DOI: 10.22620/agrisci.2017.22.011

MATHEMATICAL APPROACHES FOR IMPACT EVALUATION OF THE IRRIGATION REGIME AND FERTILIZATION ON THE GREENHOUSE TOMATO QUALITY

Velika Kuneva[1], Antoniya Stoyanova[2], Nikolay Valchev[2], Galina Pevicharova[3]

[1]Agricultural University – Plovdiv, Bulgaria
[2]Faculty of Agriculture, Trakya University – Stara Zagora, Bulgaria
[3]*Maritsa* Vegetable Crops Research Institute – Plovdiv, Bulgaria

E-mail: kuneva@au-plovdiv.bg

Abstract

The aim of the present research work was to evaluate the similarity and remoteness of the impact of different irrigation regimes for tomatoes (*Vitelio* variety) and their grouping by main biochemical indicators, using mathematical approaches (cluster analysis and factor analysis). Two-year data from a field experiment was used including a non-irrigation and an optimum option, as well as options for canceled irrigation and low irrigation norms (12 options in total). The experiment was carried out in Plovdiv in the period 2016-2017.

Cluster analysis results were in line with the conclusions from the irrigation and fertilization regime analyses and their impact on the tomato quality indicators. The strongest positive correlation existed between the indicators *common dyes* and *lycopene* for both experimental years. There was a strong negative correlation between the indicators *lycopene* and *beta-carotene.*

The basic indicators leading to the separation of the irrigation and fertilization options into clusters were the following quality indicators: titratable organic acids, ascorbic acid, common dyes, lycopene and beta-carotene combined in the first factor, responsible for 78.621% of the total dispersion of the variables.

Keywords: tomato, irrigation regime, correlation, cluster analysis, factor analysis

INTRODUCTION

Vegetable crops development for a short period during the year requires the application of high norms of fertilization. Some research workers have been searching for new technological solutions for an increase in yield and quality of greenhouse tomato production, as well as the defining of each nutrient element quantity necessary for better plant growth and high-grade fruit yield.

Bernard et al. (2009) have studied the fertilization impact using different nitrogen levels. They have registered that low nitrogen supply has a weak impact on fruit yield (-7,5%), but there is a decrease in the plant vegetative growth and an increase in the dry substance content in fruits leading to better fruit quality. Fruit quality is improved because of the lower acidity (10-16%) and the increased content of soluble sugar (5-17%).

Javaria et al. (2012) have established a positive linear correlation between the taste qualities, the common chemical elements /titratable organic acids/, lycopene and the dry substance/. It has been established that potassium concentration increase leads to determine the quality of tomato fruits, applied in a dose of 375 kg/ha K_2O along with the required fertilization norms N and P. After three-year research, Oke et al. (2005) have established that potassium impact does not contribute to statistically proved changes in tomato quality.

Resources of nutrient substances are also determining when analyzing the levels of true acids and antioxidants in greenhouse tomatoes. The average content of phenol and ascorbic acids in tomatoes grown with chicken manure and grass mulch /clover/ is 17,6% and 29%, respectively, higher than tomatoes grown with mineral nutritional solvents - Toora et al. (2006).

Parameters examination of the controlled water deficit and it's determining the quality of tomatoes can be helpful for the development of a precise strategy for water recourse management, for production optimization, and for tomato quality improvement (Favati et al. 2009: Pevicharova et al. 2013).

Using mathematical approach, the present research work aims the following:

1) to compare, by similarity and remoteness, the impact of different irrigation and fertilization regimes on tomatoes, *Vitelio* variety; to divide the regimes into groups on the base of significant qualitative indicators using cluster analysis;
2) to examine the presence of a correlation dependence between basic indicators for a more objective evaluation;
3) using a factor analysis, to reduce their total number uniting the correlated new factors.

MATERIALS AND METHODS

Two-year data of examination of different irrigation and fertilization regimes of tomatoes, *Vitelio* variety, was used – 2016 and 2017.

