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Genetic architecture of biparental progenies for yield in Eggplant (*Solanum melongena* L.)

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Abstract: The type of gene action for yield and its components was determined using biparental progenies developed from the F_2 generation of an intervarietal cross Swarna Pratibha × Hisar Shyamal (SP × H-8) of eggplant (*Solanum melongena* L.) using North Carolina Design - 1. The experiment was conducted during the *Kharif* (April-November) 2012 and 2013. The biparental and F_3 progenies differed. Biparental progenies were superior in mean performance than were F_3's generated by selfing. Dominance variances were greater than additive variance for most characters. For fruit diameter, plant height, branches per plant and total soluble solid, the additive component of genetic variance was of higher magnitude. The average degree of dominance was in over-dominance range for most traits. Plant height, branches per plant, fruit diameter and total soluble solids was 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 reciprocal recurrent selection and heterosis breeding for the development of high yielding and quality cultivars in eggplant.

Keywords: Biparental progenies, Gene action, North Carolina Design – 1, *Solanum melongena* L.

INTRODUCTION

Eggplant (*Solanum melongena* L.) is an autogamous crop adapted to wide climatic range and exhibit variation in color, size and shape of the fruit (Hazra et al. 2011). India is considered to be the centre of origin (Zeven and Zhukousky 1975) with secondary diversity in China and South East Asia (Nath et al. 1987). In eggplant, the general breeding procedures 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, improvements by this method of breeding, besides being slow, are limited to desirable recombinations among linked genes due to the rapid approach to homozygosity (Humphrey et al. 1989). Routine breeding procedures are inadequate to explore the range of useful existing genetic variability for complex characters like yield. For overcoming these limitations, another breeding method involving crosses between randomly selected plants in populations having maximum genetic variability can be used. Variability generated by breaking undesirable linkages in this way can be effectively utilized in the subsequent generations (Singh and Sharma 1983).

Inter-mating of randomly selected F_2 plants (biparental mating) in early segregating generations would help create new populations with high frequencies of rare combinations and retain greater variability by breaking undesirable linkages, for selection to be effective for a longer period. This project was undertaken to use biparental progenies as a tool for creating genetic variability in eggplant (*Solanum melongena* L.).

MATERIALS AND METHODS

The investigation was undertaken at the Experimental Farm, Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (HP), India, during the *Kharif* seasons 2012 and 2013. The experimental material was developed from an intervarietal cross between Swarna Pratibha × Hisar Shyamal (SP × H-8) as parents which were selected on the basis of contrasting characters. Biparental progenies were developed in the F_2 generation of intervarietal 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

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were developed by selfing (4 males and 16 females). The experiment was comprised of 3 such sets, totalling 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% 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 observations were recorded on randomly taken five competitive plants in each entry for most of the traits except days to 50 per cent flowering and bacterial wilt incidence (plant survival) for which observations were recorded on plot basis.

The Vegetable Research Farm of CSKHPKV, Palampur is situated at an elevation of about 1290.8 meters above mean sea level with $32^0$6' North latitude and $76^0$3' East longitude, representing mid hills 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 (BIP's) and F_3 progenies were grown in Randomized Block Design (RBD) with three replications. Each experimental plot consisted of two rows of 2.70m 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 BIP's 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 intervarietal cross Swarna Pratibha x Hisar Shyamal (SP x H-8) 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, BIP's and F_3 generations.

Transplanting was done after six weeks after thoroughly ploughing and levelling of the field. Farm yard manure @ 20 t/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 were carried out to keep the experimental field free from weeds and plant protection measures adopted to raise a healthy crop.The method of analysis of variance was as proposed by Comstock and Robinson (1948, 1952). The standard errors of s^2 m (variance of male effect) and s^2 f (variance of female effect) were calculated by the formula of Moll et al. (1960). The standard errors of s^2_A (additive genetic variance) and s^2_D (dominance variance) were calculated using 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

The data of variability for the characters of eggplant (*Solanum melongena* ,generated through the North Carolina Design-I of mating, was studied through the parameters viz., range, mean, standard deviation and coefficient of variation is presented in Table 1. The additive genetic variance, dominance variance, average degree of dominance and heritability varied (Table 2, 3). Variances due to males and additive genetic variances were non-significant for most characters except for fruit diameter, plant height, branches per plant and total soluble solids. Variances due to females and dominance variances were, significant for most characters. 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).

