Application of multivariate analysis in study of genetic diversity of greenhouse cucumber segregating populations

Mahnaz Taheri.*
Student, Islamic Azad University, Isfahan (Khorasgan) Branch, Isfahan, Iran.

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Abstract
In order to study the genetic diversity associated with total fruit yield and the morphological traits on the average of two cucumber segregating populations of S_2 and S_3, a greenhouse experiment was conducted as the augmented design in the form of randomized complete block with three replications. Based on the cluster analysis results on the average families of S_2 population, the genotypes were classified into five groups. The results showed that the genotypes of the first group were considered in terms of precocity. Other groups showed high values in terms of morphological traits and relevant traits to fruit yield and number of fruit in total harvest period. Based on the results of cluster analysis in the average S_3 population, the genotypes were classified into four groups. The first group showed a decrease in all traits, except for the number of nodes, number of leaves, fruit diameter, and total average number and weight of fruit in the middle of the growth period. The remaining groups showed a small amount for morphological traits, but for the remaining traits they showed high values. Based on the results of factor analysis in S_2 population, the first five factors had the greatest effect on genetic diversity. According to the contribution and importance, the factors can be designated as the yield and number of fruit during the growth period, latent factor of yield and number of fruits in the early growth period, leaf and stem characteristics of plant, latent factor of node ability in formation of leaf and fruit, and fruit quality. Based on the results of factor analysis in S_3 population, the six first factors had the greatest effect on genetic diversity. According to the contribution and importance, the factors can be designated as the yield and number of fruits in the middle of growth, average yield and number of fruits at the end of growth period, plant height, leaf characteristics, fruiting level in the node, and the average length of internode. In total, it was found that there is a similar diversity in both generations.

Keywords: Cucumber, average of two segregating populations, cluster analysis, factor analysis

1.INTRODUCTION

Cucumber (Cucumis sativus L.) is a plant from the Cucurbitan family, which includes 90 genera and 750 species. Cucumber is consumed in salads or in the processed form (pickle, salted). India has been reported as the primary source of cucumber diversity [13]. Genetic diversity is the basis of the choices. As genetic diversity is increased in a community, the selection range becomes wider [8]. A plant breeder can have a great success in breeding programs if there is a chance to choose suitable and diverse materials [6]. Cucumber is a plant that has a low genetic diversity and the cultivars show a low genetic diversity in terms of fruit yield. Smith and Lower [10] stated that the creation and development of a source population would be useful in the long run through the collection of germplasms of improved cultivars and lines from different parts of the world, and the use of segregating populations is applicable as an important source of genetic diversity. Considering that the taste and demand of each country differ in the case of cucumber crop [13], selection of superior cultivars and genotypes based on proper traits can have various breeding goals for increasing important traits such as fruit yield, fruit quality, strong vigor, proper fruit shape, resistance to diseases, and fruit flavor [14]. Cucumber germplasm was evaluated in the United States in terms of traits such as total yield, number of fruit, fruit weight, and number of fruits per harvest, and a significant difference was observed in all traits studied among the germplasm [9].
Using the multivariate statistical analysis methods such as factor analysis and cluster analysis, the effective traits in yield as well as other factors influencing the selection of genetic diversity can be identified. On the other hand, by examining the genetic diversity, it is possible to select the desirable genotypes according to the breeding goals, as the beginning of any breeding program requires the parents with the maximum difference in traits, and the genetic diversity of the populations can meet these goals. One of the sources of genetic diversity is the segregating populations such as S_2 and S_3, which may vary in diversity among the populations, and therefore, by comparison, the best individuals can be identified for choosing the desirable traits. Therefore, the purpose of this study is to classify the genotypes, identify the strengths and weaknesses of genotypes, determine the most effective traits in fruit yield, and compare them in two segregating generations of S_2 and S_3.

2. MATERIAL AND METHOD

In this research, the average cucumber segregating generations of S_2 and S_3, 150 genotypes in 15 families and 10 plants per generation in each family obtained from the crosses of two different parents with different morphological characteristics and yield designated as *Sina* and *Khassib* in the research greenhouse of the agricultural department of Islamic Azad University of Khorasgan (Isfahan) were cultivated in a randomized complete block design with three replications. In this study, the families of two populations were studied in

