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Genetic variability, correlation and path analysis in Moringa (*Moringa oleifera* L.)

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Abstract
Analysis of variance indicated that there is an existence of significant variability among the twenty accessions for all the characters under study. The highest GCV was recorded for pod weight, number of leaves per rachis, yield per plant. Heritability estimates were high for pod weight, yield per plant, number of pods per plant, length of pod, and number of leaves per rachis. The expected genetic advance as a percentage of mean was high for pod weight, number of leaves per rachis, yield per plant, length of pod, number of seed per pod. Yield per plant had significant and positive association with stem girth fruit setting percentage length of pod girth pod weight and number of pods per plant indicating their usefulness in selection for yield. Non-significant and negative association with plant height leaf length number of leaves per rachis length of leaf rachis number of flower per inflorescence number of seeds per pod. Among the twelve characters studied, six characters *viz*., by plant height leaf length number of leaves per rachis number of flowers per inflorescence pod weight and number of seeds per pod showed positive direct effect on yield per plant. Negative direct effect on yield per plant was recorded by stem girth length of leaf rachis fruit setting percentage length of pod girth number of pods per plant.

Keywords: Genetic variability, correlation, path analysis, Moringa

Introduction
Moringa (*Moringa oleifera* L.), belonging to the family Moringaceae, is a highly useful vegetable crop and native of India. In India it is grown all over the subcontinent for its tender pods and also for its leaves and flowers. The plants have always been vital for mankind irrespective of the era and area, all over the globe since the beginning of life. Popularly known as ‘‘Drumstick’’ tree, horseradish tree, or Ben tree, M. oleifera is a deciduous-to-evergreen shrub or small tree with a height of 5 to 10 m (Morton, 1991) [1]. In order to do develop cultivars for increased the yield, genetic variability is the prerequisite since it is the source of variation and base for yield improvement. Assessment of genetic variability is also needed for efficient parental selection in breeding program (Rahman *et al*., 2011) [2], long term selection gain and exploitation of heterosis (Rahman *et al*., 2012) [2]. Furthermore, characters associated with yield are to be determined by correlation and path coefficient analysis to assist selection in yield improvement work. Though correlation analysis indicates the association pattern of component traits with yield, it also represents the overall influence of a particular trait on yield rather than providing cause and effect relationship. The path coefficient analysis technique facilitates the partitioning of genotypic correlation into direct and indirect contribution of various characters on yield (Mahbub *et al*., 2015) [4]. Such information would be of great value in enabling the breeder to specifically identify the important component traits of yield and utilize the genetic stock for improvement in a planned way. The present investigation was undertaken to assess the 20 genotypes of Moringa for genetic variability, correlation and path analysis.

Material and Methods
The present investigation was carried out at Department of Vegetable Crops, Horticultural College and Research Institute (HC&RI), Tamil Nadu Agricultural University, Periyakulam during 2016 -2017. Twenty accessions of Moringa collected from various parts of Telangana were evaluated for different morphological and biochemical traits. Observations on morphological, and biochemical characters *viz*., plant height (cm), stem girth (cm), leaf length (cm), number of leaves per rachis, length of leaf rachis, number of flowers per inflorescence, fruit setting percentage, length of pod (cm), pod girth (cm), pod weight (g), number of pods per plant, number of seeds per pod, yield per plant (kg), and biochemical traits *viz*., chlorophyll a (mg g^{-1}), chlorophyll b (mg g^{-1}) total chlorophyll (mg g^{-1}), leaf soluble protein

(mg/100g), crude protein (%), and ascorbic acid (mg/g) contents were recorded. The variability for different quantitative traits was estimated as per procedure suggested by Panse and Sukhatme (1961) [5], GCV and PCV as per Burton (1952) [6], heritability according to Allard (1960) [7] and genetic advance as per Johnson *et al*. (1955). Correlation coefficient was worked out as per Panse and Sukhatme (1961) [5] and path coefficient analysis was done according to formula given by Dewey and Lu (1959) [9].

