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Characterization of cucumber genotypes through principle component and regression analyses

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Abstract

Indian subcontinent has a rich and varied heritage of genetic resources but these resources have not been exploited fully due to their inherent problems of large size and lack of sufficient evaluation and classification. Germplasm maintenance, evaluation and characterization of economically important traits are pre-requisite for genetic improvement program of any crop. The principal component approach could resolve several phenotypic measurements even of large collections in to fewer, more interpretable and more easily visualized dimensions. Thirty diverse genotypes of cucumber collected from different indigenous sources were characterized with respect to economically important traits by using principle component and regression analyses in kharif, 2009. The effect and contribution of each character on fruit yield per plot was measured. Principal component analysis characterized the genotypes into four principal component based on their total variation (83.72%). The first principal component accounted for more than 48% of the total variation and was the combination of number of marketable fruits per plant, fruit length, harvest duration, total soluble solids, seed germination, seed vigour index-I and II and yield per plot. The second, third and fourth principle components contributed only 15.27%, 13.50% and 6.72% of total variations, respectively. To quantify the importance of each variable in predicting average fruit weight and yield per plot, multiple linear regression models were developed. Model-I indicated that average fruit weight can be predicted satisfactorily on the basis of number of marketable fruits per plant, fruit length and breadth, while, Model-II indicated that yield per plot can be best predicted with the help of number of marketable fruits per plant, fruit length, average fruit weight, harvest duration, seed germination, seed vigour index-II and severity of powdery mildew and anthracnose. Therefore, on the basis of information on genetic diversity through principle component and regression analyses, suitable selection strategy can be formulated for getting higher yield in cucumber.

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Introduction

Cucumber *(Cucumis sativus* L.) is one of the most important cucurbitaceous vegetable crops grown extensively in tropical and sub-tropical parts of the country. It is a thermophilic and frost susceptible crop 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 pickled in its immature stage. It is a rich source of vitamin B and C, carbohydrates, Ca and P. Indian subcontinent has a rich and varied heritage of genetic resources but these resources have not been exploited fully due to their inherent problems of large size and lack of sufficient evaluation and classification. The genetic improvement of any crop mainly depends upon the amount of genetic variability present in the population and India, being the primary centre of origin of cucumber, has accumulated a wide range of variability. Because of the genetic diversity present in cucumber, there is an opportunity to select superior genotypes. Despite its importance, no systematic information is available on the genetic amelioration of cucumber, especially on the magnitude of genetic diversity.

Genetic diversity in vegetable crops is important in selecting the best genotypes to bring improvement in yield. Qualitative and quantitative traits can be choosen in parents for hybridization to exploit heterosis or to select desirable segregants in subsequent generations. Knowledge of association of various characters provides the basis of selection for yield and its components for crop improvement. Since yield is a complex quantitative trait, simple correlation and regression of characters provides limited insight into the association of various traits to yield. Few reports are available on phenotypic variability, correlation and path analysis in cucumber (Afangideh and Uyoh, 2007; Kumar *et al.*, 2008; Hanchinamani and Patil, 2009). Investigators, initially unaware of the relative importance of variables, tries to include all possible variables which are likely to influence the outcome and the data matrices become unmanageable and complicated. Principle component analysis (PCA) helps in identifying the most relevant characters that can be used as descriptors by explaining as much of total variation in the original set of variables as possible with as few components as possible and reducing the dimension of the problem. Therefore, an attempt has been made in the present investigation to access and analyze the extent of genetic diversity through Principle component and regression analyses for yield improvement in cucumber.

Materials and Methods

The present investigations were carried out at Research Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) in kharif 2009. This location is at 30°50' N latitude, 77°11'30" E longitude and is 1260 m above mean sea level and represents the mid-hill zone of Himachal Pradesh. The climate of the Experimental Farm is generally characterized as sub-humid, sub-temperate with cool winters. The total rainfall was 381.90 mm, most of which was received in July month *viz.*187.30 mm and maximum mean temperature varied from 27.2^{0}C - 33.3^{0}C and minimum from 15.9^{0}C - 19.5^{0}C during the growing season.

