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Character association and path analyses in sponge gourd

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Abstract
Knowledge about the degree of association of yield with components and the interrelationships among them may prove useful in crop improvement. Correlation and path coefficient analyses were carried out for 13 characters of yield and its components. Character association indicated that fruit yield per plant and average fruit weight was positive and significantly correlated with number of fruits per plant at genotypic and phenotypic level. Path analysis indicated that number of fruits per plant had significantly positive, direct effect on fruit yield per plant at genotypic and phenotypic level. The remaining characters had negligible to low or moderate indirect effects through other component characters. The high direct effect of these traits appeared to be the main factors for their strong association with fruit yield. Therefore, maximum weight age should be given to these characters for improvement of yield in sponge gourd.

Keywords: Sponge gourd, correlation; direct effects; indirect effects; yield

Introduction
The Cucurbits/cucurbitaceous family is largest group of summer vegetable crops and among them sponge gourd [*Luffa cylindrica* (L.) syn. *Luffa aegyptiaca* Mill] is one of the most important cucurbit grown throughout the country and world. Sponge gourd commonly known as tori, loofa, vegetable sponge, bath sponge or dish cloth gourd, is monoecious and a cross pollinated vegetable crop. It is tropical and subtropical vegetable and commercially cultivated in China, Korea, India, Japan and Central America (Bal *et al*., 2004) [6]. South and south-east Asia are reported to be the center of diversity for sponge gourd (Kalloo, 1993) [14]. The tender fruits are rich in vitamin A, vitamin C and iron (Yawalkar, 2004) [31]. Sponge gourd commonly grown for its tender fruits for vegetable purpose as well as used as packing medium, shoes mats, sound proof linings, adsorbent for removal of heavy metal [such as Nickel, Lead, Chromium, Copper, etc] in waste water, and immobilization matrix for plant, algae, bacteria and yeast (Demir *et al*., 2008) [7]. It has purgative property and is used for dropsy, nephritis, chronic bronchitis and lung complaints. It is also applied to the body in putrid fevers and jaundice. Seed oil is used in leprosy and skin diseases (Partap *et al*., 2012) [20]. Luffa seed has been shown to be effective against growth of parasites, protozoa, insects, fungi and HIV (Ng YM *et al*., 2011) [19]. Selection for crop yield improvement can only be effective when information is available on yield association with component characters. Correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. Correlation of various characters with yield is useful and provides for direct selection of component characters. Correlation analysis provides information about the degree of relationship between important plant traits and is a good index to predict yield response in relation to change in a particular character (Acquaah, 2007) [1], Aliyu (2006) [3]. Among them genotypic correlation is more stable and provide better understanding of yield components which help the plant breeder during selection (Robinson *et al*., 1951; Johnson *et al*., 1955) [24, 13]. Path coefficient analysis is simply a standardized regression coefficient which splits the correlation coefficient into direct and indirect effect. The present investigation was undertaken to determine relationships among characters and their association with sponge gourd yield.

Material and Methods
Twenty eight genotypes sponge gourd including check variety Pusa chikini were evaluated during summer season of 2015 at Main Experimental Station of Vegetable Science, Narendra Nagar (Kumarganj), Faizabad, Uttar Pradesh (24.47^0 and 26.56^0 N latitude and 82.12^0 and 83.98^0 E longitude, 113 m above the mean sea level). The experiment was conducted in Randomized Complete Block Design with three replications.

The plot size was of 3 m × 2.5 m with row to row spacing of 2.5 m and plant to plant spacing of 0.50 m. 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, number of primary branches per plant, fruit length (cm), fruit diameter (cm), number of fruits per plant, average fruit weight (g) and fruit yield per plant (kg). Genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al*. (1958) [4] using an ANOVA and covariance matrix in which total variability was split into replications, genotypes and errors. Direct and indirect contributions of various characters to fruit yield per plant were calculated through path coefficient analysis according to Wright (1921) [28] as elaborated by Dewey and Lu (1959) [8]. Residual effect measures the role of other possible independent variables that were not included in the study on the dependent variable. The residual effect was estimated using direct effects and simple correlation coefficients.

