STUDIA UBB CHEMIA, LXI, 4, 2016 (p. 295 - 303)
(RECOMMENDED CITATION)

TOTAL PHENOLS, ANTIOXIDANT ACTIVITY AND YIELD, IN TOMATOES AND PEPPERS IN A CLOSED GREENHOUSE AND COMPARISON WITH A CONVENTIONAL GREENHOUSE

NIKOLAOS GOUGOULIAS[a], ALEXANDROS PAPACHATZIS[a], IOANNIS VAGELAS[a], LIVIU GIURGIULESCU[b*], ANASTASIA KARABOULA[a], DIMITRIOS KALFOUNTZOS[c]

ABSTRACT. A study during 36 months, was conducted in a conventional greenhouse (open type) and a geothermal (closed type) of TEI Thessaly to determine the productivity, total phenols content, antioxidant activity and certain qualitative characteristics of hydroponic tomatoes and peppers. At geothermal greenhouse the concentration of total phenols in tomatoes ranged from 151 to 324.5 μg (GAE) /g fresh weight and the antioxidant activity ranged from 3.54 to 3.90 μM (AA) /g fresh weight, while in peppers the total phenols ranged from 597 to 815 μg (GAE) /g fresh weight and the antioxidant activity ranged from 6.3 to 7.2 μM (AA) /g fresh weight. At conventional greenhouse the concentration of total phenols in tomatoes ranged from 163 to 195 μg (GAE) /g fresh weight and the antioxidant activity ranged from 3.3 to 3.9 μM (AA) /g fresh weight, while in peppers the total phenols ranged from 527 to 729 μg (GAE) /g fresh weight and the antioxidant activity ranged from 5.7 to 6.8 μM (AA) /g fresh weight. In tomatoes the yield of the production was higher in the geothermal greenhouse as compared to the conventional greenhouse, while in peppers the yield of the production between of geothermal greenhouse and of conventional greenhouse showed no statistically significant differences.

Keywords: *Antioxidant activity FRAP; Hydroponic systems; Peppers; Tomatoes; Total phenols*

INTRODUCTION

In an soilless cultivation, the plants are free from diseases, and grow faster than in the soil. The development of the hydroponic systems [1-3], is based on modern distribution systems of nutrient solution [4-6].

[a] *Department of Agronomy Technology, Technological Educational Institute of Thessaly, 41110 Larissa, Greece*
[b] *Department of Chemistry and Biology, Technical University of Cluj Napoca, North Universitary Center of Baia Mare, 430122 Baia-Mare, Romania*
[c] *Department of Biosystems Engineering, Technological Educational Institute of Thessaly, 41110 Larissa, Greece.*
[*] *Corresponding author: giurgiulescu@gmail.com*

Geothermal energy is the heat from the earth, clean and sustainable, provides economic benefits, and contributes to a reduction of greenhouse gases [7-10]. The shallow geothermal energy, is derived by absorption of solar radiation, is stored from the earth's surface up to depth 200 m in a temperature 10-18 °C, while obtained from the shallow ground to hot water and is exploited with the heat pumps [11].

Tomatoes and peppers it is natural reservoir of nutrients and of natural antioxidants [12-16]. While, the techniques and cultivation systems, fertilization, irrigation and variety, affect the levels of the antioxidant activity in the tomatoes and peppers [17-19].

The purpose of this study was to compare the geothermal greenhouse with the conventional in the productivity, polyphenols content, antioxidant activity and some qualitative characteristics of hydroponic tomatoes and peppers, for three consecutive seasons.

RESULTS AND DISCUSSIONS

Tomatoes Merilia

Measurements every week in the thickness, number of inflorescences, and number of leaves per tomato plant, showed no statistically significant differences in the two types of greenhouses that were studied during of the growing seasons. Moreover, the mean plant height at the end of the third growing season it was bigger in conventional greenhouse as compared to the geothermal greenhouse (Table 1).

Table 1. Morphological characteristics of tomatoes plants during ripeness of the first, second and third cultivation periods for the conventional and the geothermal greenhouse

Morphological characteristics	Conventional greenhouse			Geothermal greenhouse		
	Cultivation period			Cultivation period		
	First	Second	Third	First	Second	Third
Mean plant height (cm)	160.5c	148c	264a	168.4c	168.1c	224b
Mean plant width (mm)	13.01a	14.07a	14.25a	13.47a	13.82a	14.75a
Mean number of leaves/plant	18b	26b	42a	21b	26b	43a
Mean number inflorescences/plant	13a	10a	9a	15a	9a	9a

Lines with the same letter do not differ significantly according to the Tukey's test (P=0.05).

