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Evaluation of various greenhouse cucumber cultivars under soil culture medium

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ABSTRACT

A large portion of available seeds in the local market of Iran is supplied from imported sources. These cultivars exhibit diversity in terms of qualitative and quantitative properties. Since they have been bred according to conditions of origin countries, it is requisite to analyze their level of adaptability to the new environment. In this study, qualitative, quantitative, and yield properties of seven cucumber cultivars were investigated. A greenhouse experiment was conducted in a soil bed medium in Varamin, based on a randomized complete block design with three replications. The grouping was performed based on the LSD test and cluster analysis. The results showed that the number of fruits per node has the highest positive effect on yield. The fruits in each internode were maximally set in the FC-043 cultivar. FC-043 cultivar were in the same class as Voila cultivar as the control in cluster analysis. This cultivar exhibited superiority and greater positive coefficients in the two main traits, including fruit number per node and yield. Generally, the results revealed that the FC-043 cultivar had high adaptability in soil bed culture medium in greenhouses and can be cultivated as a high-performance cultivar.

Keywords: *Cucumis sativus*, Cultivar, Greenhouse, Yield.
Article type: Research Article.

INTRODUCTION

Owing to its low calorie, *Cucumis sativus* L. (2n = 2x = 14) can play a crucial role in human health. Based on the available evidence, the cucumber has been planted since three thousand years ago in western Asia (Hajianfar *et al*. 2017) and is cultivated in open fields and greenhouses both in hot and moderate regions of the world (Panwar *et al*. 2013). The Cucumis genus includes 25 Asian and Australian and 30 African species. Among Cucumis species, cucumber and melon are assigned to high commercial value (Sebastian *et al*. 2010). The cultivation area of cucumber was around 2.18 million ha in 2014, and its yield rate amounted to 74.98 million tons (Ayala-Tafoya *et al*. 2019). China, India, Russia, and America are accounted as higher ranking cucumber suppliers (Call *et al*. 2012). Cucumber is the most important and widely used of cucurbit plants in Iran. Its cultivation area has been reached 92000 ha with an annual yield of 1.78 million tons (Jahad 2014). Being a rich source of valuable nutrients and bioactive compounds nominated it to be used not only as food but also in therapeutic medicine and cosmetology (Uthpala *et al.* 2020). The provision of the nutritional needs due to the rise of the global population to 9.6 billion in 2050 necessitates a change in cultivation method (Wezel *et al*. 2014). In Iran, under-cultivation area of greenhouse products increased by 69% (from 3380 to 6630 hectares) between 2002 and 2007 (Mohammadi & Omid 2010), and this trend is still incremental in recent years. So, due to the high cost of greenhouse construction, greenhouse management should be along with the best exploitation of the investment (Momeni & Ghaffarinezhad 2010) such as employing high-performance varieties. Since crop rotation usually is not performed in greenhouse conditions, the yield of crop is exposed to a reduction in soil bed cultures during successive plantations due to the risk of soil diseases. This issue, besides imposing economic losses on producers, gives rise to the inappropriate use of chemical materials. One of the approaches to declining side effects of problems is to use the cultivars that exhibit maximum adaptability and resistance as well as the highlighted performance from the aspects of qualitative and quantitative traits (Solgi & Haghighi 2015). Accordingly, in addition to the growth conditions, the genetic characteristics of the cultivar are also effective to a large extent in the case of total yield and sale capability (Premalatha *et al*. 2006). Different growth patterns in leaf production of three cucumber cultivars during different measurement stages have been reported (Mashayekh & Musavizadeh 2009). Given the genetic difference of cucumber varieties, a less significant efficiency has been observed in yield quantitative traits except for internode length, so that a close correlation has been observed between fruit yield and internode numbers in the main shoot (Bisht *et al*. 2010). Still, the differences among cultivars are not limited to yield and growth. In a study on 16 commercial greenhouse cucumber cultivars, the differences in resistance rate and plant reaction to the Palampur tomato leaf curl virus have been denoted. The reactions of cultivars were not similar in terms of the number of infected plants and severity (Sabouri & Heydarnezhad 2013; Amraei 2022; Alima *et al.* 2023). Given the varying reactions of the patch cultivars, Nemati & Banihashemi (2015) reported a remarkable difference in determining the host domain and the sensitivity reaction of resistance. The resultant difference in determining the pathogenic strength is attributed to differences in the various strains and the reactions of the employed cultivars to the disease agent. Due to the unique production and yield potentials of cultivars under various ecological conditions, it is necessary to evaluate the adaptability of new cultivars with the cultivation conditions of the region. Furthermore, owing to non-identical yields in varied meteorological conditions, it is suggested to examine the growth behavior and yield performance during the introduction (Iken & Anusa 2004). The available greenhouse cucumber cultivars are almost imported and have been bred according to the conditions of origin countries. The imported seeds exhibit great diversity in quantitative and qualitative properties. Given the fact that genetic improvement is one of the key factors for achieving maximum yield, it is recommended to carry out the required experiments on the yield qualitative and quantitative traits to investigate the level of adaptability. The object of the study was to introduce highly adapted cultivars to greenhouse conditions in Iran with the pronounced commercial yield and to identify appropriate varieties to meet farmers' preferences, quality traits, good growth, and superior yield.

