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THE VARIATION OF CUCUMBER QUALITY DEPENDING ON THE HYBRID AND THE FRUIT HARVESTING INTERVAL

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Abstract

The study evaluated the quality of cucumber production in relation to the hybrids and harvest interval. Five gynoecious cucumber hybrids were cultivated: Madrilène F1 (Seminis), Cantara F1, Kibria F1, Majestosa RZ F1 and Trilogy RZ F1 (Rjik Zwaan). An adequate watering and fertilization regime was ensured. Cucumbers were harvested daily, over a period of 67 days. The highest production of cucumbers was registered with the hybrid Madrilene F1 (Mad), 1034 kg/100 m^2, and the lowest production with the hybrid Trilogy RZ F1 (Tri), 778 kg/100 m^2 in Q1 quality classes (8-12 cm long). The Trilogy RZ F1 (Tri) hybrid had the best share of production in quality class Q1 (97.30%) among all the hybrids under the study conditions (97.10% for Cantara F1 hybrid in Q1; 96.95% for Kibria hybrid in Q1; 96.07% for Majestosa RZ F1 hybrid in Q1, and respectively 91.39% for Madrilene F1 hybrid in Q1). PC1 explained 83.538% of variance, and PC2 explained 7.4489% of variance for the quality class Q1. PC1 explained 59.126% of variance and PC2 explained 19.194% of variance for the quality class Q2.

Key words: *cluster analysis; cucumbers; harvest interval; PCA; quality classes.*

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an annual, herbaceous, fruit-bearing, climbing leguminous plant of the Cucurbitaceae family, originating in Asia, the Southern, tropical areas of the Himalayan Mountains (Qi et al., 2013; Pal et al., 2020).

Cucumber is important for nutrition and health, through the intake of fibers, proteins, carbohydrates, minerals (e.g. calcium, copper, iron, magnesium, manganese, potassium, sodium, zinc) and vitamins (e.g. A, C, K) (Niyi et al., 2019; Mallick, 2022).

Cucumber is grown on a large scale, most often in protected spaces (greenhouses, solariums), as an off-season vegetable, with high yields and economic benefits (Liu et al., 2021; Sallam et al., 2021).

The production potential and the quality of cultivated cucumber genotypes are of interest in breeding programs, and the main objectives are the commercial quality of the fruits, the nutritional quality, and the quality of the fruit aroma (Zhang et al., 2021). The determining factors for the quality of cucumber fruits are considered genetic factors and cultivation factors (technological factors) (Zhang et al., 2021), and a harmonious balance between the two factors categories leads to quality fruits.

Within the cucumber cultivation technologies, various aspects were studied in order to increase the yields, the quality of the production, the optimization of the technologies, in relation to the cultivated genotypes and the growing systems (Dinu et al., 2007; Petre et al., 2016; Biczak et al., 2020; Sallam et al., 2021; Vaudo et al., 2022).

The influence of plant density in relation to the photosynthetic processes of plants, shoot parameters, elements of productivity, production and quality of cucumber production was studied (Ding et la., 2022).

Optimizing the watering regime for cucumbers has been addressed in various studies, for increasing fruit production and increasing water productivity, quantified based on specific parameters and indices (irrigation water productivity, irrigation efficiency, economic productivity, etc.) (Liu et al., 2021).

The influence of some categories of organic fertilizers was evaluated in relation to cucumber productivity, but also to certain chemical properties of the soil in the post-harvest period (Law-Ogbomo and Osaigbovo, 2018). The authors recorded increases in cucumber production and positive changes in some chemical properties of the soil, and in accordance with the cost / benefit ratio, they identified a certain dose of fertilizers, among those tested, as appropriate for the study conditions.

Favorable results of organic fertilizers for cucumbers were quantified based on parameters and physiological indices in plants, simultaneously with the evaluation of the availability and release rate of nutrients from organic fertilizers (Li and Mattson, 2019).

The relationship of some cucumber genotypes (Sultan, Zain) was studied in relation to different fertilizing resources in order to evaluate how the biological material capitalized on the nutritional elements (Al-Bayati, 2020). Based on some physiological parameters and indexes (plant height, number of leaves, leaf surface relative to the plant), and fruit quality parameters (number of fruits on the plant, length of the fruits), the author recorded a different response of the two studied hybrids.

