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Research Note

Genetic Diversity, Trait Relationship and Path Analysis in Eggplant Landraces

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Abstract
In eggplant (*Solanum melongena* L.) significant genetic variability occurs in land races. They retain a number of distinctive features of plant breeding importance with enough diversity for further improvement. Land races can express good resistance and/or tolerance to some biotic stresses. This work was done to examine the variability among 33 land races of eggplant. Genetic divergence D^2 analysis identified that the 33 genotypes could be grouped into 3 clusters. The maximum inter-cluster distance was between clusters I and cluster III. Genotypes belonging to these clusters may be utilized for hybridization for crop improvement. Fruit yield per plant, total phenol content, fruit width, ascorbic acid content, fruit circumference, number of long styled flowers per plant and days to first flowering contributed most of the genetic divergence. On the basis of inter-cluster distance and cluster mean values, local genotypes EP 11, EP 17, EP 20, EP 23, EP 27, EP 29, EP 30 were superior. Correlation analysis indicated that fruit width, number of long styled flowers per plant, fruit circumference, fruit length, numbers of fruit per plant and average fruit weight were positively, and significantly, correlated with fruit yield per plant. Path coefficient analysis indicated that plant height, number of branches per plant, fruit length, fruit circumference, number of fruits per plant, and average fruit weight had high positive, direct, effects on fruit yield. A low direct effect occurred for internodal length. Selection among genotypes can increase improvement in fruit yield and component characters.

Keywords
Solanum melongena, multivariate analysis, direct effects, selection

Eggplant (*Solanum melongena* L.) is grown in temperate (during warm season) and tropical regions of the globe. India is regarded as centre of origin and diversity of eggplant (Isshiki et al., 1994). In Tamil Nadu production was 8.5 lakh tonnes from 0.75 lakh ha of area (Anonymous., 2010). A large indigenous biodiversity exists in eggplant with variation in plant type, stem color, leaf size, leaf tip, midrib color, fruit size, fruit shape, fruit color, fruit yield, fruit quality, cooking quality, and tolerance to pests and diseases. Germplasm is the basic material used by plant breeders to improve varieties. Land races are an important component of the germplasm and serve as the basic material for crop improvement. Land races have a broad genetic base providing them wider adaptability and protection from various stresses. Information on the nature and magnitude of variability in eggplant, and the association of plant characters, is useful as a basis for selection.

In any selection program, it may not always be possible to select based on yield alone for superior yielding genotypes because yield is a complex and collectively influenced by many components. The interrelationships between yield and yield contributing characters are estimated by correlation coefficient analysis. Such association studies provide information on the nature, extent and direction of selection. The partitioning of correlation coefficients into direct and indirect effects of yield components on yield will provide more information on selection. The present investigation was undertaken in eggplant to: i) identify high yielding local types with earliness and desirable qualities; ii) assess variability in local types, and iii) determine the nature and magnitude of variation among local types for growth and yield characters.

The experiment was conducted during the rainy season (June to October) at College Orchard, Agricultural College and Research Institute, Madurai, Tamil Nadu, India, at 9°5' N latitude and 78°5 E' longitude at an elevation of 147 m above MSL. Thirty-three eggplant germplasm were collected from in, and around, Tamil Nadu and evaluated under field conditions for yield, quality and other traits.

Seedling production and field cultivation: Seedlings were produced in raised nursery beds. Thirty-five day old seedlings were transplanted at a spacing of 60×60 cm. Each genotype consisted of 60 plants. Cultural operations were per the TNAU Crop Production Guide (2005) under irrigation.

Observations were recorded on 5 randomly selected plants in each replication. Data on plant height (cm), number of primary branches, days to first flowering, leaf area index, internodal length (cm), number of long styled flowers per plant, fruit length(cm), fruit width(cm), fruit circumference(cm), calyx length(cm), fruit pedicel length(cm), shoot borer infestation, fruit borer infestation, little leaf incidence, ascorbic acid content, total phenols content, number of fruit per plant, average fruit weight, and fruit yield per plant (g). Ascorbic acid content was estimated by a volumetric method (AOAC, 2001). The Folin-Ciocalteau reagent was used to estimate total phenols (Bray and Thrope, 1954).