The experiment was set up by the block method on a surface scheme 110+50+35, with crop plot size of 10 m^2 (V. Barov, 1982).

The following options were examined: 1)broken irrigation regime (50% of the irrigation norm) without fertilization; 2) broken irrigation regime (75% of the irrigation norm) without fertilization; 3) optimum irrigation regime (100%) without fertilization; 4) broken irrigation regime (50% of the irrigation norm) and 50% fertilization; 5) broken irrigation regime (75% of the irrigation norm) and 50% fertilization; 6) optimum irrigation regime (100%) and 50% fertilization; 7) broken irrigation regime (50% of the irrigation norm) and 75% fertilization; 8) broken irrigation regime (75% of the irrigation norm) and 75% fertilization; 9) optimum irrigation regime (100%) and 75% fertilization; 10) broken irrigation regime (50% of the irrigation norm) and 100% fertilization; 11) broken irrigation regime (75% of the irrigation norm) and 100% fertilization; 12) optimum irrigation regime (100%) and 100% fertilization.

The irrigation was conducted through a drip irrigation system with embedded droppers at a distance of 0,20 cm. During the first year, there were 33 waterings with a size of the irrigation norm - 495m^3/da. During the second year, the size of the irrigation norm was 405m^3/da by 27 waterings. The crop culture was supplied with three levels of fertilization: optimum fertilization, ½ of the fertilization norms, ⅓ of the fertilization norms. The impact of the main fertilization was examined, realized with P_{23} (under the form of P_2O_5) and K_{25} (under the form of K_2SO_4) and supply with N_{50} during vegetation (under the form of NH_4NO_3) and K_{66} (under the form of KNO_3).

Except for a particular impact of a given irrigation regime on the yield and the structural elements separately (as it is usually registered in the research articles), there was a possibility for creating a complex evaluation of data base for all measured indicators. For this purpose, the method of the cluster analysis was used. According to this analysis, the examined options were divided into groups called *clusters* on the base of particular features. The cluster analysis allows the grouping of objects by similarity and differences. Results are presented graphically through a dendrogram showing the grouping of the examined options. The method is successfully used for grouping and evaluation of varieties and lines of various crop cultures (Ivanova, I. et al., 2010, L. Krasteva et al., 2010, Ilchovska M. et al., 2013 Ilchovska, M., et al, 2014, Milev M., et al, 2015.), for grouping of soil differences (Doneva et al., 2008).

The received results can lead to an increased precision of the evaluation of a particular irrigation regime. It is a prerequisite for an increased accuracy when taking particular solutions in the practice and the real irrigation of greenhouse tomatoes.

The evaluation of the examined irrigation and fertilization regimes was conducted through the comparison of the following indicators: x_1- dry substance (% of dry substance), x_2- ascorbic acid, x_3 – titratable organic acids, x_4 – common dyes, x_5- lycopene, x_6 - beta-carotene.

The grouping of all 12 examined options of irrigation regime was conducted through a hierarchical cluster analysis. The method of the intergroup combination was used (Ward, 1963, Dyuran, B., P. Odelly, 1977). The Euclidean intergroup distance was used as a measure:

$$D(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

A dendrogram was created presenting graphically the formed clusters. The dendrogram horizontal dotted line showed the rescale distance of the formed clusters. A correlation analysis was conducted aiming at establishing the presence of statistically significant correlations between the examined indicators.

The research was continued with the application of a factor analysis (Kline, 1994) aiming at a reduction of the sixth initial indicators. The factor analysis was conducted on the method of the main components (PCA). The number of main components was determined by the number of own symbols of the correlation matrix, which are bigger than 1 (Kaiser`s criterion). The own symbols show the contribution of the own factor when explaining the common dispersion of the variables.

Data processing was conducted with the statistical program SPSS.

RESULTS AND DISCUSSION

The conducted cluster analysis showed that the impact of the irrigation regime on tomato indicators was grouped in three main clusters. Results are presented in a table - with the consequent combination of clusters and intergroup distances (Table 1), as well as graphically through a dendrogram (Figure 1).

