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Full Length Research Paper

Performance of different greenhouse cucumber cultivars (*Cucumis sativus* L.) in southern Iran

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A 2 year trial was conducted with 15 cucumber (*Cucumis sativus* L.) varieties from diverse origins in the greenhouse conditions (southern Iran) to study genetic variation and to identify genetically distant parents to be involved in a hybrid seed production as well as to identify the most effective components of grain yield. However, the potential of identifying genetically distant parents depends on genetic diversity of population. The varieties were cultivated in a randomized complete block design (RCBD) with 3 replications for 2 years (2004 - 2006 seasons). Characters such as, yield and number of fruits in surface unit (m^2), yield in cold season, diameter and length of stem, length and diameter of fruit were evaluated analyzed for 2 years. Compound variance analysis showed that there were significant differences (α = 0.01) in yield between varieties at 2 years and the highest yield (23.81 kg/m^2) was obtained for E3215516 variety. Correlation analysis of varietal means showed that the highest correlation (0.932) was observed between number of fruits (NOF) and yield, and the least (0.01) between diameter of stem (DOS) and length of fruit (LOF). Based on factor analysis, 3 components were identified, explaining 77.5% of observed variation. Factor 1 (yield factor) accounting for about 45% of the variation, was strongly associated with yield, yield in cold season and number of fruits. Factor 2 (source factor) accounting for about 18% of the variation, consisted of stem related components including diameter of stem (DOS) and length of stem (LOS). Factor 3 (sink factor) accounting for about 15% of the total variation, associated with length and diameter of fruit (LOF and DOF). Using cluster analysis, the lines were classified into 2 distinct classes A and B. Class B contained lines from different origins.

Key words: Cucumber (*Cucumis sativus* L.), greenhouse, yield comparison.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a vegetable crop of the *Cucurbitaceae* family and greenhouse's production is popular in many areas of the world. Cucumber needs a temperature between 80 to 85°F (approximately 25 to 29°C) and plenty of sunlight (Hochmuth, 2001). Greenhouse cucumbers grow quickly and should never be allowed to suffer from lack of water or nutrients. The nutrient uptake rate by greenhouse cucumbers is very high. Commercial cucumber greenhouse production in southern regions of Kerman province, southern Iran, without heating systems in greenhouses at 2005-2006 reached more than 1000 ha. More than 18000 ha are also cultivated in the small tunnels with plastic covers.

Cucumber is a primary source of vitamins and minerals for human body but its caloric and nutritional value is very low (Keopraparl, 1997). Gynoecious varieties of cucumber (100% female blossoms) usually are more productive and produce fruits with smoother skins than monoecious types, having both female and male flowers (Marr, 1995; Hochmuth, 2001). Parthenocarpic cucumbers are seedless because the fruit is produced without being pollinated. If this type of cucumber is planted near others, pollination will occur and seeds will form. This type is often grown in greenhouses (Relf and McDaniel, 2000).

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Table 1. DD cucumber cultivars used in the experiment.

S/No.	Cultivar	Production company	Origin
1	Niz Boo9	Nickerson Zwaan	Netherlands
2	ES305	Eastern Seeds	Turkey
3	Borhan	Enza Zaden	Netherlands
4	E3215150	Enza Zaden	Netherlands
5	E3215502	Enza Zaden	Netherlands
6	Ever Green	Peto Seed	U.S.A.
7	Nefer F1	YUKSEL	Turkey
8	E3215145	Enza Zaden	Netherlands
9	Kaspian RZ (2279-RZ)	Rijk Zwaan	Netherlands
10	E3215516	Enza Zaden	Netherlands
11	2289-RZ	Rijk Zwaan	Netherlands
12	Negeen	Enza Zaden	Netherlands
13	Ayat	California	U.S.A
14	Isatis (GB 251)	Nunhems Zaden	Netherlands
15	RS189 I SINA F1*	Royal Sluis	Netherlands

* Current standard variety in Jiroft and Kahnooj regions.