The experimental material consisted of diverse group of 30 genotypes of cucumber, including check cultivars *i.e.,* K-75 and K-90. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications of each genotype. The experimental field was disked and levelled. About 10 Mt ha^{-1} of well decomposed farm yard manure was mixed in the soil at the time of field preparation. The recommended fertilizer dose of N:P_2O_5:K_2O was applied at the rate of 400, 315 and 100 kg ha^{-1} as calcium ammonium nitrate, single-superphosphate, and muriate of potash, respectively. The full dose of P_2O_5 and K_2O, and half dose of N were applied at the time of sowing. The remaining half of N was applied in two equal instalments *i.e.,* first at 30 days after sowing and second on commencement of flowering. Seeds were directly sown in the field and three to four seeds per basin were sown at a spacing of 100 x 75 cm in a plot having size of 3.0 x 2.25 m^2. After the emergence of seedlings, only one healthy seedling per hill was retained. Light hoeing during initial stages of crop growth and manual weeding was done, 4-6 times during entire crop growth period. Irrigation was applied at 15 day intervals depending upon the rainfall. The observations were recorded on node number bearing first female flower (x_1), number of marketable fruits per plant (x_2), fruit length (x_3), fruit breadth (x_4), average fruit weight (x_5), days to marketable maturity (x_6), harvest duration (x_7), total soluble solids (x_8), seed germination (x_9), seed vigour index-I (x_{10}) and II (x_{11}) and severity of powdery mildew (x_{12}), anthracnose (x_{13}) and angular leaf spot (x_{14}) and yield per plot (x_{15}) from five randomly selected plants in each replication for all characters except for fruit characters for which observations were recorded on ten randomly selected fruits per replication.

The data were subjected to analysis of variance as per the procedure described by Gomez and Gomez (1983). If the numbers of the variables (p) are measured for each observation, then 'p' separate univariate statistical analyses are required. These analyses apply only to the individual components of the factor, not to the factor itself. Furthermore, the variables are usually highly inter-correlated since biological systems, being complex and highly integrated; contain a great number of interacting components which are interrelated. Consequently these variables should not be treated as independent components of the factor in question in statistical analyses. A Principal component analysis (Hotelling, 1933) restructures the data so that a general factor can be measured by 'p' correlated variables and could be expressed in terms of $n<p$ uncorrelated variables would be highly desirable. The first few components usually account for most of the variation of the original variables. Contribution of different characters towards the divergence was estimated with the help of principle component analysis in accordance with Lawley and Maxwell (1963) and Ramchander *et al.* (1979). Multiple linear regression equation was used to predict average fruit weight and yield per plot.

Results and Discussion

Genetic variability is the basic need for a plant breeder to initiate any breeding programme. Genetic improvement can be brought about by manipulating the genetic makeup of the plant for desirable characters or to remove the undesirable genes which retard, or inhibit, certain pathways. Analysis of variance indicated significant differences among the genotypes for all the characters under study. These differences indicated the presence of variability in the available germplasm and offers opportunity for improvement in yield and quality traits of cucumber.

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

Sr. No.	Genotype	Source
1.	LC-1	Dhangota, Hamirpur
2.	LC-2	Bhota, Hamirpur
3.	LC-3	Awahdevi, Hamirpur
4.	LC-4	Jahu, Hamirpur
5.	LC-5	Lambloo, Hamirpur
6.	LC-6	Taunidevi, Hamirpur
7.	LC-7	Bharari, Bilaspur
8.	LC-8	Dangar, Bilaspur
9.	LC-9	Palampur, Kangra
10.	LC-10	Paprola, Kangra
11.	LC-11	Baijnath, Kangra
12.	LC-12	Gagal, Kangra
13.	LC-13	Nerchowk, Mandi
14.	LC-14	Mori, Mandi
15.	LC-15	Sarkaghat, Mandi
16.	LC-16	Rampur, Shimla
17.	LC-17	Sainj, Shimla
18.	LC-18	Bajaura, Kullu
19.	LC-19	Katrain, Kullu
20.	LC-20	Anni, Kullu
21.	LC-21	Saru, Chamba
22.	LC-22	Khajiar, Chamba
23.	LC-23	Bhararighat, Solan
24.	LC-24	Dharampur, Solan
25.	LC-25	Arki, Solan
26.	LC-26	Amb, Una
27.	LC-27	Chintpurni, Una
28.	LC-28	Sambha, Jammu
29.	K-75*	UHF, Nauni, Solan
30.	K-90*	UHF, Nauni, Solan

