International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(5): 842-846
© 2017 IJCS
Received: 17-07-2017
Accepted: 18-08-2017

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Associated variation for principle component in cucumber (*Cucumis sativus* L.) germplasm based on economic traits

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Abstract
Evaluated forty four diverse genotypes with two checks Pant Khira-1 and Pointsette of cucumber through cluster analysis. Results revealed that total genotypes were grouped into six clusters which confirm the presence of wide genetic diversity through the formation of six clusters. The clustering pattern showed the lack of parallelism between geographic and genetic diversities. The Eigen factors of six principal components were interpreted as relative weight of variable in each component. The important variables are those which have high positive or negative weight or values. In first season the first principal component had high positive weight or value to weight of internodal length (0.388) followed by days to first female flowers (0.385) and test weight (0.075). During the second season, high positive weight to days to first fruit harvest (0.459) followed by test weight (0.327) and fruit diameter (0.212). However in pooled data, highest positive weight was due to test weight (0.517) followed by internodal length (0.470) and seed index (0.259) contributed towards high genetic divergence. Hence, these characters could respond favorably for phenotypic selection.

Keywords: cucumber (*Cucumis sativus* L.), genetic variation, principle component analysis and cluster analysis.

Introduction
Cucumber (*Cucumis sativus* L.) is an important vegetable and one of the most popular members of the *Cucurbitaceae* family (Lower and Edwards, 1986; Thoa, 1998) [14, 21]. It is one of the oldest vegetable cultivated by man with historical records dating back 5,000 years (Wehner and Guner, 2004) [22]. The crop is the fourth most important vegetable after tomato, cabbage and onion in Asia (Tatlioglu, 1997) [20], the second most important vegetable crop after tomato in Western Europe (Phu, 1997) [17].
Growers, buyers and processors all demand uniformity in plant type, fruit type, and maturity, so it is necessary that cultivars developed for sale to meet commercial standards. The scope of selection in the improvement of cucumber depends upon the genetic diversity available in the germplasm. Since, a considerable amount of variability exists in this crop, a germplasm collection is essential for any rational plant breeding programme. To formulate a sound and successful breeding programme, the importance of the study of genetic variability in the population and the pattern of correlation existing among the traits needs emphasis.

Materials and Methods
The present investigation was conducted with two season during July-October, 2014 and February-June, 2015 at Vegetable Research Centre, Department of Vegetable Science in G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Pantnagar is situated in the foot hills of Himalayan region (Shivalik hills) and falls under humid subtropical climate zone in narrow belt called Tarai. Geographically, Vegetable Research Centre is situated at the latitude of 29.5^0N, longitude 79.3^0 E and at an altitude of 243 .84 meters above the mean sea level. Total 46 genotypes of cucumber (*Cucumis sativus* L.) were used as experimental material in present experiment. The genotypes were diverse with respect to morphological and important economical traits.
The experiment was laid out in randomized block design with three replications. Healthy and uniform sowing of seeds was main field in plots with a spacing of 3 meters × 0.60 cm during the evening hours of during July-October, 2014 and February-June, 2015. The crops were

grown with standard package of practices. The observations on various growth, yield and qualitative characters viz. observed highly significant differences for all the traits under study.

Results and Discussion

The principal component analysis of 46 genotypes along with two checks based on correlation matrix of the morph-agronomical traits yielded six Eigen roots and Eigen vectors in first two season and six in pooled analysis. The Eigen roots (values) and percent variation accounted by various characters have been presented in Table 1, 2 and 3 (first season, second season and pooled respectively). The Eigen factors of six principal components were interpreted as relative weight of variable in each component. The important variables are those which have high positive or negative weight or values. The first principal component had high positive weight or value to weight of internodal length (0.388) followed by days to first female flowers (0.385) and test weight (0.075) and high negative weight to seed index (-0.563) followed by fruit weight (0.473) and yield (-0.348).During the second season, high positive weight to days to first fruit harvest (0.459) followed by test weight (gm) (0.327) and fruit diameter (cm) (0.212) and high negative weight to number of fruits per plant (-0.529) followed by yield (q/ha) (-0.479) and seed index (gm) (-0.141).However in pooled data, highest positive weight was due to test weight (gm) (0.517) followed by internodal length (cm) (0.470) and seed index (gm)(0.259) and maximum negative weight due to fruit weight (g) (-0.498) followed by primary branches/ plant (-0.257) and node number to first male flower (-0.185).