Parthenocarpic cucumbers tend to bear fruit earlier, with a more concentrated set and better yield overall.

An experiment evaluated 12 greenhouse mini-cucumber (Beit Alpha) cultivars in 2 growing systems during 2002-2003 winter seasons in Florida. Total marketable yield ranged from 1393 to 2637 g per plant. Tenor variety had the lowest total marketable yield among all varieties with 1393 g per plant. Alamir, LDC845, General and Manar varieties all had total marketable yield of 2300 g or more per plant but were not significantly different from most varieties (Hochmuth, 2004). In the other experiment 6 local cucumber varieties, from Udonthani, northeast of Thailand, were compared with 6 commercial cucumber varieties from November 1996 to January 1997. Ninja 179, a commercial variety, gave the highest marketable yield at 25.61 ton/ha, with desirable fruit quality, followed by other commercial varieties including Tank #337, Jedbai 1043 and Chumporn 534. The local varieties gave medium marketable yield and fruit characters. Correlation among the marketable and total yields was significant (Keopraparl, 1997).

16 slicing cucumber varieties were compared for yield, potential returns and overall appearance in the spring of 2002 in the horticultural research farm in Lexington. Dasher II was included as a standard (check) variety, as it is 1 of the most popular hybrids in the region (Rowell et al., 2002). This experiment replicated with 15 cultivars at spring 2003 and like last year's study, daytona, dasher II, SRQ 2983 and indy were classified in the 7 highest cultivars, along with General Lee, Greensleeves and turbo (Satanek et al., 2003). Common slicing cucumber varieties planted in California include dasher II, conquitador, thander, slicemaster and sprint (Schrader et al., 2002).

Results of screening the cucumber germplasm collection showed that there were significant differences among 817 cultigens for fruit yield and quality and for days to harvest. The interaction of cultigens and environment was significant for all traits, except for % of culls (Shatty and Wehner, 2002). In another experiment 6 Beit alpha cucumber cultivars (Alexander, Dishon, Sarig, Suzan, Ilan and Rambo) and 2 Dutch type cultivars (Bologna and Kalunga) were evaluated in 2 seasons (fall 1999 and spring 2000). Dutch type cultivars (also called European or English cucumbers) have long, thin skinned and seedless fruits. The Beit alpha fruits are shorter than Dutch cucumbers but seedless, smooth and thin skinned and are less susceptible to damage after harvest than the Dutch types. Beit alpha cultivars produced 2 - 3 times as many marketable fruit, on a per season basis, as the Dutch cucumber cultivars (Lamb et al., 2001).

The potential of identifying genetically distant parents depends on genetic diversity of population (Ahmadikhah et al., 2008). In this line, we evaluated 15 cucumber varieties from diverse origins to study genetic variation and to identify genetically distant parents to be involved in a hybrid seed production as well as to identify the most effective components of grain yield.

MATERIALS AND METHODS

15 varieties from several countries (14 gynoecious varieties and 1 monoecious variety, ES305) were selected for investigation (Table 1). The RS189 I SINA F_1 variety (predominant variety in southern Iran) selected as check variety. Each plot contained 20 plant and data collected from 6 plant of middle plot. A randomized complete block design (RCBD) with 3 replications was used in the experiment. The experiment was conducted at greenhouse of Jiroft and Kahnooj Shahid Moghbeli agricultural research center (latitude, 28° 32' 48" N, longitude 57° 51' 31"), Kerman province, for 2 years from 2004 through 2006. The greenhouse was multi pan with 3.5 m

Table 2. Combined analysis of variance of studied traits in two years.

