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Correlation and path coefficient analyses of quantitative traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] genotypes

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Abstract
Knowledge of degree of association of yield with its components is of great importance to improve the selection efficiency during cultivar improvement. The present study signifies the correlation between ten quantitative traits in ninety one bottle gourd genotypes using correlation and path analysis. Results revealed that significant and positive correlation exists between the yield per plant with fruit diameter, average fruit weight and number of fruits per plant. Significant negative correlation exists between fruit yield per plant with days to opening of first female flower and days to first fruit harvest. The path coefficient analysis revealed that number fruits per plant had maximum positive direct effect with marketable fruit yield per plant, followed by fruit diameter. There is no significant negative direct effect found on fruit yield per plant through any quantitative trait. This study demonstrated that selection for increased number of fruit per plant, fruit diameter and average fruit weight may improve genetic gain in total fruit yield in bottle gourd breeding programme. On the basis of above information genotypes like IC 0322274, IC 319470, IC 0522861 and IC 0284892 may be further utilized in bottle gourd improvement programme.

Keywords: bottle gourd, correlation, path coefficient, character association, yield

Introduction
Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] is an ancient pan-tropically distributed vegetable crop belongs to the family cucurbitaceae having chromosome number 2n=2x=22. It has its origin in Africa with a long history of cultivation in Asia and other warmer regions of the world. India is considered as a secondary center of diversity with very good repository of bottle gourd germplasm. It is commonly named as alabu, calabash, white-flowered gourd, etc. The genus *Lagenaria* includes six species among which *Lagenaria siceraria* is the cultivated having annual and monoecious character. The fresh fruit has light-green smooth skin and white flesh. However, despite its importance, the crop is considered underutilized and is under-researched.

Knowledge of degree of association of quantitative trait like yield with its components is of great importance to improve the efficiency of selection gains in plant breeding programmes (Shimelis and Hugo, 2011) [11]. Yield is not an independent trait, but is the resultant of the interactions of a number of component traits among themselves as well as with the environment in which the plants grow. Simple correlation and path coefficient analysis are served as an important statistical tool to quantify the magnitude and type of associations between selection parameters. Simple correlation coefficients can be misleading if a high correlation between two traits is a consequence of the indirect effect of other traits (Dewey and Lu, 1959) [3]. Path coefficient analysis is a standardized partial regression which was developed by Wright (1921) [13]. It is used to describe the directed dependencies among a set of variables. It separates the correlation coefficients into the path coefficient that measures the direct and indirect effect of a predictor variable upon its response variable via other predictor variables (Dewey and Lu 1959) [3]. Path coefficients reduce the timeline of a selection process by guiding selections to be made on the major few traits rather than looking at several traits with little or no impact on yield or a response trait (Ahmad *et al.*, 1991) [1]. Therefore, present study was conducted aiming at generating information regarding the nature and magnitude of association between yield and yield-related traits in 91 diverse bottle gourd genotypes using simple correlation and path analyses for effective selection. The results of the study will be useful for the breeder in formulating bottle gourd breeding programme.

Materials and Methods

The present study was carried out at the Research Farm of Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi during the *kharif* season in the year 2015-16. The geographical coordinates of New Delhi are 28° 36' 0" North, 77° 12' 0" East with an altitude of 228.6 m above mean sea level. The experimental material used for conducting the present study consists of eighty six germplasm of bottle gourd and five check varieties collected from various location of India. These collected genotypes were maintained at the Division of Vegetable Science, IARI, New Delhi. The experiment was laid out in augmented block design (Federer 1956) [4]. Two to three seeds of each genotype were sown in the hills on the ridges at a spacing of 3.0 m x 60 cm. The standard cultural practices as mentioned in Package of Practices for Vegetable Crops (Thamburaj and Singh, 2004) [12] were followed to raise the healthy crop stand. Out of 10 plants in each genotype, 5 were taken at random for recording observations. To study the correlation and path coefficient analysis observations were recorded on ten quantitative traits, on individual plant basis. The data were subjected to analysis suggested by Dewey and Lu (1959) [3]. All the statistical analysis was done based on above mentioned parameters using TNAU AGRISTAT package.