*Corresponding Author. Mail. tmahnaz24@yahoo.com
Tell: +989138829237

terms of traits such as total number of fruit, total fruit weight, average number and weight of fruit, leaf length and width, plant height in mid and late growth, fruit length, fruit diameter, number of leaf, number of node, number of fruit in node, stem diameter, average length of internode, fruit quality, total and average number and weight of fruit in early, mid and late growth period, and fruiting period. To measure different traits, all plants per generation were evaluated as a single plant. Each experimental plot was prepared as pair mounds with two rows on each mound. The distance between the plants was 40 cm and the distance between the planting rows was 80 cm. The required controls were made to maintain sufficient temperature and humidity in the greenhouse with suitable temperature using the heating and cooling systems. The performed operations are to check for non-contamination of greenhouse soil, adding the fertilizers of ammonium nitrate, magnesium, manganese sulfate, magnesium sulfate, iron chelate and potassium nitrate to fertilize the plants and improve plant growth and the chemical control of pests and diseases regularly and at appropriate intervals. In this study, traits such as flowering date (when the first flower was observed), plant height (2 times in the middle of growth and the other in the late growth of plants), fruit yield including fruit weight and number, leaf length and width, length and diameter of fruit, and diameter of stem were measured. Fruit yield was measured regularly three times a week and once the fruit size was favorite for the market. Then, based on the harvesting period, the harvest was divided according to the number and weight of the fruit into three parts: early, mid and late. In each plant, several fruits were randomly selected on different days and the length and diameter of the fruits were measured using the ruler and caliper. To calculate the length and width of leaves, three leaves were selected from each plant in the node numbers 15 to 20, and the leaf width was measured in the broadest area and the leaf length from the petiole to the leaf tip. The statistical analyses were separately performed in each generation. The grouping of cucumber genotypes using cluster analysis was performed after standardizing the data using Euclidean distance and Ward method in SPSS software. For the factor analysis after gathering information and to summarize and identify the latent factors of the studied traits, SAS software [12] was used to analyze the data. In this analysis, the principal component analysis and varimax rotation methods ere used.

3. RESULTS AND DISCUSSION

4.1 Cluster analysis results

Cluster analysis was performed using 29 evaluated traits in order to group the average of S_2 and S_3 families. The results of the average grouping of S_2 families with respect to cluster analysis based on the principal components (Figure 1), could divide all families into five groups. In the first group, there were families 2, 13, 3 and 5, in the second group, families 4, 7, 11 and 10, in the third group, families 6, 8 and 9, in the fourth group, families 12, 14, 16 and 15, and in the fifth group, only family 1.

Based on the average comparison between the cluster analysis groups of the S_2 families (Table 1), it was found that the first group while showing high values in terms of the morphological traits, number and weight of fruit at early period of growth, and fruiting period, failed to increase the yield and number of fruit throughout the harvesting period. Therefore, the first group can not be considered in terms of overall yield. The families of the second group had the highest values for all traits except plant height at the end of growth, number of leaves, number of nodes, and number and weight of fruit at the beginning of growth period. Therefore, the families of this group can be considered as the first rank in terms of both morphological traits and those related to fruit yield and number of fruits in the whole harvesting period. In the third group, traits such as plant height, number of leaves, number of nodes, stem diameter, fruit quality and average internode length showed the highest values, but the high amount of these traits did not increase the yield and number of fruits in the whole harvesting period, and the families of this group had more vegetative growth and showed more height. The plant energy seems to be used to increase plant height rather than increasing the weight and number of fruits. The fourth group in terms of leaf length and width, plant height at early growth, number of fruit per node, stem diameter, fruit quality, average internode length and fruit length, and the fifth group in terms of number of fruit per node, stem diameter and fruit quality did not show any significant difference with other groups. Although the difference in the number of fruits in the fifth group was not significant with other groups, this trait could not increase the fruit yield alone; therefore, the least fruit yield was observed in these two groups. In addition, in the fourth group, the total and average number of fruits at the end of growth period, and in the fifth group, the diameter of fruits, number of leaves and number of nodes showed the least values, which again confirmed the decrease in the yield in these two groups.

Therefore, in total, it was found that the second group had the highest fruit yield in terms of weight and number in the whole growth period, and the durability and shelf life of the plants was more than the other groups. Also, the first group is considered in terms of percocity and the crop from the families of this group will be used earlier than other groups. Some researchers negatively evaluated the relationship between the precocity and the average number of fruits per plant, and stated that the percocity does not always lead to an increase in the number of fruits per plant [3].

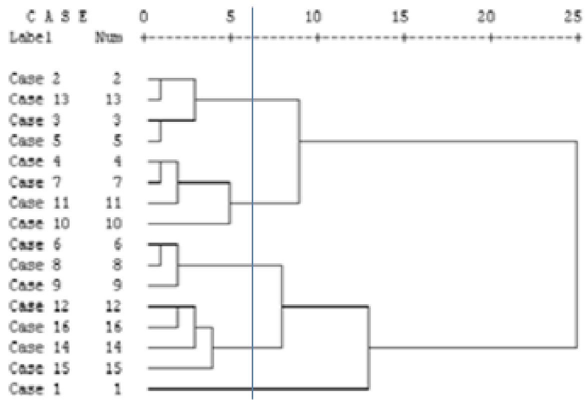

Figure 1. Dendrogram derived from cluster analysis on average families of S_2 population