For high yields, different fertilizing substances, organic and mineral, were tested for cucumbers, and based on productivity growth parameters, yield increases were recorded in relation to the fertilized variants of up to 74.6% (Sallam et al., 2021).

The favorable influence of vermicompost, applied in different quantities, was recorded on the basis of physiological indices and plant productivity in cucumbers (Jankauskienė et al., 2022). Some studies have evaluated the performance of cucumber culture in relation to organic and mineral fertilization in growing systems on artificial media, without soil (Adekiya et al., 2022). The authors used growing substrates without soil (coco peat, and rice husk), and provided nutrients through organic and mineral fertilizers (organic fertilizer based on *Tithonia diversifolia*; inorganic fertilizers, as hydroponics fertilizer), they registered considerable increases in production (137%, 198%), and determined the optimal doses for the two categories of fertilizing agents under the study conditions.

The response of cucumber crops to different biostimulant products was analyzed based on physiological indices, growth parameters, starting from seed germination, plant growth, fruiting, production and fruit quality indices (Baratova et al., 2021). The effect of water stress was studied in cucumbers and the possibility of mitigating this water stress through the use of organic and mineral fertilizers (El-Mageed and Semida, 2015).

Some studies evaluated the productivity of cucumbers in relation to different companion crops (Chang et al., 2017), and the authors quantified the influence of this growing system on some attributes of soil quality, microbial activity and the presence of pathogens, associated with the productivity of cucumber plants.

This study evaluated the production of five varieties of cucumbers, in dynamics during the harvest period and by quality classes, in protected culture conditions, modular type solar.

MATERIALS AND METHODS

The study evaluated the production of cucumbers in dynamics, by quality classes under protected culture conditions. The experiment took place in Olari locality, Arad County, Romania.

Five hybrids of cucumbers were cultivated, gynoic hybrids (with female flowers): Madrilène F1 (Seminis), Cantara F1, Kibria F1, Majestosa RZ F1, and Trilogy RZ F1 (Rjik Zwaan). Cucumbers were grown in protected space conditions, modular solar type, with a density of two plants/m^2 (Figure 1).

Watering was provided with an adequate amount of water, in the range of 1-2 L water/plant. Nutrient elements were provided by fertigation, with different fertilizing resources (potassium nitrate, calcium nitrate, magnesium nitrate, urea, complex 27:13.5:0, Ferticare I, II, III).

Harvesting was done daily, between September 16 and November 21, 2020, for a period of 67 days. Cucumber production (kg/100 m^2) was classified by quality categories Q1 (cucumbers 8-12 cm long) and Q2 (cucumbers larger than 12 cm long).

a b c

Figure 1. Aspects from the study period, cucumber culture in protected space; a - aspect after planting cucumber seedlings; b - general aspect from the protected space; c - flowering - fruiting period

In the study, the daily values of cucumber production were grouped by cucumber harvest interval (Chi) of 5 days and recalculated, by hybrids and quality classes.

For reasons of calculation, interpretation of results and graphic representation in the study, certain abbrevi-ations were made and used for the varieties of cucumbers used, the quality classes and the harvesting interval of cucumbers (Table 1).

The ANOVA test, PCA analysis, cluster analysis were used for the statistical analysis and processing of the results. Appropriate statistical parameters were used to confirm the safety of the data (standard error, p, F test, coefficient of variation, cophenetic coefficient). The PAST software (Hammer et al., 2001) and the calculation module from EXCEL were used for the processing and analysis of the experimental data.

Table 1. Abbreviation of terms used in the article

Hybrids		Quality classes		Hybrid and quality class combination		Cucumber harvesting intervals (Chi)
Hybrid name	Abbreviation	STAS (cucumbers 8 - 12 cm long)	Under STAS (cucumbers larger than 12 cm)			
Cantara F1	Can	Q1	Q2	Can Q1	Can Q2	Chi 1 to Chi 13 for each hybrid and quality class
Kibria	Kib			Kib Q1	Kib Q2	
Madrilene F1	Mad			Mad Q1	Mad Q2	
Majestosa RZ F1	Maj			Maj Q1	Maj Q2	
Trilogy RZ F1	Tri			Tri Q1	Tri Q2	

RESULTS AND DISCUSSIONS

Cucumbers were harvested daily, starting on September 16, until November 21, 2020, for a period of 67 days. Harvested cucumbers were evaluated in relation to dimensional parameters and were grouped into two quality classes: Q1 (fruits 8-12 cm long) and Q2 (fruits larger than 12 cm long) for each variety.

