Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(2): 2419-2422
Received: 21-01-2018
Accepted: 22-02-2018

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Character association and path coefficient analysis of bitter gourd (*Momordica charantia* L.) genotypes

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Abstract
Estimates of correlation and path coefficients can help the mutual relationship between various plant characters and determines component characters on which selection can be based or improvement in yield. It might be easier to increase yield by increasing the smallest yield components on an otherwise good cultivar. Thirty one genotypes of bitter gourd were evaluated for yield contributing characters to observe their associations and direct and indirect effect on fruit yield. The study revealed that in most of cases the genotypic correlation coefficient was higher than the respective phenotypic correlation coefficients. This indicated that the suppressive effect of the environment modified the phenotypic expression of these characters by reducing phenotypic correlation values. Fruit yield per plant (kg) showed significant positive association with average fruit weight (g) at genotypic and phenotypic level. Path analysis revealed that average fruit weight (g) and number of fruits per plant had the greatest direct effect on yield both at phenotypic and genotypic level suggesting their importance while imposing selection for correlation of yield in bitter gourd.

Keywords: correlation analysis, path coefficient analysis, bitter gourd genotypes

Introduction
Bitter gourd (*Momordica charantia* L.) is also called balsam pear or bitter cucumber or bitter melon (Hazra and Som 2015) [12]; is a tropical and subtropical cucurbitaceous crop belongs to the family Cucurbitaceae. The center of origin of this crop is India, with a secondary center of diversity in China and South East Asia (Grubben 1977) [10]. It is a common cucurbit of wild flora of tropical Africa which offers great resources for breeding of cultivated bitter gourd for desirable qualitative traits, tolerance to biotic and abiotic factors etc. The tender and immature fruits are highly nutritious (Gopalan *et al.* 1982) [9] and rich source of calcium (20 mg/100 g), phosphorus (55 mg/100 g), iron (1.8 mg/100 g), vitamin A (219 IU/100 g) and vitamin C (88 mg/100 g). The roots, vines, leaves, flowers and seeds of bitter gourd are also used in medicinal preparations (Morton 1967) [15].
Correlation, in general, measures the extent and direction (positive or negative) of a relationship occurring between two or more characteristics (Gomez and Gomez 1984, Rohman *et al*. 2003) [8, 18]. Simple correlation only describes the overall relationship between the two or more characteristics under study, whereas the estimates of genetic and phenotypic correlations describe the extent of genetic and phenotypic factors in establishing a relationship between two plant traits. The estimate of genetic correlation (rg) refers to the association between two plant characters due to the genetic constitution of the plant, whereas phenotypic correlation (rp) refers to the correlation between two plant characters due to their physical appearance at a morphological, anatomical, or biochemical level (Affifi 1984, Kang 1998, Zhang *et al*. 2005) [1, 14, 21]. The technique of path analysis was originally proposed in 1920s for analyzing data in social studies. It was then adopted in plant breeding experiments by Dewey and Lu (1959) [5]. More recently, path analysis has been used extensively in agronomic and environmental studies (Garcia del Moral *et al*. 2003, Zhang *et al*. 2005) [7, 21]. It is simply a standardized partial regression analysis and as such measures the direct influence of one variable upon the other and permits separation of correlation into direct and indirect effects. It has previously been reported that path analysis is a useful method for determining the contribution of component variables to a character (Rafi and Nath 2004, Zhang *et al*. 2005, Carlos *et al*., 2005) [16, 21, 4]. The objective of this present research work has been undertaken in order to determine the nature of association, direct and indirect relationship between yield and yield contributing characters and relative contribution of each character towards fruit yield in bitter gourd through character association and path coefficient analysis.

Materials and Methods

The experimental materials consisted of thirty one diverse bitter gourd genotypes including two check varieties (Pusa Vishes and Pusa Do Mausami). The crop was laid in Randomized Block Design with three replications during spring summer of 2015 at Main Experiment Station (Vegetable Research Farm), Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, India (26.47° North latitude and 82.12° East longitudes at an altitude of 113 m above the mean sea level). The plot size was of 3 m x 2 m with row to row spacing of 2 m and plant to plant spacing of 0.50m. All the recommended package of practices was followed to raise a healthy crop. The observations were recorded on five randomly selected plants from each genotype in each replication for the characters *viz*., node number to anthesis of first staminate flower, node number to anthesis of first pistillate flower, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to first fruit harvest, vine length (m), number of nodes per vine, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant and fruit yield per plant (kg). Genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al*. (1958) [2] using an ANOVA and covariance matrix in which total variability was split into replications, genotypes, and errors. The genotypic and phenotypic correlation coefficients were used to determine direct and indirect contribution toward yield per plot. The direct and indirect paths were obtained according to the method of Dewey and Lu (1959) [5].

Results and Discussion

The correlation coefficients among characters were determined at the phenotypic and genotypic levels. Genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients. This can be interpreted as a strong inherent genotypic relationship between characters studied, through their phenotypic expression was impeded by environmental influence.