According to Figure 2, family 5 in the first group had the most difference with other families, which indicates the genetic difference of this family with other families. Afterwards, families 7, 9, 10 and 15 were placed in the first group, respectively. In the second group, there were families 1, 2, 3 and 4, in the third group, families 6, 11, 13, 12, 8 and 4, and in the fourth group, only family 14. Based on the average comparison between the cluster analysis groups of the S_3 families (Table 2), it was found that the first group showed the high values in terms of length and width of leaves, plant height, fruit length, number of fruits per node, stem diameter, fruit quality, average length of internode, total and average number and weight of fruit at the end of growth period, length of fruiting period, but could not increase the yield and number of fruits in the whole harvesting period. It was also found that in this group, the number of nodes, number of leaves and diameter of fruits have the least amount, which again confirms the decrease in yield in this group. The second group had similar conditions with the first group and for all traits, except for the number of nodes, number of leaves, fruit diameter, and total and average number and weight of fruits showed a decreased in the middle of growth period, and the lowest value of the fruit diameter was observed in this group; therefore, the families of this group had long fruits compared with other groups. The third group showed a small amount in terms of fruit diameter, total and average number and weight of fruit in the early and middle periods of growth, but for the remaining traits, they showed high values. In the fourth group, due to the fact that the average traits of fruit weight, leaf length and width, plant height, number of leaf, number of nodes, average internode length, total and average number and weight of fruit in the early period of growth, and fruiting period showed a small amount, but the number and yield of fruit in the whole growth period showed a high value, which suggests the genetic difference of the families in this group with the families of other groups; therefore, the families of this group can be considered in terms of yield. Therefore, in general, the third and fourth group showed the highest values for the number and weight of fruit (fruit yield) and the families of the first and second groups in terms of morphological traits.

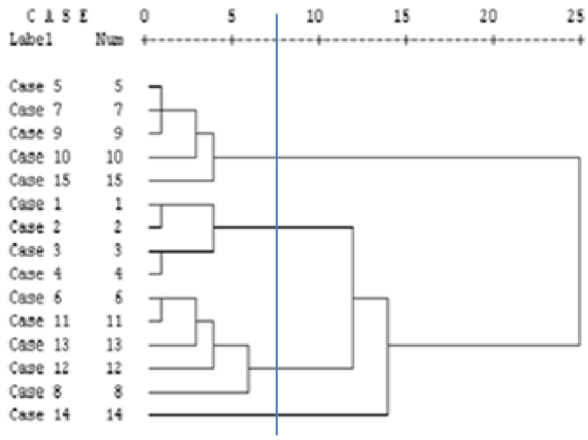

Figure 2 . Dendrogram derived from cluster analysis on average families of S_3 population

Table 1- Common Factor Rotated Coefficients for S_2 Population

Traits	Factor 1	Factor2	Factor3	Factor4	Factor5	Commonness level
x_1	38.78^{b}	47.82^{a}	33.47^{bc}	25.30^{c}	23.71^{c}	304.2^{**}
X_2	2788.4^{b}	3468.5^{a}	2361.3^{bc}	1775^{c}	1563.8^{c}	1770992.8^{*}
X_3	1.28^{b}	1.54^{a}	1.11^{bc}	0.84^{c}	0.82^{c}	0.29^{ns}
X_4	92.92^{ab}	112.33^{a}	77.98^{bc}	59.36^{c}	54.11^{c}	1739.9^{**}
X_5	23.16^{a}	22.89^{a}	22.58^{a}	23.28^{a}	15.57^{b}	13.3^{*}
X_6	25.31^{a}	24.75^{a}	24.11^{b}	25.83^{a}	15.29^{c}	23.9^{*}
X_7	198.86^{a}	175.14^{a}	182.72^{a}	186.48^{a}	133.14^{b}	946.5^{**}
X_8	326.72^{a}	265.39^{ab}	290.81^{a}	266.43^{ab}	206.57^{b}	3998.4^{**}
X_9	352.22^{a}	374.83^{a}	255.50^{ab}	260.48^{ab}	161.14^{b}	16128.7^{**}
X_{10}	50.03^{ab}	60.09^{a}	37.21^{bc}	42.85^{bc}	27.36^{c}	365.9^{**}
X_{11}	266.2^{bc}	325.5^{bc}	613.3^{a}	471.1^{ab}	104.7^{c}	83788.7^{**}
X_{12}	233.9^{bc}	303.5^{bc}	586.9^{a}	467.3^{a}	67.77^{c}	90462.2^{**}
X_{13}	2.50^{a}	2.50^{a}	1.76^{b}	3.61^{a}	3.14^{a}	11.63^{*}
X_{14}	1.74^{a}	1.85^{a}	1.42^{a}	1.97^{a}	0.86^{a}	0.34^{*}
X_{15}	1.93^{a}	2.75^{a}	2.76^{a}	2.24^{a}	1.86^{a}	0.53^{*}
X_{16}	8.76^{a}	8.73^{bc}	8.56^{c}	8.25^{ab}	6^{b}	1.73^{*}
X_{17}	8.57^{a}	6.51^{ab}	4.38^{b}	6.51^{ab}	5.14^{b}	8.15^{*}
X_{18}	1.25^{a}	0.91^{ab}	0.62^{c}	0.93^{c}	0.73^{b}	0.19^{*}
X_{19}	602^{a}	450.7^{bc}	304^{b}	449.5^{c}	378.3^{ab}	40199.5^{**}
X_{20}	86^{a}	64.39^{bc}	43.44^{b}	64.22^{c}	54.04^{ab}	820.43^{**}
X_{21}	15.53^{b}	19.85^{a}	14.28^{bc}	11.98^{c}	10.57^{c}	38.2^{*}
X_{22}	1.03^{b}	1.32^{a}	0.95^{bc}	0.80^{c}	0.70^{c}	0.18^{*}
X_{23}	1185.3^{ab}	1512.7^{a}	1028.7^{bc}	874.8^{c}	711.5^{c}	266157.3^{**}
X_{24}	80.58^{ab}	101.3^{a}	68.76^{bc}	58.32^{c}	47.43^{c}	1217.7^{**}
X_{25}	14.67^{ab}	21.61^{a}	14.81^{b}	6.81^{c}	8^{bc}	119.6^{**}
X_{26}	1.71^{ab}	2.41^{a}	1.79^{b}	0.83^{c}	1.14^{bc}	1.32^{**}
X_{27}	985.7^{b}	1505.1^{a}	1028.5^{ab}	450.7^{c}	474.1^{bc}	619761.5^{**}
X_{28}	115.88^{b}	166.64^{a}	121.77^{ab}	55.34^{c}	68.12^{bc}	6763.5^{**}
X_{29}	46.92^{ab}	45.28^{b}	42.76^{bc}	47.09^{a}	32.86^{c}	48.8^{**}

