2 generation of an inter-varietal cross Arka Keshav x Bhola Nath of brinjal, *Solanum melongena* L using North Carolina Design-1. The experiment was conducted during Kharif (April-November) 2012 and 2013 in randomized block design (RBD) with three replications at experimental farm of Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Biparental progenies were superior in mean performance than were F_3 s. Dominance variances were greater than additive variance for most characters. For fruit diameter, plant height, branches per plant and total soluble solids additive component of genetic variance was of higher magnitude. The average degree of dominance was in over-dominance range for most traits. Plant height, number of branches per plant, fruit diameter and total soluble solids were in the partial dominance range. Heritability estimates were generally low to medium. Fruit weight exhibited moderate to high heritability. The pre-ponderance of additive and non-additive genetic components of variance for most traits indicated role for additive and non-additive gene action for inheritance of marketable fruit yield and its component traits. These could be utilized through recurrent selection and heterosis breeding for the development of high yielding and quality cultivars in eggplant.

Keywords: Biparental progenies; gene action; brinjal; North Carolina Design-1

INTRODUCTION

Brinjal, *Solanum melongena* L also called as egg plant or aubergine is a member of family Solanaceae and one of the most commonly grown vegetables all the year round in the country. It is an autogamous crop adapted to wide climatic range and exhibit variation in colour, size and shape of the fruit (Hazra et al 2011). India is considered to be the centre of origin of

brinjal (Zeven and Zhukovsky 1975) with secondary diversity in China and southeast Asia (Nath et al 1987). It is grown commercially as fresh market crop especially in low and mid-hill areas of Himachal Pradesh. In spite of its economic importance no major strive has so far been made for the improvement of yield and quality traits in this crop. Based on these considerations the present investigation was therefore undertaken to obtain information

on the nature and quantum of genetic variability generated through the biparental mating along with association of characters in biparental vis a vis F_3 progenies and to study the genetic architecture of biparental progenies as inferred from the analysis for different traits such as marketable fruit yield per plant, days to 50 per cent flowering, days to first picking, number of marketable fruits per plant, fruit length, fruit diameter, average fruit diameter, plant height, number of branches per plant, fruit weight, pedicel length, total soluble solids, bacterial wilt incidence, dry matter content, iron and phenol content in an inter-varietal cross by following a biparental mating North Carolina Design-I proposed by Comstock and Robinson (1948, 1952) involving contrasting parents.

In eggplant general breeding procedure is to select desired segregants in the F_2 population and make plant to row selection in subsequent generations. Genes for desirable characters are rapidly fixed in a homozygous state in this procedure. However improvement by this method of breeding besides being slow is limited for desirable recombinations among linked genes due to rapid approach to homozygosity (Humphrey et al 1989). Routine breeding procedures are inadequate to explore the range of useful existing genetic variability and impose restrictions on the chances of better recombinations and also associated with the weakness of causing rapid homozygosis and

low genetic variability. Biparental mating on the other hand is expected to break larger linkage blocks and provides more chances for recombination to occur. It is a useful system of mating for generation of increased variability and may be applied where desired variation for traits of interest is lacking. In view of the above facts an attempt has been made in the present study to compare the performance of biparental progenies with the selfed generation in releasing genetic variability. Variability generated by breaking undesirable linkages in this way can be effectively utilized in the subsequent generations. This project was undertaken to use biparental progenies as a tool for creating genetic variability in eggplant.

MATERIAL and METHODS

The investigation was undertaken at the experimental farm of Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, HP, India during the Kharif season of 2012 and 2013. The experimental material was developed from an inter-varietal cross between Arka Keshav x Bhola Nath (AK x BN) as parents which were selected on the basis of contrasting characters.

Biparental progenies were developed in the F_2 generation of inter-varietal cross using North Carolina Design-I (NCD-1) (Comstock and Robinson

1948, 1952). The biparental progenies were developed by designating 4 F_2 plants as male parents and crossing each of these to 4 plants selected as females. The plants used as males and females were chosen at random for development of biparental progenies and no seed parent was used in more than one mating. Plants used in making biparental progenies were also selfed. There were 16 progenies (4 in each male group). Twenty F_3 families were developed by selfing (4 males and 16 females). The experiment comprised 3 sets, a total of 48 biparental progenies and 60 F_3 families. Materials were evaluated in randomized block design with 3 replications and observations were recorded for marketable fruit yield per plant, days to 50 per cent flowering, days to first harvest, number of marketable fruits per plant, fruit length, fruit diameter, average fruit diameter, plant height, number of branches per plant, fruit weight, pedicel length, total soluble solids, bacterial wilt incidence, dry matter content and iron and phenol contents.