The recorded daily values were grouped by intervals of 5 days and recalculated, in relation to the hybrids studied and the quality classes, and the obtained values are presented in Table 2. The ANOVA test confirmed the statistical reliability of the recorded data series, for each hybrid and harvest interval, as well as the presence of variance in the data set ($F>F_{crit}$, $p<0.001$; $Alpha=0.001$) (Table 3).

Starting from the cucumber production recorded during the study period (67 days), the total production was calculated for each hybrid, and the production for the two quality classes (Q1, Q2), in absolute values and in percentages (Table 4).

Table 2. Cucumber production on hybrids, quality categories and harvest interval

Trial	Kib Q1	Kib Q2	Mad Q1	Mad Q2	Maj Q1	Maj Q2	Tri Q1	Tri Q2	Can Q1	Can Q2
	(kg / 100 m²)									
Chi 1	42	1	33	2	43	4	33	0	29	1
Chi 2	44	2	39	6	49	5	36	1	34	1
Chi 3	74	3	90	5	92	3	56	2	59	3
Chi 4	65	2	73	3	100	2	76	2	74	2
Chi 5	30	3	43	5	30	0	28	3	34	0
Chi 6	71	3	78	5	74	0	65	0	53	0
Chi 7	67	0	71	6	49	1	46	4	42	0
Chi 8	95	5	119	20	94	12	87	3	94	6
Chi 9	74	1	63	3	53	0	52	0	75	2
Chi 10	60	1	90	14	45	3	47	2	69	2
Chi 11	73	1	74	9	73	2	73	1	80	3
Chi 12	68	2	72	5	64	2	73	2	61	2
Chi 13	94	3	100	6	89	1	85	1	66	1
SE	±5.20	±0.36	±6.79	±1.38	±6.34	±0.88	±5.49	±0.35	±5.53	±0.45

Table 3. ANOVA test, single factor

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	124440.7	9	13826.74	59.93953	3.26E-40	3.379237
Within Groups	27681.38	120	230.6782			
Total	152122.1	129				

Alpha = 0.001

Table 4. Distribution of cucumber production by hybrids and quality classes

Cucumber hybrid	Total production	Production by quality classes			
		Quality class Q1		Quality class Q2	
	(kg/100 m²)	(kg/100 m²)	(%)	(kg/100 m²)	(%)
Kib	884	857	96.95	27	3.05
Mad	1034	945	91.39	89	8.61
Maj	890	855	96.07	35	3.93
Tri	778	757	97.30	21	2.70
Can	793	770	97.10	23	1.90

From the analysis of the obtained data, it was found that the highest production of cucumbers was registered with the hybrid Madrilene F1 (Mad), of 1034 kg/100 m^2, and the lowest production with the hybrid Trilogy RZ F1 (Tri), of 778 kg/100 m^2. From the point of view of placing the fruits in the two quality classes (Q1, Q2), the same positions were kept for the production in Q1, absolute values, respectively the hybrid Madrilene F1 (Mad) with the production of 945 kg/100 m^2 and the hybrid Trilogy RZ F1 (Tri) with the production of 757 kg/100 m^2. As for the weight of the production registered by quality class (expressed in %) of the total production, it was found that the hybrid Trilogy RZ F1 (Tri) had the best weight, of 97.30% in the Q1 quality class, among all the hybrids in study conditions (97.10% for the Cantara F1 hybrid in Q1; 96.95% for the Kibria hybrid in Q1; 96.07% for the Majestosa RZ F1 hybrid in Q1, and respectively 91.39% for the Madrilene F1 hybrid in Q1).