The averages with at least one common letter do not have a significant difference at the 1% probability level with the Duncan test.

X_1: total number of fruits per plant, X_2: average number of fruits per plant, X_3: total fruit weight per harvest, X_4: average fruit weight per harvest, X_5: leaf length, X_6: leaf width, X_7: plant height in middle of growth period, X_8: plant height at end of growth, X_9: fruit length, X_{10}: fruit diameter, X_{11}: number of leaves, X_{12}: number of nodes, X_{13}: number of fruits per node, X_{14}: stem diameter, X_{15}: fruit quality, X_{16}: average internode length, X_{17}: total number of fruits per plant in early growth period, X_{18}: average number of fruits per plant in early growth period, X_{19}: total fruit weight per harvest in early growth period, X_{20}: average weight of fruit per harvest in early growth period, X_{21}: total number of fruits per plant in middle growth period, X_{22}: average number of fruits per plant in middle of growth period, X_{23}: total fruit weight per harvest in middle of growth period, X_{24}: average weight of fruit per harvest in middle of growth period, X_{25}: total number of fruits per plant at end of growth period, X_{26}: average number of fruits per plant at end of growth period, X_{27}: total fruit weight per harvest at end of growth period, X_{28}: average fruit weight per harvest at end of growth period, X_{29}: fruiting period.