Data analysis: Mean data of all crosses for each character were subjected to correlation analysis using formulae of Johnson et al. (1955); path coefficients were obtained with the method of Dewey and Lu (1959). Genetic diversity was studied following Mahalanobis's (1936) generalized distance (D^2) extended by Rao (1952). Based on D^2 values, genotypes were grouped into clusters following the method of Tocher (Rao, 1952). Intra- and inter-cluster distances were calculated by methods of Singh and Chaudhury (1977). Statistical analyses were carried out using GENRES software. Genotypic and phenotypic coefficients of variation were calculated using formulae of Burton (1952).

Genetic divergence studies

Clustering Pattern: There was wide genetic diversity 3 gene constellations being formed (Table 1). Cluster I had the most genotypes, but they were not resolved according to geographical origin. Geographic diversity is not the only factor determining genetic divergence. Singh and Prasad (1991) stated that geographical distribution need not directly be related to genetic diversity as estimated by D^2 statistics. Cluster II was highly divergent with 2 genotypes coming from the same geographical origin. Cluster III had 7 genotypes from the same geographical locations.

Intra- and Inter-cluster distances: Cluster III had the maximum intra D^2 value, followed by Cluster I (Table 2). Genotypes included in these clusters are very diverse. The inter-cluster D^2 value was highest between Clusters I and III. Genotypes in Clusters I and III could have greater genetic divergence and inter-mating between genotypes in the clusters would give more transgressive segregates in advanced generations. Selection of genotypes belonging to clusters with maximum inter-cluster distance had been proposed by Mehta et al.(2004), in eggplant.

Cluster mean for different characters: Cluster means for characters (Table 3) provide scope to identify parents for recombination breeding. Cluster II, which only had genotypes EP 29 and EP 30, had the lowest values for plant height, leaf area index, internodal length, fruit width, fruit circumference, calyx length, fruit pedicel length, average fruit weight, ascorbic acid content, total phenol content, fruit borer infestation and most numbers of long styled flowers per plant, longest fruit, most fruit per plant, most harvests, and highest fruit yield per plant. The cluster mean for fruit yield per plant was highest in Cluster II followed by Clusters I and III. High cluster means for most yield contributing traits, coupled with inter-cluster distance, was in Clusters II and III indicating the possibility of obtaining high heterotic vigor and selection of superior segregants by inter-crossing genotypes from these clusters (Mehta et al., 2004).

Contribution of characters to genetic divergence:

Fruit yield per plant was the maximum contributor for genetic divergence, followed by total phenol content, fruit width, ascorbic acid, fruit circumference, number of long styled flowers per plant and days to first flowering (Table 4). The importance of fruit circumference in genetic divergence of eggplant had been reported (Babu and Patil, 2004). Mehta et al. (2004) reported the high contribution of fruit length towards genetic divergence in eggplant. There was no or very little contribution due to number of primary branches, little leaf incidence and fruit borer infestation affecting divergence among genotypes. The contributions of average fruit weight, total number of harvests, number of fruit per plant, leaf area index and plant height were also minimal.

Association analysis:

Correlation studies:

Correlation studies between fruit yield and its component traits: Of 19 characters, fruit width, number of long styled flowers per plant, total phenol content, fruit circumference, average fruit weight, fruit length, and number of fruit per plant were significantly associated with fruit yield (Table 5). Fruit yield was significantly, and negatively, associated with ascorbic acid content. The optimum content of ascorbic acid could be considered an important criterion during selection for fruit yield. Fruit width had the highest correlation with fruit yield per plant followed by number of long styled flowers per plant, total phenol content, fruit circumference, average fruit weight, fruit length and number of fruit per plant had high positive, significant, associations with fruit yield per plant.

Intercorrelations among important yield attributing components: The inter-correlation among component characters indicated significant,