Source of variation (SOV)	D.f	Mean of squares (MS)						
		Yield (kg/m^2)	NOF (m^2)	YICS (kg/m^2)	DOS (cm)	LOS (m)	LOF (cm)	DOF (cm)
Year	1	814.27**	176053.98**	162.3**	1.67**	0.107 n.s	1.521 n.s	0.095 n.s
Replication (year)	4	29.49**	1868.58**	0.8 n.s	0.037*	0.332 n.s	5.814**	0.021 n.s
Variety	14	31.57**	4733.31**	3.11**	0.085**	1.473*	5.98**	0.2*
Variety* Year	14	4.7 n.s	1204.44**	0.76 n.s	0.044**	0.47 n.s	1.463 n.s	0.031 n.s
Experimental Error	56	5.85	47019	1.023	0.011	0.64	1.06	0.105
Coefficient of Variance (CV%)		13.78	11.47	16.9	8.75	24.54	7.06	10.4

NOF (m2) = Number of fruit in m^2; YICS (kg/ m^2) = Yield in cold season; DOS (m) = Diameter of stem; LOS (m) = Length of stem; LOF (cm) = Length of fruit (cm); DOF (cm) = Diameter of fruit; * = Significant at (α = 0.05); ** = High significant at (α = 0.01); n.s = Non significant.

gutter altitude and without heating and ventilation system. Air circulation carried out with opening the doors, side and roof windows. Greenhouse temperature varied between 0 - 40°C for 7 months.

For germinating, the seeds were immerged in water (at 35°C) for 4 h and then wrapped in a wetted towel for 48 h. The germinated seeds were planted in plastic trays (containers) filled with peat and sand (70% peat and 30% sand) so that during the seedling and transplanting stages the cucumber did not experience water stress. 15 -20 day-old seedlings with 2 - 3 true leaves were transplanted in 2 double rows in each plot with 30 cm spacing between the rows and plants on each row. 1 m walkway was considered between 2 double rows. Irrigation system was micro-tube with 20 cm dripper distance. Plots were irrigated daily until they were adapted with greenhouse conditions and then were not irrigated for 25 days until stem length reached up to 30 cm. At this stage root system well expanded and several blooms appeared. After this stag irrigation was conducted in 2 - 4 days periods and at the end of season plants were irrigated 3 times every day as temperature increased more than 38°C. The duration of each watering was from 30 to 45 min.

Chemical fertilizers were used based on the soil and leaf analysis. Recommended doses of soluble fertilizers were injected in the irrigation water or applied before planting date. Plants were supplied for micronutrient deficiencies with soluble fertilizers by injecting in the irrigation water or sprayed on the leaves (except for Fe that used with irrigation system). Used soluble fertilizers were such as ammonium sulfate, potassium sulfate (with low solubility), super phosphate triple (with low solubility), magnesium sulfate, manganese sulfate, zinc sulfate and Fe chelat.

The most serious pests observed in greenhouse were leaf miner, mites, white fly, aphids and leaf cutter. For pests control pesticides such as Confider (Imidacloprid), Permethrin (Abush) and Neoron (Bromopropilat) were used. The observed diseases were downy mildew, leaf spot and gray mold. They were controlled with ventilation and air circulation in the greenhouse and using fungicides such as Ridomil, Daconil and Rovral Iperdion. Just before planting soil solarization was carried out for 45 days at summer season.

Cucumbers were harvested when diameter of fruit reached more than 2.5 cm. Harvesting was initiated approximately at 35 days after transplanting and terminated approximately after 200 days.

Factor analysis calculations were performed using SPSS factor analysis programme. Estimates of factor loadings were based on data from all plants for all populations. The principal factor analysis method explained by Harman (1976) was followed in the extraction of the factor loadings. The array of communality, the amount of the variance of a variable accounted by the common factor together, was estimated by the highest correlation coefficient in each array as suggested by Seiller and Stafford (1985). The number of factors was estimated using the principal component method. The Varimax rotation method was used in order to make each factor uniquely defined as a distinct cluster of intercorrelated variables (Rao, 1952). The factor loadings of the rotated matrix, the % variability explained by each factor and the communalities for each variable were determined.

