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Correlation and path analysis studies for yield and its attributes in cucumber (*Cucumis sativus* L.)

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Abstract
A 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. Correlation studies revealed that yield per plot had positive and significant association with number of marketable fruits per plant, average fruit weight, harvest duration, seed germination and seed vigour index-I, while significant negative correlations were observed with node number bearing first female flower, days to marketable maturity, anthracnose and angular leaf spot, both at phenotypic and genotypic levels. Path coefficient analysis revealed that severity of powdery mildewhad maximum positive direct effect on yield per plot followed by TSS, fruit length, average fruit weight, days to marketable maturity, number of marketable fruits per plant, seed vigour index-I, severity of anthracnose, harvest duration, fruit breadth, severity of angular leaf spot and seed vigour index-II. While, negative direct effect of seed germination and node number bearing first female flower was observed on yield per plot. Future breeding should focus on selecting the characters having direct effects to improve yield per plot.

Keywords: Cucumber, genotypic correlation, phenotypic correlation and path analysis

1. 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 considered as 4th most important vegetable crop after tomato, cabbage and onion. Cucumber is a thermophilic and frost susceptible species growing best at a temperature above 20°C. 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) [13]. Cucumber is thought to be indigenous to India. India is endowed with the wealth of cucumber germplasm, comprising of both wild and cultivated forms (Sharma *et al.*, 2018) [12]. Inspite of being native to Indian sub-continent and endowed with enormous variability for different horticultural traits, cucumber remains underutilized in terms of its economic potential and unexploited from breeding point of view. Therefore, there is a need to screen cucumber germplasm for the identification of genotypes with improved quality and yield which may be directly used as varieties after extensive evaluation or as parents in the hybridization programmes. (Kumar *et al.*, 2011) [11].

Information on association of characters, direct and indirect effects contributed by each character towards yield will be of great advantage in aiding the selection process. Correlation and path analysis establish the extent of association between yield and its components and also bring out relative importance of their direct and indirect effects, thus giving an understanding of their association with yield. Ultimately, this kind of analysis could help the breeder to design his selection strategies to improve yield. 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.

2. Materials and Methods
The present investigations was carried out at the Experimental farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan Himachal Pradesh, India during kharif season of 2016 located at an altitude of 1276 metres above mean sea level at a longitude of 770 11' 30'' E and a latitude of 300 52′ 30″ N and is

1260 m above mean sea level. The experimental material comprised of thirty genotypes including check cultivar K- 75 collected from different exotic and indigenous germplasm of cucumber (Table 1). The experiment was laid out in Randomized Complete Block Design with three replications of each genotype. Three to four seeds per basin were sown at a spacing of 100 x 50 cm in a plot had size of 3.0 x 2.0 m2, accommodating 12 plants per plot. After the emergence of seedlings, only one healthy plant per hill was retained. The standard cultural practices as recommended in the Package of Practices for Vegetable Crops, were followed to ensure a healthy crop stand (Anonymous, 2014) [2]. Observations were recorded on node number bearing first female flower, days to marketable maturity, number of marketable fruits per plant, harvest duration, fruit length, fruit breadth, average fruit weight, total soluble solids, yield per plot, seed germination, seed vigour index-I and II and severity of powdery mildew, anthracnose and angular leaf spot from five random plants in each replication for all characters except for fruit characters for which observations were recorded on ten random fruits per replication.

The genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al.* (1958) [1] by using analysis of variance and covariance matrix. The genotypic and phenotypic correlation coefficients were used to find out their direct and indirect contributions towards yield per plot. The direct and indirect paths were obtained according to the method given by Dewey and Lu (1959) [5].

Table 1: List of cucumber genotypes studied along with their sources

Genotype	Source
CGN-19533, CGN-20269, CGN-20515, CGN-20827, CGN-20930, CGN-20953, CGN-20969, CGN-21585, CGN-22930	Centre for Crop Genetic Resources, the Netherlands
PI-426170, PI-5754, PI-618894	North Central Regional Plant Introduction Station, USA
UHF-CUC-4, UHF-CUC-5, UHF-CUC-6, UHF-CUC-7, UHF-CUC-8, UHF-CUC-9, UHF-CUC-10, UHF-CUC-11, UHF-CUC-12, UHF-CUC-13, UHF-CUC-14, UHF-CUC-15, UHF-CUC-16, UHF-CUC-17, UHF-CUC-18, UHF-CUC-19, Poinsette, K-75 (Check)	Department of Vegetable Science, UHF, Solan, HP

3. Results and Discussion

Correlation studies

The correlation coefficients among the different characters were worked out at phenotypic and genotypic levels (Table 2). In general, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients. The knowledge of degree of association of yield with the various yield contributing and horticultural traits is of great importance because, yield is not an independent character and it is the result of interaction of number of component traits among themselves as well as environmental interactions. 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.

