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Character association and path analysis in bottle gourd [*Ligenaria siceraria* (Mol.) Standl.]

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Abstract
Fifty diverse genotypes of bottle gourd were evaluated during summer 2015 for correlation and path analysis. The values of genotypic correlation, in general, were higher as compared to the corresponding phenotypic correlation. This indicated that though there was high degree of association between two variables at genotypic level, its phenotypic expression was deflated by the influence of environment. The character fruit yield per vine was found to be significantly and positively correlated with fruit length, average fruit weight, vine length and fruit girthat both the genotypic and phenotypic levels. Thus, these characters were the most important traits and may contribute considerably towards higher fruit yield. Fruit yield per vine also registered positive, but non-significant correlation with number of primary branches per vine, days to first picking, ratio of male to female flowers, number of fruits per vine and number of male flowers. The yield components exhibited varying trends of association among themselves. The interrelationship among yield components would help in increasing the yield levels and, therefore, more emphasis should be given to yield components, while selecting better plant types in bottle gourd. The genotypic path coefficient analysis revealed that ratio of male to female flowers followed by number of female flowers, days to opening of first male flower and average fruit weight exhibited high and positive direct effect on fruit yield per vine and was found to be the most important yield components. The characters fruit length and vine length had moderate and positive direct on fruit yield per plant, while number of fruit per vine, fruit girth and number of node bearing first female flower had low and positive direct effect on fruit yield per vine.

Keywords: Correlation, Path analysis, Bottle gourd

1. Introduction
Among the cultivated vegetables, cucurbits are associatedwith the origin of agriculture and dawn of civilization. Among foodcrops, cucurbits are largest producer of biological water, easilydigestible and recommended even to sick and frail patients. Bottlegourd [*Lagenaria siceraria* (Mol.) Standl.] is one of the most importantcucurbit in India, both as rainy and summer season vegetable. It isalso known as white-flowered gourd and most important vegetablesof ancient China. Because of hard mature rind of mature fruits, it isknown as gourd. It is also commonly grown in Ethiopia, Africa, Central America and other warmer regions of the world. Out of allthe cultivated cucurbits, bottle gourd with its high yield potential andadaptability to diverse climatic conditions holds a great promise tocope up with the per capita per day requirement of vegetables inthe balanced diet of the fast growing population pressure and greaterdietary awareness, particularly among the literate masses of a countrylike India (Singh, 1998). Bottle gourd was one of the first plantspecies to be domesticated for human use, providing food, medicineand a wide variety of utensils and musical instruments made fromthe large hard shelled mature fruits. A total of six species have beenrecognized belonging to the genus Lagenaria. Out of six species ofLagenaria only *Lagenariasiceraria* is domesticated annual andmonoecious in nature while, the other five are wild congeners,perennial and dioecious (Bisognin, 2002) [2]. It is highly cross pollinated crop due to its monoecious and andromonoecious nature (Swiander *et al*., 1994) [12] and had wide genetic diversity. In India, bottle gourd has a tremendous potential for export and has created a huge demand in Gulf markets already. Yield is a complex trait and usually has low genetic gain. So, direct selection may not give accurate outcome in any crop improvement. Hence, correlation studies between yield and its attributing traits which are otherwise simple and highly heritable have been immense help in selecting suitable genotype. Path coefficient analysis gives an indication of direct effect as well as indirect effect of interrelated variables on yield. An attempt was, therefore made in the present investigation to study the

interrelationship of quantitative traits and their direct and indirect effects contributing to yield, so as to assist the plant breeder in forming a basis for selection.

Materials and Methods

Fifty genotypes of bottle gourd were sown in a Randomized Block Design (RBD) with three replications during summer 2015. Each genotype was accommodated in a single row of 10 m length with a spacing of 2.0 m between row and 1.0 m between plants within the row. The experiment was surrounded by two guard rows to avoid damage and border effects. Other recommended agronomical practices in vogue were followed for reaping good crop. The observations were recorded on various quantitative characters *viz*., days to opening of first female flower, days to opening of first male flower, number of node bearing first female flower, internodal length (cm), number of male flowers, number of female flowers, ratio of male to female flowers, days to first picking, vine length (cm), number of primary branches per vine, number of fruits per vine, average fruit weight, fruit length (cm), fruit girth (cm) and fruit yield per vine (kg) were recorded on five competitive randomly selected plants in each entry and replication and their mean values were used for statistical analysis.Correlations were computed and path coefficient analysis was carried out by method suggested to partition the genotypic correlation coefficient into measures of direct and indirect effects (Johnson *et al*., 1955; Dewey and Lu, 1959) [8, 4].