The estimation of the cucumbers production variability, classified according to the registered quality classes, depending on the cucumber harvesting interval (Chi 1 to Chi 13), was made on the basis of the coefficient of variation (CV). For production in the Q1 quality class, high variability was found in the hybrid Majestosa RZ F1, CV_{Maj}= 34.7671, followed by the hybrid Trilogy RZ F1 CV_{Tri}= 34.0092. The lowest value of variability was recorded for the Kibria hybrid, CV_{Kib} = 28.4630, within which the best level was found in terms of the uniformity of cucumbers in the quality class Q1, and the harvest times.

Based on PCA, correlation, the distribution diagrams of cucumber production, in relation to the harvest interval (Chi 1 to Chi 13), and in relation to the studied hybrids (as biplot) were obtained. For the Q1 quality class (Figure 2), the independent positioning of the intervals Chi 1, Chi 2, Chi 5, Chi 7 was found. An intermediate position was observed at Chi 9 and Chi 10. The other harvesting intervals were positioned associated with the genotypes studied. PC1 explained 83.538% of variance, and PC2 explained 7.4489% of variance.

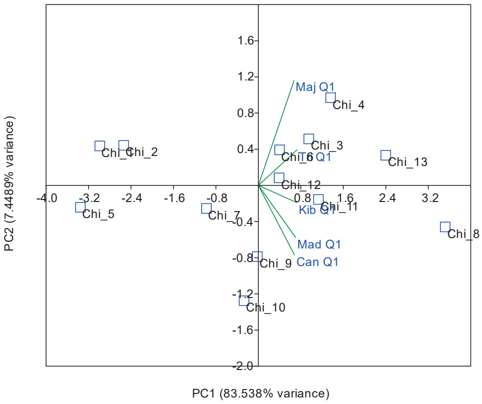

Figure 2. PCA diagram for harvest periods (Chi) for cucumbers and studied hybrids, quality class Q1

For the quality class Q2 (Figure 3), most of the harvest periods were positioned independently, with the exception of Chi 3, Chi 8 and Chi 10; intermediate position were Chi 2 and Chi 11. PC1 explained 59.126% of variance, and PC2 explained 19.194% of variance.

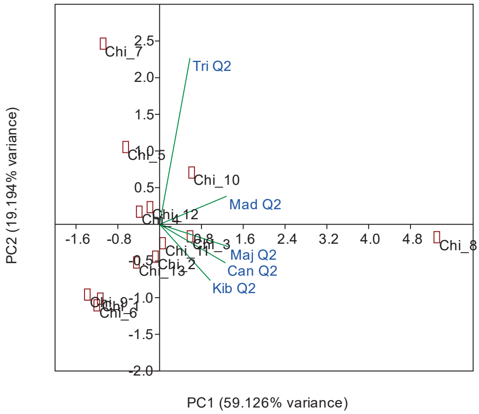

Figure 3. PCA diagram for harvest periods (Chi) for cucumbers and studied hybrids, quality class Q2

The cluster analysis led to the grouping of the variants in relation to the cucumber production per harvest interval and the studied genotypes. In relation to the quality class Q1 (Figure 4), the grouping of the variants based on similarity for the production of cucumbers (intervals Chi 1 to Chi 13), respectively of the studied hybrid, was found, in conditions of statistical safety (Coph.corr = 0.774). A high level of similarity was recorded for the Cantara F1 (Can Q1) and Trilogy RZ F1 (Tri Q1) hybrids.

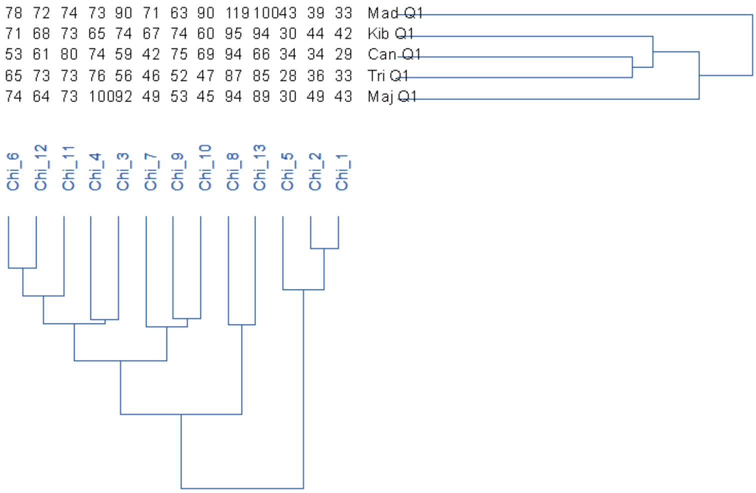

Figure 4. Cluster grouping (two ways) in relation to the production of cucumbers in class Q1