* Check cultivar

For genetic improvement in any crop, inter-crossing among the genotypes with outstanding mean performance has been suggested by Roy and Sharma (1996). Significant differences were observed among all the genotypes for all the characters under study (Table 3). Among the horticultural traits, comparatively wide range was observed for node number bearing first female flower (3.53-13.53) and days to marketable maturity (55.67-78.33), which determine the earliness of a variety. Fruit length, breadth and weight are the major yield contributing traits, wide variations were observed with respect to these traits (8.11-22.76 cm, 3.08-7.18 cm, 95.00-430.00 g, respectively). Tremendous variations with respect to number of marketable fruits per plant (5.01-8.57), harvest duration (14.00-28.67 days), total soluble solids (2.03-4.07 ^{0}B) and yield per plot (4.37-27.31 kg) were obtained. Wide variations with respect to various horticultural characters were also reported by Kumar (2006), Munshi *et al.* (2007), Kumar *et al.* (2008), Hanchinamani *et al.* (2008) and Yogesh *et al.* (2009) in cucumber. For seed characters *viz.* seed germination (61.00–87.67 %), seed vigor index-I (438.33–1930.00) and seed vigor index-II (1642.28–3167.28), a wide variation was observed. Similar results were also reported by Hamid *et al.* (2002) for seed germination and Nerson (2007) for seedling vigour. All the genotypes studied, respond differently to the attack of different diseases *viz.* powdery mildew (8.50-29.40 %), anthracnose (7.70-26.20 %) and angular leaf spot (6.50-18.30 %). These findings are in agreement with Webner and Shetty (2000) and Cohen *et al.* (1995). These wide variations in the genotypes for different characters would help in selecting the best genotypes from existing collections.

The estimates of phenotypic and genotypic coefficients of variability gave a clear picture of amount of variations presents in the available germplasm (Table 3). For all the characters studied, phenotypic coefficients of variability were higher in magnitude than genotypic coefficients of variability, though difference was not much in all the cases. Thus, showing that these traits are not much influenced by environmental factors. Hence, selection based on phenotypic performance will be more reliable. Coefficients of variability varied in

Table 2: Analysis of variance for different horticultural traits in cucumber

Character	Source of variation			
	Genotype (29)[a]	Replication (2)	Error (58)	Total (89)
Node number bearing first female flower	23.61*	114.00	5.29	142.90
Number of marketable fruits per plant	3.70*	3.52	0.29	7.51
Fruit length (cm)	26.07*	17.90	0.97	44.94
Fruit breadth (cm)	1.68*	0.31	0.08	2.07
Average fruit weight (g)	12518.49*	11884.63	649.26	25052.38
Days to marketable maturity	119.11*	289.43	15.36	423.90
Harvest duration (days)	63.14*	249.87	10.75	323.76
TSS (^{0}B)	0.95*	2.24	0.11	3.30
Seed germination (%)	203.06*	161.47	12.46	376.99
Seed vigor index-I	664805.62*	2229599.67	96125.43	2990530.70
Seed vigor index-II	684473.69*	2007898.64	96649.04	2789021.40
Severity of powdery mildew (%)	95.20*	424.36	19.13	538.69
Severity of anthracnose (%)	62.95*	422.92	18.61	504.48
Severity of angular leaf spot (%)	33.43*	231.96	10.17	275.56
Yield/plot (kg)	86.71*	5.94	1.51	94.16

* Significant at 5% level of significance   [a] Values in the parenthesis are degree of freedom

Table 3 Estimates of range, mean, standard error of mean and phenotypic and genotypic coefficient of variation for different characters of cucumber

Characters	Range		Mean	± SE(d)	Coefficients of variability (%)		Critical difference
	Maximum	Minimum			Phenotypic	Genotypic	
Node number bearing first female flower	3.53	13.53	8.63	1.88	39.12	28.63	3.76
Number of marketable fruits per plant	5.01	8.57	6.64	0.44	18.00	16.06	0.88
Fruit length (cm)	8.11	22.76	14.13	0.81	21.63	20.47	1.61
Fruit breadth (cm)	3.08	7.18	5.01	0.24	15.71	14.57	0.48
Average fruit weight (g)	95.00	430.00	249.63	20.80	27.19	25.20	41.65
Days to marketable maturity	55.67	78.33	71.20	3.20	9.93	8.26	6.40
Harvest duration (days)	14.00	28.67	19.36	2.68	27.44	21.59	5.36
TSS (^{0}B)	2.03	4.07	2.75	0.28	22.85	19.21	0.55
Seed germination (%)	61.00	87.67	70.89	2.88	12.30	11.24	3.83
Seed vigor index-I	438.33	1930.00	1002.12	253.15	53.34	43.45	506.80
Seed vigor index-II	1642.28	3167.28	2250.03	253.84	24.04	19.67	508.18
Severity of powdery mildew (%)	8.50	29.40	19.62	3.57	34.00	25.66	0.88
Severity of anthracnose (%)	7.70	26.20	15.20	3.52	38.02	25.29	1.04
Severity of angular leaf spot (%)	6.50	18.30	11.62	2.60	36.44	23.96	0.83
Yield per plot (kg)	4.37	27.31	15.14	1.00	36.12	35.20	2.01