MATERIALS AND METHODS

Yield, quantitative and qualitative properties of 7 cucumber cultivars Viola, Mirsoltan, Mito, Emilie, CUB-9042, FC-21, CUB-9045 were evaluated in greenhouse conditions with a soil culture medium in Varamin, Central Iran. Viola and Mirsoltan cultivars were nominated as control cultivars to be compared with. The experiment was conducted in the format of a randomized complete block design with three replications (as cultivation row and 10 plants in each replication). The seeds of the experimented cultivars were cultivated in a transplant tray in late December and transferred to the main greenhouse in early January. The minimum and maximum temperatures of the greenhouse ambient were 18 ºC at night and 25ºC in the day. Two weeks after seedlings transference, the bushes were fastened by jute yarns to the wires positioned on cultivation lines. The distance between plants was 50 cm on the rows and 45 cm between the rows. Plants were pruned by the removal of lateral branches and trained following the single vertical branch along the yarns that were fastened to the 2-meter wires parallel with cultivation rows. Fertilizer treatments were applied according to the soil test in the form of fertigation involving NPK in different formulas regarding growth phase supplied by Zigler brand (20-20-20, 15-5-30, 12-12-36 and 10-52-10, 4 kg/1000 m^2) as weekly application; Humic acid in liquid form, Grow More brand, 2.5 L/1000 m^2; foliar Ca spraying as weekly routine; Micronutrients- Boron and Ca Supplied from Germany with the dosage of 200 mL/100 Lit) were also supplied to the plants through weekly foliar spaying. The irrigation and fertilization conditions were similar in all treatments. Plants were irrigated every other day. The main properties of experimental cultivars are shown in Table 1. During the vegetative and reproductive growth, the crop properties such as the internode distance, number of flowers and fruits per node, stiffness of the fruit tissue, and yield were recorded. For yield measurement, the single-plant product of each cultivar was taken in the experimental replication and weighed by digital scale. After average estimation, the yield of each cultivar/replication per area unit was calculated. The stiffness of fruit texture was measured by the FT011 stiffness measurement system. To determine the difference among variables, multivariate variance analysis via Wilk's Lambda was estimated. Recursive fitting was performed on the linear multivariate regression/ the linear multivariate regression underwent recursive fitting and the significant variables effective in describing yield in a linear model were selected. To categorize the experimental cultivars and examine their conditions in relation to control varieties. Analyzing with principal components was performed using the correlation coefficient matrix. Also, to categorize the hybrids under examination, cluster analysis was performed based on the mean standardized data by applying the Ward method and the distances were calculated considering the evaluated traits using the SPSS software. The resulting groups were displayed in tree diagrams. All statistical analyses were conducted by the SAS statistical software version 9.2. The mean of traits was compared by the LSD test. The diagrams were drawn by SPSS software version 2.