The first cluster was more homogenous. It combined the options 5, 8, 6, 4 and 7 that had similar indicators: dry substance, titratable organic acids, common dyes and lycopene, and the options that had broken irrigation regime and least Euclidean distance between them.

The second main cluster included the options 9, 11 and 12 that had small or moderate water deficit. They had the highest similarity of titratable organic acids and common dyes.

Options 2, 3 and 1 formed the third cluster. They were identical in dry substance and ascorbic acid. All of them had broken irrigation regime, without fertilization.

Options 1 and 4 were most distant. They had broken irrigation regime (50% of the irrigation norm) and an intergroup distance of 17.957coefficient (Table 1).

Table 1. Combination of the clusters and the intergroup distances

Steps	Combined clusters		Coefficients
	Cluster 1	Cluster 2	
1	5	8	1.727
2	4	7	2.361
3	5	6	2.578
4	9	11	3.344
5	2	3	4.023
6	4	5	4.277
7	9	12	4.717
8	9	10	8.398
9	1	2	9.278
10	4	9	10.585
11	1	4	17.957

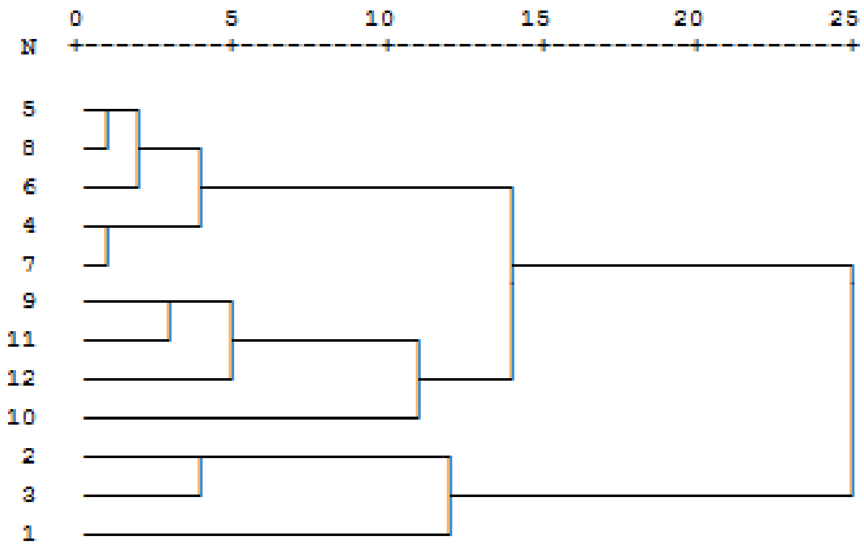

***Fig. 1.** A dendrogram on the base of the average intergroup distances*

The correlation components expressing the relation between the examined indicators are presented in the correlation matrix (Table 2).

There was a strong positive correlation between *lycopene* and *common dyes*, and average correlation dependence between *lycopene* and *titratable organic acids,* with correlation coefficients r = 0.977 and r = 0.581, respectively.

There was a strong negative correlation between the indicators beta-carotene and titratable organic acids, common dyes and lycopene, with correlation coefficients: r = - 0.846; -0.742 and -0. 852. All correlation coefficients were statistically proved at a degree of significance - $\alpha = 0.001$.

Table 2. A correlation matrix

X_i	x_1	x_2	x_3	x_4	x_5	x_6
x_1	1.00	-0.454	-0.037	-0.050	-0.062	0.003
x_2		1.00	-0.515	-0.127	-0.235	0.542
x_3			1.00	0.488	0.581*	-0.846**
x_4				1.00	0.977**	-0.742**
x_5					1.00	-0.852**
x_6						1.00

The conducted correlation analysis and the statistically proved high values of *r* gave us a reason to apply the methodology of the factor analysis. The method of the main components was applied in the factor analysis. It was concluded that both factors had values of their own vectors bigger than 1, which defined the choice of two main components (Figure 2).