The Madrilene F1 hybrid with the highest values in Chi 8 (110 kg/100 m^2), and Chi 13 (100 kg/100 m^2) was placed in independent position.
Regarding the production of cucumbers by harvesting intervals, a high level of similarity was found for Chi 1 and Chi 2 (low production in Q1, being the first harvests), and Chi 6 and Chi 12, with an average level of the production of harvested cucumbers in Q1. Chi 8 and Chi 13 were associated with the highest production of cucumbers in Q1 (119, respectively 100 kg/100 m^2).

Within the quality class Q2 (Figure 5), the grouping on the basis of similarity of the variants for the production of cucumbers (intervals Chi 1 to Chi 13), respectively of the studied hybrids, was found, in conditions of statistical safety (Coph.corr = 0.949).
A high level of similarity was recorded for the hybrids Kibria (Kib Q2) and Cantara F1 (Can Q2). The Madrilene F1 hybrid was placed in independent position with the highest values in Chi 10 (14 kg/100 m^2) and Chi 8 (20 kg 100 m^2).

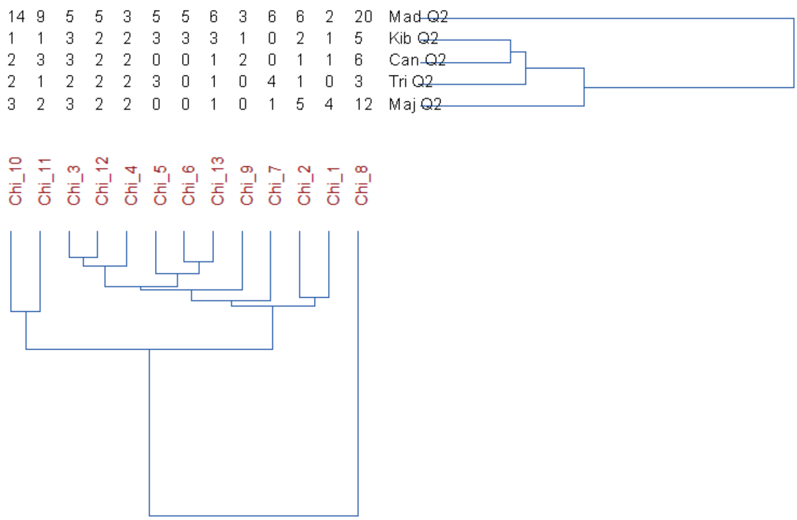

Figure 5. Cluster grouping (two ways) in relation to the production of cucumbers in class Q2

Regarding the production of cucumbers by harvesting intervals, a high level of similarity was found for Chi 3 and Chi 12 (average production of cucumbers harvested in Q2) and Chi 6 and Chi 13, with low production of cucumbers harvested in Q2. Chi 8 was positioned with the highest production (3-20 kg/100 m^2, in relation to the cucumber hybrid).
The five gynoic hybrids of cultivated cucumbers responded differently to the cultivation conditions and the applied technology, response quantified based on the production of cucumbers during the harvest period, and its quality.
The highest total production was recorded for the hybrid Madrilene F1 (Mad), 1034 kg/100 m^2, followed by the hybrid Majestosa RZ F1 (Maj) with a production of 890 kg/100 m^2, and the hybrid Kibria, with a production of 884 kg/100 m^2.
Regarding the production of quality I (Q1), the order of hybrids is maintained, the Madrilene F1 hybrid took first place with a Q1 quality production of 945 kg/100 m^2, followed by the Kibria and Majestosa RZ F1 hybrids with productions of 857 kg/100 m^2, and 855 kg/100 m^2, respectively. In terms of the percentage weight of quality I production from the total production, a high weight was recorded in the hybrids Trilogy RZ F1 (97.30%) and Cantara F1 (97.10%), and the lowest weight was recorded in the case of the hybrid Madrilene F1 (91.39 %).