Table 2- Cluster Analysis of S_2 Family

Traits	Group1	Group2	Group3	Group4	Mean Square
x_1	27.40^{b}	34^{a}	39.16^{a}	36.67^{a}	85.07^{**}
X_2	1869.6^{b}	2423.3^{a}	2832.8^{a}	2436.6^{a}	779313.11^{**}
X_3	0.93^{b}	1.11^{ab}	1.29^{a}	1.22^{ab}	0.085^{*}
X_4	64.47^{c}	79.27^{b}	96.16^{a}	79.07^{ab}	838.11^{**}
X_5	22.77^{c}	23.31^{a}	22.96^{a}	19.28^{b}	4.51^{*}
X_6	24.74^{a}	25.15^{a}	24.77^{a}	20.44^{b}	6.27^{**}
X_7	204.20^{a}	179.17^{ab}	205.93^{a}	143.67^{b}	1548.93^{**}
X_8	283.09^{a}	300.46^{a}	320.38^{a}	186.83^{b}	5242.006^{**}
X_9	57.15^{a}	52.62^{a}	74.51^{a}	54.73^{b}	434.002^{**}
X_{10}	11.37^{bc}	8.03^{c}	13.53^{b}	19.65^{a}	44.77^{**}
X_{11}	423.1^{ab}	234.4^{b}	635.3^{a}	135^{c}	150178.86^{**}
X_{12}	418.4^{ab}	227.1^{b}	626.2^{a}	131.3^{c}	148190.43^{**}
X_{13}	2.9^{a}	1.7^{b}	2.1^{a}	2.4^{a}	1.069^{*}
X_{14}	1.47^{a}	2.16^{a}	1.99^{a}	1.15^{a}	0.57^{*}
X_{15}	2.03^{c}	2.79^{b}	2.70^{a}	2.67^{a}	0.56^{*}
X_{16}	8.64^{a}	8.75^{a}	8.57^{a}	8.72^{a}	0.025^{*}
X_{17}	5.76^{b}	8.62^{a}	7.10^{b}	7^{ab}	6.05^{*}
X_{18}	0.83^{b}	1.24^{a}	1.01^{b}	1^{ab}	0.13^{*}
X_{19}	376.67^{c}	642.84^{a}	538.46^{b}	439.27^{bc}	56084.19^{**}
X_{20}	54.31^{c}	92.29^{a}	76.92^{b}	62.92^{bc}	1138.32^{**}
X_{21}	12.29^{c}	15.04^{b}	15.36^{b}	20.33^{a}	21.01^{**}
X_{22}	0.82^{c}	1.002^{b}	1.03^{b}	1.36^{a}	0.095^{*}
X_{23}	852.69^{b}	1077.58^{a}	1174.95^{a}	1269.7^{a}	107982.7^{**}
X_{24}	57.20^{b}	72.22^{a}	78.33^{a}	84.65^{a}	466.73^{**}
X_{25}	9.33^{b}	10.33^{ab}	17.16^{a}	12.33^{ab}	59.19^{**}
X_{26}	1.29^{bc}	1.21^{c}	2.18^{a}	1.4^{c}	0.94^{*}
X_{27}	640.3^{b}	702.9^{ab}	1119.4^{a}	727.6^{ab}	224308.01^{**}
X_{28}	91.54^{bc}	82.32^{c}	152.51^{a}	82.46^{c}	4847.21^{**}
X_{29}	47.25^{a}	45.76^{b}	46.56^{ab}	40^{c}	14.71^{**}

The averages with at least one common letter do not have a significant difference at the 1% probability level with the Duncan test.

X_1: total number of fruits per plant, X_2: average number of fruits per plant, X_3: total fruit weight per harvest, X_4: average fruit weight per harvest, X_5: leaf length, X_6: leaf width, X_7: plant height in middle of growth period, X_8: plant height at end of growth, X_9: fruit length, X_{10}: fruit diameter, X_{11}: number of leaves, X_{12}: number of nodes, X_{13}: number of fruits per node, X_{14}: stem diameter, X_{15}: fruit quality, X_{16}: average internode length, X_{17}: total number of fruits per plant in early growth period, X_{18}: average number of fruits per plant in early growth period, X_{19}: total fruit weight per harvest in early growth period, X_{20}: average weight of fruit per harvest in early growth period, X_{21}: total number of fruits per plant in middle growth period, X_{22}: average number of fruits per plant in middle of growth period, X_{23}: total fruit weight per harvest in middle of growth period, X_{24}: average weight of fruit per harvest in middle of growth period, X_{25}: total number of fruits per plant at end of growth period, X_{26}: average number of fruits per plant at end of growth period, X_{27}: total fruit weight per harvest at end of growth period, X_{28}: average fruit weight per harvest at end of growth period, X_{29}: fruiting period.

Cui et al [2] using 15 pure cucumber cultivars and lines and evaluating 22 different traits such as average fruit yield, number of fruits, number of leaves, number of nodes, length and diameter of fruit, divided the genotypes in different groups using 8 different cluster analysis methods. The comparison between different methods did not yield similar results, although there were significant differences in the interference of high genetic distances between the cultivars and inbreds.

Comparison between cluster analysis groups on the average of S_2 and S_3 families showed that in the S_2 population, the second group for all traits except for morphological traits, number and weight of fruits in the early growth period, and in the S_3 population, the third group for traits of total fruit yield, fruit diameter, number and weight of fruit in the early and middle growth periods had the most difference with other groups, which indicates the genetic difference in the families of these two groups with the families of other groups. Therefore, it is possible to consider the families of these two groups in terms of fruit yield. Also, the least values was seen in the fifth group in the S_2 population in terms of fruit diameter, number of leaves, number of nodes, yield in number and weight of fruits in the middle of growth period, and the fourth group in terms of number and weight of fruits in the middle and late growth periods, and the second group in the S_3 population in terms of fruit diameter, and the first group in terms of number and weight of fruit in the early growth period.