The Vegetable Research Farm of CSK HPKV, Palampur is situated at an elevation of about 1290 meters amsl with 32°6' North latitude and 76°3' East longitude representing mid-hill zone of Himachal Pradesh and has a sub-temperate climate with high rainfall during monsoon season. The soil of this zone is silt clay loam with acidic reaction. The biparental progenies (BIPs) and F_3 progenies were

grown in randomized block design (RBD) with three replications. Each experimental plot consisted of two rows of 2.70 m length for biparental and F_3 progenies with inter- and intra-plant distance of 60 cm and 45 cm respectively. These progenies were arranged in three sets, each comprising sixteen BIPs and twenty F_3 progenies. The sets and progenies within the sets were randomized separately. In addition six rows of each F_2 , two rows each of the original parents and F_1 s were also included in each replication for making comparisons. The F_2 seeds of inter-varietal cross Arka Keshav x Bhola Nath (AK x BN) obtained from crosses attempted during Kharif 2012 were sown during March 2012. This material was used to produce seeds of biparental and F_3 progenies. The seeds of F_1 were also obtained by making fresh crosses. The final experiment was conducted during Kharif 2013 with the experimental material comprising parents (P_1 , P_2), F_1 , F_2 , BIPs and F_3 generations.

Transplanting was done after six weeks after thoroughly ploughing and levelling the field. Farm yard manure @ 20 tons/ha was added in the soil at the time of field preparation. The chemical fertilizers were applied in the soil before transplanting the crop as per recommended package of practices (100 kg N, 75 kg P_2O_5 and 50 kg K_2O /ha). One third of N and full dose of P_2O_5 and K_2O were applied before transplanting. Remaining two-third N was top-dressed in

equal doses after 30 and 45 days after transplanting. The intercultural operations were carried out as per recommended package of practices. Regular weeding was carried out to keep the experimental field free from weeds and plant protection measures were adopted to raise a healthy crop.

The method of analysis of variance as proposed by Comstock and Robinson (1948, 1952) was used. The standard errors of $\sigma^2 m$ and $\sigma^2 f$ were calculated by the formula of Moll et al (1960). The standard errors of $\sigma^2 A$ and $\sigma^2 D$ were calculated as per the method of Panse and Sukhatme (1984). Expected gains from full-sib family selection were calculated according to Robinson et al (1949). An approximate procedure was used to estimate the expected gains from mass selection (Goodman 1965).

RESULTS and DISCUSSION

Analysis of variance for 48 biparental and 60 F_3 progenies revealed that the mean squares for BIPs in sets and F_3 progenies in sets were significant for all the characters (Table 1 and 2). The mean squares for males in sets and females in males in sets in BIPs were also found to be significant for all the characters (Table 2). These results suggest that the breeding material possesses high amount of genetic diversity amongst the populations.

Additive genetic variance, dominance and average degree of dominance were estimated from component analysis in 48 biparental progenies for various traits (Table 3). In this study certain additive and dominance variation was found to be negative. Such negative estimates are not unusual and have been reported by a number of workers earlier in maize, cauliflower, garden pea and other crops (Dadlani et al 1983, Chand et al 1984, Lal et al 1990, Kalia and Sharma 1998). Variance being quadratic quantities can never be negative. It is therefore reasonable to conclude that true values might be small and positive. According to the above workers and also by Obilana et al (1979) the negative estimates could be due to factors such as sampling variance, assortative mating, linkage effects, estimates of genotypic environmental interaction, deficiency in the genetic model and estimates of actual zero values. In the present study also the negative variance could be attributed to above factors resulting in bias estimates of total genetic variance as the experiment was conducted at one location during one season only. A perusal of components of variances (Table 3) revealed that variances due to males and additive genetic variances were non-significant for most of the characters except for fruits per plant, average fruit diameter, plant height and branches per plant in cross Arka Keshav x Bhola Nath (AK x BN). The variances due to females and dominance variances were however