RESULTS AND DISCUSSION

1. Univariate tests

1.1. Results of analysis of variance and mean comparison of experimented traits

The results showed significant differences among cultivars-related yield, the number of fruit per node, stiffness of fruit tissue, and internode distance traits. The experimented cultivars, except for fruit tissue stiffness, reflected a significant difference at 0.01 and 0.05 probability levels in fruit tissue stiffness trait (Tables 1-2). The mean comparison categorized cultivars into separated groups. The number of lateral branches in all cultivars exceeded one. In all varieties and genotypes, lateral branches were exceeded a single so extra branches were pruned. All cultivars exhibited a proper similar condition in terms of placement of plants after seedlings transfer to the mainland. There were significant differences among cultivars in their internode distances. The minimum internode distance, ranging from 4.30 to 7.66, was associated with CUB-9045, FC-21, CUB-9042, Emilie, and Mito, respectively. FC-043 and Mirsoltan, with average distances of 7.66 and 7.38 cm displayed the maximum internode distances and statistically fell into the group *a*. The experimented cultivars were significantly different in the number of flowers per node, in a way that the smallest and largest numbers were in categories respectively. The highest fruit number per node was related to the FC-043 cultivar, with an average of 4.03. It was statistically different from CUB-9042 and Voila, with averages of 3.6 and 3.7.

Table 1. Characteristic of applied varieties in experiment.

Cultivar	Amount of flowers	Measurements	Fruit/bush type	Resistance to disease	Growing Season	Advantages
Viola	Flowery	Fruit between 16 and 18 cm long	Cylindrical and stripped fruit	Against powdery mildew, CVYV and ZYMV viruses	Spring	Not known
Mirsoltan	Flowery	Short-distance internodes, short and low-fertile lateral branches	Strong bush, small leaf canopy	Against the SCAB disease and CMV virus	Spring	High yield , marketability
Mito	One or two flowers per node	Average creeping	Strong bush, abundant lateral branches, high leaf canopy	-	Spring	Not known
Emilie	Average; number of flowers according to the light lux	16-18 cm fruit	Well-adjusted bushes, grooved fruit	Against the ZYMV and CVYV viruses	Spring	Self-regulating
CUB-9042	Flowery	Fruit between 12 and 14cm long	Bushes have High recovery power	Against powdery mildew	Spring	Highest marketability, low water consumption
FC-21	Single-flower	Fruit between 14 and 17 cm long	Cylindrical and grooved fruits, strong root system, high	Against CCU and CMV.	Spring	Not known

			vegetative growth and leaf canopy			
CUB-9045	Flowery	Fruit between 18 and 20 cm long	Dark green slender fruits and self-pruning bush	Against the CVYV virus and powdery mildew	Spring	Not known

Table 2. Variance analysis for mean of experimented traits of different cultivars of greenhouse cucumber

Variation sources	Degree of freedom	Number of flowers per node	Number of fruits per node	Stiffness of fruit tissue	Internode	Yield
Genotype	8	3.98**	395.03**	0.21*	5.5**	52772**
Replication	2	0.02	2.37	0.08	0.07	55509
Experimental error	16	0.06	6.66	0.05	0.02	80192
C.V.	-	8.1	8.4	6.31	2.82	1.77

Note: * and ** indicate probability levels of <0.05 and <0.01, respectively.

The fruit yield revealed that FC-361 and Mito, with averages of 75341 and 65763.33 kg ha^{-1} had the maximum yield in a single cultivation period compared to the control cultivars of Viola and Mirsoltan with an average of 43172 and 42849 kg ha^{-1} respectively (Table 3). Regarding the stiffness of fruit texture, CUB-9042 with an average of 4.1 exhibited the highest rate of fruit tissue stiffness. It was significantly different from Mito, CUB-9045, and FC-21 and thus fell into a separated statistical category (Table 3).

Table 3. Comparing means of traits in greenhouse cucumber cultivars experimented by LSD. Cultivars with similar letters are not significantly different at the 0.05 probability level.