The juice of the fruit during ripeness showed higher total acidity in the conventional greenhouse as compared to the geothermal greenhouse at the third growing season, while the pH and Brix degrees showed no statistical differences regarding the geothermal greenhouse or the conventional (Table 2). Also, the mean weight of the fruit during the harvest was greater in geothermal greenhouse as compared to the conventional greenhouse, by (11.5, 5.5, and 7) % respectively, for all growing seasons, well as the yield of the production was higher in the geothermal greenhouse as compared to the conventional greenhouse (Table 2). The monitoring of water by the use of water meters during for the three growing seasons revealed that the water consumption in the geothermal greenhouse was 10 % less as compared to the conventional greenhouse.

Table 2. Yield and chemical properties of the tomato juice

Properties	Conventional greenhouse			Geothermal greenhouse		
	Cultivation period			Cultivation period		
	First	Second	Third	First	Second	Third
Total acidity (g citric acid / 100 ml juice)	0.44b	0.45b	0.61a	0.36b	0.41b	0.46b
^{0}Brix	3b	3.5b	4.1a	3.3b	3.2b	4.0a
pH	5.09a	4.46b	4.23b	5.22a	4.51b	4.21b
Mean weight of fruit	208c	208c	225b	235a	220b	242a
Yield (tons /ha)	240.9	219.81	267.50	248.34	232.49	287.71

Lines with the same letter do not differ significantly according to the Tukey's test (P=0.05).

During the fruit ripeness in the first crop season (winter crop), the total phenols content in tomato of the geothermal greenhouse was higher than that of the conventional greenhouse, while in the second and third growing season (spring crops) the content of total phenols in tomato showed no statistically significant differences between the two greenhouses. While the antioxidant capacity FRAP of hydroponic tomato showed no statistical differences regarding the geothermal greenhouse or the conventional greenhouse in all the growing seasons (Figure 1).

Peppers Shelby

In hydroponic peppers cultivation, the geothermal greenhouse as compared to the conventional greenhouse showed no statistical differences regarding the mean plant width, and mean number inflorescences per plant. Also, mean number of leaves per plant at the end of the first and third growing season it was greater in conventional greenhouse as compared to the geothermal greenhouse (Table 3). Moreover, at the end of the second growing season, the mean plant height of the pepper was greater in geothermal greenhouse as compared to the conventional greenhouse (Table 3).

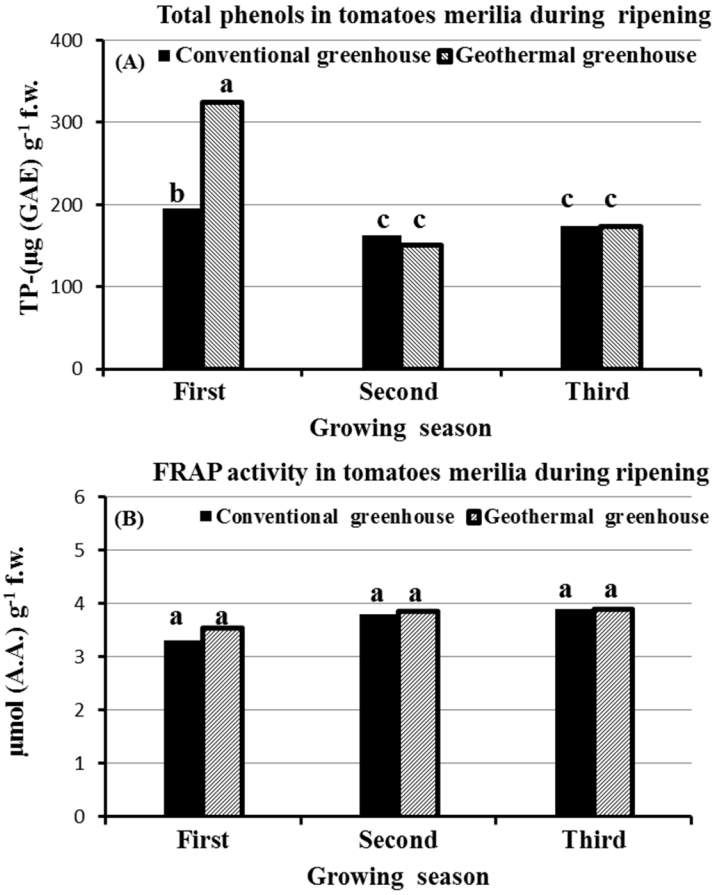


Figure 1. Total phenolic content (A) and antioxidant activity FRAP (B) of tomatoes merilia at the stage ripening in geothermal and conventional greenhouse. Columns in each graph with the same letter do not differ significantly according to the Tukey's test (P=0.05).