magnitude from character to character, indicating that there was a great diversity in the experimental material used. Genotypic coefficient of variability (GCV) was ranged from 8.26 to 43.45% with maximum value for seed vigor index-I followed by yield per plot. This reflects greater genetic variability among the genotypes for these characters for making further improvement by selection. Whereas, moderate GCV were recorded for node number bearing first female flower, severity of powdery mildew, anthracnose and angular leaf spot, average fruit weight, harvest duration, fruit length, seed vigor index-II, total soluble solids, number of marketable fruits per plant and for fruit breadth. For, seed germination and days to marketable maturity, GCV were low. Similar results had also been reported by Singh (1997) and Yogesh *et al.* (2009). However, high and low GCV for node number bearing first female flower was reported by Joshi *et al.* (1981) and Kumar *et al.* (2008), respectively which contradicts present studies and this may be due to difference in experimental material used.

The characters contributing more to the divergence gave greater emphasis for deciding on the cluster for the purpose of further selection and the choice of parents for hybridization (Jagadev *et al*., 1991). The results of principle component analysis indicated that the first four components account for the maximum explained variations (83.72%). Factor analysis was applied to extract the basic factors underlying the observed traits of cucumber. The factors were extracted individually on the basis of eigen values (Table 4) and revealed the pattern and principle component analysis of the data. The first four components having eigen values greater than 1 were retained in the analysis because of the substantial amount of the variations. The factors corresponding to eigen values less than 1 were not considered. These factors were ignored due to " Guttmans lower bound principle" according to which eigen values less than unity (ë<1) should be ignored (Kaiser, 1958). The orthogonal factors were extracted. The centroid method of analysis (Lawley and Maxwell, 1963) was used. The four factors obtained for the estimation of components are as follows:

Factor 1: $0.93X_2 + 0.52X_3 + 0.90X_7 + 0.79\ X_8 + 0.65\ X_9 + 0.82\ X_{10} + 0.77\ X_{11} + 0.90X_{15}$

Factor 2: $0.74X_4 + 0.71X_5 + 0.33X_{12}$

Factor 3: $0.48X_1 + 0.52X_6 + 0.65X_{14}$

Table 4 Loadings of the cucumber characters on the first four principal components

Character	Principle Component*			
	PC_1[#]	PC_2	PC_3	PC_4
Node number bearing first female flower	-0.664	0.300	0.486**	0.339
Number of marketable fruits per plant	0.939	-0.129	-0.132	-0.007
Fruit length (cm)	0.526	0.507	-0.276	0.406
Fruit breadth (cm)	0.362	0.741	0.327	-0.195
Average fruit weight (g)	0.664	0.712	0.027	0.020
Days to marketable maturity	-0.542	0.303	0.527	0.485
Harvest duration (days)	0.901	0.023	-0.030	0.039
TSS (^{0}B)	0.794	-0.233	-0.129	0.204
Seed germination (%)	0.651	-0.448	0.460	0.098
Seed vigor index-I	0.829	-0.246	0.351	0.026
Seed vigor index-II	0.778	-0.263	0.336	-0.023
Severity of powdery mildew (%)	-0.648	0.339	0.016	-.456
Severity of anthracnose (%)	-0.482	-0.161	-0.643	0.438
Severity of angular leaf spot (%)	-0.377	-0.284	.656	0.038
Yield per plot (kg)	0.903	0.416	-0.037	0.005
Eigen Value	7.231	2.292	2.026	1.009
Percentage of variance	48.204	15.279	13.507	6.729
Cumulative % of variance	48.204	63.483	76.990	83.719

[#]PC: Principal component

[*]Extracted through principle component analysis

[**]Bold value indicates the highest Eigen Vector for the corresponding trait amongst the four principal components

Factor 4: $0.43X_{13}$

The first four factors had the variances of 7.231, 2.292, 2.026 and 1.009 with 48.204, 15.279, 13.507 and 6.729% of total variation, respectively and aggregating to 83.72% of total variation.