Results and Discussion

Genotypic correlations in general were higher than phenotypic correlations (Table 1). The lower phenotypic values might be due to environmental interactions. Similar observations were noticed in ridge gourd earlier (Karuppaiah *et al*., 2005; Rao *et al*., 2000) [15, 23]; Khule *et al*. (2011) [16] and Yadav *et al*. (2017) [30] in sponge gourd and Tyagi *et al*. (2018) [27] in bitter gourd. This may be due to relative stability of genotypes because the majority of them were subjected to a certain amount of selection (Engida *et al*., 2006) [9]. Fruit yield per plant exhibited significant and positive correlation with number of fruit per vine (rg = 0.931), while number of fruit per vine (rp = 0.187), fruit length (rp = 0.016) (rg = 0.031) and node number to anthesis of first pistillate flower (rp = 0.010) showed positive non-significant association with fruit yield per plant. Therefore, this single trait should be taken into consideration while making selection for improvement in fruit yield. Similar opinions were also exhibited by Janaranjani *et al*. (2015) [12], Singh *et al*. (2012) [25], Prakash *et al*. (2000) [21], and Raja *et al*. (2006) [22]. Among the traits, average fruit weight had negative significant correlated with number of fruit per plant (rp = -0.577**, rg = -0.678) and significant positive correlated with days to anthesis of first staminate flower (rp = 0.400*, rg = 0.476), days to anthesis of first pistillate flower (rg = 0.416) and days to first fruit harvest (rg = 0.439). Other character like fruit length was significantly positive correlated with number of primary branches per plant (rp = 0.471**, rg = 0.523) and number of nodes per vine (rp = 0.389*, rg = 0.451). Number of primary branches per plant was significant positive correlated with number of nodes per vine (rp = 0.588 **, rg = 0.650), vine length (rp = 0.641**, rg = 0.696) and days to first fruit harvest (rg = 0.371*). Number of nodes per vine was significantly positive correlated with vine length (rp = 0.847, rg = 0.934). Days to first fruit harvest significantly positive correlated with days to anthesis of first pistillate flower (rp = 0.987**, rg = 0.991), days to anthesis of first staminate flower (rp = 0.902** rg = 0.956), node number to anthesis of first pistillate flower (rp = 0.549**, rg = 0.727) and node number to anthesis of first staminate flower (rp = 0.516**, rg = 0.605). Days to anthesis of first pistillate flower significantly positive correlated with days to anthesis of first staminate flower (rp = 0.911, rg = 0.961), node number to anthesis of first pistillate flower (rp =0.565**, rg = 0.738) and node number to anthesis of first staminate flower (rp = 0.529**, rg = 0.621). Days to anthesis of first staminate flower significantly positive correlated with node number to anthesis of first pistillate flower (rp = 0.499**, rg = 0.605) and node number to anthesis of first staminate flower (rp = 0.508**, rg = 0.567). Node number to anthesis of first pistillate flower significantly positive correlated with node number to anthesis of first staminate flower (rp = 0.611**, rg = 0. 678). The results are in conformity with the observations of Khule *et al*. (2011) [16] and Yadav *et al*. (2017) [30] in sponge gourd; Yadagiri *et al*. (2017) [29] and Tyagi *et al*. (2018) [27] in bitter gourd.

Path analysis

Path analysis was carried out to find out direct and indirect effects of twelve characters as independent variable of present study on fruit yield per plant as dependent variable and the results are presented in Table 2. Path analysis facilitates the partitioning of the correlation coefficient into direct and indirect effects on yield and any other attributes (Islam *et al*., 2010) [11] and (Hefny, 2011) [10]. The residual effect (rp = 0.478, rg = 0.307) indicated that most of the characters contributing towards the yield were included in the study (Table 2). Path analysis at phenotypic level revealed that the number of fruits per plant contributed the maximum positive direct effect (1.003) followed by average fruit weight (0.316), number of nodes per vine (0.208). Similar results were also reported by Thakur *et al*. (2017) [26] and Ananthan *et al*. (2017) [5]. However, At genotypic level days to first fruit harvest (2.078) followed by number of nodes per vine (1.920), number of fruit per vine (1.025), number of primary branches per plant (0.522) and average fruit weight (0.377) had direct positive effect on fruit yield per vine and also by others Kumar *et al*. (2013) [17], Aliya *et al*. (2014) [2] and Yadav *et al*. (2017) [30]. The highest indirect positive effect on average fruit yield per plant showed by the number of nodes per vine with vine length (0.177) and number of primary branches per plant (0.123). The negative indirect effect on average fruit yield per plant showed by the average fruit weight with number of fruits per plant (-0.182). The present results confirm the findings of Kumar *et al*. (2013) [17], Khule *et al*. (2011) [16] and Yadav *et al*. (2017) [30] in sponge gourd; Kumar *et al*. (2018) [18] in pumpkin and Tyagi *et al*. (2018) [27] in bitter gourd.