Table 1a. Analysis of variance for various traits in biparental progenies of the cross Arka Keshav x Bhola Nath (AK x BN)

Source	df	Mean square									
		Marketable yield/plant	Days to 50% flowering	Days to first picking	# marketable fruits/plant	Fruit length	Fruit diameter	Average fruit diameter	Plant height		
Sets	2	0.02	101.01	188.47	46.91	9.33	0.01	0.38	117.45		
Replication in sets	6	0.01	1.85	8.71	1.52	0.87	0.19	0.26	12.42		
BIPs in sets	45	0.02*	52.22*	70.48*	29.73*	11.04*	1.07*	0.95*	91.72*		
Males in sets	9	0.02*	88.21*	133.72*	51.05*	17.65*	1.22*	1.32*	116.68*		
Females in males in sets	36	0.01*	43.22*	54.67*	33.65*	9.39*	1.03*	0.86*	85.48*		
Remainder among Plots	90	0.09	1.79	3.86	0.76	0.56	0.24	0.14	6.27		

*Significant at P <0.05

Table 1b. Analysis of variance for various traits in biparental progenies of the cross Arka Keshav x Bhola Nath (AK x BN)

Source	df	Mean square									
		# branches /plant	Fruit weight	Pedicle length	Total soluble solids	Dry matter content	Iron content	Phenol content	Bacterial wilt incidence		
Sets	2	3.98	276.07	0.51	1.08	3.33	0.35	394.24	36.69		
Replication in sets	6	0.55	4.66	2.32*	0.24	0.89	0.01	6.58	2.88		
BIPs in sets	45	1.12*	65.77*	1.12*	0.62*	0.90*	1.02*	109.17*	20.46*		
Males in sets	9	1.39*	51.76*	1.39*	0.61*	1.91*	0.32*	198.55*	44.35*		
Females in sets	36	1.04*	69.28*	1.05*	1.04*	0.65*	0.98*	86.82*	14.48*		
Remainder among plots	90	0.76	5.02	0.80	0.87	1.36	0.00	5.74	1.44		

*Significant at P <0.05

Table 2a. Analysis of variance for various traits in F₋₃ progenies of the cross Arka Keshav x Bhola Nath (AK x BN)

Source	df	Mean square							
		Marketable yield/plant	Days to 50% flowering	Days to first picking	# marketable fruits/plant	Fruit length	Fruit diameter	Average fruit diameter	Plant height
Sets	2	0.41	97.05	82.79	21.29	21.02	10.88	10.08	690.80
Replication in sets	6	0.001	0.83	3.86	0.12	1.71	0.13	0.17	13.64
F ₃ progenies in sets	57	0.49*	16.56*	24.08*	3.23*	5.66*	0.58*	0.56*	66.92*
Remainder among plots	114	0.002	3.74	4.68	1.12	1.69	0.23	0.23	17.18

*Significant at P < 0.05

Table 2b. Analysis of variance for various traits in F₋₃ progenies of the cross Arka Keshav x Bhola Nath (AK x BN)

Source	df	Mean square							
		# branches /plant	Fruit weight	Pedicel length	Total soluble solids	Dry matter content	Iron content	Phenol content	Bacterial wilt incidence
Sets	2	2.15	206.11	0.23	2.02	0.63	0.004	188.81	98.18
Replication in sets	6	0.38	6.90	0.39	0.12	0.90	0.001	24.40	1.36
F ₃ progenies in sets	57	1.22*	23.74*	0.41*	0.62*	0.87*	0.24*	64.95*	9.31*
Remainder among plots	114	0.31	5.48	0.17	0.31	0.52	0.002	15.68	2.17

*Significant at P < 0.05

Table 3. σ^2m , σ^2f , σ^2A , σ^2D and average degree of dominance for various characters in cross Arka Keshav x Bhola Nath (AK x BN)