The first factor extracted had the combination of number of marketable fruits per plant (x_2), fruit length (x_3), harvest duration (x_7), total soluble solids (x_8), seed germination (x_9), seed vigour index-I (x_{10}) and II (x_{11}) and yield per plot (x_{15}). The first factor has high positive loadings for all variables except fruit length. The second factor was a combination of fruit breadth (x_4), average fruit weight (x_5) and severity of powdery mildew (x_{12}). The third factor accounted for the combination of node number bearing first female flower (x_1), days to marketable maturity (x_6) and angular leaf spot (x_{14}) and the fourth factor accounted for the only one variable i.e., anthracnose (x_{13}). The positive value of different characters under study in different components indicated its importance in divergence among 30 genotypes of cucumber, whereas negative values showed the lowest contribution to the divergence (Table 4). Hence, main emphasis should be given on the average fruit weight, number of marketable fruits per plant, fruit length and harvest duration to increase the fruit yield of cucumber crop. Similar findings have also been reported for cucurbits by Zhang and Cui (1993), Portis *et al.* (2006) and Koutsos *et al.* (2000). The factors could be used for further breeding programs for exploiting the hybrid vigor for higher fruit yield.

To estimate the average fruit weight and yield per plot, step wise multiple linear regression models were extracted with average fruit weight (x_5) and yield per plot (x_{15}) as dependent variables and node number bearing first female flower (x_1), number of marketable fruits per plant (x_2), fruit length (x_3), fruit breadth (x_4), days to marketable maturity (x_6), harvest duration (x_7), total soluble solids (x_8), seed germination (x_9), seed vigour index-I (x_{10}) and II (x_{11}) and severity of powdery mildew (x_{12}), anthracnose (x_{13}) and angular leaf spot (x_{14}) as independent variables. The prediction of average fruit weight (Model I) and yield per plot (Model II) with values in parentheses indicating standard errors of the regression coefficients have been give in the Table 5.

Average fruit weight (Model I) can be best predicted by number of marketable fruits per plant (x_2), fruit length (x_3) and fruit breadth (x_4). These characters had positive effects on estimation of average fruit weight. Inclusion of extra characters in Model I had little impact on prediction of yield per plot (Fig. 1). The model II indicates that yield per plot could be best predicted with the help of number of marketable fruits per plant (x_2), fruit length (x_3), average fruit weight (x_5), harvest duration (x_7), seed germination (x_9), seed vigour index- II (x_{11}), severity of powdery mildew (x_{12}) and anthracnose (x_{13}). The characters number of marketable fruits per plant, fruit length, average fruit weight, harvest duration, seed germination and seed vigour index-II had positive effects on estimation of yield per plot, whereas severity of powdery mildew and anthracnose had negative effect on yield (Fig. 2). The coefficient of determination (R^2)

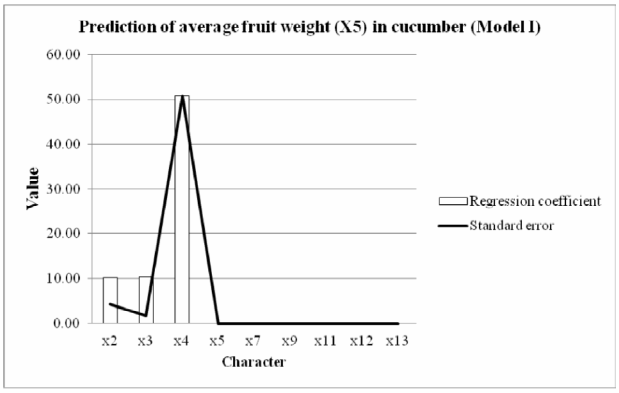

Figure 1. Regression coefficient and standard error of Model-I based on 3 characters in genotypes of cucumber