RESULTS AND DISCUSSION

Yield

High significant differences in the yield (P < 0.01) were observed among the varieties (Table 2) in 2 years (combined analysis of variance). Total yield ranged from 14.29 to 23.81 kg/m^2. The highest yield (23.81 kg/m^2) was obtained for E3215516 variety, which was significantly different from other varieties and so cluster analysis of morphological data (Figure 1) showed group B includes only this variety. However, Nefer F1 had the lowest yield (14.29 kg/m^2) among all of varieties. Yield of RS189 I SINA F1 variety (standard current variety) was 18.43 kg/m^2 (Table 3 and Figure 1). One of the breeding objectives in cucumber breeding programs is increase fruit yield (Cramer and Wehner, 1998). The total average yields of the varieties were 20.564 kg/m^2 in the first year and 14.548 kg/m^2 for second year. Population of cucumber differed in fruit yield and yield components. Yield and component differed between seasons and years (Cramer and Wehner, 1998). It seems that cold season and chilling injury caused yield decrease in second year. For example, yield of E3215516 variety in first year was 26.16 kg/m^2. The results shows that use of heating system is necessary for this region.

Fruit number

The high significant differences in the fruit number (α = 0.01) were observed between varieties in 2 years (Table 2). Heritability of fruit number has higher than fruit mass (Smith et al., 1978) and effects of environment conditions on this trait are lower than fruit mass. Measurement of cucumber yield as fruit number rather than fruit weight or

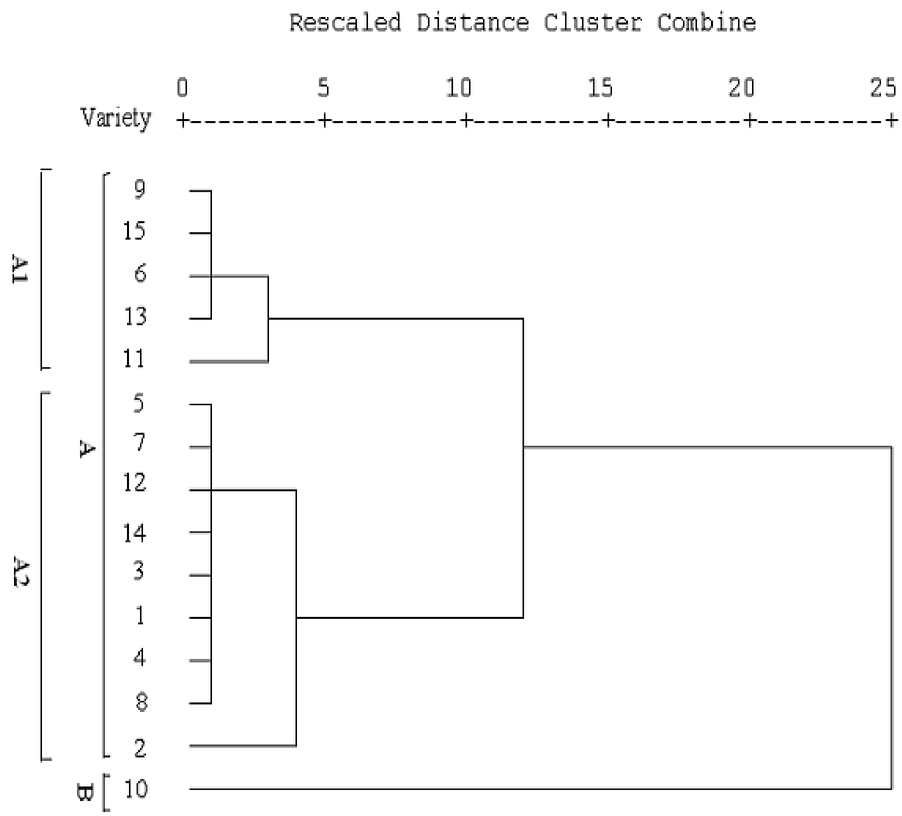

Figure 1. Dendrogram of 15 cucumber varieties (see Table 1) generated by morphological data using the UPGMA method.

Table 3. Mean of studied characters (data in table) and Duncan's multiple range test results (α = 0.05).