Cultivar	Yield	Internode distance	Fruit tissue stiffness	Number of flowers per node	Number of fruits per node
Mito	65763.33	4.42 cd	3.94 ab	2.53 d	3.47 b
CUB- 9045	40805 f	4.30 d	3.94 ab	1.96 e	2.18 d
CUB- 9042	39481 fg	4.36 cd	4.10 a	3.7 c	3.24 bc
Emilie	38427 g	4.38 cd	3.23 d	1.1 d	1.2 e
FC- 21	48048 d	4.33 cd	3.77 abc	2.7 d	3 c
FC-043	59331 c	7.66 a	3.69 bc	4.53 a	4.06 a
FC-361	75341 a	4.6 c	3.48 c	2.8 d	3.42 b
Mirsoltan	43172 e	5.37 b	3.81 abc	4.3 ab	3.7 ab
Viola	42849 e	7.38 a	3.06 bcd	3.96 bc	3.6 abc

Results of multivariate analysis of variance

The results of multivariate analysis of variance of four quantitative traits, including internode distance, number of flowers per node, number of fruits per node, and yield by Wilk's Lambda presented that there were considerable differences among the evaluated cultivars. Thus, minimally one cultivar was statistically different from other experimented cultivars within the multivariate analysis of variance ($p < 0.05$).

1.1 Multivariate regression

The relationship of dependent variable y_i with independent variables, including internode distance, number of flowers, and fruits per node was fit with the linear multivariate regression and could significantly justify the yield variations at the $p < 0.05$ level. The backward method was employed for the removal of non-significant variables.

The internode distance variable was eliminated from the model. Other variables, involving the number of flowers and fruits per node, were remained in the model. The linear formula below was determined for the regression model variables of the aforementioned traits.

$$Y_i = 184184 - 1872.92\, NOFL\, (Number\ of\ Flowers\ per\ Plant$$
$$+ 28825\, NOFP (Number\ of\ Fruits\ per\ Plant)$$

The regression model revealed that the number of fruits per node trait had the maximum positive effect on yield ($p < 0.05$). The regression coefficient for the number of flowers per node was negative. Determining the correlations among different traits enables the breeder to opt for the most appropriate ratio among the components with the potential of higher yield.

2. Analysis into the principal components

The trait correlation matrix was employed and the experimental data relevant to four quantitative traits was analyzed into the principal components. The results showed that the first two main components justified about 90% of the differences among the cultivars. The traits coefficients were determined as per below:

PC1(Principal Component) = 0.49IND + 0.59NOF + 0.6 NOFP + 0.23Yi

PC2 = - 0.36IND - 0.24NOF + 0.18 NOFP + 0.88Yi

Concerning the PC1 component, the coefficients of studied traits were positive. The largest trait coefficient was associated with NOFP; however, the Y_i coefficient in the first component was smaller than other traits coefficients. Cultivars with higher coefficients in their first main component had higher NOFP even with less contribution to the yield trait. In the second main component, the yield coefficient was large and positive (0.88). Straightforwardly, the cultivars with higher PC2s had higher yields in contrast to their negative IND and NOF[2] coefficients. The distribution graph of cultivars illustrates that FC-361 with high PC2 values had maximum Y_i and NOFP[3] values and could be placed in first quarter. Mito (No. 1) is also in the first quarter; however, with a smaller PC2 value (Fig. 1). Control varieties were placed in the second quarter far from FC-361. This cultivar had the highest positive value in the main component. Regarding the positive coefficient of Y_i in the first component, it owned a high yield value. Results showed that due to having the highest effects in the regression model, first main component, and the positive effect on the PC2 equation, the number of fruits per node had an incremental influence on yield. In contrast, the number of flowers per node decreased both in the regression model and the second main component.