Table 2: Phenotypic and genotypic coefficients of correlation among different traits in cucumber

Traits		NNBFFF	NMF	FL	FB	AFW	DMM	HD	TSS	SG	SVI-I	SVI-II	SPM	SA	SALS	YPP
NNBFFF	P	1.000	-0.306**	-0.164	0.048	-0.184	0.335**	-0.384**	0.096	-0.152	-0.158	-0.083	0.016	0.565**	0.297**	-0.278**
	G	1.000	-0.334**	-0.222*	0.118	-0.193	0.342**	-0.442**	0.080	-0.243*	-0.188	-0.103	0.051	0.654**	0.324**	-0.302**
NMF	P		1.000	0.044	-0.278**	0.087	-0.283**	0.480**	0.191	0.342**	0.292**	-0.025	-0.078	-0.337**	-0.497**	0.773**
	G		1.000	0.076	-0.341**	0.132	-0.336**	0.557**	0.255*	0.380**	0.309**	-0.027	-0.057	-0.369**	-0.515**	0.850**
FL	P			1.000	-0.132	0.021	-0.158	0.149	-0.243*	0.088	0.110	0.251*	-0.198	-0.251*	-0.423**	0.151
	G			1.000	-0.222*	0.034	-0.175	0.186	-0.414**	0.142	0.137	0.296**	-0.251*	-0.307**	-0.504**	0.189
FB	P				1.000	0.211*	0.237*	-0.148	-0.087	-0.099	0.042	0.096	-0.176	0.214*	0.238*	-0.158
	G				1.000	0.218*	0.342**	-0.275**	-0.133	-0.095	0.047	0.166	-0.182	0.293**	0.307**	-0.200
AFW	P					1.000	-0.156	0.272**	0.181	0.348**	0.210*	0.109	-0.302**	-0.053	-0.160	0.251*
	G					1.000	-0.203	0.267*	0.245*	0.520**	0.266*	0.177	-0.400**	-0.046	-0.169	0.276**
DMM	P						1.000	-0.180	0.005	-0.029	-0.084	0.085	-0.224*	0.221*	0.250*	-0.284**
	G						1.000	-0.207	-0.000	-0.035	-0.077	0.148	-0.244*	0.253*	0.274**	-0.300**
HD	P							1.000	0.374**	0.441**	0.391**	0.126	-0.291**	-0.329**	-0.460**	0.531**
	G							1.000	0.496**	0.600**	0.477**	0.182	-0.367**	-0.357**	-0.482**	0.604**
TSS	P								1.000	0.360**	0.187	-0.047	-0.235*	0.070	-0.081	0.096
	G								1.000	0.609**	0.305**	0.057	-0.288**	0.059	-0.109	0.104
SG	P									1.000	0.509**	0.378**	-0.160	-0.130	-0.470**	0.381**
	G									1.000	0.522**	0.435**	-0.160	-0.159	-0.607**	0.485**
SVI-I	P										1.000	0.474**	-0.353**	0.028	-0.303**	0.446**
	G										1.000	0.554**	-0.454**	0.038	-0.342**	0.514**
SVI-II	P											1.000	-0.183	-0.029	-0.258*	0.103
	G											1.000	-0.257*	0.001	-0.327**	0.150
SPM	P												1.000	-0.058	-0.049	-0.160
	G												1.000	-0.056	-0.063	-0.166
SA	P													1.000	0.379**	-0.221*
	G													1.000	0.414**	-0.226*
SALS	P														1.000	-0.556**
	G														1.000	-0.599**

YPP	P															1.000
	G															1.000

*Significant at 5% level of significance
**Significant at 1% level of significance

Where,
NNBFFF = Node number bearing first female flower, NMF = Number of marketable fruits perplant, FL = Fruit length, FB = Fruit breadth, AFW = Average fruit weight, DMM = Days to marketable maturity, HD = Harvest duration, TSS = Total soluble solids, SG =Seed germination, SVI-I = Seed vigour index-I, SVI-II = Seed vigour index-II, SPM = Severity of powdery mildew, SA = Severity of anthracnose, SALS = Severity of angular leaf spot, YPP = Yield per plot

