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Character association and path analysis for fruit yield and it's contributing traits in cucumber genotypes (*Cucumis sativus*L.) under naturally ventilated polyhouse during off season

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Abstract
Ten cucumber genotypes were evaluated at B.C.K.V. under naturally ventilated polyhouse during 2016-17. This study was conducted to examine relationship between important traits of cucumber and their direct and indirect effects on yield. The relationships between fruit yield and yield components in cucumber genotypes were investigated as well as how those relationships changed with selection for improved fruit yield. In this study, genotypic correlation was higher than phenotypic correlations indicating the highly heritable nature of the traits. Correlation studies revealed that intermodal length has exhibited highly significant positive association with fruit yield per plant followed by fruit length, fruit weight, number of fruits per plant and vine length. Direct selection based on these traits would improve yield. The path coefficient analysis revealed that the days to fifty percent flowering, number of fruits per vine, internodal length, fruit weight, fruit length, fruit diameter, TSS and moisture percentage have direct positive phenotypic and genotypic effect on yield. Future breeding should focus on selecting the characters having direct effects to improve yield per plot.

Keywords: cucumber genotypes, correlation, path-coefficient analysis

Introduction
Cucumber (*Cucumis sativus* L.) is one of the most important cucurbitaceous vegetable crops grown extensively in tropical and subtropical parts of the country. It is grown for its tender fruits, which are consumed either raw as salad, cooked as vegetable or as pickling cucumber in its immature stage (Sharma *et al*., 2017) [15].Cucumber is a thermophilic and frost susceptible species growing best at a temperature above 20 °C. So, Cucumber can be grown successfully in the off-season in greenhouse for higher fruit yield (More and Chandra, 1998) [11]. It is highly cross pollinated crop with large amount of variation for many economically important traits. Yield is a complex character and is governed by polygenic system. Moreover, it is highly influenced by environmental fluctuations.

Crop improvement through selection depends not only on fruit yield alone but also depends upon the inter-relationship of number of contributing traits as because yield is a complex polygenic character and direct evaluation of this character is difficult. The study of correlation between plant characters is of great importance to a plant breeder as it provides a measure of the degree of association between yield and other yield attributes. Knowledge of association between different characters serves two purposes from breeder's point of view. Firstly, inter-character relationships are very important for indirect selection for characters that are not easily measured and for those that exhibit low heritability. Secondly, this information makes available to the breeder, the sources of information as the nature, extent and direction of selection pressure among the characters. However, correlation does not provide a clear picture of nature and extent of contributions made by number of independent traits. The path coefficient analysis is partitioned the correlation in direct and indirect effects and thus may be useful in choosing the characters that have direct and indirect effects on yield. Hence, study of correlations (genotypic and phenotypic) and path coefficient analysis of yield would be helpful in selection of yield component traits in the genetic improvement of quantitative traits, which are positively correlated. Adams and Grafius (1971) [1] have mentioned that yield should be considered as end product of a number of traits and breeder should not ignore the principle of balance among these traits. Therefore, the present study was undertaken to assess the nature and magnitude of association among yield and its contributing traits for selecting high yielding genotypes of cucumber (Saikia *et al*., 1995) [14].

Materials and Methods

The present investigation experiment was conducted in the naturally ventilated arched saw teeth type polyhouse, at Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, during September to December of 2016-2017. The experiment was laid out in Completely Randomized Design. The treatment factor includes ten cucumber genotypes namely *viz.* Evergreen Plus, Susoma, Suvan, NS404, Kamini, Malini, Happy Dance, Monoroma, Nina Plus and Cucumber Dabang. The experiment was done in 30 plots and total number of plants allotted was 10 plants per plot. In the experiment, recommended dose of NPK (150: 90: 90 kg/ha) was applied in the field. For the conveniences of planting light irrigation, time to time pruning and training was adopted. Observations were recorded from 15 randomly selected plants of each plot in each replication. The characters studied were vine length(m), internodal length(cm), days to first female flowering, nodal position of first female flower, days to fifty percent flowering, days to first fruit picking, fruit length(cm), fruit diameter(cm), fruit weight(gm), number of fruits per vine, total soluble solid, moisture percentage, fruit yield per vine(kg). Correlation coefficients at genotypic and phenotypic levels were calculated as per Miller *et al*. (1958) [10]. Path coefficient analysis as suggested by Dewey and Lu (1959) [3] was used to partition the phenotypic correlation coefficient into direct and indirect effects.