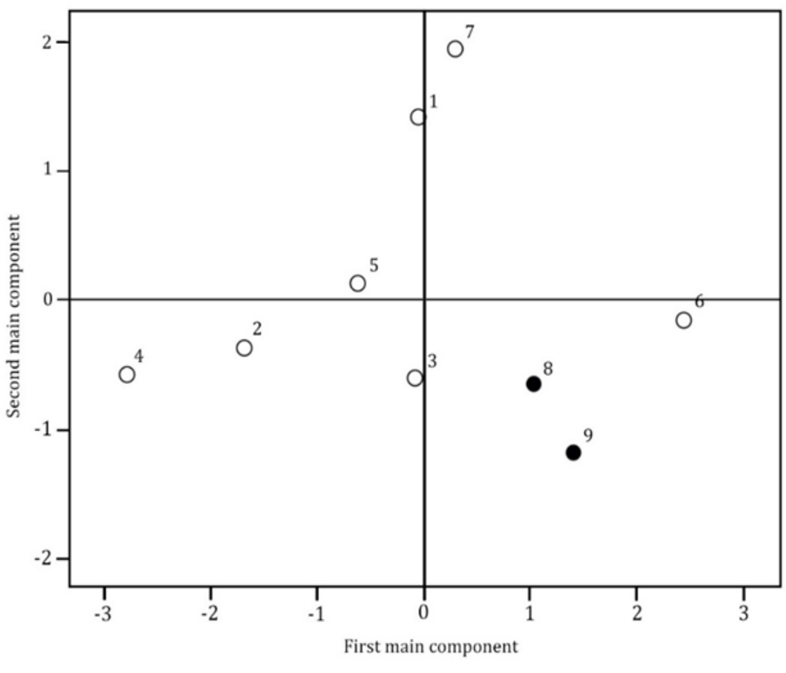

Fig. 1. Distribution graph of cultivars according to the first and second main components.

3. Cluster Analysis

The tree diagram based on experimented traits was drawn using cluster analysis following the Ward method (Fig. 2). Cultivars were categorized into four groups. In the diagram, the first clade comprised Mito and FC-361 cultivars, which had higher yields compared to others. These cultivars of cucumber were in the positive quarter of X and Y axes in the graph of the principal component when being analyzed into factors. FC-043 was the only cultivar that was co-grouped with Voila in terms of Euclidean distance. However, compared to the control cultivar, it exhibited a considerable higher advantage in the first two components of principal component analysis, regarding higher and positive coefficients in the number of fruits per node and yield traits (Fig. 1).

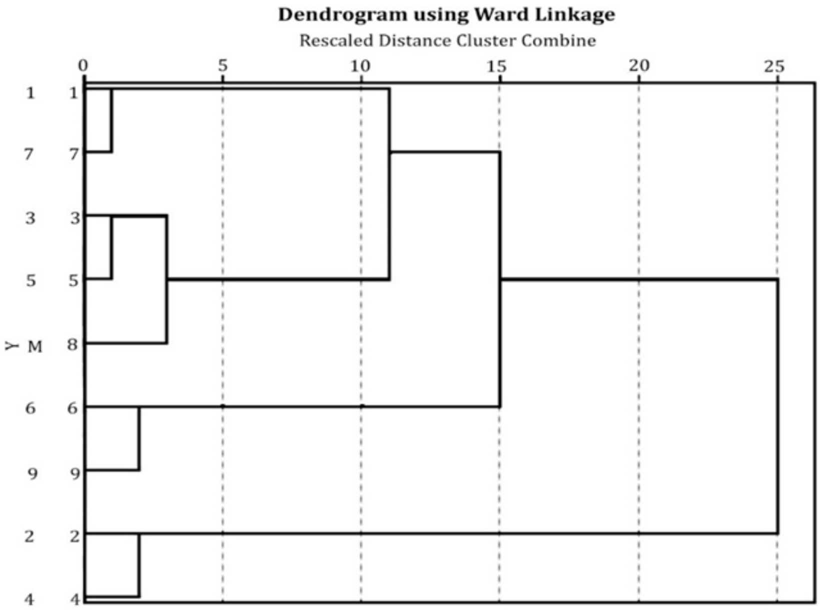

Fig. 2. Tree diagram of experimented cultivars of greenhouse cucumber, using Ward method.

The results of univariate, multivariate, and cluster analyses manifested that FC-361, Mito, and FC-403 cultivars exhibited superiority over other cultivars by having higher yields, yield homogeneity, and the number of fruits per node, besides the suitable color and outward shape of fruits. Analysis of the principal components revealed that the FC-043 cultivar had the largest coefficient in the second main component exhibiting a high competency due to the larger number of fruits per node and subsequently a larger number of fruits in each harvest.