Correlation studies revealed that yield per plot had significant positive association with number of marketable fruits per plant (0.773, 0.850), average fruit weight (0.251, 0.276), harvest duration (0.531, 0.604), seed germination (0.381, 0.485) and seed vigour index-I (0.446, 0.514), while significant negative correlations were observed with node number bearing first female flower (-0.278, -0.302), days to marketable maturity (-0.284, -0.300), anthracnose (-0.221, -0.226) and angular leaf spot (-0.556, -0.599), both at phenotypic and genotypic levels, respectively. Total soluble solids (TSS) showed significant positive correlation with harvest duration (0.374, 0.496), while significant negative correlation was found with fruit length (-0.243, -0.414). Seed vigour index-I exhibited significant positive correlation with seed germination (0.509, 0.522), harvest duration (0.391, 0.477), number of marketable fruits per plant (0.292, 0.309) and average fruit weight (0.210, 0.266), whereas seed vigour index-II exhibited significant positive correlation with seed vigor index-I(0.474, 0.554), seed germination (0.378, 0.435) and fruit length (0.251, 0.296), both at phenotypic and genotypic levels. Similar correlation studies of yield with various other horticultural trait had also been reported by Dhiman and Chander (2005) [6], Kumar *et al.* (2008) [9], Arunkumar *et al.* (2011) [3], Veena *et al.* (2013) [14], Hasan *et al.* (2015) [7] and Chinatu *et al.* (2017) [4].

Path Coefficient Analysis
Path coefficient analysis depicts the effects of different independent characters individually and in combination with other characters on the expression of different characters on fruit yield. However, provides a realistic basis for allocation of appropriate weightage 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.
It is evident from the data that severity of powdery mildew (1.978) has maximum positive direct effect on yield per plot followed by TSS (1.733), fruit length (1.699), average fruit weight (1.448), days to marketable maturity (1.183), number of marketable fruits per plant (1.061), seed vigour index-I (0.978), severity of anthracnose (0.421), harvest duration (0.375), fruit breadth (0.155), severity of angular leaf spot (0.064) and seed vigour index-II (0.007). Positive direct effects of number of fruits per hill and per plot, fruit girth on fruit yield was also reported by Dhiman and Chander (2005) [6]. Kumar *et al.* (2008) [9] reported positive direct effects of number of fruits per plant and number of primary branches per plant on yield. While, negative direct effect of seed germination (-2.340) and node number bearing.

Table 3: Estimates of direct and indirect effects of different traits on yield of cucumber

Traits	NNBFFF	NMF	FL	FB	AFW	DMM	HD	TSS	SG	SVI-I	SVI-II	SPM	SA	SALS	GCCYP
NNBFFF	-0.465	-0.354	-0.378	0.018	-0.280	0.405	-0.166	0.138	0.568	-0.184	-0.001	0.100	0.275	0.021	-0.302**
NMF	0.155	1.061	0.130	-0.053	0.191	-0.398	0.209	0.442	-0.888	0.302	0.000	-0.113	-0.155	-0.033	0.850**
FL	0.103	0.081	1.699	-0.035	0.050	-0.208	0.070	-0.718	-0.332	0.135	0.002	-0.496	-0.129	-0.032	0.189
FB	-0.055	-0.361	-0.378	0.155	0.315	0.404	-0.103	-0.231	0.223	0.046	0.001	-0.361	0.123	0.020	-0.200
AFW	0.090	0.140	0.058	0.034	1.448	-0.240	0.100	0.424	-1.217	0.260	0.001	-0.792	-0.019	-0.011	0.276**
DMM	-0.159	-0.357	-0.298	0.053	-0.294	1.183	-0.078	-0.001	0.083	-0.075	0.001	-0.484	0.106	0.018	-0.300**
HD	0.206	0.591	0.316	-0.043	0.387	-0.245	0.375	0.859	-1.403	0.467	0.001	-0.725	-0.150	-0.031	0.604**
TSS	-0.037	0.271	-0.704	-0.021	0.354	0.000	0.186	1.733	-1.425	0.299	0.000	-0.570	0.025	-0.007	0.104
SG	0.113	0.403	0.241	-0.015	0.753	-0.042	0.225	1.055	-2.340	0.511	0.003	-0.316	-0.067	-0.039	0.485**
SVI-I	0.087	0.328	0.234	0.007	0.385	-0.091	0.179	0.529	-1.222	0.978	0.004	-0.899	0.016	-0.022	0.514**
SVI-II	0.048	-0.028	0.502	0.026	0.257	0.176	0.068	0.100	-1.018	0.542	0.007	-0.507	0.000	-0.021	0.150
SPM	-0.024	-0.060	-0.426	-0.028	-0.580	-0.289	-0.137	-0.499	0.374	-0.445	-0.002	1.978	-0.023	-0.004	-0.166
SA	-0.304	-0.392	-0.522	0.046	-0.067	0.299	-0.134	0.102	0.372	0.037	0.000	-0.110	0.421	0.027	-0.226*
SALS	-0.151	-0.547	-0.857	0.048	-0.244	0.325	-0.181	-0.188	1.420	-0.334	-0.002	-0.125	0.174	0.064	-0.599**