4.2. Factor analysis results

The multivariate analysis, such as factor analysis, can be used to measure genetic diversity in cucumber germplasms [5]. The eigenvectors, eigenvalues, variance ratio justified by each component, and total variance justified for the average S_2 population are given in Table [3]. Based on the results of factor analysis in the S_2 population, the first five factors, which justified 90.16% of the diversity of the traits, were used for evaluation. The maximum diversity justified by the first factor was 46.29% and in the rest of the factors was 18.85%, 14.80%, 5.95% and 4.27%, respectively. In the first factor, the importance and contribution of effective traits in justifying genetic diversity were related to the total number and weight of fruit, number and weight of fruit at the end of growth period, and average number and weight of fruit, length of fruit, number and weight of fruit in the middle of growth period. As can be seen, all of the effective traits in this factor are related to the weight and number of fruit and hence, it can be designated as the factor of fruit yield during the growth period. In the second factor, the weight and number of fruits in the early growth period had the greatest positive effect on the justification of genetic diversity. Therefore, the second factor was designated as the latent factor of fruit yield in early growth period. In the third component, the traits of leaf length, leaf width, fruit length, average internode length and height in the middle growth period justified the genetic diversity. Therefore, the third factor can be designated as leaf and stem characteristics of the plant.

In the fourth component, the positive trait of number of fruit in the node and the negative trait of number of nodes and number of leaves had the greatest effect on the justification of genetic diversity. Therefore, this factor can be designated as the latent factor of ability of the node to form the leaf and fruit. In the fifth factor, the traits influencing the genetic diversity were related to the stem diameter and fruit quality and designated as fruit quality factor. In general, the selection of the evaluated families in S_2 based on the factor load of factors 1 to 5 can meet different goals.

Therefore, the choice based on the first latent factor selects the families with the highest fruit yield throughout the harvesting period, but based on the second factor, only families are selected that perform well in the early growth period. Therefore, the families selected on the basis of the second latent factor for the purposes such as early entry into the consumer market can be significant. Selection of genotypes based on factors 3 and 4 will select individuals with desirable characteristics of leaves, stems and nodes, and the selection based on the fifth factor increases the fruit quality. Huhl et al[4] in the study of quantitative traits of watermelon masses collected from Korea and Turkey showed that the traits of fruit weight, number of fruit and fruit width justified 12, 26 and 35% of total diversity, and in the first component were of more relative importance. Golabadi et al [1], based on factor analysis, found that four factors of plant shape, stem length, fruit yield (including weight and number of fruits) and number of fruits were desirable for screening of cucumber genotypes. Based on this study, selection of genotype based on these four factors can separate the genotypes with a high degree of diversity. For example, the selection based on the third factor (fruit yield) can be considered as the appropriate criteria for a superior selection in the genotypes with high weight and number of fruit.

Table 3. Eigenvector, variance ratio and total variance justified in studied traits in average S_2 population

Traits	Factor 1	Factor2	Factor3	Factor4	Factor5	Commonness level
x_1	0.97	0.16	0.11	-0.03	-0.009	0.99
X_2	0.95	0.19	0.11	-0.07	0.08	0.98
X_3	0.97	0.18	0.11	-0.03	-0.02	0.99
X_4	0.95	0.21	0.11	-0.07	0.07	0.98
X_5	0.18	0.07	0.96	0.0001	0.10	0.98
X_6	0.11	0.10	0.96	0.06	0.14	0.97
X_7	0.12	0.43	0.68	-0.22	0.01	0.72
X_8	0.10	0.47	0.49	-0.50	-0.15	0.75
X_9	0.68	0.26	0.34	-0.06	0.24	0.72
X_{10}	0.67	0.16	0.41	0.39	0.03	0.81
X_{11}	-0.20	-0.42	0.34	-0.62	0.39	0.88
X_{12}	-0.23	-0.41	0.35	-0.58	0.41	0.86
X_{13}	-0.36	0.03	0.11	0.85	-0.02	0.88
X_{14}	0.21	0.15	0.31	-0.05	0.82	0.85
X_{15}	0.27	-0.45	0.002	-0.11	0.64	0.71
X_{16}	0.42	-0.07	0.69	-0.26	0.08	0.73
X_{17}	0.14	0.94	0.22	0.02	-0.06	0.96
X_{18}	0.13	0.94	0.23	0.03	-0.006	0.96
X_{19}	0.18	0.95	0.18	0.03	0.01	0.97
X_{20}	0.18	0.95	0.18	0.03	0.01	0.97
X_{21}	0.92	0.06	0.16	0.10	0.16	0.92
X_{22}	0.92	0.07	0.17	0.10	0.16	0.92
X_{23}	0.91	0.12	0.19	0.10	0.19	0.93
X_{24}	0.91	0.12	0.20	0.09	0.18	0.93
X_{25}	0.96	-0.06	0.01	-0.12	-0.08	0.95
X_{26}	0.95	-0.10	-0.01	-0.14	-0.12	0.96
X_{27}	0.94	-0.03	0.01	-0.19	0.007	0.92
X_{28}	0.94	-0.05	-0.01	-0.18	-0.004	0.93
X_{29}	0.06	0.30	0.88	0.07	0.12	0.90
Relative variance	46.29	18.85	14.8	5.95	4.27	
Total Variance	46.29	65.14	79.93	85.89	90.15	