Results and Discussion

The simple correlation coefficients among the different quantitative traits were estimated (Table 1) which revealed that fruit yield per plant had highly significant positive association with fruit diameter (0.319), average fruit weight (0.720) and number of fruits per plant (0.661). It had significant negative correlation with days to opening of first female flower (-0.229) and days to first fruit harvest (-0.211).

Besides, days to first fruit harvest had highly significant positive association with days to opening of first female flower (0.931). The fruit length had positive and highly significant association with ovary length of female flower (0.504). Fruit diameter had a significant negative correlation with days to opening of first female flower (-0.212) and highly significant correlation with ovary length on the day of anthesis (-0.494) and fruit length (-0.595). The average fruit weight of plant had highly significant positive association with fruit diameter (0.492). Peduncle length of fruit was found to be significantly negatively associated with days to opening of first female flower (-0.228) and days to first fruit harvest (-0.248). Vine length had highly significant positive correlation with number of fruits per plant (0.335), fruit yield per plant (0.298) and peduncle length of fruit (0.188) whereas a highly significant negative correlation was observed with days to opening of first female flower (-0.370) and days to first fruit harvest (-0.360).

Above result revealed that yield per plant had significantly positive association with fruit diameter, average fruit weight and number of fruits per plant. It suggested selection of these three characters may directly impact on yield in a positive manner. Similar correlations of yield with various quantitative traits have also been reported earlier by several workers *viz.* Rahman *et al.* (1986) [10], Kumar *et al.* (2007) [7], Narayanankutty *et al.* (2006) [9] and Deepthi *et al.* (2013) [2].

Significant negative result for correlation exists between fruit yield per plant with days to opening of first female flower and days to first fruit harvest. The present findings clearly indicate that an increase in number of fruits per vine would indirectly affect the total yield, which is more dependent on fruit weight and fruit diameter.

Although correlation studies are helpful in determining the components of yield, but it does not provide a clear picture of the nature and extent of contributions made by number of independent traits. Path coefficient analysis devised by Dewey and Lu (1959) [3], however, provides a realistic basis for allocation of appropriate weightage to various attributes, while designing a pragmatic programme for the improvement of yield. Path coefficient analysis depicts the effects of different independent traits individually and in combination with other traits on the expression of different traits on marketable fruit yield per plant.

The data on path coefficient analysis showing the direct and indirect effects of significant traits over fruit yield per plant have been presented in Table 2. The data revealed that number fruits per plant (0.720) have maximum highly significant positive correlation with marketable fruit yield per plant, followed by fruit diameter (0.492). The direct effect of fruit diameter was also positive (0.0533) on yield. Besides, it contributed indirectly in a positive direction via days to opening of first female flower (0.0003), average fruit weight (0.0594), number of fruits per plant (0.4021) and vine length (0.0026) on fruit yield per plant. Maximum negative indirect effects of fruit diameter was noted via ovary length on the day of anthesis (-0.0040), days to first fruit harvest (-0.0009), fruit length (-0.223) and peduncle length (-0015) on fruit yield per plant. Number of fruits per plant had a positive direct effect on fruit yield per plant. It also contributed indirectly in a positive direction through days to opening of first female flower (0.0003), fruit length (0.0038), fruit diameter (0.0170), peduncle length (0.0018) and vine length (0.0226) towards yield. For the trait number of fruits per plant less number of negative indirect effects were recorded for ovary length on the day of anthesis (-0.0002), days to first fruit harvest (-0.0010) and average fruit weight (-0.5695) on fruit yield per plant.

Above finding revealed that number fruits per plant had maximum positive direct effect with marketable fruit yield per plant, followed by fruit diameter. Significant positive direct effect of different quantitative traits on fruit yield in bottle gourd was also been reported earlier by Yadav *et al.* (2007) [14], Kumar and Syamal (2010) [8], Husna *et al.* (2011) [5] and Janaranjani and Kanthaswamy (2015) [6] indicating their true positive and significant association with yield. Fruit diameter contributed indirectly in a positive direction via days to opening of first female flower, average fruit weight, number of fruits per plant, vine length whereas number of fruits per plant contributed indirectly in a positive direction through days to opening of first female flower, fruit length, fruit diameter, peduncle length and vine length towards yield. This indicated that indirect selection on the basis of these traits will result in appreciable improvement in fruit yield. There is no significant negative direct effect found on fruit yield per plant but negative indirect effects was found for fruit diameter via ovary length on the day of anthesis, days to first fruit harvest, fruit length and peduncle length whereas for the trait number of fruit per plant, less number of negative indirect effects were found for ovary length on the day of anthesis, days to first fruit harvest and average fruit weight on fruit yield per plant.