Where,
NNBFFF = Node number bearing first female flower, NMF = Number of marketable fruits / plant, FL = Fruit length, FB = Fruit breadth, AFW = Average fruit weight, DMM = Days to marketable maturity, HD = Harvest duration, TSS = Total soluble solids, SG =Seed germination, SVI-I = Seed vigour index I, SVI-II = Seed vigour index II, SPM = Severity of powdery mildew, SA = Severity of anthracnose, SALS = Severity of angular leaf spot, GCCYP = Genotypic correlation coefficient with yield/plot

Residual effect 0.31098
Diagonal figures represent the direct effect first female flower (-0.465) was observed on yield per plot. Negative direct effect of node at which first female flower appears, days to first male floweropening, days to first harvest and fruit breadth on yield were reported by Veena *et al.* (2013) [14]. Positive indirect effects of severity of angular leaf spot (1.420) and node number bearing first female flower (0.568) via seed germination and seed germination (1.055), harvest duration (0.859), seed vigour index-I (0.529), number of marketable fruits per plant (0.442) and average fruit weight (0.424) via TSS was of sufficient magnitude. Further, the high positive indirect effect of seed germination (0.753), harvest duration (0.387), seed vigour index-I (0.385) via fruit weight was observed on yield per plot. Positive indirect effect of harvest duration (0.591), seed germination (0.403) via number of

marketable fruits per plant were also recorded on yield per plot. Positive indirect effect of seed vigour index-II (0.542) and harvest duration (0.467) viaseed vigour index-I was also notable. Maximum negative indirect effects of TSS (-1.425), harvest duration (-1.403), seed vigour index-I (-1.222), average fruit weight (-1.217), seed vigour index-II (-1.018) and number of marketable fruits per plant (-0.888) via seed germination and seed vigour index-I (-0.889), average fruit weight (-0.792) and harvest duration (-0.725) via severity of powdery mildew were noticed on yield per plot. The positive indirect effect of fruit diameter via average fruit weight was earlier confirmed by Hossain *et al.* (2010) [8] and Kumar *et al.* (2011) [11]. Negative indirect effects of powdery mildew severity via harvest duration and angular leaf spot via average fruit weight was also reported by Kumar *et al.* (2011) [11]. The positive indirect effects of fruit breadth, fruit length, harvest duration and number of marketable fruits per plant via average fruit weight on yield and negative indirect effects of severity of anthracnose, angular leaf spot and powdery mildew via average fruit weight on yield per plot were reported by Kumar *et al.* (2013) [10]. At genotypic level residual effect was found to be 0.31098.

4. Conclusion

The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. The results indicated that yield per plot had significant positive association with number of marketable fruits per plant, average fruit weight, harvest duration, seed germination and seed vigour index-I. Thus, from the correlation studies it is concluded that selection should be made on the basis of higher average fruit weight, longer harvest duration, more number of fruits per plant with minimum susceptibility to different diseases to bring desired improvement in the yield of cucumber. The path coefficient analysis revealed that the high positive direct effects towards fruit yield per plant contributed by severity of powdery mildew followed by TSS, fruit length, average fruit weight, days to marketable maturity, number of marketable fruits per plant, seed vigour index-I, severity of anthracnose, harvest duration, fruit breadth, severity of angular leaf spot and seed vigour index-II, thus indicating that direct selection for yield improvement in cucumber can be performed.

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