Character	σ^2m	σ^2f	σ^2A	σ^2D	Average degree of dominance
Marketable fruit yield/plant (kg)	0.01 $\pm$ 0.03	0.02* $\pm$ 0.01	0.041 $\pm$ 0.03	0.063* $\pm$ 0.06	1.24
Days to 50% flowering	3.75 $\pm$ 3.24	13.81* $\pm$ 3.31	14.99 $\pm$ 12.96	40.24* $\pm$ 18.52	1.64
Days to first picking	6.59 $\pm$ 4.86	16.94* $\pm$ 4.18	26.35 $\pm$ 19.46	41.39* $\pm$ 25.66	1.25
# marketable fruits/plant	3.59 $\pm$ 0.40	6.52* $\pm$ 0.74	14.37* $\pm$ 1.60	11.72 $\pm$ 3.36	0.90
Fruit length (cm)	0.69 $\pm$ 0.65	2.95* $\pm$ 0.71	2.75 $\pm$ 2.60	9.02* $\pm$ 3.88	1.81
Fruit diameter (cm)	0.02 $\pm$ 0.04	0.27* $\pm$ 0.07	0.06 $\pm$ 0.19	0.99* $\pm$ 0.37	4.06
Average fruit diameter (cm)	0.20* $\pm$ 0.04	0.24* $\pm$ 0.06	0.79* $\pm$ 0.33	0.15 $\pm$ 0.13	0.44
Plant height (cm)	23.80* $\pm$ 4.45	26.40* $\pm$ 6.54	95.20* $\pm$ 31.67	10.40* $\pm$ 9.82	0.33
# branches/plant	0.11* $\pm$ 0.02	0.15 $\pm$ 0.08	0.49* $\pm$ 0.09	0.16 $\pm$ 0.21	0.57
Fruit weight (g)	1.46 $\pm$ 1.26	24.34* $\pm$ 5.30	5.84 $\pm$ 4.06	91.51* $\pm$ 23.07	3.96
Pedicle length (cm)	0.03 $\pm$ 0.02	0.09 $\pm$ 0.08	0.11 $\pm$ 0.10	0.22 $\pm$ 0.21	1.41
Total soluble solids (%)	0.00 $\pm$ 0.02	-0.14* $\pm$ 0.06	-0.00 $\pm$ 0.09	-0.56 $\pm$ 0.29	\$
Dry matter content (%)	0.10 $\pm$ 0.06	-0.24* $\pm$ 0.08	0.42 $\pm$ 0.27	-1.37* $\pm$ 0.43	\$
Iron content (mg/100 g)	0.001 $\pm$ 0.00	0.006* $\pm$ 0.001	0.005 $\pm$ 0.002	0.014* $\pm$ 0.005	1.67
Phenol content (mg/100 g)	9.31 $\pm$ 7.24	27.03* $\pm$ 6.64	37.24 $\pm$ 28.99	70.86 $\pm$ 39.33	1.38
Bacterial wilt incidence (%)	1.86 $\pm$ 1.60	4.35* $\pm$ 1.10	7.43 $\pm$ 7.08	9.95* $\pm$ 6.40	1.16

*Significant at P < 0.05

significant for most of the characters. Additive component of genetic variance was found to be of higher magnitude in case of number of marketable fruits per plant, average fruit diameter, plant height and branches per plant in Arka Keshav x Bhola Nath (AK x BN).

For the remaining traits dominance variance was greater than additive genetic variance. Although significant non-additive effects for various traits have also been revealed by several other studies in different crops yet estimates of dominance as well as the average degree of dominance in the analysis of NCD-1 as in case of present study are likely to be biased due to genic interactions (Comstock and Robinson 1952). Moreover as recognized by Gardner et al (1953) the over-dominance estimates could result from repulsion phase linkages involving genes no more than partially or completely dominant. It may also be pointed out that superior performance of BIPs over F_3 could also be the result of considerable heterozygosity (heterotic effects) in BIPs and that of in breeding depression in the F_3 progenies. The importance of additive genetic variance for fruit length, fruit weight, plant height, number of branches per plant, fruits per plant, number of days to flowering, yield per plant, fruit diameter, days to first flowering and average fruit weight in brinjal was observed by Singh and Kumar (2005), Golani et al (2007), Kaur and Thakur (2007), Dhameliya and Dobariya (2009), Thangavel et al (2011)