positive, association for plant height with internodal length, leaf area index, pedicel length, average fruit weight, fruit circumference, number of primary branches with ascorbic acid content, total number of harvest, number of fruit per plant, days to first flowering with fruit width, fruit circumference, total phenols content, leaf area index, pedicel length, fruit length, average fruit weight, internodal length, internodal length with average fruit weight, pedicel length, fruit weight, leaf area index with average fruit weight, internodal length, total phenol content, fruit width, fruit circumference, calyx length, number of long styled flowers per plant with number of fruits per plant and fruit yield per plant, fruit length with fruit yield per plant, fruit width with fruit circumference, average fruit weight, fruit yield per plant, total phenol content, fruit circumference with average fruit weight, total phenol content, fruit yield per plant, calyx length with pedicel length, average fruit weight, pedicel length with average fruit weight, average fruit weight with total phenol content, fruit yield per plant, number of fruits per plant with fruit yield per plant, ascorbic acid content with total number of harvests while negative significant negative correlation was observed for fruit length with total number of harvest, fruit girth with ascorbic acid and fruit weight with total number of harvest and ascorbic acid. The intentional selection of number of primary branches per plant, number of fruit per plant, fruit weight, fruit width, plant height, total phenols, fruit length and total number of harvest may result in simultaneous improvement of fruit yield per plant and are inter-correlated. These characters are highly reliable components of fruit yield since they are expressed significant correlation with fruit yield and could be utilized as yield indicators. The characters days to first flowering, days to first harvest and ascorbic acid, an important quality trait, were negatively associated with fruit yield per plant. Selection for this trait will result in reduction of fruit yield.

Path analysis: Plant height, number of primary branches per plant, fruit length, fruit circumference, number of fruit per plant, average fruit weight, had positive direct effects on yield (Table 6). Direct selection for these characters are likely to bring about an overall improvement in fruit yield per plant.. The residual effect was 0.181 which indicated 97.5% of variability in fruit yield per plant was explained by 19 variables. Plant height, number of primary branches per plant, fruit length, fruit circumference, number of fruit per plant, average fruit weight, are important characters to bring about overall improvement in fruit yield per plant.

There was adequate genetic variability within the germplasm evaluated for the improvement of fruit yield, growth and related traits, which can be utilized for further improvement through selection. Positive correlations between yield and its contributing characters show simple, indirect selection criteria in the development of high yielding cultivars.

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Table 1. Clustering pattern of 33 genotypes of eggplant.

Cluster	Number of genotypes	Genotype	Origin
I	24	Kariapatty Local	Kariapatty, Virdhunagar D.t
		Sedapatty Local (Ramakkai Blue)	Sedapatty, Madurai D.t
		Sedapatty Local (Ramakkai Green)	Sedapatty, Madurai D.t
		Alavayal Local	Alavayal, Madurai D.t
		Palamedu Local	Palamedu, Madurai D.t
		Melur Local	Melur, Madurai D.t
		Kallampatty Local	Kallampatty, Madurai D.t
		Alagarkovil Local	Alagarkovil, Madurai D.t
		Singampunari Local 1	Singampunari, Sivagangai D.t
		Singampunari Local 2	Singampunari, Sivagangai D.t
		Veerakkal Local (Sempatty Authur)	Sempatty, Dindigul D.t
		Keerikai	Sempatty, Dindigul D.t
		Nilakottai Local	Nilakottai, Dindigul D.t
		SM 1	Department of Horticulture, AC & RI, Madurai
		SM 2	Department of Horticulture, AC & RI, Madurai
		SM 3	Department of Horticulture, AC & RI, Madurai
		SM 4	Department of Horticulture, AC & RI, Madurai
		SM 5	Department of Horticulture, AC & RI, Madurai
		EP 3	Vegetable Research Station, Palur
		EP 4	Vegetable Research Station, Palur
		EP 5	Vegetable Research Station, Palur
		EP 7	Vegetable Research Station, Palur
		EP 9	Vegetable Research Station, Palur
		EP 10	Vegetable Research Station, Palur
II	2	EP 29	Vegetable Research Station, Palur
		EP 30	Vegetable Research Station, Palur
III	7	EP11	Vegetable Research Station, Palur
		EP 17	Vegetable Research Station, Palur
		EP 20	Vegetable Research Station, Palur
		EP 21	Vegetable Research Station, Palur
		EP 23	Vegetable Research Station, Palur
		EP 27	Vegetable Research Station, Palur
		EP 28	Vegetable Research Station, Palur

Table 2. Inter- and intra-cluster distances.

Cluster	I	II	III
I	1057.82	734.08	1881.71
II		62.63	1763.33
III			1683.42

Intra-cluster divergence = diagonal values, Inter-cluster divergence = values in columns.

Table 3. Cluster means for nineteen characters of eggplant.