Certain additive and dominance variation were negative, which is not unusual (Lal et al., 1990). Variance being a quadratic quantity can never be negative. It is, reasonable to conclude that true values might be small and positive. Negative estimates could be due to sampling variance, assortative mating, linkage effects, genotypic environmental interaction, deficiency in the genetic model and estimates of actual zero values (Obilana et al., 1979). Negative variance attributable to these factors may have resulted in biased estimates of total genetic variance, as the experiment was conducted at one location during one season only.

The over-dominance estimates could result from repulsion phase linkages involving genes no more than partially or completely dominant (Gardner et al., 1953). The superior performance of BIP's over F_3 could be the result of considerable heterozygosity in BIP's and of inbreeding depression in F_3 progenies. Conflicting reports on inheritance of yield and its component traits in eggplant exist. 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,

Table 1. Range, mean, standard deviation and coefficient of variation for different traits in biparental and F_3 progenies in cross Swarna Pratibha x Hisar Shyamal (SP x H-8)

Traits	Range		Mean		Standard deviation		Coefficient of variation (%)	
	BIP's	F_3	BIP's	F_3	BIP's	F_3	BIP's	F_3
Marketable fruit yield/plant (kg)	0.76-1.97	0.72-1.58	1.21	0.97	0.32	0.25	27.11	26.08
Days to 50% flowering	46.09-52.45	49.30-60.65	46.73	52.54	1.98	1.98	4.24	3.77
Days to first picking	51.53-72.66	52.54-67.37	62.42	64.85	1.39	1.72	2.23	2.65
Marketable fruits per plant	10.69-17.82	11.55-17.05	15.72	14.59	2.93	2.20	18.67	15.08
Fruit length (cm)	10.86-17.53	11.04-16.63	14.58	14.07	0.99	0.91	6.79	6.47
Fruit diameter(cm)	3.39-6.63	3.72-5.74	5.08	4.42	0.75	0.47	14.76	10.63
Average fruit diameter (cm)	2.73-6.15	3.57-4.56	4.75	3.82	0.64	0.18	13.47	4.71
Plant height (cm)	73.92-112.27	78.00-101.19	91.83	87.77	3.24	2.96	3.53	3.37
Number of branches per plant	5.65-10.03	6.93-9.46	9.48	8.34	0.91	0.87	9.25	10.43
Fruit weight (g)	47.55-93.48	51.21-77.81	67.25	60.68	5.25	4.19	7.81	6.91
Pedicel length (cm)	3.58-5.85	3.76-5.85	5.65	4.68	0.97	0.78	17.17	16.66
Total soluble solids (%)	6.56-9.28	7.15-8.56	8.19	7.99	0.49	0.72	5.98	9.94
Dry matter content (%)	7.10-9.77	7.11-9.66	8.49	7.55	0.33	0.99	3.89	13.11
Iron content (mg/100g)	0.86-0.95	0.76-0.96	0.90	0.86	0.20	0.16	22.22	18.74
Phenol content (mg/100g)	14.83-44.16	21.05-40.42	36.52	33.14	4.12	3.36	11.28	10.13
Bacterial wilt incidence (%)	2.17-14.78	2.83-13.91	8.54	11.47	2.47	2.89	28.92	25.20

Table 2. s^2m, s^2f, s^2A, s^2D and average degree of dominance for characters in the biparental progenies of Swarna Pratibha × Hisar Shyamal (SP × H-8) cross.