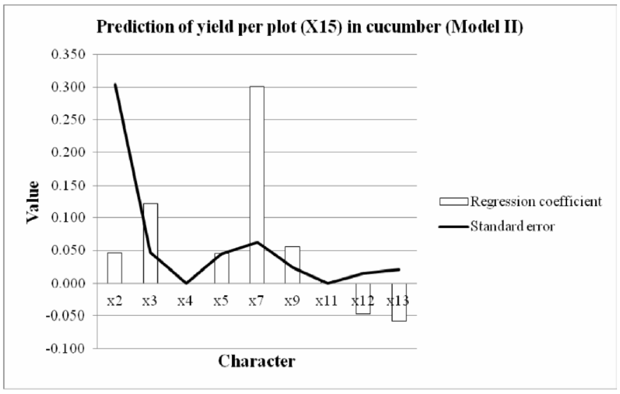

Figure 2. Regression coefficient and standard error of Model-II based on 7 characters in genotypes of cucumber

Table 5 Values of partial regression coefficient to predict average fruit weight and yield per plot

Model	Dependent variables	Independent variables										$^bR^2$
		Intercept	(X_2)	(X_3)	(X_4)	(X_5)	(X_7)	(X_9)	(X_{11})	(X_{12})	(X_{13})	
I	Average fruit weight (x_5)	–219.532	10.194 (4.38)	10.427 (1.69)	50.675 (50.675)	^{a}–	–	–	–	–	–	0.939
II	Yield per plot (x_{15})	–3.82	0.046 (0.304)	0.122 (0.047)	–	0.045 (0.045)	0.301 (0.063)	0.056 (0.024)	0.002 (0.001)	– 0.047 (0.016)	– 0.057 (0.021)	0.999

^{a}– = Variables not influencing average fruit weight and yield per plot $^bR^2$ = Regression coefficient for both the models was high *viz.* 0.93 (Model I) and 0.99 (Model II). Ninety nine per cent of total variation in average fruit weight and ninety three per cent of yield per plot was influenced by these characters. Use of number of marketable fruits per plant, fruit length, average fruit weight and harvest duration was the best model for predicting yield per plot. There is an opportunity for improvement through hybridization and selection due to genetic diversity in the genotypes. Therefore, these models can be used for development of new varieties/hybrids of cucumber.

सारांश

खीरे की कुल 30 जननद्रव्यों का एकत्रीकरण विभिन्न भारतीय क्षेत्रों से कर उनका चरित्रीकरण प्रिंसीपल कम्पोनेंट तथा प्रतिगमन विश्लेषण द्वारा वर्ष 2009 में खरीफ मौसम में किया गया। प्रत्येक गुणों का प्रभाव एवं योगदान उपज प्रति क्यारी के अनुसार मापन किया गया। प्रिंसीपल कम्पोनेन्ट विश्लेषण से चरित्रीकृत प्रभेदों को कुल विभिन्नता (83.72 प्रतिशत) को चार समूहों में बाँटा गया। प्रथम प्रिंसीपल कम्पोनेट में 48 प्रतिशत से ज्यादा विभिन्नता समाहित थी तथा बाजार योग्य कुल फलों की संख्या प्रति पौध, फल की लम्बाई, तुड़ाई की अवधि, कुल विलेय ठोस, बीज जमाव, बीज ओज सचूकांक–I तथा II एवं उपज/क्यारी को इस विभिन्नता में सम्मिलित थी। द्वितीय, तृतीय एवं चतुर्थ प्रिंसीपल कम्पोनेन्ट में क्रमशः 5.97 प्रतिशत, 13.50 प्रतिशत तथा 6.72 प्रतिशत की विभिन्नता थी। परिवर्तन शीलता के मात्रात्मक प्रत्येक घटक को महत्व देने के औसत फल भार तथा उपज/क्यारी हेतु बहुरेखीय प्रतिगमन माडल का विकास किया गया। माडल–I से संकेत मिला कि औसत फल भार का अनुमान बाजार योग्य फल/पौध, फल की लम्बाई तथा चौड़ाई के आधार पर संतोषजनक पाया गया जबकि माडल–II से संकेत मिला कि उपज/क्यारी की अनुमान बाजार योग्य फलों की संख्या/पौध, फल की लम्बाई, औसत फल भार, तुड़ाई अवधि, बीज जमाव, बीज ओज सूचकांक–II तथा चूर्णिल आसिता एवं एन्थ्रेक्नोज की प्रबलता के आधार पर की जा सकती है। इस प्रकार उपरोक्त सूचना के आधार पर आनुवांशिक विविधता हेतु प्रिंसीपल कम्पोनेन्ट तथा प्रतिगमन विश्लेषण से कार्क चयन तार्किकी के माध्यम से खीरे की अधिक उपज हेतु कार्यक्रम बनाये जा सकते हैं।

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