Clusters and characters	I	II	III
Plant height (cm)	127.02	125.54*	129.98**
Number of primary branches	8.12**	6.14	5.98*
Days to first flowering	79.60*	82.00	83.28**
Leaf area index	121.28	115.50*	168.76**
Internodal length (cm)	8.77*	9.76*	8.97
Number of long styled flowers per plant	25.29	32.24**	25.06*
Fruit length (cm)	7.07*	9.62**	7.69
Fruit width(cm)	4.81	4.64*	5.41**
Fruit circumference(cm)	15.30	14.51*	18.16**
Calyx length(cm)	3.34	2.99*	3.55**
Fruit pedicel length(cm)	4.69	4.68*	4.78**
Number of fruit per plant	25.63	32.53**	24.07*
Average fruit weight (g)	52.64	55.26*	65.62**
Fruit yield per plant (kg)	1.26	10.57**	1.40*
Total number of harvests	11.62	12.75**	1.79*
Fruit borer infestation	47.65	39.58*	48.21**
Little leaf disease incidence	18.22	12.50*	22.02**
Ascorbic acid content (mg/g)	10.80**	7.54*	8.98
Total phenols content(mg/g)	71.22	62.09*	131.77**

**, * = in row highest mean or least mean.

Table 4. Relative contribution of different characters to genetic diversity in eggplant.

Character	Number of first rank	Percent of contribution
Plant height	1	0.86
Number of primary branches	0	0.00
Days to first flowering	25	4.76
Leaf area index	1	0.75
Internodal length	12	2.88
Number of long styled flowers per plant	27	4.88
Fruit length	3	2.44
Fruit width	33	10.40
Fruit circumference	15	6.27
Calyx length	3	1.12
Fruit pedicel length	1	0.86
Number of fruit per plant	1	0.16
Average fruit weight	1	0.27
Fruit yield per plant	99	34.18
Total number of harvests	1	0.18
Shoot borer infestation	0	0.00
Little leaf disease incidence	0	0.00
Ascorbic acid content	24	6.43
Total phenols content	89	23.56
Total	336	100

Table 5. Genotypic correlation between yield and traits.

Character	X2 [a]	X3	X4	X5	X9	X10	X11	X12	X13	X14	X15	X18	Fruit yield/plant
X1	-0.439*	0.197	0.406*	0.410*	0.298*	0.171	0.400*	0.352*	-0.298*	-0.169	0.095	-0.040	0.121
X2		-0.509*	-0.588*	-0.655*	-0.509*	-0.205	-0.320*	-0.536*	0.311*	0.672*	-0.485*	0.385*	-0.268
X3			0.399*	0.292*	0.451*	0.197	0.355*	0.318*	-0.158	-0.726*	0.430*	-0.246	0.261
X4				0.500*	0.412*	0.365*	0.228	0.813*	-0.584*	-0.472*	0.488*	-0.273	0.154
X5					0.287	0.258	0.408*	0.503*	-0.425*	-0.523*	0.253	-0.286	0.155
X6			-0.499*	-0.348*	0.009	-0.319*	-0.234	-0.514*	0.872*	0.049	-0.112	0.164	0.457*
X7		0.320			0.075	0.139	0.276	0.158	0.005	-0.313*	0.087	0.181	0.303*
X8	-0.485*	0.511*	0.455	0.360	0.869*	0.230	0.245	0.497*	-0.196	-0.473*	0.447*	-0.177	0.459*
X9						0.196	0.248	0.464*	-0.169	-0.438*	0.456*	-0.336*	0.426*
X10							0.447*	0.355*	-0.369*	-0.009	0.251	0.051	-0.022
X11								0.305*	-0.292*	-0.267	0.277	-0.052	0.142
X12									-0.683*	-0.435*	0.599*	-0.212	0.407*
X13										0.073	-0.239	0.166	0.297*
X14											-0.447*	0.297*	-0.474*
X15												-0.265	0.442*

*Significance at 5% level.

[a] X1 = Plant height; X2 = Number of primary branches per plant; X3 = Days to first flowering; X4 = Leaf area index; X5 = Internodal length; X6 = Number of long styled flowers per plant; X7 = Fruit length; X8 = Fruit width ; X9 = Fruit circumference; X10 = Calyx length; X11 = Pedicle length; X12 = Average fruit weight; X13 = Number of fruit per plant; X14 = Ascorbic acid content; X15 = Total phenols content; X16 = Little leaf disease incidence; X17 = Fruit borer infestation; X18 = Total numbers of harvests;

Table 6. Direct and indirect effects of different traits on yield.