Results and Discussion

Genotypic correlations provide a measure of genetic association between characters and are generally used in selecting for one character as means for improving another. Correlation among traits may result from pleiotrophy, linkage or physiological associations among characters. The linkage is a cause of transit correlations particularly in a population derived from crosses between divergent strains. The correlation is the overall or net effect of the segregating genes; some of the genes may increase both the characters causing the positive correlation, while the others may increase the one and decrease the other causing the negative correlation (Falconer, 1989) [5]. Thus, to accumulate optimum combination of yield contributing characters in a single genotype, it is essential to know the implication of the interrelationship of various characters.

The genotypic and phenotypic correlations coefficients between yield and its components were estimated and presented in Table 1. In general, the values of genotypic correlation were higher than their corresponding phenotypic correlation in the present investigation for most of the characters. This indicated that though there was high degree of association between two variables at genotypic level, its phenotypic expression was deflated by the influence of environment. It also indicated that there was an inherent relationship between the characters studied, which is in agreement with the conclusions of Kumar and Syamal (2010) [14] and Varpe *et al.* (2014) [13].

In the present study, fruit yield per vine was found to be significantly and positively correlated with fruit length (r_g= 0.6920, r_p = 0.6486), average fruit weight (r_g= 0.4852, r_p = 0.4554), vine length (r_g= 0.4489, r_p = 0.4325) and fruit girth (r_g= 0.4285, r_p = 0.3897) at both the genotypic and phenotypic levels. This indicated that these traits are very important in selection programme and any increase in these traits would bring about an enhancement in the yield. Such positive interrelationship between fruit yield per vine and these attributes has also been reported in bottle gourd by several researchers. The positive genotypic association has been reported between fruit yield per vine and fruit length (Yadav *et al*., 2010; Raut *et al*., 2013;Varpe *et al*., 2014) [14, 10, 13];average fruit weight (Kumar and Syamal, 2010; Yadav *et al*., 2010; Husna *et al*., 2011; Raut *et al*., 2013; Ara *et al*., 2014 and Deepthi *et al*., 2014) [9, 14, 6, 10, 1, 3];vine length (Yadav *et al*., 2010 and Deepthi *et al*., 2014) [14, 3]; fruit girth (Ara *et al*., 2014; Deepthi*et al*., 2014 [3] andJanaranjani and Kanthaswamy, 2015) [7]. Thus, on the basis of correlations, the fruit length, average fruit weight, vine length and fruit girth were proved to be the outstanding characters influencing fruit yield in bottle gourd and needs to be given due importance in selection to achieve higher fruit yield. Further, the fruit yield per vineregistered positive, but non-significant correlation with number of primary branches per vine, days to first picking, ratio of male to female flowers, number of fruits per vine and number of male flowers.

The present results on correlation coefficient thus, revealed that the fruit length, average fruit weight, vine length and fruit girthwere the most important attributes and may contribute considerably towards higher fruit yield. The interrelationship among yield components would help in increasing the yield levels and therefore, more emphasis should be given to these components while selecting better plant types in bottle gourd.

Generally, the value of correlation coefficients lies between -1.0 to 1.0. In the present study all the values of correlation coefficient ranged from -1.0 to 1.0 except one case, the value of correlation coefficient was more than 1; it may be due to when covariance is over estimated whereas variance is under estimated (Roy, 2000) [11].

When two or more variables are included in the correlation studies, it becomes difficult to determine which characters enhance the yield. The technique of path coefficient analysis overcomes this situation which partitions the forces of association and examines the relative contribution of direct and indirect effects of the independent variables on the dependent variables. The direct and indirect effects of variance characters along with fruit yield are executed in Table 2.

The genotypic path coefficient analysis (Table 2) revealed that ratio of male to female flowers (1.0449) followed by number of female flowers (0.6819),days to opening of first male flower (0.3555) and average fruit weight (0.3130) exhibited high and positive direct effect on fruit yield per vine and were found to be the most important yield components. The characters fruit length (0.2350) and vine length (0.2782) had moderate and positive direct effect on fruit yield per plant, while number of fruits per vine (0.1705), fruit girth (0.1405) and number of node bearing first female flower (0.1385) had low and positive direct effect on fruit yield per vine. High and positive direct effect of number of female flowers and average fruit weight on fruit yield per vine has also been reported in bottle gourd by Deepthi *et al*. (2014) [3] and Janaranjani and Kanthaswamy(2015) [7]. Thus, these characters *viz.*, ratio of male to female flowers followed by number of female flowers, days to opening of first male flower and average fruit weight turned out to be the major components of fruit yield and direct selection for these traits will be rewarding for yield improvement.