Results and Discussion

Correlation studies

Information generated from the studies of character association serve as the most important indicator (plant character) that ought to be considered in the selection programme. Such studies would also help us to know the suitability of multiple characters for indirect selection, because selection for one or more traits results in correlated response in several other traits. It provides advantages of selection for more than one character at a time. The correlation coefficients among different characters were worked out both at phenotypic and genotypic levels (Table-1&2). Phenotypic and genotypic correlation co-efficient, in general, agreed very closely. However, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients. This can be interpreted as a strong inherent genotypic relationship between the characters studied through their phenotypic expression was impeded by environmental influence. The higher values of genotypic, than phenotypic, correlation indicated genotypic effects were more important that environmental factors (Falconer, 1988) [5]. The phenotypic expression of each trait is due to the genotype, the environment and the interaction of both. Further each character is likely to be modified by action of genes present in the genotypes of plant and also by the environment and it becomes difficult to evaluate this complex character directly. Therefore, correlation analysis of yield with various characters has been executed to find out the yield contributing factors. In this study, thirteen characters including growth and reproductive characters were recorded and their genotypic and phenotypic correlation co-efficient were analyzed.

Correlation studies revealed that yield per vine had significant positive association at genotypic level with inter-nodal length (0.993), fruit length (0.915), fruit weight (0.782), number of fruits per vine (0.772) and TSS (0.995) and in case of phenotypic correlation the character inter-nodal length (0.657) and TSS (0.700) showed positive significant association. The results indicated that vines with large inter-node, fruit length, yielding high number of fruits per vine and maximum fruit weight would results in higher fruit yield per vine. Fruit weight and number of fruits per vine are major factors for positive significant effect with yield as reported by Kumar *et al.* (2008) [7], Pal *et al*. (2017) [12] and Mehedi and Khan (2009) [9] and also Hossain *et al*. (2010) [6].They revealed that yield per plant of cucumber had high positive and significant association with fruit length and diameter, average fruit weight and number of fruits per plant. Besides, these characters namely; vine length (0.607) and fruit diameter (0.244) had positive but non-significant genotypic correlation and also vine length (0.279), fruit length (0.627), fruit diameter (0.306), fruit weight (0.581) and number of fruits per vine (0.494) showed phenotypic non-significant correlation coefficients with fruit yield/vine. This character manifestation amply suggested the possibility of improving fruit yield per vine through improving internodal length, fruit length, fruit diameter, number of fruits per vine and fruit weight. Significant negative correlations of yield per vine at both genotypic and phenotypic levels were observed with nodal position of first female flower (0.937, 0.651), days to first female flowering (0.998, 0.731), days to fifty percent flowering (0.892, 0.735), days to first fruit picking (0.989, 0.735) and moisture percentage (0.681, 0.416). These results are in agreement with the findings of Pal *et al*. (2017) [12]. Number of fruits per vine had significant positive genotypic correlation with internodal length (0.882), days to first female flowering (0.838), fruit length (0.503), fruit diameter (0.004) and fruit weight (0.236) and other characters are positively non significant. In case of phenotypic correlation, number of fruits per vine showed significant positive correlation with vine length (0.109), internodal length (0.632), fruit length (0.415) and fruit weight (0.247) and days to first female flowering (0.795), nodal position of first female flower (0.653), days to fifty percent flowering (0.768), days to first fruit picking (0.805) and fruit diameter (0.031) had negative non-significant correlation. Fruit weight had positive correlation with vine length (0.293, 0.295), intermodal length (0.590, 0.481), fruit length (0.980, 0.872). While negative correlation with days to first female flowering (0.462, 0.439), nodal position of first female flower (0.428, 0.410), days to fifty percent flowering (-0.569, -0.535) and days to first fruit picking (-0.541, -0.504). Fruit length showed positively non significant association ship with vine length (0.193, 0.168), internodal length (0.728, 0.517), and nodal position of first female flower (0.485, 0.440) in genotypic and phenotypic level of correlation. Days to harvest showed negative correlation with fruit length and fruit diameter indicating that early maturing varieties showed lower length and diameter while the late maturing varieties had higher length and diameter in cucumber.

Path coefficient analysis

The complexity of character relationships among themselves and with fruit yield becomes evident from the discussion alone did not provide a comprehensive picture of relative importance of direct and indirect influences of each character to fruit yield, as these traits were the resultant product of combined effects of various factors complementing or counteracting. Though correlation gives information about the components of complex character like yield, it will not provide an exact picture of relative importance of the direct and indirect contribution of the component characters to yield.