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	Fruit yield/plant
X1	0.049	-0.190	-0.019	-0.384	0.064	-0.217	0.025	-0.115	0.184	0.129	-0.014	0.241	0.157	0.077	-0.020	0.017	0.141	0.025	0.121
X2	-0.022	0.421	0.052	0.559	-0.104	0.208	-0.161	0.238	-0.394	-0.178	0.012	-0.364	-0.153	-0.308	0.102	-0.017	0.056	-0.257	-0.268
X3	0.010	-0.256	-0.086	-0.435	0.048	-0.131	0.295	-0.244	0.354	0.052	-0.012	0.232	0.074	0.382	-0.104	0.003	0.016	0.127	0.261
X4	0.020	-0.252	-0.040	-0.933	0.078	-0.480	0.138	-0.209	0.297	0.352	-0.009	0.540	0.281	0.213	-0.101	-0.017	0.118	0.181	0.154
X5	0.020	-0.284	-0.026	-0.475	0.155	-0.342	0.010	-0.151	0.169	0.229	-0.015	0.339	0.212	0.240	-0.053	0.031	-0.082	0.196	0.155
X6	-0.011	0.094	0.012	0.479	-0.056	0.936	-0.054	0.006	-0.005	-0.272	0.008	-0.346	-0.417	-0.022	0.023	0.011	0.199	-0.128	0.457
X7	0.001	-0.094	-0.035	-0.180	0.002	-0.071	0.717	-0.044	0.022	0.076	-0.006	0.120	0.013	0.164	-0.021	0.010	-0.273	-0.095	0.303
X8	0.015	-0.268	-0.056	-0.522	0.062	-0.017	0.085	-0.374	0.514	0.098	-0.006	0.407	0.114	0.259	-0.113	-0.005	0.254	0.155	0.459
X9	0.017	-0.312	-0.057	-0.521	0.049	-0.009	0.029	-0.362	0.531	0.121	-0.005	0.422	0.112	0.266	-0.128	-0.004	0.218	0.247	0.426
X10	0.010	-0.121	-0.007	-0.531	0.057	-0.410	0.088	-0.059	0.104	0.619	-0.012	0.359	0.246	0.005	-0.079	-0.041	-0.150	-0.054	-0.022
X11	0.031	-0.236	-0.048	-0.389	0.105	-0.364	0.220	-0.102	0.125	0.349	-0.022	0.367	0.254	0.215	-0.103	0.027	-0.076	-0.045	0.142
X12	0.018	-0.231	-0.030	-0.761	0.079	-0.489	0.130	-0.230	0.339	0.336	-0.012	0.662	0.323	0.196	-0.125	-0.007	0.122	0.127	0.407
X13	-0.017	0.140	0.014	0.570	-0.07	0.847	-0.021	0.093	-0.129	-0.331	0.012	-0.464	0.460	-0.034	0.051	0.008	0.112	-0.078	0.297
X14	-0.008	0.287	0.073	0.440	-0.082	0.046	-0.262	0.215	-0.314	-0.007	0.010	-0.288	-0.035	-0.451	0.093	-0.013	-0.011	-0.194	-0.474
X15	0.004	-0.207	-0.043	-0.455	0.039	-0.107	0.073	-0.204	0.328	0.238	-0.011	0.398	0.114	0.201	-0.207	-0.026	0.156	0.173	0.442
X16	-0.010	0.089	0.004	-0.202	-0.060	-0.137	-0.093	-0.026	0.028	0.316	0.007	0.060	0.004	-0.072	-0.067	-0.081	0.130	-0.030	-0.097
X17	0.010	0.034	-0.002	-0.158	-0.018	0.266	-0.280	-0.135	0.166	-0.132	0.002	0.115	-0.073	0.007	-0.046	-0.015	-0.700	-0.059	0.275
X18	0.008	0.217	0.022	0.339	-0.060	0.239	0.136	0.116	-0.263	0.067	-0.002	-0.168	-0.072	-0.175	0.072	-0.005	0.083	-0.499	0.060

Residual effect = 0.181

[a] X1 = Plant height; X2 = Number of primary branches per plant; X3 = Days to first flowering; X4 = Leaf area index; X5 = Internodal length; X6 = Number of long styled flowers per plant; X7 = Fruit length; X8 = Fruit width ; X9 = Fruit circumference; X10 = Calyx length; X11 = Pedicle length; X12 = Average fruit weight; X13 = Number of fruit per plant; X14 = Ascorbic acid content; X15 = Total phenols content; X16 = Little leaf disease incidence; X17 = Fruit borer infestation; X18 = Total numbers of harvests;