Results and Discussion

Results indicated considerable variability for all the traits under study (Table 1). The PCV values were slightly greater than GCV values for most of the traits. The close relationship between genotypic and phenotypic coefficient of variability for most of the traits indicated that there was very little influence of environment on their expression. the higher estimates of genotypic and phenotypic coefficients of variation were observed for number of leaves per rachis, length of pod, pod girth, pod weight, number of pods per plant, number of seeds per pod, yield per plant, indicating that the variability existing in these traits is due to the presence of genetic constitution. These results are in accordance with findings of Raja and Bagle (2008) [10], Selvakumari (2013) [11], Sheetal and Maurya (2015) [12] in Moringa, Rana *et al*., (2005) [13] in Amaranthus Hypochondriacus, Adiger *et al*., (2011) [14]; Praseetha (2015) [15] in okra and Meena *et al*., (2012) [16] in cabbage. Moderate estimates of genotypic and phenotypic coefficients of variation were observed for plant height, stem girth, leaf length, length of leaf rachis, Number of flower per inflorescence, fruit setting percentage, chlorophyll a content and ascorbic acid content. Rest of the traits showed low estimates of genotypic and phenotypic coefficients of variation. Similar results were observed by Adiger *et al*., (2011) [14] and Chandra *et al*., (2014) [17] in okra. Low estimates of genotypic and phenotypic coefficients of variation were however observed for chlorophyll b content, total chlorophyll content, leaf soluble protein, and crude protein content.

high heritability coupled with high genetic advance as per cent of mean was observed for the characters viz., plant height, stem girth, leaf length, number of leaves per rachis, length of leaf rachis, number of flowers per inflorescence, fruit setting percentage, length of pod, pod girth, pod weight, number of pods per plant, number of seeds per pod, yield per plant, chlorophyll a content and ascorbic acid content. Whereas, high heritability and moderate genetic advance was observed for the chlorophyll b content, total chlorophyll content, leaf soluble protein content, high heritability and low genetic gain was observed for the crude protein content. Similar observation was recorded by Raja and Bagle (2008) [10]; Selvakumari (2013) [11]; Sheetal and Maurya (2015) [12] in moringa, Adiger *et al*., (2011) [14]; Das *et al*., (2012) [18]; Praseetha (2015) [15] in okra. Further, high heritability accompanied with high genetic advance indicated the involvement of additive gene action, therefore selection may be effective at later generations.

Phenotypic and genotypic correlations of twelve characters in all possible combinations were calculated to know the relationship among them (Table 2&3). In general, genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients for most of the traits (Table 2). Yield per plant had significant and positive association with stem girth (0.419), fruit setting percentage (0.481), Length of pod (0.342), pod girth (0.376), pod weight (0.535), and number of pods per plant (0.361). Such association were also reported by Roy *et al*., (2006); Raja and Bagle (2008) [10]; Sheetal and Maurya (2015) [12]; Selvakumari and Ponnuswamy (2015) [20] in Moringa.

Path coefficient analysis (Table 4) revealed that positive and high direct effect on yield was recorded by plant height (0.296) and pod weight (0.290). Among the twelve characters, these two traits contributed the most towards yield per plant. Further, leaf length, number of leaves per rachis, number of flower per inflorescence and number of seeds per pod showed positive but negligible low direct effect and indicated strong positive association on yield per plant. Similar result was also given by Raja and Bagle (2008) [10] in Moringa. The rest of the traits such as stem girth, length of leaf rachis, fruit setting percentage, length of pod, pod girth, number of pods per plant registered negative direct effect on yield per plant. The indirect effects of length of pod through pod weight, pod girth through pod weight, pod weight through number of seeds per pod, number of pods per plant through pod weight, number of seeds per pod through pod weight, were positive and comparatively higher. Thus based on path analysis, the traits viz., pod length, pod weight, number of pods per plant and pod girth may be considered as selection indices for yield improvement.

