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GENETICS AND PLANT BREEDING

Character Association and Path Analysis for Fruit Yield and it's Contributing Traits in Cucumber (*Cucumis sativus* L.)

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ABSTRACT

Experiment was conducted with thirty cucumber genotypes at the Experimental Farm of the Department of Vegetable Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during *Kharif* season of 2015 with an objective to find out the contribution of nineteen important traits on yield. Results revealed that yield plant^{-1} had positive significant association with average fruit weight, fruit length and diameter, marketable fruits plant^{-1}, harvest duration, vine length, primary branches plant^{-1}, seed length, hundred seed weight, germination percentage, seed vigour index I and II, whereas, yield plant^{-1} had negative significant correlation with node number bearing first female flower, days to first harvest, total soluble solids and severity of four foliar diseases. Path analysis provided a clear picture that, harvest duration had maximum positive direct effect, followed by marketable fruits plant^{-1} while, days to first harvest had maximum negative direct effect followed by severity of downy mildew on yield plant^{-1}. Further, harvest duration exerted maximum positive indirect effect via marketable fruits plant^{-1} whereas; severity of powdery mildew showed maximum negative indirect effect via harvest duration on yield plant^{-1}. Thus, while conducting selection for yield improvement in cucumber, a breeder will have to emphasize on the early genotypes having more average fruit weight, longer fruits, more fruit diameter, more number of marketable fruits and primary branches plant^{-1}, longer vine as well as harvest duration, more seed length, seed germination percentage, vigour index I and II with minimum severity of economically important foliar diseases.

Highlights

- Yield plant^{-1} had positive and significant association with average fruit weight, fruit length, fruit diameter, marketable fruits plant^{-1}, harvest duration, vine length, primary branches plant^{-1}, seed length, hundred seed weight, germination percentage, seed vigour index I and II.
- Harvest duration had maximum positive direct effect on yield plant^{-1} followed by marketable fruits plant^{-1}.

Keywords: Association, cucumber, correlation, path analysis, yield

Cucumber (*Cucumis sativus* L.) is an important salad vegetable crop grown both under open field and protected conditions throughout India. In Asia, it is considered as fourth most important vegetable crop after tomato, cabbage and onion (Tatlioglu 1993). It is basically monoecious, thermophillic, frost susceptible, day neutral annual having climbing or trailing habit through axillary un-branched tendrils. Immature fruits believed to possess cooling effects on our body and are considered good for people suffering from constipation, jaundice and indigestion. Though India is the primary centre of origin of cucumber, very less attention has been paid for its improvement.

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. By the use of variance and covariance matrix, contribution of each character towards yield can be estimated through correlation studies. However, correlation does not provide a clear picture of nature and extent of contributions made by number of independent traits. Here, path coefficient analysis helps in partitioning the correlation coefficients into its components due to direct and indirect effects, permits critical examination of specific factors and also provides a realistic basis for allocation of appropriate weightage to various attributes while designing a yield improvement programme. Therefore, the present study was undertaken with an objective to estimate the nature and magnitude of association among yield and its contributing traits in cucumber.

MATERIALS AND METHODS

Experimental Site and Environment

The present study was conducted at the Experimental Farm of the Department of Vegetable Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan in Himachal Pradesh during *Kharif* season of 2015. This location is at 30^{o} 52′ 30″ N latitude and 77^{o} 11′ 30″ E with an altitude of 1260 m above mean sea level and represents the mid-hill zone of Himachal Pradesh.