Variety	Mean of character						
	Yield (kg/m^2)	NOF (m^2)	YICS (kg/m^2)	DOS (cm)	LOS (m)	LOF (cm)	DOF (cm)
Niz Boo9	16.98bcde	183.14cde	6.13abc	1.17defg	3.04bc	14.1cde	2.84c
ES305	15.42cde	146f	4.26d	1.56a	3.72ab	13.70e	3.46ab
Borhan	16.5cde	173.04cdef	6.02abc	1.12fg	3.03bc	13.95de	3.18abc*
E3215150	18.36bc	185.36cde	5.74abc	1.27bcd	3.14b	14.74bcde	3.21abc
E3215502	14.5de	169.23def	5.76abc	1.2cdefg	3.15b	15.92ab	3.09abc
Ever Green	17.41bcde	197.16cd	6.47abc	1.32bc	3.68ab	14.93abcde	3.06bc
Nefer F1	14.29e	164.29ef	5.26cd	1.10g	2.03c	12.43f	3.17abc
E3215145	18.24bc	180.82cde	6.995a	1.13efg	3.28ab	14.21cde	3.11abc
Kaspian RZ (2279-RZ)	17.49bcde	195.85cd	5.48bcd	1.19cdefg	3.34ab	16.27a	2.96c
E3215516	23.81a	256.68a	7.12a	1.34b	4.23a	13.71e	3.51a
2289-RZ	19.9b	225.54b	6.77ab	1.24bcdef	3.74ab	15.63ab	3.02bc
Negeen	16.55cde	176.63cde	5.55bc	1.19cdefg	2.88bc	14.59bcde	3.02bc
Ayat	17.58bcd	201.26bc	6.14abc	1.18cdefg	3.35ab	15.17abcd	2.98c
Isatis (GB 251)	17.9bc	176.34cde	6.01abc	1.11fg	3.01bc	14.19cde	3.0c
RS189 I SINA F1*	18.43bc	195.64cd	6.04abc	1.26bcde	3.31ab	15.36abc	3.27abc
First year	20.564a	233.289a	7.326a	1.088b	3.226a	14.722a	3.157a
Second year	14.548b	144.832b	4.64b	1.361a	3.295a	14.462a	3.09a

NOF (m^2) = Number of fruit in m^2; YICS (kg/ m^2) = Yield in cold season; DOS (m) = Diameter of stem; LOS (m) = Length of stem; LOF (cm) = Length of fruit; DOF (cm) = Diameter of fruit; * = a, b, c, d, e, f and g show rank of Duncan's multiple range test results (α = 0.05).

Table 4. Correlations between different morphological traits and yield.

	NOF	YICS	DOS	LOS	LOF	DOF
Yield	.932**	.831**	-.380**	.332**	.089	.077
NOF		.843**	-.476**	.252**	.139	.072
YICS			-.566**	.196*	.127	-.040
DOS				.243*	-.010	.039
LOS					.074	-.028
LOF						.034

NOF (m^2) = Number of fruit in m^2; YICS (kg/ m^2) = Yield in cold season; DOS (m) = Diameter of stem; LOS (m) = Length of stem; LOF (cm) = Length of fruit; DOF (cm) = Diameter of fruit.
* and ** represent significance at P ≤ 0.05 and P ≤ 0.01, respectively.

value provided the most stable measure of yield in a once over harvest system (Ells and McSay, 1981). Therefore, the selecting of variety with high fruit number in the first step and with high fruit mass in the second step can help in successful cucumber production. Select of E3215516 variety for commercial production at this region is beneficial because the highest number of fruit (256.68 fruits in m^2) and the highest yield was obtained from this variety. ES305, non greenhouse variety, had the lowest number of fruit (146 fruits in m^2).