and Arunkumar et al (2013). Preponderance of dominance and non-additive genetic variance for yield per plant, number of days to flowering, number of branches, fruit length, fruit weight, plant height, number of marketable fruits per plant, plant spread in brinjal and fruit diameter was observed by Indiresht et al (2005) and Kaur and Thakur (2007). However Peter and Singh (1976), Dharmegowda (1977) and Dixit et al (1984) observed that both additive and non-additive genetic variance were almost equally important for yield and its component traits in brinjal. Such controversial reports are also available in wheat (Gill et al 1973), watermelon (Partap et al 1984), cauliflower (Chand et al 1984, Lal et al 1990), garden pea (Kalia and Sharma 1998) and muskmelon (Singh and Vashisht 2015). The discrepancies in the earlier and the present studies could be attributed to the differences in material tested and also to the different environmental conditions sampled for these genetic studies.

The estimates of average degree of dominance (Table 3) indicated the presence of over-dominance for marketable fruit yield per plant, days to 50 per cent flowering, days to first picking, fruit length, fruit diameter, fruit weight, pedicel length, iron content, phenol content and bacterial wilt incidence. These estimates however revealed partial dominance for number of marketable fruits per plant, average fruit diameter, plant height and branches per

plant in cross Arka Keshav x Bhola Nath (AK x BN). Chadha and Hegde (1987) and Kaur and Thakur (2007) also confirm the similar findings for yield and other characters in brinjal.

The estimate of heritability (Table 4) was high for number of marketable fruits per plant, average fruit diameter, plant height and number of branches per plant in cross Arka Keshav x Bhola Nath (AK x BN). The average estimate of heritability was however observed for days to 50 per cent flowering, fruit length, fruit weight, bacterial wilt incidence and iron content. The estimates of heritability were low for the remaining traits. These estimates were in general low in both the crosses. The reason may be the presence of higher value of dominance variance for most of the characters. For improvement of characters of high as well as low heritability in brinjal, inter-mating in early generations coupled with selection would be most appropriate as suggested by Singh and Dwivedi (1978) and Kingshlin et al (1996) in wheat and pigeonpea respectively.

In brinjal moderate to high estimates of heritability have earlier been reported for fruit yield per plant (Singh and Kumar 2005, Dhameliya and Dobariya 2007, Kaur and Thakur 2007), days to flowering (Thangavel et al 2011), plant height, fruits per plant, fruit length, fruit diameter, fruit weight and number of branches per plant (Golani et al 2007, Kaur

and Thakur 2007, Dhameliya and Dobariya 2009). Low to moderate estimates of heritability on the other hand were reported for yield per plant, fruit girth and plant height (Thangavel et al 2011) in brinjal. Full-sib family selection was always superior to mass selection for all the characters (Table 4). The predicted genetic gain for full-sib family selection indicated considerable improvement in marketable fruit yield per plant (4.04%). Full-sib family selection may be more effective as compared to mass selection which is based on the phenotype alone because additive genetic variances may be more profitably exploited in the full-sib family selection. Thus the material generated from biparental approach as in the present study could be subjected to population improvement techniques later on.

In autogamous crops also like that of cross-pollinated ones, improvement can be affected through recurrent selection but because of certain physical and economic reasons this procedure has not been widely employed even though there is no genetic reason to exclude its use.

Some plant breeding comparisons for fruit yield per plant were made for the top 5 per cent BIPs and F_3 progenies with parents involved in the original crosses, F_1 s and F_2 s. Top 5 per cent BIPs were superior to top 5 per cent F_3 progenies as well as to those of corresponding F_1 s and F_2 s generations (Table 5). In inter-varietal cross Arka Keshav x Bhola Nath (AK x BN),

Table 4. Estimates of heritability and predicted genetic gain from one cycle of selection in cross Arka Keshav x Bhola Nath (AK x BN)