The juice of the fruit during ripeness showed higher Brix degrees (soluble solids) in conventional greenhouse as compared to the geothermal greenhouse at the second growing season (spring crop), while the pH and total acidity of juice in conventional greenhouse as compared to the geothermal greenhouse showed no statistical differences (Table 4). Also, the mean weight of the fruit during the harvest showed no statistically significant differences regarding the geothermal greenhouse or the conventional greenhouse in all the growing seasons, well as the yield of the production between of geothermal greenhouse and conventional (Table 4).

Table 3. Morphological characteristics of peppers plants during ripeness of the first, second and third cultivation periods for the conventional and the geothermal greenhouse

Morphological characteristics	Conventional greenhouse			Geothermal greenhouse		
	Crop season			Crop season		
	First	Second	Third	First	Second	Third
Mean plant height (cm)	139.25c	161.5b	138c	141c	185.4a	119c
Mean plant width (mm)	13.38a	18.75a	14a	15.5a	18a	13a
Mean number of leaves/plant	146b	196a	144b	116c	187a	119c
Mean number inflorescences/plant	14c	59a	42b	19c	62a	41b

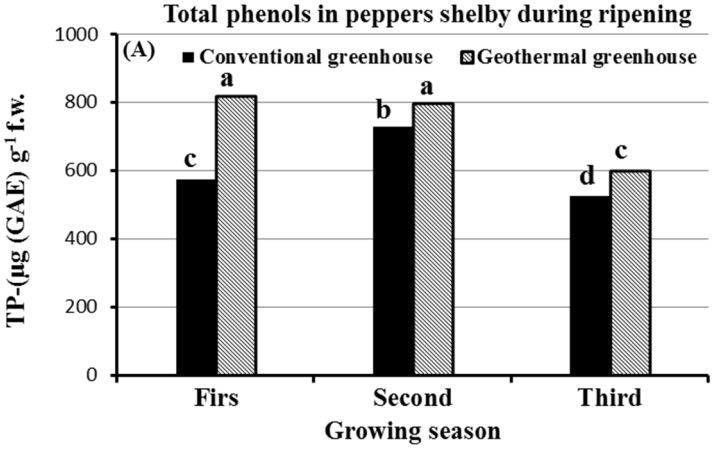
Lines with the same letter do not differ significantly according to the Tukey's test (P=0.05).

Table 4. Yield and chemical properties of the peppers juice

Properties	Conventional greenhouse			Geothermal greenhouse		
	Crop season			Crop season		
	First	Second	Third	First	Second	Third
Total acidity (g citric acid / 100 ml juice)	0.09a	0.13a	0.12a	0.12a	0.13a	0.13a
^{0}Brix	2.8c	3.70a	3.9a	2.7c	3.20b	4.0a
pH	6.26a	6.31a	5.64b	6.38a	6.13a	5.75b
Mean weight of fruit	94a	100a	102a	95a	102a	105a
Yield (tons /ha)	99.33	105.6	113.18	102.9	113.1	113.73

Lines with the same letter do not differ significantly according to the Tukey's test (P=0.05).

During ripeness of the fruit, the total phenols content and antioxidant activity FRAP of the peppers was higher in geothermal greenhouse as compared to the conventional greenhouse in all the growing seasons (Figure 2).



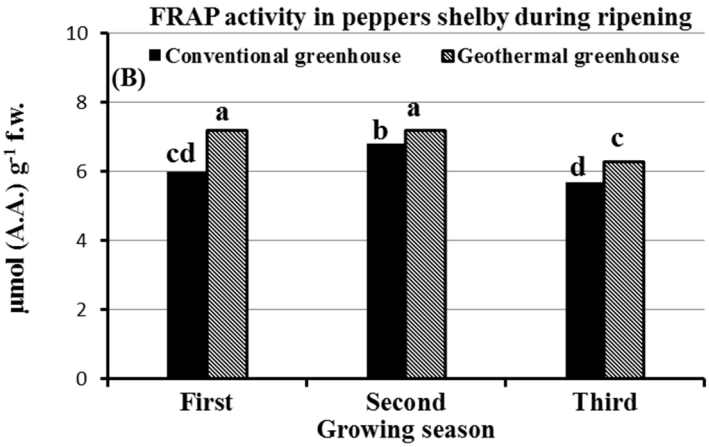


Figure 2. Total phenolic content (A) and antioxidant activity FRAP (B) of peppers at the stage ripening in geothermal and conventional greenhouse. Columns in each graph with the same letter do not differ significantly according to the Tukey's test (P=0.05).

Studies have shown that the total content of phenols and antioxidant activity in hydroponic peppers and tomatoes depends on the differently extracts, maturity stage and cultivars [20-22].