X_1: total number of fruits per plant, X_2: average number of fruits per plant, X_3: total fruit weight per harvest, X_4: average fruit weight per harvest, X_5: leaf length, X_6: leaf width, X_7: plant height in middle of growth period, X_8: plant height at end of growth, X_9: fruit length, X_{10}: fruit diameter, X_{11}: number of leaves, X_{12}: number of nodes, X_{13}: number of fruits per node, X_{14}: stem diameter, X_{15}: fruit quality, X_{16}: average internode length, X_{17}: total number of fruits per plant in early growth period, X_{18}:

average number of fruits per plant in early growth period, X_{19}: total fruit weight per harvest in early growth period, X_{20}: average weight of fruit per harvest in early growth period, X_{21}: total number of fruits per plant in middle growth period, X_{22}: average number of fruits per plant in middle of growth period, X_{23}: total fruit weight per harvest in middle of growth period, X_{24}: average weight of fruit per harvest in middle of growth period, X_{25}: total number of fruits per plant at end of growth period, X_{26}: average number of fruits per plant at end of growth period, X_{27}: total fruit weight per harvest at end of growth period, X_{28}: average fruit weight per harvest at end of growth period, X_{29}: fruiting period.

The results of factor analysis in population S_3 are shown in Table (4). The first six factors justifying about 88.53% of the data diversity were used for analysis. Maximum diversity was 34.42% by the first factor and the rest were 20.43%, 16.13%, 4.83%, 4.23%, respectively. In the first factor, the importance and contribution of traits in justifying the genetic diversity of the traits were related to the total and average traits of fruit weight in the middle of growth period, weight and number of fruits in the early stages of growth, fruit quality, total fruit, total fruit yield and average fruit number. Therefore, this factor can be designated as the factor of fruit yield in the middle of growth period. In the second factor, the yield and number of fruits at the end of growth period, average number and weight of fruit, total weight of fruit and total number of fruits had the most effects in justifying genetic diversity. Therefore, this factor was designated as the latent factor of the average fruit yield at the end of growth period. In the third factor, the number of leaves, number of nodes, height in the middle of plant growth, fruit length, height at the end of plant growth and stem diameter justified the genetic diversity. Therefore, the third factor can be designated as the plant height factor. In the fourth factor, the traits of leaf width, leaf length and fruit harvesting period had the greatest effects on the justification of genetic diversity. Therefore, this factor was designated as the latent factor of leaf properties. In fifth factor, the number of fruit per node in positive manner and the stem diameter in negative manner had the greatest effects on the justification of genetic diversity. Therefore, this factor can be designated as the factor of fruiting level in the node. In the sixth factor, the effective trait in justifying genetic diversity was related to the average internode length, which is the same as the third factor. In a study, Zhang et al.[16] showed that the average weight of fruit had an effect on plant growth and nutrient level, and therefore, it was designated as the physiological factor and indicated that this factor was a positive load in the early growth periods and has a direct and positive effect on the fruit weight.

Naroui Rad [7] analyzing the factors of the traits in watermelon determined that the first two factors justify 55% of the total diversity. In the first factor, the fruit width (54%), fruit yield (53%), fruit weight (50%), fruit length (37%), and in the second component, the number of fruits (52%) and seed weight (48%) had the greatest effect in justifying the total diversity.

Table 4- Common Factor Rotated Coefficients for S_3 Population

Traits	Factor 1	Factor2	Factor3	Factor4	Factor5	Factor6	Commonness level
x_1	0.59	0.60	-0.34	-0.17	-0.10	0.27	0.95
X_2	0.52	0.83	0.05	0.03	-0.08	-0.003	0.98
X_3	0.59	0.61	-0.22	-0.18	-0.10	0.29	0.91
X_4	0.48	0.84	0.18	0.05	-0.06	-0.02	0.99
X_5	0.001	-0.12	0.15	0.88	0.13	-0.19	0.87
X_6	-0.04	-0.0009	0.03	0.91	0.12	-0.14	0.86
X_7	-0.37	-0.03	0.84	0.13	-0.17	0.09	0.90
X_8	-0.15	0.26	0.65	0.49	-0.39	-0.02	0.92
X_9	0.17	0.23	0.76	0.02	0.26	0.02	0.74
X_{10}	0.10	0.19	0.48	-0.74	0.16	0.04	0.86
X_{11}	-0.17	-0.01	0.93	-0.02	-0.12	0.01	0.92
X_{12}	-0.17	0.10	0.92	-0.02	-0.12	0.01	0.92
X_{13}	-0.20	-0.08	-0.19	0.11	0.91	-0.02	0.94
X_{14}	0.23	-0.05	0.50	0.36	-0.53	-0.31	0.82
X_{15}	0.72	0.006	-0.05	-0.06	-0.21	0.005	0.57
X_{16}	0.30	-0.15	0.005	-0.12	-0.02	0.65	0.56
X_{17}	0.73	0.0009	-0.31	0.30	-0.38	0.28	0.95
X_{18}	0.72	-0.01	-0.32	0.31	-0.38	0.27	0.94
X_{19}	0.74	0.07	-0.008	0.41	-0.41	0.22	0.94
X_{20}	0.73	0.06	-0.01	0.41	-0.41	0.22	0.93
X_{21}	0.81	0.25	-0.21	-0.36	0.12	0.09	0.93
X_{22}	0.81	0.25	-0.22	-0.37	0.11	0.08	0.93
X_{23}	0.90	0.33	0.09	-0.14	0.12	0.06	0.97
X_{24}	0.91	0.32	0.07	-0.12	0.13	0.06	0.97
X_{25}	0.24	0.67	0.21	-0.07	-0.52	0.54	0.86
X_{26}	0.17	0.65	0.37	-0.05	0.05	0.53	0.88
X_{27}	0.008	0.97	0.02	-0.01	-0.03	-0.11	0.96
X_{28}	-0.09	0.91	0.27	0.001	0.02	-0.18	0.95
X_{29}	-0.10	0.11	0.12	0.83	-0.30	0.18	0.87
Relative variance	34.42	20.43	16.13	8.47	4.85	4.23	
Total Variance	34.42	54.85	70.98	79.45	84.3	88.54	