The residual effect in the present study was 0.6570indicating that the characters studied contributed 34 per cent of the yield. It is suggested that maximum emphasis should be given on the charactersratio of male to female flowers, number of female flowers, days to opening of first male flower and average fruit weightin selecting bottle gourd for getting higher yield. It is also suggested that further study should be made with more characters to find out other traits which contribute rest of the percentage of the yield.

Table 4.3: Genotypic (rg) and phenotypic (rp) correlation coefficients among 15 characters in 50 genotypes of bottle gourd

Characters		Days to opening of first female flower	Days to opening of first male flower	Number of node bearing first female flower	Internodal length (cm)	Number of male flowers	Number of female flowers	Ratio of male to female flowers	Days to first picking	Vine length (cm)	Number of primary branches per vine	Number of Fruits per vine	Average fruit weight (kg)	Fruit length (cm)	Fruit girth (cm)
Fruit yield per vine (kg)	r_g	0.3681**	0.3142**	-0.2502**	0.3956**	0.0115	-0.1392	0.1621	0.2590	0.4489**	0.2162	0.0358	0.4852**	0.6920**	0.4285**
	r_p	0.2026	0.2709	-0.1578	0.3528*	0.0182	-0.1185	0.1537	0.2490	0.4325**	0.1962	0.0369	0.4554**	0.6486**	0.3897**
Days to opening of first female flower	r_g	1.0000	1.1433**	-0.0677	0.0383	0.4526**	-0.5386**	0.5211**	0.5239**	0.1695	0.1917	-0.1866	0.3075*	0.1126	0.0408
	r_p	1.0000	0.7189**	-0.0373	0.0274	0.2312	-0.2524	0.2836*	0.2925**	0.0897	0.0931	-0.1177	0.2108	0.0796	0.0157
Days to opening of first male flower	r_g		1.0000	-0.2976*	0.0366	0.1192	-0.1032	0.1444	0.4808**	0.1128	0.1977	-0.0578	0.1321	0.2344	0.2628
	r_p		1.0000	-0.1561	0.0810	0.1047	-0.0861	0.1347	0.4191**	0.1160	0.1769	-0.0631	0.1214	0.2367	0.2137
Number of node bearing first female flower	r_g			1.0000	-0.0461	-0.0630	-0.0646	-0.0864	0.1648	-0.3178*	0.1225	-0.4320**	0.0053	-0.0422	0.0481
	r_p			1.0000	-0.1028	-0.0714	0.0420	-0.0703	0.0701	-0.2172	0.0563	-0.2771	0.0157	-0.0630	0.0172
Internodal length (cm)	r_g				1.0000	0.1207	0.1631	0.0179	0.0051	0.7297**	0.3986*	0.0754	0.1872	0.4500**	-0.0835
	r_p				1.0000	0.1144	0.0389	0.0455	0.0051	0.6380**	0.3482*	0.0605	0.1569	0.4214**	0.0007
Number of male flowers	r_g					1.0000	-0.5611**	0.7174**	-0.1410	0.2927*	0.2187	0.2341	-0.0811	-0.1536	0.2985*
	r_p					1.0000	-0.4871**	0.6974**	-0.1243	0.2821	0.1959	0.2165	-0.0576	-0.1362	0.2359
Number of female flowers	r_g						1.0000	-0.9589**	0.0166	0.0993	0.2214	-0.2166	-0.1225	0.2017	-0.2890*
	r_p						1.0000	-0.8888**	0.0005	0.0700	0.1733	-0.1781	-0.0918	0.1642	-0.2161
Ratio of male to female flowers	r_g							1.0000	-0.0445	0.0641	-0.0320	0.1608	0.0589	-0.1086	0.3349*
	r_p							1.0000	-0.0387	0.0666	-0.0364	0.1537	0.0608	-0.0984	0.2654
Days to first picking	r_g								1.0000	-0.1118	-0.0801	-0.1028	0.1916	0.2395	0.3546*
	r_p								1.0000	-0.1021	-0.0594	-0.0877	0.1667	0.1950	0.3089*
Vine length (cm)	r_g									1.0000	0.3782**	0.1648	0.1388	0.5915**	0.1282
	r_p									1.0000	0.3707**	0.1578	0.1326	0.5571**	0.1013
Number of primary branches per vine	r_g										1.0000	0.2216	0.1093	0.2789*	0.1312
	r_p										1.0000	0.2092	0.1006	0.2550	0.0975
Number of fruits per vine	r_g											1.0000	-0.1788	0.1385	0.0065
	r_p											1.0000	-0.1642	0.1241	0.0125
Average fruit weight (kg)	r_g												1.0000	0.4717**	0.3862**
	r_p												1.0000	0.4212**	0.2991**
Fruit length (cm)	r_g													1.0000	0.1106
	r_p													1.0000	0.1206
Fruit girth (cm)	r_g														1.0000
	r_p														1.0000