The technique of path coefficient analysis involves a method of partitioning the total correlation between the dependent variable and the independent component variable i.e., directs effect of independent variable and its indirect effect via third variable on the dependent variable. However, provides a realistic basis for allocation of appropriate weight-age to various attributes while designing a pragmatic programme for the improvement of yield. The data on path coefficient analysis at genotypic level showing the direct and indirect effects of significant characters over fruit yield per plot have been represented in table-3.

Among the thirteen yield component traits; it is evident from the data that has maximum positive direct effect of days to fifty percent flowering (0.844), fruit weight (0.394) on yield/vine followed by intermodal length (0.032), number of fruits per vine (0.079), moisture percentage (0.075), fruit diameter (0.017), TSS (0.013) and fruit length (0.001), also showed highly positive direct effects on fruit yield/vine. Positive direct effect of fruit length, fruit weight, number of fruits per plant on yield was reported by Sharma *et al.* (2018) [16], Hossain *et al*. (2010) [6] and Dhiman and Chander (2005) [4]. Positive direct effects of average fruit weight, marketable fruits plant^{-1}, node number bearing first female flower on yield plant^{-1} were reported by Kumar *et al.* (2008) [7] and Kumar *et al*. (2011) [8].The traits *viz*., vine length (0.090) days to first female flowering (0.323), nodal position of first female flower (0.941) and days to first fruit picking (0.952) have negative direct effect on yield. Number of fruits per vine has positive indirect effect through days to first female flowering (0.238), nodal position of first female flower (0.194), days to fifty percent flowering (0.232), days to first fruit picking (0.245) and TSS (0.119). Besides, the fruit weight exhibited the positive direct effect on days to first female flowering (0.009), nodal position of first female flower (0.008), days to 50% flowering (0.012), days to first fruit picking (0.011) and number of fruits per vine (0.010). At genotypic level residual effect was found 0.045. Similar findings were also reported by Arunkumar *et al*. (2011) [2] and Kumar *et al*. (2008) [7] in cucumber.

Table 1: Genotypic correlations among thirteen characters of cucumber genotypes

Characters	VL(m)	IL(cm)	DFF	NFF	DFiF	DFP	FL(cm)	FD(cm)	FW(gm)	NFV	TSS	MP
VL(m)												
IL(cm)	0.395											
DFF	-0.534	-0.991**										
NFF	-0.712*	-0.980**	0.927**									
DFiF	-0.485	-0.856**	0.973**	0.922**								
DFP	-0.370	-0.907**	0.936**	0.769**	0.910**							
FL	0.193	0.728*	-0.612	0.485	-0.716*	-0.712*						
FD	0.012	0.310	-0.151	-0.120	-0.141	-0.225	0.263					
FW	0.293	0.590	-0.462	-0.428	-0.569	-0.541	0.980**	0.436				
NFV	0.110	0.882**	0.838**	-0.684*	-0.816**	-0.861**	0.503	0.004	0.236			
TSS	-0.620	-0.941**	0.995**	-0.930**	-0.951**	-0.960**	0.574	0.205	0.478	-0.789**		
MP	-0.592	-0.656**	0.546	0.615	0.524	0.472	-0.434	-0.523	-0.493	-0.277*	-0.537	
FYV	0.607	0.999**	-0.998**	-0.937**	-0.892**	-0.989**	0.915**	0.244	0.782**	0.772**	0.995**	-0.681*

(VL-Vine Length, IL- Internodal Length, DFF-Days to first female flowering, NFF-Nodal position of first female flower, DFiF- Days to fifty percent flowering, DFP-Days to first fruit picking, FL- Fruit Length, FD-Fruit Diameter, FW-Fruit Weight, NFV-Number of fruits per vine, TSS-Total soluble solid, MP- Moisture percentage, FYV- Fruit yield per vine)(*Values ranged from ≥ 0.632 to ≤ 0.765, significant at 0.05% level of probability; **Values ≥ 0.765, significant at 0.01% level of probability)