The second principal component had high positive weight or value to node number to first female flower (0.184) followed by fruit length (0.055) and seed index (0.019) and high negative weight to number of fruits per plant (-0.648) followed by yield (-0.452) and internodal length (-0.331). During the second season, high positive weight to fruit weight (0.524) followed by fruit length (0.236) and fruit diameter (0.089) and high negative weight due to seed index (-0.542) followed by plant height (met.) (-0.528) and test weight (-0.182). However in pooled data, highest positive weight was due to days to first male flower (0.156) followed by yield (0.098) followed by fruit weight (0.071) and maximum negative weight due to node number to first female flower (-0.643) followed by number of fruits per plant (-0.606) and node number to first male flower (-0.250). The third principal component had high positive weight or value to days to first male flowers (0.571) followed by fruit diameter (0.492) and plant height (0.178) and high negative weight to days to first fruit harvest (-0.444) followed by test weight (-0.349) and fruit length (-0.165). During the second season, high positive weight to fruit diameter (0.527) followed by node number to first male flower (0.284) and test weight (0.191) and maximum negative weight due to internodal length (-0.611) followed by fruit length (-0.375) and node number to first female flower (-0.093). However in pooled data, highest positive weight was due to fruit length (0.622) followed by fruit weight (0.098) and no. of fruits per plant (0.073) and maximum negative weight due to plant height (-0.638) followed by seed index (-0.415) and days to first fruit harvest (-0.061).

The fourth principal component had high positive weight or value to days to first female flowers (0.222) followed by yield (0.184) and fruit weight (0.101) and high negative weight to fruit length (-0.582) followed by plant height (-0.569) and node number to first female flower (-0.384). During the second season, high positive weight to days to first female flowers (0.101) followed by primary branches/ plant (0.046) and test weight (0.041) and high negative weight to node number to first female flower (-0.769) followed by node number to first male flower (-0.525) and fruit length (-0.272). However in pooled data, highest positive weight was due to days to first female flowers (0.542) followed by yield (0.472) and days to first male flowers (0.264) and maximum negative weight due to internodal length (-0.363) followed by node number to first female flower (-0.270) and primary branches/ plant (-0.246).

The fifth principal component had high positive weight or value to node number to first male flower (0.630) followed by test weight (0.424) and internodal length (0.337) and high negative weight to days to first female flowers (-0.487) followed by days to first fruit harvest (-0.181) and seed index (-0.084).During the second season, high positive weight to primary branches/ plant (0.663) followed by node number to first male flower (0.389) and test weight (0.154) and high negative weight to days to first female flowers (-0.369) followed by days to first fruit harvest (-0.292) and no. of fruits per plant (-0.253). However in pooled data, highest positive weight was due to fruit diameter (0.705) followed by days to first male flowers (0.474) and primary branches/ plant (0.402) and maximum negative weight due to seed index (-0.190) followed by no. of fruits per plant (-0.116) and node number to first male flower (-0.009).

The sixth principal component had high positive weight or value to days to first male flowers (0.223)followed by internodal length (cm) (0.214) and days to first fruit harvest (0.163) and high negative weight to primary branches/ plant (-0.696) followed by node number to first female flower (-0.471) and days to first female flowers (-0.243). During the second season, high positive weight to days to first male flowers (0.643) followed by days to first female flowers (0.372) and fruit length (cm) (0.368) and high negative weight to plant height (m.) (-0.315) followed by node number to first male flower (-0.110) and fruit weight (g) (-0.097). However in pooled data, highest positive weight was due to days to first fruit harvest (0.552) followed by fruit diameter (cm) (0.249) and plant height (met.) (0.154) and maximum negative weight due to node number to first male flower (-0.578) followed by primary branches/ plant (-0.357) and days to first male flowers (-0.281).