Experimental Material, Layout and Observations

The experimental materials comprised of thirty indigenous cucumber genotypes (Table 1) and the experiment was laid out in a Randomized Complete Block Design with three replications. The hills were placed at 125 cm × 50 cm and three to four seeds per hill were directly sown in June, 2015. After germination one plant was kept on each hill, thereby ten plants in each replication of each genotype were kept. Standard cultural practices recommended in the Package and Practices for Vegetable Crops were followed to ensure a healthy crop stand (Anonymous 2013). Data were recorded on five randomly selected plants in each replication except for fruit and seed characters, for which observations were recorded on ten random fruits and seeds, respectively. The traits studied were node number bearing first female flower (NNBF), days to first harvest (DFH), average fruit weight (AFW), fruit length (FL), fruit diameter (FD), total soluble solids (TSS), marketable fruits plant^{-1} (MFP), harvest duration (HD), vine length (VL), primary branches plant^{-1} (PBPP), seed length (SL), hundred seed weight (HSW), seed germination percentage (GP), vigour index I (VI-I) and vigour index II (VI-II), severity of angular leaf spot (SALS), anthracnose (SANT), downy mildew (SDM) and powdery mildew (SPM) and yield plant^{-1} (YPP). Seed germination was tested in a modified method, originally suggested by ISTA (Anonymous 1985) and seed vigour index I and II were calculated as per formula of Abdul-Baki and Anderson (1973). The disease severity of angular leaf spot was recorded on modified 0-9 scale of Woltman *et al.* (2009) and severity of anthracnose, downy mildew and powdery mildew was recorded on 0-5 scale of Akem and Jovicich (2011). For all the four diseases, the observations were recorded from ten leaves in each vine, five such vines in each replication. Disease severity was calculated by adopting the formula of McKinney (1923).

Statistical Analysis

The genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al.* (1958) by using analysis of variance-covariance matrix. Further, path analysis, according to Dewey and Lu (1959) was carried out using genotypic correlation coefficient. The statistical analysis was carried out by using OP-STAT Software available from the website of CCS-HAU, Hisar.

RESULTS AND DISCUSSION

Correlation studies

The correlation coefficients among twenty characters were worked out both at genotypic and phenotypic levels (Table 2). In general, the genotypic correlation coefficients were higher in magnitude than the corresponding phenotypic correlation coefficients, indicating a strong inherent genotypic relationship between the characters studied, although their phenotypic expression was modified by environmental factors.

Analysis revealed that yield plant^{-1} had significant positive association at both genotypic and phenotypic levels with average fruit weight, fruit length, fruit diameter, marketable fruits plant^{-1}, harvest

Table 1: List of cucumber genotypes under study along with their sources

Genotypes	Sources	Genotypes	Sources
LC-1	Jampur, Hooghly, West Bengal.	LC-16	Uluberia, Howrah, West Bengal
LC-2	Maheshwarpur, Hooghly, West Bengal	LC-17	Mangalbaria, West Sikkim, Sikkim
LC-3	Sheoraphully, Hooghly, West Bengal	LC-18	Allahabad, Uttar Pradesh
LC-4	Champadanga, Hooghly, West Bengal	LC-19	Varanasi, Uttar Pradesh
LC-5	Bhanderhati, Hooghly, West Bengal	LC-20	Hubli, Dharwad, Karnataka
LC-6	Sibaichandi, Hooghly, West Bengal	LC-21	Ettinagudda, Dharwad, Karnataka
LC-7	Harit, Hooghly, West Bengal	LC-22	Bhuira, Sirmour, Himachal Pradesh
LC-8	Gopalpur, Nadia, West Bengal	LC-23	Narag, Sirmour, Himachal Pradesh
LC-9	Simurali, Nadia, West Bengal	LC-24	Gohar, Mandi, Himachal Pradesh
LC-10	Barasat, N-24 Parganas, West Bengal	LC-25	Manali, Kullu, Himachal Pradesh
LC-11	Amtala, S-24 Parganas, West Bengal	LC-26	Sarkaghat, Mandi, Himachal Pradesh
LC-12	Kamdebpur, N-24 Parganas, West Bengal	LC-27	Deothi, Solan, Himachal Pradesh
LC-13	Memari, Burdwan, West Bengal	LC-28	Joharji, Solan, Himachal Pradesh
LC-14	Diamond Harbour, S-24 Parganas, West Bengal	LC-29	Bhojnagar, Solan, Himachal Pradesh
LC-15	Paskura, West Medinipur, West Bengal	K-75	UHF, Nauni, Solan, Himachal Pradesh