The differentiated response of two cucumber hybrids to organic fertilization was evaluated in conditions of protected spaces (Al-Bayati,

2020), and the author recorded the differentiated way in which the two tested hybrids capitalized on the nutritional conditions, based on some physiological indices, productivity parameters (number of fruits per plant, yield per plant) and early fruit harvesting, in relation to the nutritional options provided.

The yield variation in cucumbers was analyzed associated with treatments with different biostimulators (Baratova et al., 2021), and the authors reported differential increases in yields (10.28% to 24.27%; 0.9 to 2.7 t/ha) in relation to the applied biostimulator, which shows the receptivity, the capitalization capacity and the differentiated specificity of the plants in relation to the genotype to the elements of technology used.

The increase in cucumber yields was recorded in relation to the addition of organic fertilizers (poultry litter) and minerals (NPK) to the plant growth substrate (Sallam et al., 2021). Through multivariate analyses, the authors of the study identified the experimental variant (combination of substrate, organic and mineral fertilizer) which generated high yield in statistically safe conditions and which can be recommended for similar conditions of study and cultivation of cucumbers.

The quality of plant seedlings and the yield of the cucumber culture were analyzed in relation to different culture substrates, represented by peat with the addition of vermicompost in different percentages (Jankauskienė et al., 2022). The authors of the study communicated the positive effect of vermicompost in relation to the weight of its presence in the substrate, positive effects recorded on the basis of plant height, leaf surface mass of fresh leaves and mass of roots. Associated with these positive effects at the plant level, the yield of cucumbers was 7.4% to 11.1% higher compared to plants grown on peat substrate.

The variation of production residuals and the economic increase in the cucumber culture was analyzed in relation to the irrigation treatments (Liu et al., 2021), and the authors detected the irrigation variants with favorable effects and economic profitability for the study conditions.

Some studies have analyzed the possibility of valorizing organic waste from greenhouse horticultural crops (cucumbers, tomatoes, peppers) in obtaining fodder for animals (Özbilgin and Ince, 2019), and the authors of the study have communicated notable results in this direction.

Such complementary directions for the valorization of organic waste from such horticultural crops can contribute to increasing the degree of valorization of the biological production of these crops, the yields of protected spaces (greenhouses, solariums), but also the energy yields, in the current context of the energy crisis.

The results obtained in the present study highlighted the behavior of the hybrids tested in the study conditions, their differentiated ability to capitalize on the conditions provided by the culture technology.

The variation of production over the harvest interval, and the distribution of production by quality classes calculated over harvest periods, the PCA and CA analysis facilitated the distribution and the clear highlighting of the differences between the analyzed categories, useful aspects in planning the valorization of cucumber production, and adjusting the harvest interval for the foreheads to be included in quality class I (Q1).

CONCLUSIONS

The five gynoic cucumber hybrids studied (Madrilène F1, Cantara F1, Kibria F1, Majestosa RZ F1, Trilogy RZ F1), have differentiated the vegetation conditions ensured by the culture technology, in protected conditions, modular type solar.

During the fruit harvesting period, over an interval of 67 days (September 16 - November 21, 2020), differentiated values of total production and production by quality classes were recorded (Q1, cucumbers of 8-12 cm length; Q2 , cucumbers larger than 12 cm long).

The hybrid Madrilene F1 (Mad) achieved the highest production of cucumbers, 1034 kg/100 m^2, and the lowest production was recorded in the hybrid Trilogy RZ F1 (Tri), 778 kg/100 m^2 in the quality class Q1 (8 -12 cm long).

The Trilogy RZ F1 (Tri) hybrid had the best share of production in the Q1 quality class (97.30%) among all the hybrids grown under the study conditions, followed by the Cantara F1 hybrid (97.10%).

The differentiation of the studied hybrids, in relation to the total production, the production by quality classes (Q1, Q2) and the production per harvest interval of cucumbers (Chi) was made by the multicriteria analysis and confirmed on the basis of the main components (PC1, PC2) and by the analysis clustering.

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