The present finding is in confirmatory with the finding of Levi *et al*. (2001) [13]. The Eigen vectors of four principal components were interpreted as relative weight of variables in each component. The important variables are those which have high positive or negative weights or values. Principal component analysis (PCA) revealed that only the first three principal component axes in the PCA analysis had eigen-vector values whose loads were more than unity. The present findings are in accordance with the results of Levi *et al*. (2001) [13]. Value of Eigen root fell lower than one after the 3rd principal component. The first principal component largely accounted for the variation among the genotypes which alone contributed 45.238 % of the variations. This result is also supported by Kumar *et al*. (2008) [11] in muskmelon. Including these three principal components circa 75.741% has been estimated, which is not enough to completely comprehend divergence in cucumber collection. Increment of circa more than 80% of total variance is sufficient that is why fourth principal component is considered for analyzing divergence.

PCA was performed to transform all the variables into new set of independent variables. The principal components that account for more than 90% of variation were used for non-hierarchical Euclidean cluster analysis reported that covering 90 per cent of total variation is useful and should be adopted to explain the variation in the breeding material. According to (Kuper *et al*., 1988) [12] the principal components are interpreted as the relative weight given to the variables in each component and important variables are those which possess high positive and high negative weights. The characters *viz*., plant height, node number to first staminate flower appearance, days to first pistillate flower anthesis, fruit diameter, number of fruits per plant and fruit yield per plant are important characters that should be considered for selection of superior genotypes.

Similar studies have been done by several scientists in different cucurbit crops including cucumber *i.e*. cucumber Golabadi *et al*., 2013 and Kumar *et al*., 2008) [10, 11].

Principal component of analysis help in identifying the most characters that can be used as descriptors by explaining as much of total variation in the origin set of variables as possible with as few components as possible and reducing the dimension of the problem. It is the statistical procedure that uses an orthogonal variation to convert a set of explanations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding constituent in turn has the highest variance possible under the constraint that it is orthogonal to (i.e. uncorrelated with) the preceding components. The principal components are orthogonal because they are the Eigen vectors of the covariance matrix, which is symmetric. The results of PCA are usually discoursed in terms of constituent scores, sometimes called factors and loading (the weight by which each standardized original variable should be multiplied to get the component score).

Conclusion

The clustering pattern showed the lack of parallelism between geographic and genetic diversities. The Eigen factors of six principal components were interpreted as relative weight of variable in each component. The important variables are those which have high positive or negative weight or values to useful of these traits for improving upon fruit yield in cucumber. Therefore, it may be possible to improve fruit yield and quality by selecting the accessions on that basis.

Acknowledgment

Authors are thankful to the administrative team and all the supporting staff involved in the present research especially Dr. M. L. Kushwaha, Professor at Department of Vegetable Science and Dr. C. P. Singh, Professor at Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), India for valuable suggestions and support during entire research work.

Table 1: Eigen vector, Eigen root and associated variation for principle component in cucumber based on economic traits (first season)

S. no	Traits	Clusters					
		1	2	3	4	5	6
1	Days to first male flowers	-0.017	-0.002	0.571	0.087	-0.059	0.223
2	Node number to first male flower	0.016	-0.055	0.111	0.058	0.630	-0.131
3	Days to first female flowers	0.385	-0.254	-0.134	0.222	-0.487	-0.243
4	Node number to first female flower	0.042	0.184	-0.017	-0.384	-0.054	-0.471
5	Internodal length (cm)	0.388	-0.331	-0.078	-0.080	0.337	0.214
6	Days to first fruit harvest	-0.101	-0.251	-0.444	-0.162	-0.181	0.163
7	No. of fruits per plant	0.040	-0.648	0.078	-0.098	-0.015	-0.059
8	Fruit length (cm)	0.048	0.055	-0.165	-0.582	0.055	-0.070
9	Fruit diameter (cm)	0.069	-0.183	0.492	-0.150	0.046	-0.174
10	Fruit weight (g)	-0.473	-0.123	-0.092	0.101	0.086	-0.172
11	Test weight (gm.)	0.075	0.012	-0.349	0.029	0.424	0.012
12	Seed Index (gm.)	-0.563	0.019	-0.001	-0.108	-0.084	0.091
13	Primary branches/ Plant	-0.078	-0.106	0.030	0.094	0.073	-0.696
14	Plant height (met.)	-0.079	-0.195	0.178	-0.569	-0.080	0.138
15	Yield (q/ha)	-0.348	-0.452	-0.043	0.184	0.042	0.013
	Root	1.000	1.000	1.000	1.001	1.000	1.000
	% variation	6.666	6.667	6.664	6.673	6.666	6.664
	Cumulative variation	16.664	33.331	49.992	66.673	83.339	100.000