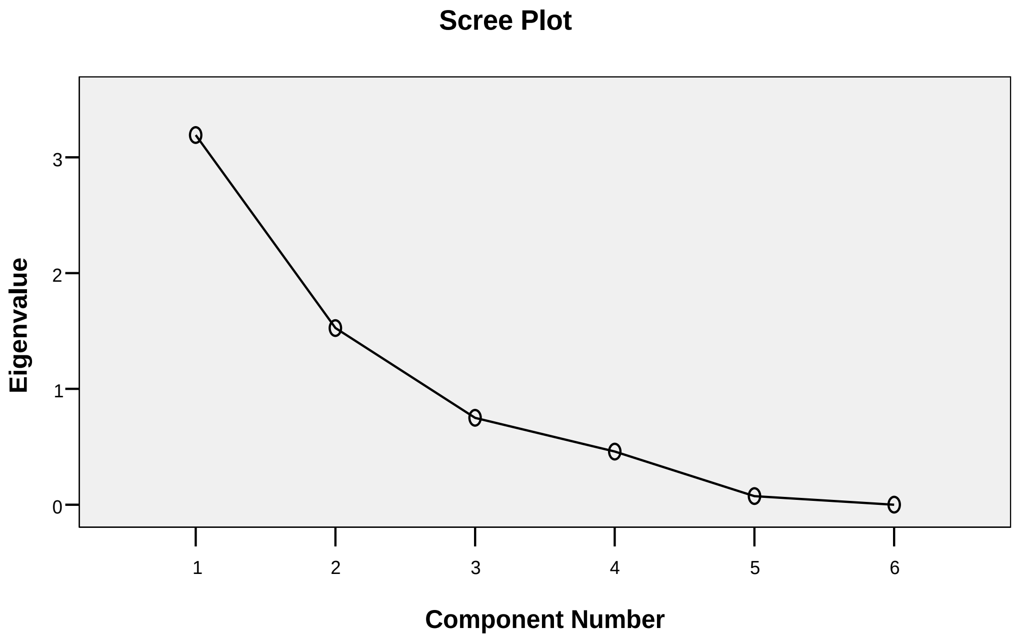

Fig. 2. *Values of the own vectors*

Table 3 shows the factor weights and the distribution of the main component variation. The components explain 78,621% of the total extract dispersion. The first main component explains 53,199 % of the dispersion, and the second - 21,7 % of the dispersion.

Table 3. A factor matrix received on the method of the main components

№	Indicators	Main components		Symbols
		1	2	
1.	Dry substance (% of dry substance)	-0.403	-0.557	x_1
2.	Ascorbic acid	-0.211	0.881	x_2
3.	Titratable organic acids	0.831	-0.257	x_3
4.	Common dyes	0.806	0.420	x_4
5.	Lycopene	0.946	0.193	x_5
6.	Beta-carotene	-0.867	0.400	x_6
Percentage of the total variation, %		53.199	25.421	
Cumulative percentage of the total variation, %		53.199	78.621	

The variables x_3, x_4 x_5 and x_6 had high factor weights in the first component. This factor should be mainly related to titratable organic acids, common dyes, lycopene, and beta-carotene. The factor could be defined as general for the indicators having the most relative weight in tomato grouping. The second component was mainly related to the ascorbic acid.

The received results from the applied factor analysis were synchronized with the results from the cluster analysis in their grouping into clusters according to their similarity on the base of the same indicators.

CONCLUSIONS

The presented mathematical approach allowed a maximum objective evaluation of the complex impact of the control water deficit and fertilization levels on the basic chemical components in greenhouse tomatoes.

Cluster analysis results were synchronized with the conclusions from the analysis of the applied irrigation and fertilization regimes and their indicators impact the quality of tomatoes.

As a result of the conducted correlation analysis, correlation dependences between the examined indicators were established. The strongest positive correlation had the indicators *common dyes* and *lycopene* for both experimental years. There was a strong negative correlation between the indicators *lycopene* and *beta-carotene.*

The basic indicators that had the strongest impact on the grouping into clusters of the irrigation and fertilization options were the indicators: *titratable organic acids, common dyes, lycopene, and beta-carotene,* joined in the first cluster that explained 78,621 % of the total dispersion of the variables.