Character	s^2m	s^2f	s^2A	s^2D	Average degree of dominance
Marketable fruit yield/plant (kg)	0.08 ± 0.02	0.24* ± 0.01	0.32 ± 0.12	0.64* ± 0.11	1.41
Days to 50% flowering	0.112 ± 0.25	0.88* ± 0.30	0.33 ± 0.63	2.81* ± 1.89	1.69
Days to first harvest	0.23 ± 0.18	1.70* ± 0.54	0.91 ± 0.33	5.91* ± 1.82	2.53
Fruit per plant	1.61 ± 1.38	20.48* ± 5.65	4.45 ± 2.15	77.47* ± 23.52	4.17
Fruit length (cm)	0.04 ± 0.02	0.44* ± 0.49	0.16 ± 0.08	1.61* ± 0.22	3.17
Fruit diameter(cm)	1.35* ± 0.04	1.96* ± 0.16	5.41* ± 0.19	2.43* ± 0.67	0.67
Average fruit diameter (cm)	0.32 ± 0.05	0.89* ± 0.15	1.29 ± 0.22	2.27* ± 0.66	1.33
Plant height (cm)	20.73* ± 0.19	23.65* ± 4.14	82.95* ± 76.86	11.71* ± 0.65	0.14
Branches per plant	0.10 ± 0.11	0.17* ± 0.19	0.41* ± 0.03	0.29 ± 0.88	0.84
Fruit weight (g)	0.48 ± 0.26	6.32* ± 4.79	1.90 ± 0.04	23.37* ± 12.46	3.51
Pedicel length (cm)	0.006 ±0.01	0.086* ± 0.08	0.024 ± 0.15	0.32* ± 0.06	3.65
Total soluble solids (%)	0.10* ± 0.005	0.16* ± 0.008	0.39* ± 0.22	0.25 ± 0.20	0.64
Bacterial wilt incidence (%)	2.94 ± 3.11	6.34* ± 2.31	11.76 ± 12.47	13.61* ± 11.52	1.07
Dry matter content (%)	0.14 ± 0.09	0.31* ± 0.07	0.56 ± 0.36	0.67* ± 0.48	1.20
Iron content (mg/100g)	-0.001 ± 0.001	0.013* ± 0.002	-0.005 ± 0.004	0.05 ±0.01	$
Phenol content (mg/100g)	-0.33 ± 0.07	0.97* ± 16.93	-1.33 ± 17.08	2.56* ±82.49	$

* Significant at P < 0.05; $ Negative average degree of dominance resulting from negative estimates of additive genetic variance

days to first flowering and average fruit weight in eggplant has been reported by Negi et al. (2000), Singh and Kumar (2005), Golani et al. (2007), Kaur and Thakur (2007), Dhameliya and Dobariya (2009), Thangavel et al. (2011). Pre-ponderance 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 fruits per plant, plant spread and fruit diameter in eggplant has been reported by Indiresh et al. (2005) and Kaur and Thakur (2007). However, Peter and Singh (1976), Dharmegowda (1977) and Dixit et al. (1984) reported that both additive and non-additive genetic variance were almost equally important for yield and its component traits in eggplant. Such controversial reports also exist in wheat (Singh and Dwivedi, 1978), water melon (Partap et al., 1984), cauliflower (Lal et al., 1990), garden pea (Kalia and Sharma, 1998), rice (Mahalingam et al., 2011) and muskmelon (Singh and Vishisht, 2015). The discrepancies in studies could be due to the differences in the tested material and in the sampled environmental conditions for these genetic studies. The estimated average degree of dominance indicated over-dominance for marketable fruit yield per plant, days to 50% flowering, fruits per plant, days to first harvest, fruit length, fruit weight, pedicel length, average fruit diameter, dry matter content and bacterial wilt incidence (Table 2). These estimates also indicated partial dominance for plant height, branches per plant, fruit diameter and total soluble solids. The current work supports findings by Kaur and Thakur (2007) for yield and other characters in eggplant.

The heritability estimates were found to be low to high. Estimated heritability was highest for plant height whereas, average estimates were observed for branches per plant, fruit diameter and total soluble

Table 3. Estimates of heritability and predicted genetic gain from 1 cycle of selection in the biparental progenies of Swarna Pratibha x Hisar shyamal (SP × H-8) cross.

		Predicted genetic gains from 1 cycle of selection	
Character	**Heritability; narrow sense (%)**	**Full-sib family selection (% of mean)**	**Mass selection (% of mean)**
Marketable fruit yield/plant (kg)	26.46	15.22	3.20
Days to 50% flowering	8.35	1.40	0.37
Days to first harvest	6.34	0.80	0.78
Fruit per plant	14.76	2.43	1.57
Fruit length (cm)	12.08	1.72	0.90
Fruit diameter(cm)	31.89	4.65	2.50
Average fruit diameter (cm)	17.62	5.16	1.86
Plant height (cm)	59.01	1.79	1.08
Branches per plant	43.17	13.14	4.11
Fruit weight (g)	13.02	3.19	2.19
Pedicel length (cm)	5.54	1.22	0.56
Total soluble solids (%)	37.09	9.05	1.92
Dry matter content (%)	9.45	1.43	0.73
Iron content (mg/100g)	*	0.75	**
Phenol content (mg/100g)	*	6.47	**
Bacterial wilt incidence (%)	21.40	19.36	0.84