Character	Heritability in narrow sense (%)	Predicted genetic gains from one cycle of selection	
		Full-sib family selection (% of mean)	Mass selection (% of mean)
Marketable fruit yield/plant (kg)	8.54	4.04	2.03
Days to 50% flowering	15.87	3.68	1.59
Days to first picking	7.10	0.58	0.19
# marketable fruits/plant	52.27	4.08	1.07
Fruit length (cm)	20.75	3.48	1.43
Fruit diameter (cm)	25.21	6.12	2.10
Average fruit diameter (cm)	35.73	4.30	2.27
Plant height (cm)	66.35	5.98	1.88
# branches/plant	30.56	8.31	3.16
Fruit weight (g)	15.82	3.81	1.35
Pedicle length (cm)	7.56	2.31	1.16
Total soluble solids (%)	*	*	**
Dry matter content (%)	*	*	**
Iron content (mg/100g)	26.03	0.82	0.21
Phenol content (mg/100g)	9.01	6.35	4.10
Bacterial wilt incidence (%)	11.42	7.90	3.71

*Small negative estimate, **Not computed

Table 5. Average fruit yield/plant of different populations for plant breeding comparisons

Population	Average fruit yield/plant (kg)
Arka Keshav	0.77
Bhola Nath	0.63
F ₁ (Arka Keshav x Bhola Nath)	0.86
F ₂ (Arka Keshav x Bhola Nath)	0.81
Biparental progenies	1.02
F ₃ progenies	0.94

Table 6a. Mean performance of best biparental progenies for various traits

Biparental progenies	Marketable fruit yield/plant (kg)	Days to 50% flowering	Days to first picking	# fruits /plant	Fruit length	Fruit diameter	Average fruit diameter	Plant height
$M_2 \times F_6$	0.93	63.73	71.42	16.68	15.87	4.02	3.10	89.61
$M_2 \times F_{23}$	0.96	53.30	65.15	14.33	12.68	3.75	3.38	87.18
$M_4 \times F_{30}$	0.91	61.60	71.16	17.36	18.02	4.29	4.14	92.27
$M_1 \times F_{34}$	0.91	61.75	71.45	17.67	18.09	4.81	4.63	92.20
$M_2 \times F_{38}$	0.98	61.11	71.86	17.89	15.03	4.57	3.59	86.33
$M_3 \times F_{41}$	0.96	59.14	63.00	16.10	11.83	3.80	3.15	86.16
$M_4 \times F_{45}$	1.13	60.22	71.36	19.18	17.25	3.29	2.78	99.91

Table 6b. Mean performance of best biparental progenies for various traits

Biparental progenies	# branches/plant	Fruit weight	Pedicel length	Total soluble solids	Dry matter content	Iron content	Phenol content	Bacterial wilt incidence
$M_2 \times F_6$	7.89	58.88	4.41	8.23	8.45	0.85	23.81	9.38
$M_2 \times F_{23}$	6.79	50.84	5.17	8.05	7.49	0.81	40.36	8.61
$M_4 \times F_{30}$	8.40	60.10	5.44	8.39	8.45	0.76	38.30	5.55
$M_1 \times F_{34}$	8.26	61.12	6.03	7.61	8.43	0.85	37.67	6.06
$M_2 \times F_{38}$	8.49	57.76	5.31	8.16	8.49	0.82	34.01	9.68
$M_3 \times F_{41}$	7.71	60.39	5.08	8.33	8.90	0.67	36.70	4.63
$M_4 \times F_{45}$	7.79	61.42	4.43	7.70	9.70	0.96	40.73	2.67

the BIPs $M_2 \times F_6$, $M_2 \times F_{23}$, $M_4 \times F_{30}$, $M_1 \times F_{34}$, $M_2 \times F_{38}$, $M_3 \times F_{41}$ and $M_4 \times F_{45}$ showed high mean values (Table 6) for fruit yield, quality traits and yield contributing components. The outstanding combinations were $M_4 \times F_{45}$, $M_2 \times F_{38}$ and $M_2 \times F_{23}$ which recorded increase in marketable fruit yield to the tune of 46.75, 27.27, and 24.68 per cent; 79.36, 55.55 and 52.38 per cent and 31.39, 13.95 and 11.62 per cent over the respective parents, Arka Keshav (AK), Bhola Nath (BN) and the F_1 produced from them as well as 39.51, 20.99 and 18.52 per cent and 20.21, 4.26 and 2.13 per cent over F_2 and F_3 generations.

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