The results reflected that cultivars were significantly different in the number of fruits. FC-043 cultivar yielded the highest number of fruit per node (Table 2). The result confirmed the finding of Ahmed *et al*. (2004) who reported the differences among cultivars in their number of fruits. They also reported differences in vegetative growth, number of days till fructification, fruit size, and yield while investigating 6 cultivars. Furthermore, the pot culture of 14 cucumber cultivars showed considerably different yields (Crane *et al*. 2018). Similarly, an investigation on cucumber cultivars showed that cultivars were different in stem diameter, number, length, diameter of fruits, and total yield (Soleimani *et al*. 2009). In examining the effect of pot and soil culture media on 4 cucumber cultivars, Solgi and Haghighi (2015) observed growth differences in plant length, number, size of leaves, number of flowers, and yield. Likewise, the investigation of morphological traits of 4 cucumber cultivars displayed that the cultivars were different in plant height, the number of leaves, and leaf area index (Adinde *et al*. 2016). It has been reported that yield and number, size and weight of fruit were intensely influenced by genes (Ullah *et al*. 2012). Despite the differences in leaf area, dry weight of the plant, morphology, and fruit weight in three cultivated cultivars, no difference was observed in the total yield of investigated cultivars (Mashayekhi & Mousavizadeh 2009). Different growth and yield traits of cucumber cultivars, except for the number of days required to the first harvest and fruit diameter strongly depend on cultivar and there was a high morphological diversity given the emergence of the first node, the first production of the female flower, number of fruits, single-plant yield and plant height (Kanwar & Rana 2006). The climatic condition impacts the appearance of genetic traits in cucumbers (Sharma & Sengupta 2013). The number of fruits is generally considered as the main indicator of yield (Adindeh *et al*. 2016); therefore, the FC-043 cultivar was superior to others regarding this trait (Table 2). In cucumbers, the rate of yield is demonstrated by the fruit number or total weight of fruits in the plant. According to the experiments, the fruit number of the plant was a more stable trait than the total weight of all developed fruits of the plant (Wehner *et al*. 1989). Voila had the next position in terms of fruit number. This trait and the shorter internode distance were good production traits; however, this cultivar showed a sharp decline in yield compared to FC-043 (Table 2). As Table 2 illustrated, the internode distance was heavily influenced by cultivar. During genetics and phenotypic studies on 24 different cucumber cultivars, a significant diversity was found considering yield, fruit tissue stiffness, and fruit number (Pushpalatha *et al*. 2016). The growth and yield differences can be attributed to genetic differences of cultivars and their parents (Ahmadikhah *et al*. 2008). In this respect, in addition to the yield, traits including growth characteristics such as plant height, runner stem, leaf area, and the number of lateral branches are influenced by genetic factors of the cultivar. The yield differences in cucumber cultivars are associated with the interactions between genetic traits and environmental conditions (Ojejifo *et al*. 2008). The diversity in the phenotype and yield of the studied cultivars may rise from their genotypic variation, which is useful in selecting the suitable cultivar for a culturing region. So, genetic diversity can play a significant role in the better selection and adopting the management programs for increasing crop yield (Ndukauba *et al*. 2015).

CONCLUSION

The results of this study showed that the number of fruits per node had a great effect on the produced yield. Although different cultivars were performed in separate ways still the high-yields were more highlighted in FC-361, Mito, and FC-043 cultivars which place them in the category of high-yield produced ones. The supremacy of cultivars was evaluated by univariate and multivariate statistical methods, as well as cluster analysis. It was found that the number of fruits per node and total yield were the main determinant traits to select the most favored cultivars. Although the internode distance was posed as an effective component with a negative effect on yield, the variations among the under-investigation cultivars in this trait were not sufficiently capable of determining the ascendency of cultivars. Among the examined cultivars, the FC-043 was being outranked in the aforementioned two determinant traits so can be introduced as the superior cultivar in the research. Regarding high labor cost, energy, agricultural resources mountain the final cost of the product, so to compensate the cost and make the production process more economic, it is wise to increase the production of crop by selecting the most appropriate variety. According to the obtained results, the production potential of the new imported varieties adjusted for greenhouse should be probed so that productive and qualified varieties can be introduced to greenhouse owners as a recommendation to save up cost and produce more units of crop yield in each square meter.

Conflict of interest

The authors have no conflict of interest.

Author's contributions

Hossein Tajik Khademi and Mohsen Khodadadi designed the study. Davoud Hassan Panah and Ramin Hajainfar contributed to collecting the data. Raheleh Ebrahimi wrote the manuscript. All authors read and approved the manuscript.

Ethical approval

The Ethical Committee of Islamic Azad University approved the study.

Consent to participate

Not applicable.

Consent for publication

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