Table 1: Estimates of phenotypic (rp) and genotypic (rg) correlation coefficient among different characters of sponge 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**	**Vine length (m)**	**Number of nodes / vine**	**Number of primary branches / plant**	**Fruit length (cm)**	**Fruit diameter (cm)**	**Number of fruit/ plant**	**Average fruit weight (g)**	**Fruit yield/ plant (kg)**
Node number to anthesis of first staminate flower	rp	0.611**	0.508**	0.539**	0.516**	0.117	0.040	0.301	-0.020	-0.349	-0.031	0.031	-0.091
	rg	0.678	0.567	0.621	0.605	0.127	0.030	0.319	-0.018	-0.384	-0.019	0.042	-0.095
Node number to anthesis of first pistillate flower	rp		0.499**	0.565**	0.549**	0.251	0.137	0.302	0.109	-0.229	-0.094	0.196	0.010
	rg		0.605	0.738	0.727	0.271	0.113	0.354	0.155	-0.271	-0.103	0.213	-0.036
Days to anthesis of first staminate flower	rp			0.911**	0.902**	0.251	0.108	0.157	-0.174	-0.103	-0.224	0.400*	-0.129
	rg			0.961	0.956	0.281	0.129	0.233	-0.155	-0.139	-0.306	0.476	-0.147
Days to anthesis of first pistillate flower	rp				0.987**	0.284	0.128	0.257	-0.074	-0.042	-0.226	0.333	-0.173
	rg				0.991	0.310	0.196	0.364	-0.039	-0.093	-0.337	0.416*	-0.186
Days to first fruit harvest	rp					0.302	0.137	0.254	-0.067	-0.021	-0.236	0.340	-0.188
	rg					0.341	0.214	0.371*	-0.022	-0.058	-0.354	0.439*	-0.200
Vine length (m)	rp						0.847**	0.641**	0.249	-0.113	-0.143	0.206	-0.094
	rg						0.934	0.696	0.289	-0.162	-0.193	0.264	-0.133
Number of nodes / vine	rp							0.588**	0.389*	0.050	-0.165	0.133	-0.087
	rg							0.650	0.451	0.065	-0.152	0.171	-0.161
Number of primary branches / plant	rp								0.471**	-0.096	-0.037	0.010	-0.026
	rg								0.523	-0.153	-0.027	0.026	-0.088
Fruit length (cm)	rp									0.363	0.008	0.059	0.016
	rg									0.419	0.019	0.021	0.031
Fruit diameter (cm)	rp										-0.150	0.128	-0.113
	rg										-0.162	0.099	-0.195
Number of fruit / plant	rp											0.577**	0.187
	rg											0.678	0.931
Average fruit weight (g)	rp												-0.267
	rg												-0.352