Table 1: Estimates of variability and genetic parameters in Moringa

Characters	Mean	Range	GCV (%)	PCV (%)	Heritability (per cent)	GA (per cent) of mean
Plant height (cm)	224.42	173.43-283.60	15.88	16.15	96.74	32.18
Steam girth(cm)	19.17	14.30-22.93	12.32	12.67	94.57	24.68
Leaf length(cm)	32.36	26.20-42.86	12.77	13.04	95.89	25.76
Number of leaves per rachis	42.63	21.57-82.43	35.86	36.03	99.03	73.51
Length of leaf rachis (cm)	12.60	9.63-16.10	11.63	11.91	95.25	23.38
Number of flower per inflorescence	17.41	14.53-20.67	10.47	10.69	95.86	21.12
Fruit setting percentage	14.15	10.21-18.27	16.84	17.00	98.11	34.37
Length of pod(cm)	39.47	24.97-66.53	29.36	29.50	99.07	60.21
Pod girth(cm)	6.50	3.17-9.60	23.17	23.30	98.93	47.49
Pod weight(g)	87.08	22.40-186.93	57.59	57.64	99.81	118.52
Number of pods per plant	20.03	12.67-31.83	25.47	25.58	99.16	52.25
Number of seeds per pod	16.73	12.00-25.10	26.21	26.37	98.73	53.65
Yield per plant(kg)	4.69	2.20-8.87	31.97	32.03	99.59	65.72
Chlorophyll a(mg g^{-1})	1.52	1.27-1.87	10.17	10.47	94.38	20.36
Chlorophyll b(mg g^{-1})	1.17	1.06-1.38	5.96	6.52	83.46	11.22
Total chlorophyll (mg g^{-1})	2.69	2.60-3.25	7.33	7.71	90.38	14.36
Leaf soluble protein (mg/100g)	22.93	20.95-27.36	6.98	7.51	86.38	13.36
Crude protein (%)	22.27	20.62-23.83	5.19	5.78	80.63	9.60
Ascorbic acid (mg/g)	0.21	0.15-0.29	15.68	15.88	97.42	31.88

Table 2: Genotypic correlation coefficients for yield and yield components in Moringa

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	1.000	0.043	0.212	0.247	0.355*	0.174	-0.033	-0.298	0.074	-0.155	0.129	-0.294	-0.045
X2		1.000	-0.207	-0.045	-0.074	0.132	-0.172	0.400*	0.465*	0.660**	0.433*	0.411*	0.432*
X3			1.000	0.089	0.421*	0.045	-0.014	0.012	-0.066	-0.149	0.370*	0.149	-0.101
X4				1.000	0.393*	-0.049	-0.072	-0.360*	0.345*	0.080	0.241	0.160	-0.019
X5					1.000	0.201	-0.263	-0.150	0.157	-0.089	-0.158	0.300*	-0.272
X6						1.000	-0.220	-0.048	0.061	-0.035	0.114	0.328*	-0.067
X7							1.000	0.300*	-0.141	0.069	-0.089	-0.394*	0.489*
X8								1.000	0.195	0.689**	0.166	0.449*	0.344*
X9									1.000	0.750**	0.530*	0.413*	0.380*
X10										1.000	0.496*	0.571*	0.537*
X11											1.000	0.390*	0.363*
X12												1.000	-0.073
X13													1.000

X1.Plant height (cm)	X2.Stem girth(cm)	X3.Leaf length (cm)	X4.Number of leaves per rachis	X5.Length of leaf rachis (cm)
X6.Number of flower per Inflorescence	X7.Fruit setting percentage	X8.Length of pod (cm)	X9.Pod girth (cm)	X10.Pod weight (g)
X11.Number of pods per Plant	X12.Number of seeds per pod	X13.Yield per plant (kg)		

** Significant at 1% level
* Significant at 5% level

Table 3: Phenotypic correlation coefficients for yield and yield components in Moringa