*, ** significant at 5% and 1% levels,

Table 4.4: Genotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on fruit yield in 50 genotypes of bottle gourd

Characters	Days to opening of first female flower	Days to opening of first male flower	Number of node bearing first female flower	Internodal length (cm)	Number of male flowers	Number of female flowers	Ratio of male to female flowers	Days to first picking	Vine length (cm)	Number of primary branches per vine	Number of fruits per vine	Average fruit weight (kg)	Fruit length (cm)	Fruit girth (cm)	Genotypic correlation with fruit yield per vine
Days to opening of first female flower	-0.1344	0.4065	-0.0094	-0.0001	-0.1819	-0.3673	0.5445	-0.0074	0.0472	-0.0262	-0.0318	0.0962	0.0265	0.0052	0.3681**
Days to opening of first male flower	-0.1536	0.3555	-0.0412	-0.0001	-0.0479	-0.0702	0.1509	-0.0068	0.0314	-0.0270	-0.0099	0.0413	0.0551	0.0368	0.3142**
Number of node bearing first female flower	0.0091	-0.1058	0.1385	0.0001	0.0253	-0.0444	-0.0902	-0.0023	-0.0844	-0.0167	-0.0736	0.0016	-0.0104	0.0067	-0.2502
Internodal length (cm)	-0.0051	0.0130	-0.0064	-0.0014	-0.0485	0.1113	0.0187	0.0001	0.2030	-0.0545	0.0129	0.0586	0.1057	-0.0117	0.3956**
Number of male flowers	-0.0608	0.0424	-0.0087	-0.0002	-0.4019	-0.3826	0.7496	0.0020	0.0814	-0.0299	0.0399	-0.0254	-0.0361	0.0418	0.0115
Number of female flowers	0.0724	-0.0367	-0.0089	-0.0002	0.2255	0.6819	-1.0019	-0.0002	0.0276	-0.0303	-0.0369	-0.0383	0.0474	-0.0405	-0.1392
Ratio of male to female flowers	-0.0700	0.0513	-0.0120	0.0000	-0.2883	-0.6539	1.0449	0.0006	0.0178	0.0044	0.0274	0.0184	-0.0255	0.0469	0.1621
Days to first picking	-0.0704	0.1710	0.0288	0.0000	0.0567	0.0113	-0.0465	-0.0141	-0.0310	0.0110	-0.0175	0.0600	0.0563	0.0497	0.2597
Vine length (cm)	-0.0228	0.0401	-0.0440	-0.0010	-0.1176	0.0677	0.0670	0.0016	0.2782	-0.0517	0.0281	0.0434	0.1390	0.0180	0.4459**
Number of primary branches per vine	-0.0258	0.0703	0.0170	-0.0006	-0.0879	0.1511	-0.0334	0.0011	0.1052	-0.1367	0.0378	0.0342	0.0655	0.0184	0.2162
Number of fruits per vine	0.0251	-0.0206	-0.0598	-0.0001	-0.0941	-0.1477	0.1680	0.0014	0.0458	-0.0303	0.1705	-0.0560	0.0325	0.0009	0.0358
Average fruit weight (kg)	-0.0413	0.0470	0.0007	-0.0003	0.0326	-0.0835	0.0616	-0.0027	0.0386	-0.0149	-0.0305	0.3130	0.1108	0.0541	0.4852**
Fruit length (cm)	-0.0151	0.0833	-0.0061	-0.0006	0.0617	0.1376	-0.1134	-0.0034	0.1645	-0.0381	0.0236	0.1476	0.2350	0.0155	0.6920**
Fruit girth (cm)	-0.0052	0.0935	0.0067	0.0001	-0.1199	-0.1971	0.3499	-0.0050	0.0357	-0.0179	0.0011	0.1209	0.0260	0.1401	0.4285**

*, ** Significant at 5% and 1% levels, respectively, Residual effect, R = 0.6570, **N.B.:** Values at diagonal indicate direct effects of respective characters

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