duration, vine length, primary branches plant^{-1}, seed length, hundred seed weight, germination percentage, vigour index I and vigour index II. Significant negative correlations of yield plant^{-1} at both genotypic and phenotypic levels were observed with node number bearing first female flower, days to first harvest, severity of four foliar diseases *viz.* angular leaf spot, anthracnose, downy mildew and powdery mildew. Total soluble solids recorded significant negative association with yield plant^{-1} only at genotypic level.

Further, significant positive correlation was observed between marketable fruits plant^{-1} with harvest duration, vine length, primary branches plant^{-1}, germination percentage, vigour index I and vigour index II; seed length with average fruit weight, fruit length, fruit diameter, harvest duration and primary branches plant^{-1} at genotypic and phenotypic levels, respectively. Significant negative correlations were observed at both genotypic and phenotypic levels between total soluble solids with average fruit weight, fruit length, fruit diameter; node number bearing first female flower with marketable fruits plant^{-1}, harvest duration, vine length and primary branches plant^{-1}.

Seed vigour index I and II exhibited significant positive genotypic as well as phenotypic correlation with hundred seed weight, germination percentage, marketable fruits plant^{-1}, harvest duration, vine length and primary branches plant^{-1} whereas, significant negative correlations of seed vigour index I and II were observed with node number bearing first female flower, days to first harvest and total soluble solids.

Similar associations of yield with various other horticultural and yield contributing traits had also been reported by numerous researchers (Hossain *et al.* 2010, Kumar *et al.* 2011, Bhardwaj and Kumar 2012, Ullah *et al.* 2012 and Veena *et al.* 2012). Negative significant association of yield with severity of diseases *viz.* angular leaf spot, anthracnose and powdery was earlier reported by Kumar *et al.* (2011). Further, negative significant association of total soluble solids with yield was reported by Mehta *et al.* (2009) in muskmelon.

Path Coefficient analysis

Although, correlation studies are helpful in determining important yield contributing traits, path analysis, which estimates either direct or indirect and positive or negative effects of each independent character on the dependent trait i.e. yield plant^{-1}, permits a critical examination of the relative importance of each trait.

Path analysis at genotypic level (Table 3) revealed that harvest duration exerted maximum positive direct effect on yield plant^{-1} followed by marketable fruits plant^{-1}, seed vigour index II and seed vigour index I, vine length, average fruit weight, primary branches per plant, fruit length, severity of angular