Table 1: Simple correlations among different quantitative traits in bottle gourd

Genotypes	Days to opening of first female flower	Ovary length (on the day of anthesis) (cm)	Days to first fruit harvest	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Number of fruits/plant	Fruit yield/ plant (kg)	Peduncle length at harvest maturity (cm)	Vine length (m)
Days to opening of first female flower	1.000	0.067	0.931**	0.034	-0.212*	-0.152	-0.181	-0.229*	-0.228*	-0.370**
Ovary length (on the day of anthesis) (cm)		1.000	0.067	0.504**	-0.494**	-0.132	0.108	-0.031	0.126	-0.021
Days to first fruit harvest			1.000	0.056	-0.192	-0.154	-0.151	-0.211*	-0.248**	-0.360**
Fruit length (cm)				1.000	-0.595**	0.117	0.044	0.118	0.172	-0.084
Fruit diameter (cm)					1.000	0.492**	-0.069	0.319**	-0.070	0.114
Average fruit weight (g)						1.000	-0.024	0.720**	0.164	0.116
Number of fruits/plant							1.000	0.661**	-0.035	0.335**
Fruit yield/ plant (kg)								1.000	0.084	0.298**
Peduncle length at harvest maturity (cm)									1.000	0.188*
Vine length (m)										1.000

*, ** Significant at 5% and 1% level of probability, respectively.

Table 2: Estimates of direct and indirect effects of different quantitative traits on marketable fruit yield per plant in bottle gourd

Genotypes	Days to opening of first female flower	Ovary length (on the day of anthesis) (cm)	Days to first fruit harvest	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Number of fruits/plant	Peduncle length at harvest maturity (cm)	Vine length (m)	Correlation (R) with fruit yield/ plant (kg)
Days to opening of first female flower	-0.0015	0.0005	0.0044	0.0011	-0.0113	0.1562	-0.2883	-0.0050	-0.0084	-0.152
Ovary length (on the day of anthesis) (cm)	-0.0001	0.0080	0.0003	0.0163	-0.0263	-0.0932	-0.0394	0.0027	-0.0005	-0.132
Days to first fruit harvest	-0.0014	0.0005	0.0047	0.0018	-0.0102	0.1301	-0.2656	-0.0054	-0.0081	-0.154
Fruit length (cm)	0.0000	0.0040	0.0003	0.0323	-0.0317	-0.0382	0.1482	0.0037	-0.0019	0.117
Fruit diameter (cm)	0.0003	-0.0040	-0.0009	-0.0192	0.0533	0.0594	0.4021	-0.0015	0.0026	0.492**
Average fruit weight (g)	0.0003	0.0009	-0.0007	0.0014	-0.0037	-0.8622	0.8329	-0.0008	0.0076	-0.024
Number of fruits/plant	0.0003	-0.0002	-0.0010	0.0038	0.0170	-0.5695	1.2610	0.0018	0.0067	0.720**
Peduncle length at harvest maturity (cm)	0.0003	0.0010	-0.0012	0.0056	-0.0037	0.0305	0.1054	0.0217	0.0042	0.164
Vine length (m)	0.0005	-0.0002	-0.0017	-0.0027	0.0061	-0.2889	0.3759	0.0041	0.0226	0.116

Residual effect = 0.0368 (Diagonal bold figures represent the direct effect; ** Significant at 1% level of probability)

Summary and Conclusion

Correlation and path coefficient analysis depict a clear scenario that fruit yield per plant showed highly significant and positive association with fruit diameter (0.310), average fruit weight (0.720) and number of fruits per plant (0.661) which suggests the possibility of simultaneous improvement of these traits in improving fruit yield per plant. Keeping the above findings in view we can select genotype IC 0322274, IC 319470, IC 0522861 and IC 0284892 for using them in further crop improvement programme to get high yielding varieties in our seed basket.

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