The estimates of correlation coefficient (Table 1) revealed that fruit yield per plant was positively and significantly correlated with average fruit weight (rp= 0.805**, rg= 0.811**) while significant negative correlation were observed for node number to anthesis of first staminate flower (rg= -0.468**), number to anthesis of first pistillate flower (rg= -0.363*), days to anthesis of first staminate flower (rg= -0.433*), days to anthesis of first pistillate flower (rg= -0.675**), days to first fruit harvest (rg= -0.699**) which confirmed well with the findings of Bhave *et al.* (2003) [3], Dey *et al.* (2005) [6], Singh *et al.* (2012) [19]. Among the traits, average fruit weight recorded significant negative correlation coefficient with node number to anthesis of first staminate flower (rg= -0.448*), days to anthesis of first staminate flower (rg= -0.496**), days to anthesis of first pistillate flower (rg= -0.593**), days to first fruit harvest (rg= -0.720**) and number of fruits per plant (rp= 0.590**, rg= 0.425*) however, fruit length (rp= 0.085, rg= 0.107) was found positive correlation but non significant. Number of fruits per plant showed highly significant positive correlation coefficient with days to anthesis of first staminate flower (rg= 0.480**) and days to first fruit harvest (rg= 0.498**). Character like days to first fruit harvest was positively and significantly correlated with node number to anthesis of first staminate flower (rp= 0.445*, rg= 0.559**), node number to anthesis of first pistillate flower (rp= 0.381*), days to anthesis of first staminate flower (rp= 0.682**, rg= 0.923**) and days to anthesis of first pistillate flower (rp= 0.846**, rg= 0.854**), days to first fruit harvest (rg= -0.720**). While days to anthesis of first staminate flower showed highly significant and positive association with node number to anthesis of first staminate flower (rp= 0.519) and node number to anthesis of first staminate flower (rp= 0.519**, rg= 0.547**). Hence, node number to anthesis of first pistillate flower showed highly significant and positive association with node number to anthesis of first staminate flower (rp= 0.625**, rg= 0.771**) The results are in conformity with the observations of Islam *et al.* (2009) [13], Rani *et al*. (2015) [17], Yadagiri *et al*. (2017) [20].

The association of characters as determined by the simple correlation coefficient may not provide an exact representation of the relationship between yield and yield attributes. In contrast, path coefficient analysis permits a critical examination of specific direct and indirect effects of characters and measures the relative importance of each of them in determining the ultimate goal yield. Path analysis (Table 2) indicated that average fruit weight had highest positive direct effect on fruit yield per plant (1.210, 1.156) followed by number of fruits per plant (0.967, 0.528) and node number to anthesis of first staminate flower (1.468, 0.091) at the genotypic and phenotypic level. Thus, direct selection for these characters would be effective for crop improvement. Corroborating the findings of present investigation positive and direct effect on fruit yield per plant has also been reported in bitter gourd by Islam *et al.* (2009) [13], Gupta *et al*. (2015) [11], Rani *et al*. (2015) [17], Yadagiri *et al*. (2017) [20].

Table 1: Estimates of phenotypic (rp) and genotypic (rg) correlation coefficient among different characters of bitter gourd genotypes

Characters		Node number to anthesis of first pistillate flower	Days to anthesis of first staminate flower	Days to anthesis of first pistillate flower	Days to first fruit harvest	Numbe of nodes per vine	Vine length (m)	Fruit length (cm)	Fruit diameter (cm)	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (kg)
Node number to anthesis of first staminate flower	rp	0.625**	0.519**	0.579**	0.445*	-0.104	0.189	-0.116	-0.081	-0.049	-0.220	-0.221
	rg	0.771**	0.547**	0.714**	0.559**	-0.073	0.276	-0.149	-0.105	0.176	-0.448*	-0.468**
Node number to anthesis of first pistillate flower	rp		0.265	0.578**	0.381*	-0.287	-0.059	-0.175	-0.089	-0.277	-0.081	-0.064
	rg		0.250	0.564**	0.281	-0.376*	-0.070	-0.239	-0.176	-0.126	-0.142	-0.363*
Days to anthesis of first staminate flower	rp			0.689**	0.682**	0.002	-0.088	-0.059	0.201	-0.010	-0.103	-0.060
	rg			0.919**	0.923**	-0.005	-0.143	-0.093	0.295	0.480**	-0.496**	-0.433*
Days to anthesis of first pistillate flower	rp				0.846**	-0.127	-0.086	-0.095	0.164	-0.188	-0.057	-0.116
	rg				0.854**	-0.237	-0.170	-0.189	0.168	0.292	-0.593**	-0.675**