Table 2: Correlation coefficients among different traits in cucumber

Traits		NNBF	DFH	AFW	FL	FD	TSS	MFP	HD	VL	PBPP	SL	HSW	GP	VI-I	VI-II	SALS	SANT	SDM	SPM	YPP
NNBF	G		0.582**	-0.148	-0.218	-0.110	0.151	-0.430**	-0.444**	-0.761**	-0.633**	-0.115	-0.041	-0.599**	-0.516**	-0.523**	0.227	0.654**	0.463**	0.562**	-0.437**
	P		0.549**	-0.136	-0.211	-0.085	0.101	-0.423**	-0.389**	-0.428**	-0.617**	-0.109	-0.044	-0.558**	-0.500**	-0.476**	0.215	0.621**	0.451**	0.539**	-0.429**
DFH	G			-0.093	-0.202	-0.129	0.540**	-0.596**	-0.902**	-0.827**	-0.748**	-0.192	-0.073	-0.669**	-0.706**	-0.614**	0.604**	0.752**	0.604**	0.645**	-0.648**
	P			-0.087	-0.177	-0.115	0.365**	-0.561**	-0.826**	-0.401**	-0.691**	-0.167	-0.074	-0.603**	-0.655**	-0.537**	0.557**	0.684**	0.559**	0.590**	-0.605**
AFW	G				0.900**	0.856**	-0.428**	-0.304*	0.303*	-0.079	0.132	0.525**	0.179	-0.279*	0.289*	0.288*	0.294*	0.117	0.074	0.125	0.334*
	P				0.826**	0.709**	-0.292*	-0.288*	0.272	-0.014	0.164	0.484**	0.170	-0.180	0.319*	0.274*	0.230	0.051	0.035	0.076	0.344*
FL	G					0.773**	-0.514**	-0.154	0.391**	0.143	0.234	0.484**	0.153	-0.135	0.359**	0.346*	0.124	-0.039	-0.058	0.006	0.404**
	P					0.700**	-0.343*	-0.146	0.336*	0.049	0.222	0.433**	0.145	-0.113	0.340*	0.297*	0.100	-0.042	-0.059	0.004	0.379**
FD	G						-0.589**	-0.111	0.407**	-0.025	0.220	0.528**	0.278*	-0.154	0.398**	0.372**	0.133	0.041	-0.013	0.052	0.448**
	P						-0.373**	-0.109	0.301*	-0.024	0.181	0.438**	0.241	-0.130	0.339*	0.325*	0.108	0.032	-0.004	0.066	0.386**
TSS	G							-0.276*	-0.601**	0.008	-0.312*	0.005	0.110	-0.304*	-0.372**	-0.430**	0.399**	0.511**	0.606**	0.539**	-0.390**
	P							-0.203	-0.367**	-0.059	-0.191	-0.021	0.050	-0.200	-0.244	-0.235	0.302*	0.362**	0.393**	0.343*	-0.254
MFPP	G								0.522**	0.952**	0.742**	-0.001	0.012	0.844**	0.680**	0.702**	-0.815**	-0.864**	-0.763**	-0.795**	0.678**
	P								0.448**	0.551**	0.727**	-0.004	0.010	0.799**	0.666**	0.629**	-0.789**	-0.829**	-0.751**	-0.766**	0.670**
HD	G									0.702**	0.721**	0.347*	0.107	0.523**	0.796**	0.758**	-0.578**	-0.650**	-0.564**	-0.545**	0.800**
	P									0.307*	0.622**	0.291*	0.081	0.477**	0.698**	0.610**	-0.505**	-0.552**	-0.491**	-0.500**	0.697**
VL	G										0.827**	0.164	0.189	0.837**	0.837**	0.825**	-0.675**	-0.876**	-0.814**	-0.688**	0.786**
	P										0.463**	0.132	0.099	0.435**	0.458**	0.399**	-0.370**	-0.468**	-0.451**	-0.367**	0.432**
PBPP	G											0.389**	0.248	0.760**	0.910**	0.876**	-0.647**	-0.788**	-0.583**	-0.715**	0.875**
	P											0.368**	0.236	0.754**	0.902**	0.804**	-0.646**	-0.780**	-0.589**	-0.708**	0.870**
SL	G												0.619**	-0.125	0.468**	0.431**	0.021	0.059	0.096	0.087	0.469**
	P												0.553**	-0.101	0.432**	0.379*	0.007	0.055	0.083	0.076	0.445**

(Cont...)

HSW	G													-0.091	0.337*	0.342*	-0.108	0.073	-0.007	0.001	0.285*
	P													-0.084	0.320*	0.292	-0.101	0.067	-0.003	0.006	0.274*
GP	G														0.621**	0.657**	-0.727**	-0.920**	-0.774**	-0.888**	0.554**
	P														0.632**	0.600**	-0.729**	-0.908**	-0.766**	-0.872**	0.554**
VI-I	G															0.938**	0.653**	-0.669**	0.563**	-0.634**	0.966**
	P															0.865**	-0.655**	-0.672**	-0.570**	-0.631**	0.959**
VI-II	G																-0.690**	-0.726**	-0.710**	-0.687**	0.946**
	P																-0.626**	-0.660**	-0.654**	-0.625**	0.872**
SALS	G																	0.752**	0.727**	0.764**	-0.668**
	P																	0.750**	0.723**	0.752**	-0.665**
SANT	G																		0.881**	0.961*	-0.646**
	P																		0.873**	0.936**	-0.640**
SDM	G																			0.858**	-0.561**
	P																			0.847**	-0.565**
SDM	G																				-0.596**
	P																				-0.592**