CONCLUSIONS

Total phenols content of hydroponic tomatoes at the ripening stage, was higher in geothermal greenhouse as compared to the conventional greenhouse at the wintry growing season. Total phenols content and antioxidant activity FRAP of hydroponic peppers at the ripening stage, was higher in geothermal greenhouse as compared to the conventional greenhouse in all the growing seasons.

Mean weight of tomatoes fruit during the harvest was greater in geothermal greenhouse as compared to the conventional greenhouse, by (11.5, 5.5, and 7)% respectively, for the three growing seasons, well as the yield of the production was higher in the geothermal greenhouse as compared to the conventional greenhouse. Mean weight of peppers fruit during the harvest, well as the yield of the production showed no statistically significant differences regarding the geothermal greenhouse or the conventional greenhouse in all the growing seasons.

The geothermal greenhouse as compared at the conventional greenhouse, showed higher production on tomato crop, while about of the pepper crop showed greater total phenols content and greater antioxidant activity, for the three growing seasons.

EXPERIMENTAL SECTION

Greenhouse facilities

The experiment was conducted in two greenhouses of Technological Educational Institute of Thessaly. The greenhouse (A), closed type to the system water recycling, that based on shallow geothermal energy and the greenhouse (B), conventional. For the geothermal greenhouse, the energy requirements covered by ground heat exchangers, that constructed adjacent to from the glasshouse at a depth of 100 meters, while the air dehumidifying system it includes the air collection duct, heat exchangers for the cooling of air and plastic tank to collect water for the irrigation. Also in the geothermal greenhouse are located tubes for collection of the nutrient solution during outflow from the greenhouse. The remaining ventilation systems in both greenhouses are identical, as well as dimensions and cover materials. Also, for the air conditioning of both greenhouses, there is system with both heat pumps.

Nutrient solution

The overall flow of the nutrient solution in the greenhouses is controlled by modern automation. The crops was fertilized through a stable chemical nutritive solution at the rates of 58.9 ml/min for 3 minutes, repetitively 4 times a day. The nutritive solution consisted of Ca^{2+} = 169 meq/L, K^{+} = 253.4 meq/L, Mg^{2+} = 64.8 meq/L, NH_4^{+} = 18.3 meq/L, H^{+} = 112 meq/L, Fe^{2+} = 0.6 meq/L, NO_3^{-} = 281.3 meq/L, PO_4^{3-} = 143.3 meq/L and SO_4^{2-} = 193.5 meq/L, while its pH was about 6 and electrical conductivity EC about 2dS m^{-1}.

Cultivation

In an area of 200 m^2 for each greenhouse, was cultivated hydroponic tomatoes Merilia (100m^2) and peppers Shelby (100m^2) for three consecutive seasons. The substrate it was from stone wool slabs in double rows, with a distance of plants for each slab 30 cm, namely three plants. The duration of the first growing season was from 21- 10-2014 to 21-01-2015, the second growing season from 05-03-2015 to 17- 06-2015, and the third growing season had duration from 04-02-2016 to 28-06- 2016. Eight plants from each greenhouse were selected for measurements. The four of those were always the same, while the other four were selected randomly. The width and the height of plants, the number of leaves and inflorescences were measured once per week.

Preparation of the methanol extracts

The fruits harvested in the ripeness (Figure 4). Ten g of the fruit samples were two rounds treated by 20 ml of 80% aqueous methanol. Samples were incubated for 24 h in the extractant at stirring; the supernatant material was

removed. The pellet was re-treated with aqueous methanol for 2 h at stirring at ambient temperature. The extract was gathered after centrifugation/filtration and the volume was made up to 50 ml with aqueous methanol and used for further chemical analysis [23].

Determination of total polyphenolics (TP)

Total polyphenolic content was determined with the Folin-Ciocalteu (F-C) reagent according to the method of [24] using the microvariant proposed by [25] and the results were expressed as gallic acid equivalent (GAE) in μg/g fresh weight.

Determination of ferric reducing antioxidant power (FRAP)

The antioxidant activity of the methanol extracts was determined on the basis of the method of [26] and was expressed as ascorbic acid equivalent (AA) in μM /g fresh weight.

Determination of total acidity, pH and Brix degrees

The pH, the Brix degrees and the total acidity were measured in fruit juice. The Brix degrees by a Zeiss refractometer while the total acidity by titration with 0.1N NaOH solution and expressed in g of citric acid / l00 ml juice.

Statistical analysis

Data were analyzed using the MINITAB [27] statistical package. The experiment had eight replications. Analysis of variance was used to assess treatment effects. Mean separation was made using Tukey's test when significant differences (P=0.05) between treatments were found.

ACKNOWLEDGMENTS

LIFE 'Adapt agricultural production to climate change and limited water supply' (Adapt2Change).

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