X_1: total number of fruits per plant, X_2: average number of fruits per plant, X_3: total fruit weight per harvest, X_4: average fruit weight per harvest, X_5: leaf length, X_6: leaf width, X_7: plant height in middle of growth period, X_8: plant height at end of growth, X_9: fruit length, X_{10}: fruit diameter, X_{11}: number of leaves, X_{12}: number of nodes, X_{13}: number of fruits per node, X_{14}: stem diameter, X_{15}: fruit quality, X_{16}: average internode length, X_{17}: total number of fruits per plant in early growth period, X_{18}: average number of fruits per plant in early growth period, X_{19}: total fruit weight per harvest in early growth period, X_{20}: average weight of fruit per harvest in early growth period, X_{21}: total number of fruits per plant in middle growth period, X_{22}: average number of fruits per plant in middle of growth period, X_{23}: total fruit weight per harvest in middle of growth period, X_{24}: average weight of fruit per harvest in middle of growth period, X_{25}: total number of fruits per plant at end of growth period, X_{26}: average number of fruits per plant at end of growth period, X_{27}: total fruit weight per harvest at end of growth period, X_{28}: average fruit weight per harvest at end of growth period, X_{29}: fruiting period.

According to the results of factor analysis in two populations, it was found that in both populations S_2 and S_3, the first, second and third factors played a more important and significant role, so that in two populations, the number and weight of total fruit, average number and weight of fruit, and number and weight of fruits in the middle of growth period had the greatest effect on the genetic diversity. In family S_2, 46.29% and in S_3 family, 34.42% of the data diversity was justified by the first factor. The second factor in the S_2 family was related to the number and weight of fruit in the middle of growth period, whereas in the S_3 family, this factor was related to the number and weight of fruit in the whole growth period, and average number and weight of fruits at the end of growth period, as in S_2 family, 18.85%, and in S_3 family, 20.43% of the data variance was justified by this factor. The third factor in family S_2 was related to the length and width of leaf and plant height, and in S_3 family was related to plant height, fruit length and diameter, number of leaves and number of nodes, so that in S_2family, 14.80% and in S_3 family, 16.13% of the variance was justified by these traits.

Although the first factor in both populations was related to the same traits, the diversity justified by these traits in the S_2 population was much higher than that of the S_3 population. Therefore, the importance of the mentioned traits (weight and number of fruits, etc.) in S_2 population is more than S_3. On the other hand, in the second factor, although in both populations, the traits related to the number and weight of fruits again had the highest load factor, but in S_2, the number and weight of fruits in the middle of growth period, and in the population S_3, the total number and weight of fruit in the growth period justified the data diversity. Thus, in the S_2 population, only the middle of growth period was able to justify the diversity of data equivalent to the total growth period in the S_3 population. The third factor in both populations was related to the morphological traits of the plant such as leaf and height characteristics, and hence, these traits have almost the same importance in both populations.

5. Conclusion

Cluster analysis in the S_2 population in the second group and in the S_3 population in the third group had the most differences with the other groups in terms of the characteristics of total fruit, which indicates the genetic difference in the families of these two groups with the families of other groups. Therefore, it is possible to consider the families of these two groups in terms of fruit yield.

Based on the results of factor analysis in both S_2 and S_3 populations, the traits related to the total number and weight of fruits in the growth period, number and weight of fruits in the middle of growth period and the morphological traits of plant, such as leaf and height characteristics, had the highest factor load. Therefore, these traits in both populations were able to justify the diversity of data, and have almost the same significance.

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