* Small negative estimates; **Not computed because of negative estimates

solids. For the remaining traits these estimates were low. The reason may be presence of higher value of dominance variance for most characters. For improvement of characters of high and low heritability in eggplant, intermating in early generations coupled with selection would be appropriate (Singh and Dwivedi, 1978). In eggplant, moderate to high estimates of heritability have been reported for fruit yield per plant (Singh and Kumar, 2005; Dhameliya and Dobariya, 2007; Kaur and Thakur, 2007), days to flowering (Negi et al., 2000; Thangavel et al., 2011), plant height, fruits per plant, fruit length, fruit diameter, fruit weight and number of branches per plant (Dhameliya and Dobariya, 2007; Golani et al., 2007; Kaur and Thakur, 2007; Dhameliya and Dobariya, 2009). In another study low to moderate estimates of heritability were reported for marketable yield per plant, fruit girth and plant height (Thangavel et al., 2011), in eggplant. Our results show that full-sib family selection is superior to mass-selection, for all characters (Table 3). The predicted genetic gain for full-sib family selection indicated considerable improvement in marketable fruit yield per plant in the Swarna Pratibha × Hisar Shyamal (SP × H-8). Full-sib family selection may be more effective compared to mass selection, which is based on the phenotype alone, because additive genetic variances may be more profitably exploited in full-sib family selection. The material generated from biparental crosses could be subjected to population improvement techniques. In autogamous crops also like that of cross -pollinated ones, improvement can be affected through recurrent selection. However, due to certain physical and economic reasons this procedure has not been widely employed even though there is no genetic reason to exclude its use.

Conclusion

Biparental mating is an effective tool for creating variability as well as for getting information on genetic architecture of a crop. This information can be utilized for selection of proper breeding methodology for further improvement of the crop. Genetic analysis revealed that the average degree of dominance lies in over-dominance range for marketable fruit yield (1.41), days to 50% flowering (1.69), days to first picking (2.53), fruit length (3.17), fruit weight (3.51), pedicel length (3.65) and bacterial wilt incidence (1.07) indicating pre-ponderance of non-additive genetic variance. Whereas the additive genetic variance was pre-dominant for plant height (0.14), branches per plant (0.84), fruit diameter (0.67) and total soluble solids (0.64). The pre-ponderance of additive and non-additive genetic component of variance for most of the traits studied revealed the role of additive and non-additive gene action for the inheritance of marketable fruit yield and its component traits which could be exploited through recurrent selection and heterosis breeding for the development of high yielding and quality cultivars in brinjal. Thus, biparental mating, which would exploit both additive and non-additive types of gene effects, was suggested for the improvement of the traits in the cross studied.

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Table 4. Analysis of variance for various traits in biparental progenies of the cross Swarna Pratibha X Hisar Shyamal (SP x H-8)

Source	df	Mean squares															
		Marketable yield / plant	Days to fifty per-cent flowering	Days to first picking	Number of marketable fruits per plant	Fruit length	Fruit diameter	Average fruit dia-meter	Plant height	Number of branches per plant	Fruit weight	Pedicel length	Total soluble solids	Dry matter content	Iron content	Phenol content	Bacterial wilt inci-dence
Sets	2	0.39	161.20	192.58	20.03	9.26	1.42	1.82*	152.47	13.74	2484.96	0.62	0.36	8.26	0.16	471.81	147.19
Replication in sets	6	0.43	3.05	4.56	2.34	1.09	0.67	0.76	2.75	0.86	7.39	1.07	0.68	0.72	0.00	11.87	10.68
BIP's in sets	45	2.08*	46.37*	77.73*	10.02*	6.39*	1.83*	1.83*	222.09*	2.52*	325.33*	0.93*	1.33*	1.19*	0.03*	238.76*	41.25*
Males in sets	9	1.17*	59.15*	99.13*	15.90*	6.01*	0.84*	1.12*	220.41*	2.77*	329.89*	0.94*	1.38*	2.54*	0.02*	309.15*	86.28*
Females in males in sets	36	0.85*	43.18*	72.38*	8.55*	6.49*	2.07*	2.00*	222.52*	2.45*	324.19*	0.93*	1.32*	0.86*	0.04*	221.16*	29.99*
Remainder among plots	90	0.04	1.53	1.27	1.11	0.90	0.57	0.52	10.83	0.81	5.24	0.92	1.02	0.89	0.00	17.24	5.70
Total	143																

* Significant at $P < 0.05$

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