Table2: Phenotypic correlations among thirteen characters of cucumber genotypes

Characters	VL(m)	IL(cm)	DFF	NFF	DFiF	DFP	FL(cm)	FD(cm)	FW(gm)	NFV	TSS	MP
VL(m)												
IL(cm)	0.332											
DFF	-0.482	-0.808**										
NFF	-0.654*	-0.802**	0.927**									
DFiF	-0.430	-0.838**	0.974**	0.920**								
DFP	-0.323	-0.731*	0.936**	0.771**	0.915**							
FL	0.168	0.517	-0.549	0.440	-0.636*	-0.624						
FD	-0.001	0.178	-0.108	-0.091	-0.096	-0.154	0.239					
FW	0.295	0.481	-0.439	-0.410	-0.535	-0.504	0.872**	0.334				
NFV	0.109	0.632*	-0.795**	-0.653*	-0.768**	-0.805**	0.415	-0.031	0.247			
TSS	0.564	0.736*	-0.941**	-0.888**	-0.885**	-0.885**	0.530	0.140	0.447	0.754*		
MP	-0.536	-0.514	0.524	0.594	0.497	0.497	-0.373	-0.408	-0.456	-0.251	-0.522	
FYV	0.279	0.657*	-0.731*	-0.651*	-0.735*	-0.735*	0.627	0.306	0.581	0.494	0.700*	-0.416

(VL-Vine Length, IL- Internodal Length, DFF-Days to first female flowering, NFF-Nodal position of first female flower, DFiF- Days to Fifty percent flowering, DFP-Days to first fruit picking, FL- Fruit Length, FD-Fruit Diameter, FW-Fruit Weight, NFV-Number of fruits per vine, TSS-Total soluble solid, MP- Moisture percentage, FYV- Fruit yield per vine) (*Values ranged from ≥ 0.632 to ≤ 0.765, significant at 0.05% level of probability; **Values ≥ 0.765, significant at 0.01% level of probability)

Table3: Phenotypic path analysis for thirteen characters of cucumber genotypes

Characters	VL(m)	IL(cm)	DFF	NFF	DFiF	DFP	FL(cm)	FD(cm)	FW(gm)	NFV	TSS	MP
VL(m)	-0.090	0.013	0.172	0.670	-0.409	0.352	0.000	0.000	-0.006	-0.031	-0.098	0.045
IL(cm)	-0.035	0.032	0.320	0.922	-0.875	0.863	0.001	0.005	-0.012	-0.251	-0.109	0.077
DFF	0.048	-0.032	-0.323	-0.872	0.822	-0.891	-0.000	-0.002	0.009	0.238	0.090	-0.080
NFF	0.064	-0.032	-0.299	-0.941	0.778	-0.732	-0.007	-0.002	0.008	0.194	0.102	-0.070
DFiF	0.044	-0.034	-0.314	-0.868	0.844	-0.866	-0.001	-0.002	0.012	0.232	0.087	-0.082
DFP	0.033	-0.029	-0.302	-0.724	0.768	-0.952	-0.001	-0.004	0.011	0.245	0.078	-0.082
FL	0.017	0.023	0.198	0.457	-0.605	0.678	0.001	0.005	-0.020	-0.143	-0.072	0.069
FD	-0.001	0.010	0.049	0.113	-0.119	0.214	0.000	0.017	-0.008	-0.001	0.087	0.018
FW	-0.026	0.019	0.149	0.403	-0.480	0.514	0.001	0.008	0.394	-0.067	-0.082	0.059
NFV	-0.010	0.029	-0.177	-0.580	0.442	-0.449	-0.002	-0.009	0.010	0.079	0.166	-0.051
TSS	0.053	-0.021	0.572	-0.084	-0.028	-0.133	0.053	0.069	-0.386	0.119	0.013	0.205
MP	-0.054	0.034	0.346	0.882	-0.997	1.044	0.001	0.004	-0.016	-0.219	-0.113	0.075

(Residual effect= 0.045, Direct effect= Bold diagonal)(VL-Vine Length, IL- Internodal Length, DFF-Days to first female flowering, NFF-Nodal position of first female flower, DFiF- Days to fifty percent flowering, DFP-Days to first fruit picking, FL- Fruit Length, FD-Fruit Diameter, FW-Fruit Weight, NFV-Number of fruits per vine, TSS-Total soluble solid, MP- Moisture percentage, FYV- Fruit yield per vine)

Conclusion

In this study, genotypic correlation was higher than phenotypic correlations indicating the highly heritable nature of the traits. It was observed that intermodal length has exhibited highly significant positive association with fruit yield per plant followed by fruit length, fruit weight, number of fruits per plant and vine length. Direct selection based on these traits would improve yield. The path coefficient analysis revealed that the days to fifty percent flowering, number of fruits per plant, intermodal length, fruit weight, fruit length, fruit diameter, TSS and moisture percentage have direct positive phenotypic and genotypic effect on yield. These findings showed that direct selection on the basis of above characters will be rewarding for crop improvement in cucumber.

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