REFERENCES

Barov, V., 1982. Analiz i shemi na polskia opit. NAPS, Sofia.

Doneva, K., I. Ivanova, V. Ilieva, 2008. Grupirane na razprostraneni pochveni razlichia chrez klaster analiz, vaz osnova na danni za osnovni svoystva na pochvite i toplinnite im svoystva, II Balkanska nauchna konferentsia, 26-27 septemvri, Blagoevgrad, 325-332.

Dyuran, B., P. Odelly, 1977. Klasterniy analiz. M., Statistika.

Ilchovska, M., I.Ivanova, 2014. Usage of cluster analysis for grouping hybrids and evaluation of experimental mutant maize hybrids. Agricultural Science And Technology, Vol. 6, N^o 1, pp 14 – 16.

Ivanova, I., S. Grozeva, V. Rodeva, 2010. Otsenka na mutantni formi domati i tehnite izhodni linii chrez klasteren analiz i faktoren analiz, Nauchni trudovena AU-Plovdiv, v. LV, kn.1.

Kline, P., 1994. An easy guide to factor analysis, Routledge, London.

Krasteva, L., I. Ivanova, N. Velcheva, 2010. Grouping of determinate local tomato varieties on the basis of cluster analysis, Agricultural science and technology, vol. 2, No 3, pp. 113-115.

Milev, M., Kr. Nikolova, Ir. Ivanova, M. Dobreva, 2015. Usage of K-Cluster and factor analysis for grouping and evaluation the quality of olive oil in accordance with physicochemical parameters, AIP Conf. Proc.1690, 020021-1—020021-5.

Panayotov, N., V. Gueorguiev, I. Ivanova, 2000. Characteristics and grouping of F_1 pepper (*Capsicum annuum* L.) hybrids on the basis of cluster analysis by morphological characteristics of fruits. Capsicum & eggplant newsletter. № 19, University of Turin, Italy, 62-65.

Ward, J. H., 1963. Hierarchical grouping to optimize an objective function. Journal of the American Statistical Association. 58, 236-244.

Toora, R. K., P. G. Savage, A. Heeb, 2006. Influence of different types of fertilizers on the major antioxidant components of tomatoes. Journal of Food Composition and Analysis. Volume 19, Issue 1, February 2006, pages 20-27.

Pevicharova, G., D. Ganeva, D. Zamir, 2013. Effect of Irrigation on Ascorbic Acid Content of *Solanum cheesmaniae* Tomato Collection. Plant science, 50, pages 70-74.

Moustapha, Oke, Taehyun Ahn, Andrew Schofield, and Gopinadhan Paliyath. 2005. Effects of Phosphorus Fertilizer Supplementation on Processing Quality and Functional Food Ingredients in Tomato. J. Agric. Food Chem., 2005, 53 (5), pages 1531–1538.

Fabio Favatia Stella Lovellib Fernanda Galganoa Vito Miccolisb Teodoro Di Tommasob Vincenzo Candidob, 2009. Processing tomato quality as affected by irrigation scheduling. Scientia Horticulturae. Volume 122, Issue 4, 3 November 2009, pages 562-571.

Javaria, S., M. Q. Khan and I. Bakhsh, 2012. Effect of potassium on chemical and sensory attributes of tomato fruit. The Journal of Animal & Plant Sciences, 22(4): 2012, page: 1081-1085.

Bénard, C., H. Gautie, F. Bourgaud, D. Grasselly, B. Navez, C. Caris-Veyrat, M. Weiss and M. Génard, 2009. Effects of Low Nitrogen Supply on Tomato (Solanum lycopersicum) Fruit Yield and Quality with Special Emphasis on Sugars, Acids, Ascorbate, Carotenoids, and Phenolic Compounds. J. Agric. Food Chem., 2009, 57 (10), pages 4112–4123.