Table 2: Eigen vector, Eigen root and associated variation for principle component in cucumber based on economic traits (second season)

S.no	Traits	Clusters					
		1	2	3	4	5	6
1	Days to first male flowers	-0.130	-0.052	0.050	0.010	0.094	0.643
2	Node number to first male flower	-0.035	-0.034	0.284	-0.525	0.389	-0.110
3	Days to first female flowers	-0.060	-0.179	0.143	0.101	-0.369	0.372
4	Node number to first female flower	-0.069	-0.040	-0.093	-0.769	-0.119	0.007
5	Internodal length (cm)	0.135	-0.108	-0.611	-0.043	0.064	0.009
6	Days to first fruit harvest	0.459	0.025	0.026	-0.135	-0.292	0.091
7	No. of fruits per plant	-0.529	-0.056	0.014	-0.082	-0.253	0.089
8	Fruit length (cm)	0.182	0.236	-0.375	-0.272	-0.130	0.368
9	Fruit diameter (cm)	0.212	0.089	0.527	-0.096	-0.063	0.189
10	Fruit weight (g)	-0.061	0.524	0.172	-0.003	0.026	-0.097
11	Test weight (gm.)	0.327	-0.182	0.191	0.041	0.154	0.303

2	Seed Index (gm.)	-0.141	-0.542	-0.047	-0.007	0.121	0.107
12	Primary branches/ Plant	0.045	-0.055	-0.063	0.046	0.663	0.166
13	Plant height (met.)	0.156	-0.528	0.141	-0.086	-0.189	-0.315
14	Yield (q/ha)	-0.479	0.021	0.052	-0.057	0.016	0.102
15	Root	1.000	1.000	1.000	1.000	1.000	1.000
	% variation	6.667	6.667	6.667	6.668	6.664	6.667
	Cumulative variation	16.667	33.334	50.001	66.672	83.332	100.000

Table 3: Eigen vector, Eigen root and associated variation for principle component in cucumber based on economic traits (pooled)

S.no	Traits	Clusters					
		1	2	3	4	5	6
1	Days to first male flowers	0.160	0.156	0.011	0.264	0.474	-0.281
2	Node number to first male flower	-0.185	-0.250	-0.051	0.156	-0.009	-0.578
3	Days to first female flowers	-0.012	-0.093	-0.042	0.542	0.017	0.113
4	Node number to first female flower	0.102	-0.643	-0.001	-0.270	0.069	-0.052
5	Internodal length (cm)	0.470	-0.018	0.040	-0.363	0.123	0.019
6	Days to first fruit harvest	-0.152	-0.132	-0.061	0.080	0.080	0.552
7	No. of fruits per plant	0.041	-0.606	0.073	0.262	-0.116	0.024
8	Fruit length (cm)	0.038	-0.189	0.622	-0.030	0.064	0.022
9	Fruit diameter (cm)	0.038	-0.011	0.028	-0.018	0.705	0.249
10	Fruit weight (g)	-0.498	0.071	0.098	-0.081	0.026	0.022
11	Test weight (gm.)	0.517	-0.016	0.064	0.103	0.022	0.015
12	Seed Index (gm.)	0.259	0.047	-0.415	-0.156	-0.190	-0.174
13	Primary branches/ Plant	-0.257	-0.068	-0.059	-0.246	0.402	-0.357
14	Plant height (met.)	-0.052	-0.214	-0.638	0.073	0.182	0.154
15	Yield (q/ha)	0.174	0.098	0.040	0.472	0.053	-0.156
	Root	1.000	0.998	1.000	1.000	1.000	1.003
	% variation	6.666	6.651	6.665	6.665	6.668	6.685
	Cumulative variation	16.666	33.292	49.954	66.617	83.288	100.000

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