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	1.000	0.044	0.215	0.241	0.335*	0.162	-0.035	-0.294	0.071	-0.155	0.127	-0.288	-0.045
X2		1.000	-0.197	-0.043	-0.071	0.144	-0.166	0.393*	0.452*	0.640**	0.423*	0.388*	0.419*
X3			1.000	0.089	0.401*	0.044	-0.016	0.011	-0.074	-0.146	0.360*	0.139	-0.097
X4				1.000	0.380*	-0.053	-0.071	-0.356*	0.338*	0.079	0.236	0.157	-0.020
X5					1.000	0.192	-0.250	-0.15	0.157	-0.085	-0.153	0.292	-0.261
X6						1.000	-0.212	-0.044	0.068	-0.033	0.116	0.318*	-0.067
X7							1.000	0.296	-0.137	0.067	-0.088	-0.390*	0.481*
X8								1.000	0.194	0.686**	0.166	0.442*	0.342*
X9									1.000	0.746**	0.529*	0.408*	0.376*
X10										1.000	0.495*	0.567*	0.535*
X11											1.000	0.383*	0.361*
X12												1.000	-0.073
X13													1.000

X1.Plant height(cm)	X2.Stem girth(cm)	X3.Leaf length(cm)	X4.Number of leaves per rachis	X5.Length of leaf rachis (cm)
X6.Number of flower per Inflorescence	X7.Fruit setting percentage	X8.Length of pod(cm)	X9.Pod girth(cm)	X10.Pod weight(g)
X11.Number of pods per Plant	X12.Number of seeds per pod	X13.Yield per plant(kg)		

** Significant at 1% level
* Significant at 5% level

Table 4: Path coefficient analysis showing direct and indirect effects of 12 traits in moringa on yield per plant

	1	2	3	4	5	6	7	8	9	10	11	12	Correlation with Yield
1	0.29677	-0.01033	0.02659	0.01879	-0.09974	0.0008	0.00563	0.00576	-0.00579	-0.04488	-0.0147	-0.02399	-0.045
2	0.01263	-0.24279	-0.02596	-0.00342	0.02071	0.0006	0.0293	-0.00772	-0.03628	0.1914	-0.04925	0.03352	0.432
3	0.06306	0.05037	0.12516	0.00679	-0.11829	0.0002	0.00233	-0.00023	0.00514	-0.04337	-0.04211	0.01215	-0.101
4	0.07324	0.01089	0.01116	0.07615	-0.11044	-0.0002	0.01222	0.00696	-0.0269	0.02315	-0.02747	0.01303	-0.019
5	0.10539	0.01791	0.05272	0.02994	-0.28085	0.0009	0.04493	0.00289	-0.01222	-0.02573	0.01794	0.02449	-0.272
6	0.05173	-0.03196	0.00561	-0.00373	-0.05634	0.0047	0.03755	0.00093	-0.00474	-0.01018	-0.01303	0.02674	-0.067
7	-0.00978	0.04164	-0.00171	-0.00545	0.07387	-0.001	-0.17082	-0.0058	0.01098	0.0201	0.01009	-0.03213	0.489
8	-0.08845	-0.09701	0.00146	-0.02741	0.04203	-0.0002	-0.05126	-0.01933	-0.01523	0.19995	-0.01885	0.03663	0.344
9	0.02203	-0.11283	-0.00824	0.02623	-0.04395	0.0003	0.02402	-0.00377	-0.07808	0.21778	-0.06032	0.03376	0.380
10	-0.0459	-0.16012	-0.01871	0.00607	0.0249	-0.0001	-0.01183	-0.01332	-0.05859	0.29022	-0.05652	0.04662	0.537
11	0.03831	-0.10503	0.04629	0.01837	0.04425	0.0005	0.01513	-0.0032	-0.04137	0.14408	-0.11385	0.03187	0.363
12	-0.08721	-0.09969	0.01862	0.01216	-0.08426	0.0015	0.06723	-0.00867	-0.03229	0.16572	-0.04444	0.08164	-0.073

Residual effect= 0.231 Bold letters indicate direct effects

1.Plant height (cm)	2.Stem girth (cm)	3.Leaf length (cm)	4.Number of leaves per rachis
5.Length of leaf rachis (cm)	6.Number of flower per inflorescence	7.Fruit setting percentage	8.Length of pod (cm)
9.Pod girth (cm)	10.Pod weight (g)	11.Number of pods per plant	12.Number of seeds per pod

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