*Significant at 5% level significance

**Significant at 1% level significance

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

Traits	NNBF	DFH	AFW	FL	FD	TSS	MFP	HD	VL	PBPP	SL	HSW	GP	VI-I	VI-II	SALS	SANT	SDM	SPM	GCCYPP
NNBF	**-0.391**	-0.184	-0.181	0.330	0.309	-0.062	0.269	-0.092	-0.099	-0.195	0.081	0.152	-0.085	0.112	0.281	-0.002	-0.680	-0.003	0.003	-0.437*
DFH	0.180	**-0.531**	-0.212	-0.450	0.260	-0.143	0.238	0.003	0.315	0.399	0.006	0.075	0.309	-0.166	0.204	-0.035	-0.761	-0.240	-0.099	-0.648*
AFW	0.248	-0.068	**0.661**	0.131	0.079	0.012	-0.045	0.42	0.131	0.219	-0.015	-0.020	-0.212	-0.029	0.060	-0.330	-0.258	-0.316	-0.334	0.334*
FL	-0.067	0.126	0.278	**0.598**	-0.149	-0.271	0.169	0.036	0.128	0.140	0.069	0.063	0.011	-0.013	-0.297	0.003	-0.380	-0.108	0.068	0.404*
FD	0.273	-0.034	0.559	-0.095	**-0.287**	0.064	0.090	0.175	-0.006	0.017	0.132	0.017	0.072	0.101	-0.116	0.024	0.005	-0.116	-0.427	0.448*
TSS	-0.330	0.260	-0.241	-0.191	-0.455	**-0.180**	-0.259	-0.287	-0.151	-0.082	-0.010	-0.143	-0.009	0.225	0.258	0.340	0.300	0.235	0.330	-0.390*
MFPP	0.246	0.044	-0.075	-0.133	0.073	-0.240	**0.813**	0.215	-0.204	0.203	-0.300	0.287	0.178	0.248	-0.370	-0.204	-0.213	-0.340	0.450	0.678*
HD	-0.366	-0.317	0.014	-0.145	0.180	0.008	0.603	**0.875**	0.234	0.132	0.191	-0.008	-0.242	-0.254	-0.258	-0.125	0.051	0.100	0.127	0.800*
VL	-0.053	-0.033	0.174	0.103	-0.213	-0.019	0.593	-0.019	**0.784**	0.056	-0.216	-0.195	0.001	-0.122	-0.245	0.080	0.100	0.006	0.004	0.786*
PBPP	-0.196	0.055	-0.087	0.170	0.132	-0.230	0.568	0.311	-0.195	**0.625**	-0.243	0.006	0.010	-0.008	-0.009	-0.001	-0.012	-0.020	-0.001	0.875*
SL	-0.235	-0.142	-0.018	0.234	0.454	0.058	0.042	0.003	0.208	0.001	**-0.010**	0.023	0.005	-0.007	0.002	0.010	-0.107	-0.009	-0.043	0.469*
HSW	0.075	0.048	0.155	-0.052	0.442	-0.090	0.081	-0.005	0.149	0.014	-0.210	**-0.056**	-0.120	0.121	0.214	-0.164	-0.125	-0.100	-0.092	0.285*
GP	-0.185	-0.354	0.050	0.126	-0.278	-0.117	0.277	0.222	-0.103	0.226	-0.261	0.219	**-0.120**	0.545	0.539	-0.112	-0.090	-0.079	0.049	0.554*
VI-I	-0.159	-0.012	0.248	0.011	-0.180	-0.078	0.046	-0.250	0.323	0.179	-0.053	-0.041	0.120	**0.811**	0.071	-0.214	0.015	0.100	0.029	0.966*
VI-II	-0.061	-0.053	0.008	0.098	0.070	-0.112	0.221	0.060	0.124	0.157	0.021	-0.148	-0.153	0.030	**0.813**	-0.042	-0.063	-0.040	0.016	0.946*
SALS	0.202	0.117	-0.644	-0.198	0.087	-0.106	-0.265	-0.210	0.096	-0.229	-0.005	-0.040	0.082	0.041	0.011	**0.128**	0.210	0.030	0.025	-0.668*
SANT	0.202	0.049	0.017	-0.010	-0.015	0.091	-0.659	-0.128	-0.234	0.127	0.054	-0.010	0.133	-0.006	-0.103	0.210	**0.054**	-0.224	-0.194	-0.646*
SDM	0.143	0.039	-0.120	-0.047	0.216	0.145	-0.127	-0.453	-0.129	-0.187	0.091	-0.121	-0.071	-0.012	0.070	0.213	0.240	**-0.493**	0.042	-0.561*
SPM	0.073	0.052	-0.280	0.073	0.039	-0.035	-0.476	-0.739	0.029	0.173	0.082	0.043	0.024	0.047	0.098	0.214	-0.050	-0.002	**0.039**	-0.596*