rp= Phenotypic correlation, rg = Genotypic correlation

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

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

Characters	r	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 / vine	Number of primary branches / plant	Fruit length (cm)	Fruit diameter (cm)	Number of fruit/ plant	Average fruit weight (g)	Fruit yield/ plant (kg)
Node number to anthesis of first staminate flower	P	-0.176	0.119	0.058	0.018	-0.103	-0.028	0.008	0.031	0.001	0.001	-0.031	0.009	-0.093
	G	-0.536	0.598	1.014	-0.249	1.257	-0.292	0.059	0.167	0.006	0.119	-0.019	0.015	2.140**
Node number to anthesis of first pistillate flower	P	-0.108	0.195	0.057	0.019	-0.11	-0.061	0.028	0.031	-0.01	0.001	-0.095	0.062	0.009
	G	-0.360	0.892	1.084	-0.955	1.511	-0.621	0.218	0.185	-0.050	0.084	-0.106	0.080	1.962**
Days to anthesis of first staminate flower	P	-0.089	0.097	0.115	0.031	-0.18	-0.061	0.022	0.016	0.016	0.0005	-0.224	0.126	-0.131
	G	-0.304	0.540	1.789	-3.848	1.988	-0.643	0.248	0.121	0.050	0.043	-0.134	0.179	0.029
Days to anthesis of first pistillate flower	P	-0.095	0.11	0.105	0.034	-0.197	-0.068	0.026	0.026	0.007	0.0002	-0.227	0.105	-0.174
	G	-0.333	0.658	1.720	-4.002	2.060	-0.711	0.377	0.190	0.012	0.028	-0.346	0.157	-0.190
Days to first fruit harvest	P	-0.091	0.107	0.104	0.033	-0.200	-0.073	0.028	0.026	0.006	0.0001	-0.237	0.107	-0.190
	G	-0.324	0.648	1.711	-3.960	2.078	-0.781	0.411	0.194	0.007	0.018	-0.363	0.165	-0.196
Vine length (m)	P	-0.02	0.049	0.029	0.009	-0.06	-0.242	0.177	0.066	-0.023	0.0005	-0.143	0.065	-0.093
	G	-0.068	0.242	0.502	-1.243	0.709	-2.290	1.794	0.363	-0.094	0.050	-0.198	0.099	-0.134
Number of nodes / vine	P	-0.007	0.026	0.012	0.004	-0.027	-0.205	0.208	0.06	-0.036	-0.0002	-0.165	0.042	-0.088
	G	-0.016	0.101	0.231	-0.786	0.445	-2.139	1.920	0.339	-0.147	-0.020	-0.156	0.064	-0.164
Number of primary branches / plant	P	-0.053	0.059	0.018	0.008	-0.051	-0.155	0.123	0.102	-0.044	0.0005	-0.037	0.003	-0.027
	G	-0.171	0.316	0.417	-1.458	0.773	-1.594	1.248	0.522	-0.170	0.047	-0.028	0.010	-0.088
Fruit length (cm)	P	0.003	0.021	-0.02	-0.002	0.013	-0.06	0.081	0.048	-0.094	-0.0017	0.008	0.018	0.014
	G	0.009	0.139	-0.278	0.156	-0.046	-0.661	0.867	0.273	-0.326	-0.129	0.020	0.008	0.032
Fruit diameter (cm)	P	0.061	-0.044	-0.011	-0.001	0.004	0.027	0.01	-0.01	-0.034	-0.004	-0.15	0.04	-0.112
	G	0.206	-0.242	-0.250	0.372	-0.121	0.370	0.124	-0.080	-0.136	-0.309	-0.166	0.037	-0.195
Number of fruit / plant	P	0.005	-0.018	-0.025	-0.007	0.047	0.034	-0.034	-0.003	-0.0008	0.0007	1.003	-0.182	0.820**
	G	0.010	-0.092	-0.548	1.350	-0.736	0.443	-0.293	-0.014	-0.006	0.050	1.025	-0.256	0.933**
Average fruit weight (g)	P	-0.005	0.038	0.046	0.011	-0.068	-0.05	0.027	0.001	-0.005	-0.0006	-0.579	0.316	-0.269
	G	-0.022	0.190	0.852	-1.668	0.912	-0.604	0.329	0.013	-0.007	-0.030	-0.695	0.377	-0.353

Phenotypic residual effect (rp)= 0.478, Genotypic residual effect (rg)= 0.307; Bold values on diagonal indicate direct effects.; *Values ranged between ≥ 0.367 and ≤ 0.471, significant at 0.05% level of probability ; **Values ≥ 0.471;** Significant at 0.01% level of probability. r= correlation coefficient; p= Phenotypic correlation, rg = Genotypic correlation

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