Yield in cold season

The obtained yields of varieties in cold season (for 70 days) were analyzed and results have been shown in Table 2. Cucumber plants are very susceptible to chilling injury in field and tender than tomatoes or peppers (Schrader et al., 2002 and Hochmuth, 2001). Results shown that there was high significant difference (α = 0.01) between varieties in 2 years (Table 2). E3215516 had the highest (7.12 kg/m^2) and ES305 had the lowest yield in cold season. Average yield in cold season in each year (7.326 kg/m^2 in first year and 4.64 kg/m^2 in second year) shows significant difference (α = 0.01) between years (Table 3). Temperature in first year was lower than second year and in the greenhouse heating system was not used (as producers at this time does not use heating system, however, recently are using).

Diameter of stem

The stems of the cucumber are veining, therefore can be trained on trellises to save space and improve yield and fruit quality. Diameter of stem at the end of production season (June 2005 and 2006) was measured and its analysis showed significant difference (α = 0.01) between varieties (Table 2). The highest (1.56 cm) and lowest (1.1 cm) stem diameter obtained for ES305 and Nefer F1 (Turkish varieties), respectively. E3215516, high yielding variety, had second stem diameter (1.34 cm) and showed significant difference (α = 0.05) from ES305 variety (Table 3).

Length of stem

Results showed there were high significant differences (α = 0.01) in length of stem between varieties (Table 2). Among those, E3215516 had the highest (4.23 m) and Neffer F1 had the lowest (2.03 m) length of stem (Table 3).

Length of fruit

The experimental results showed that there were significant differences (α = 0.01) among varieties in length of fruit (Table 2). The Kaspian RZ (2279-RZ) had the highest (16.27 cm) and the Nefer F1 had the shortest (12.43 cm) length of fruit (Table 3). This character is the most important of marketable and commercial character in Iran.

Diameter of fruit

Results showed that there were significant differences (α = 0.05) in diameter of fruit between the varieties. Nizboo9 variety had the shortest (2.84 cm) and E3215516 gave the highest diameter of fruit (3.51 cm) followed by ES305 with 3.46 cm and RS189 I SINA F1 (standard current variety) with 3.27 cm.

Multivariate regression of yield on other traits

Stepwise regression was used to determine the contribution of studied traits in final yield. Only 1 trait remained in the model and as such is seen as significant determinants of final yield. The final regression of yield on other traits is

Y= 3.482 + 0.07444 (NOF; kg/m^2).

The coefficient of determination (R^2) of fitted model indicates that > 83.0% of the variation of the dependent variable (yield) is explained by NOF in the equation.

Correlations of varietal means

Correlation analysis of varietal means showed that the highest correlation (0.932) was observed between number of fruits (NOF) and yield and the least (0.01) between diameter of stem (DOS) and length of fruit (LOF) (Table 4). For once-over harvest of cucumbers, fruit number per plot is a more stable measure of yield than fruit mass

Table 5. Total variance explained by different components. Extracted components with initial Eigenvalues > 1 are in boldface.

Component	Total	Variance (%)	Cumulative (%)
1	3.137	44.820	44.820
2	1.263	18.037	62.858
3	1.026	14.664	77.521
4	0.957	13.672	91.194
5	0.399	5.706	96.900
6	0.158	2.261	99.161
7	5.872E-02	0.839	100.000

Table 6. Component score coefficient matrix after VARIMAX rotation with Kaiser normalization (Kaiser, 1958). The coefficient values with a high weight (higher than ± 0.25) are shown in boldface.

Parameter	1	2	3
Yield	0.286	0.132	0.060
NOF	0.297	0.047	0.071
YICS	0.307	-0.019	-0.055
DOS	-0.237	0.492	0.112
LOS	0.044	0.710	-0.032
LOF	0.007	0.106	0.403
DOF	-0.064	-0.158	0.876

NOF (m^2) = Number of fruit in m^2; YICS (kg/ m^2) = Yield in cold season; DOS (m) = Diameter of stem; LOS (m) = Length of stem; LOF (cm) = Length of fruit; DOF (cm) = Diameter of fruit.