Where, GCCYP= Genotypic Correlation Coefficient with Yield Plant^{-1}

Residual effect: 0.019

Diagonal figures (bold and underlined) represent the direct effects.

leaf spot, severity of anthracnose and severity of powdery mildew. Maximum negative direct effect was exerted by days to first harvest followed by severity of downy mildew, node number bearing first female flower, fruit diameter, total soluble solids, seed germination percentage, hundred seed weight and seed length on yield plant^{-1}.

Positive indirect effect of harvest duration, vine length and primary branches plant^{-1} via marketable fruits plant^{-1} was of sufficient magnitude. Further, the positive indirect effect of seed germination on yield plant^{-1} via vigour index I and vigour index II was also notable. High positive indirect effects of fruit diameter via average fruit weight and effects of seed length as well as hundred seed weight via fruit diameter were also recorded on yield plant^{-1}. Maximum negative indirect effect of powdery mildew and effect of downy mildew was exerted via harvest duration, whereas, negative indirect effects of anthracnose and powdery mildew via marketable fruits plant^{-1} and effect of angular leaf spot via average fruit weight was recorded on yield plant^{-1}. At genotypic level, the residual effect was 0.019; indicating approximately 98.10 per cent yield contribution has been covered by the traits under study and the traits which are not studied could contribute to an extent of about 1.90 per cent.

Positive direct effects of average fruit weight, harvest duration, seed vigour index II, marketable fruits plant^{-1}, severity of angular leaf spot, anthracnose and powdery mildew and negative direct effect of fruit diameter, seed germination percentage and node number bearing first female flower on yield plant^{-1} were reported by Kumar *et al.* (2008) and Kumar *et al.* (2011). Positive direct effects of fruit length, average fruit weight and marketable fruits per plant was also reported Hossain *et al.* (2010) and Dhiman and Chander (2005). Negative direct effect of days to first harvest and the positive indirect effect of fruit diameter via average fruit weight were confirmed Hossain *et al.* (2010) and Kumar *et al.* (2011). Negative indirect effects of powdery mildew severity via harvest duration and angular leaf spot via average fruit weight was reported by Kumar *et al.* (2011).

CONCLUSION

Thus, based on the findings of correlation and path analysis, while conducting selection for yield improvement in cucumber, a breeder will have to emphasize on the early genotypes having more average fruit weight, longer fruits, more fruit diameter, more numbers of marketable fruits and primary branches plant^{-1}, longer vine as well as harvest duration, more seed length, seed germination percentage, vigour index I and II with minimum severity of economically important foliar diseases *viz.* angular leaf spot, anthracnose, downy mildew and powdery mildew.

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