Days to first fruit harvest	rp					0.003	-0.055	-0.184	0.230	-0.030	-0.171	-0.145
	rg					-0.083	0.537**	-0.330	0.300	0.498**	-0.720**	-0.699**
Number of nodes per vine	rp						0.574**	0.235	0.207	0.022	-0.205	-0.227
	rg						-0.163	0.203	0.162	0.016	-0.251	-0.266
Vine length (m)	rp							0.170	0.183	-0.106	-0.005	-0.063
	rg							0.142	0.139	-0.162	0.003	-0.062
Fruit length (cm)	rp								0.355*	-0.221	0.085	-0.043
	rg								0.294	-0.336	0.107	-0.062
Fruit diameter (cm)	rp									-0.073	-0.075	-0.155
	rg									-0.127	-0.112	-0.236
Number of fruits per plant	rp										-0.590**	-0.126
	rg										-0.425*	0.241
Average fruit weight (g)	rp											0.805**
	rg											0.811**

*, ** significant at P ≤ 0.05 or P ≤ 0.01, respectively.
rg = Genotypic correlation coefficient.
rp = Phenotypic correlation coefficient.

Table 2: Direct and indirect effects of different characters of fruit yield per plant (kg) at phenotypic and genotypic level of bitter gourd

Characters		**Node number to anthesis of first staminate flower**	**Node number to anthesis of first pistillate flower**	**Days to anthesis of first staminate flower**	**Days to anthesis of first pistillate flower**	**Days to first fruit harvest**	**Number of nodes per vine**	**Vine length (m)**	**Fruit length (cm)**	**Fruit diameter (cm)**	**Number of fruits per plant**	**Average fruit weight (g)**	**Fruit yield per plant (kg)**
Node number to anthesis of first staminate flower	P	0.091	0.057	0.047	0.053	0.040	-0.009	0.017	-0.010	-0.007	-0.004	-0.020	-0.221
	G	1.468	1.133	0.804	1.049	0.821	-0.107	0.406	-0.220	-0.154	0.259	-0.659	-0.468**
Node number to anthesis of first pistillate flower	P	-0.062	-0.099	-0.026	-0.057	-0.038	0.028	0.005	0.017	0.008	0.027	-0.008	-0.064
	G	-0.936	-1.213	0.303	-0.684	-0.341	0.456	0.085	0.291	0.213	0.153	0.172	-0.363*
Days to anthesis of first staminate flower	P	0.001	-0.000	0.001	0.001	0.001	0.000	-0.000	-0.00	0.000	0.000	-0.000	-0.060
	G	-0.688	-0.314	-1.256	-1.155	-1.160	0.006	0.180	0.117	-0.371	-0.603	0.624	-0.433*
Days to anthesis of first pistillate flower	P	-0.010	0.010	-0.011	-0.017	-0.014	0.002	0.001	0.001	-0.002	0.003	0.001	-0.116
	G	0.850	0.671	1.093	1.189	1.016	-0.282	-0.202	-0.225	0.200	0.348	-0.705	-0.675**
Days to first fruit harvest	P	0.039	-0.033	0.060	0.075	0.088	0.000	-0.004	-0.016	0.020	-0.002	-0.015	-0.145
	G	-0.564	-0.284	-0.931	-0.862	-1.009	0.084	0.164	0.333	-0.303	-0.503	0.727	-0.699**
Number of nodes per vine	P	0.001	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.227
	G	-0.014	-0.274	-0.001	-0.046	-0.016	0.197	0.106	0.040	0.032	0.003	-0.049	-0.266
Vine length (m)	P	-0.004	0.001	0.002	0.002	0.001	-0.014	-0.024	-0.004	-0.004	0.002	-0.000	-0.063
	G	-0.191	0.048	0.099	0.118	0.113	-0.372	-0.691	-0.098	-0.096	0.112	-0.002	-0.062
Fruit length (cm)	P	-0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.003	0.001	-0.000	0.000	-0.043
	G	0.041	0.066	0.026	0.052	0.091	-0.056	-0.039	-0.277	-0.081	0.093	-0.029	-0.062
Fruit diameter (cm)	P	0.003	-0.003	-0.088	-0.007	-0.010	-0.092	-0.008	-0.015	-0.044	0.003	0.003	-0.155
	G	-0.061	-0.103	0.171	0.098	0.176	0.095	0.081	0.172	0.585	-0.074	-0.066	0.236
Number of fruits per plant	P	-0.026	-0.146	-0.005	-0.099	-0.016	0.011	-0.056	-0.116	-0.039	0.528	-0.312	-0.126
	G	0.170	-0.122	0.464	0.283	0.482	0.016	-0.156	0.325	-0.123	0.967	-0.411	0.241
Average fruit weight (g)	P	-0.254	0.094	-0.119	-0.066	-0.198	-0.237	0.000	0.098	-0.087	-0.683	1.156	0.805**
	G	-0.154	-0.171	-0.601	-0.718	-0.872	-0.304	0.003	0.129	-0.136	0.514	1.210	0.811**

Diagonal bold figures represent direct effects; Phenotypic residual effect = 0.388; Genotypic residual effect = Sqrt (1-1.12835)

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