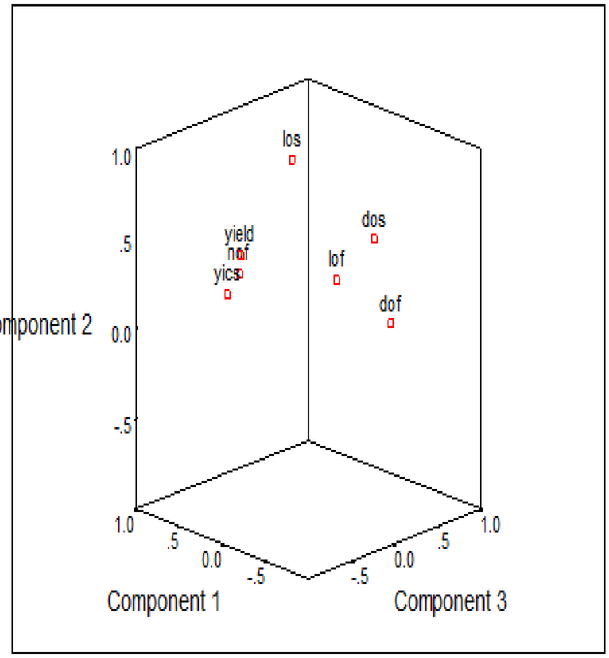

Figure 2. Componenet plot in rotated space. nof (m^2) = Number of fruit in m^2; yics (kg/ m^2) = yield in cold season; dos (m) = diameter of stem; los (m) = length of stem; lof (cm) = length of fruit; dof (cm) = diameter of fruit.

(Wehner, 1989). Heritability of fruit number has higher than fruit mass and is highly correlated with mass (Smith et al., 1978). Therefore fruit number is one of the best traits to select of high yielding cultivars or use to breeding programs. However, the correlation between yield components and fruit yield were often influenced by the environment, particularly when strong correlations existed (Cramer and Wehner, 1998).

Factor analysis

For identifying more important components contributing in total variation, factor analysis was conducted. The total variance and Eigenvalues explained by factors are indicated in Table 3. The first 2 factors (with initial Eigenvalues > 1) accounted for more than 77% of the total variance. The contributions of factors 1 - 3 to the total variance were 44.82, 18.04 and 14.66% respectively (Table 5).

A principal factor matrix after varimax rotation with Kaiser normalization for these 3 factors is given in Table 6. The values in the table for factor loadings indicate the contribution of each variable to the factors. To interpret the result, only those factor loadings having greater values which are in boldface in Table 6 are considered. Factor 1, which accounted for about 45% of the variation, was strongly associated with yield in cold season and number of fruits. This factor was regarded as a yield factor, since it consist mostly of yield-dependent traits. All important variables in factor 1 had positive loadings. The sign of the loading in Table 6 indicates the direction of the relationship between the factor and the variable. Factor 2, which accounts for about 18% of the variation, was named source factor since it consist of stem-related components including diameter of stem (DOS) and length of stem (LOS). In this factor both variables also had positive loadings. Factor 3 was named sink factor, which is positively associated with length and diameter of fruit (LOF and DOF). This factor accounted for about 15% of the total variation. In Figure 2, relative position of each component in a rotated space is shown.

Cluster analysis

Cluster analysis of morphological data from samples allowed the discrimination of varieties based on individual plants. Genetic distances (GDs) among genotypes varied from 1.98 to 119.93. According to the distance matrix, the least distance (1.98) belonged to variety numbers 6 and 15, and the highest distance (119.93) belonged to variety numbers 2 and 10.

According to cluster analysis and cutting dendrogram in a single distance coefficient, studied varieties was divided into 2 groups (Figure 1). Group B includes only variety number 10, a variety from Netherlands, namely E32155 16. Superiority of this variety in most traits may explain this clustering. Group A includes the remaining genotypes, which are subdivided into 2 subclasses of A1 and A2. Subgroup A1 includes varieties number 6, 9, 11, 13 and 15 while subgroup A2 includes varieties number 1, 2, 3, 4, 5, 7, 8, 12 and 14 (Figure 1).

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