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PRODUCTION CONDITIONS FOR GREENHOUSE VEGETABLE PRODUCTION ON SMALL SCALE FAMILY FARMS

PROIZVODNI USLOVI U OBJEKTIMA ZAŠTIĆENOG PROSTORA

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ABSTRACT

The aim of this research was to investigate the microclimatic parameters in the different tunnel greenhouse constructions in order to see if the choice of the greenhouse construction can improve the production conditions inside the greenhouse. A new type of round shape greenhouse construction is introduced that should lead to more energy efficient vegetable production. Production conditions were tracked in the open field and in the greenhouses. Results show that temperature pattern and its values during the night and day depend on the greenhouse construction, plant specie and production season.

Key words: *vegetables, tunnel greenhouse, round-shape greenhouse, production conditions, uniformity.*

REZIME

Cilj ovog rada je da prikaže rezultate istraživanja mikroklimatskih parametara u objektima zaštićenog prostora na malim, porodičnim gazdinstvima i da ukaže na mogućnosti unapređenja proizvodnje povća na malom posedu. Cilj istraživanja je bio pokazati da proizvodni uslovi u objektima zaštićenog prostora zavise od tipa konstrukcije objekta i od gajene biljne vrste. Obzirom na nisku energetsu efikasnost objekata tunel tipa, posebno u zimskoj proizvodnje, prikazan je predlog nove konstrukcije objekta zaštićenog prostora, namenjen isključivo porodičnim gazdinstvima.

Ključne reči: *povrće, tunel plastenik, plastenik kružne osnove, proizvodni uslovi, uniformnost.*

INTRODUCTION

Greenhouse is a very complex and intensive agricultural production system. It is intensive in terms of production, energy consumption, labor and cost *(Dimitirjević et al., 2015)*. From their beginning in the early fifties in 20th century greenhouse technology passed various phases of development regarding construction material, shape and covering materials *(Dimitrijevic et al., 2012)*. Reason for this intensive development are various and are starting from plain men curiosity how to "play" with the nature and are finishing with the global energy, ecology and economy issues.

In the rushing world the customers increasingly prefer brushed and cut packed vegetables which can be used at home easily. Minimally processed leafy vegetables consumption has been increasing in all developed countries *(Csajbokne and Gilingerne, 2011)*. In this sense a great attention is given to the possibilities of organic vegetable production possibilities and systems *(Milić et al., 2012)*.

Tomato and cucumber are most important vegetables in the human nutrition. These can be grown in the open filed, in the semi-controlled production conditions and in the greenhouses. In the open field and in the semi-controlled production conditions, they cover large surfaces and the adequate technical systems for the open filed production are used *(Mago, Jakovac, 2007)*. Greenhouse cucumber production is more sophisticated. The species are adapted on the specific conditions in the greenhouse and are sensitive to the conditions outside the greenhouse. Concerning this, special attention is carried in controlling the production conditions in the greenhouse production.

Factors that determine the greenhouse production system are air temperature, relative humidity of air and soil, air quality and light conditions. Tracking these micro-climatic conditions is of a great importance for the successful greenhouse production *(Ponjičan et al., 2011)*. Purpose of tracking the greenhouse production continuously is to optimize the plant productions in the greenhouse. It is necessary to know the correlation between greenhouse construction, covering material and type of the plant production.

Temperature conditions in the greenhouses influence the overall plant growth, yield and fruit quality. If the air temperature and relative humidity in the greenhouse are lower than optimal plants will be shorter with smaller dark green leaves. In the case of lower temperature and higher relative air humidity flowering of the plants will be delayed and the yield will be lower. Higher night temperatures cause the higher consumption of organic matter by plants which grow with the long pale green gently leaves with the lower yield and deformed fruits. It is stated *(Enoch, 1978; Hanan, 1998; Lazić et al., 2001, Nelson, 2003)* that night temperatures and the temperatures during the day should be 3–5 °C lower compared outside temperatures during the sunny days. It is also stated that temperature variations during the day should not be more than 2 do 3 °C. Literature sources *(Lazić et al., 2001; Hanan, 1998; Nelson, 2003; Sengar and Kothari, 2008; Singh and Tiwari, 2000; Dimitrijević et al., 2014)* confirm the statement that temperature in greenhouses varies along their length, width and height. The pattern of this variation is influenced by the greenhouse type of construction and its dimensions, covering material, orientation and applied heating and venting systems.

The aim of this paper was to show how the type of greenhouse construction and plant species can influence the uniformity of the micro-climatic conditions in the greenhouses.

MATERIAL AND METHOD

For the purpose of the research a tunnel type (TUN 1) 5.5 × 24 m covered with 180 μm PE UV IR outside folia, a tunnel type (TUN 2) greenhouse 8 × 60 m and with 180 μm inner folia and 220 μm outside folia were used and new round-shape type of greenhouse construction (RND) covered with PE UV IR 180 μm folia. Experiment was carried out at the private property in Pancevo (44^0 52$^{'}$ 46$^{''}$N, 20^0 38$^{'}$ 50$^{''}$E) (Serbia) and at a private property near Jagodina (44^0 02$^{'}$ 14$^{''}$N, 21^0 16$^{'}$ 15$^{''}$E) (Serbia).

Temperature and air humidity were measured using the sets of WatchDog Data loggers 150 Temp/RH, t= 0.6 °C and RH = 3 % and a WatchDog Data Logger Model 450 – Temp, Relative Humidity - Temp/RH, t= 0.6 °C and RH= 3 %. In the greenhouses tomato and cucumber production conditions were analysed for the summer 2015 production season.

Statistical analysis of the results was based on variance analysis, F tests and LZD tests which were used to determine if the temperature and relative humidity are uniform along the greenhouses and if the type of construction influences the temperature, relative humidity uniformity and solar radiation transmition. Data used for the analysis represent the five days average values.

RESULTS AND DISCUSSION

Temperature distribution

Temperature measurements in both of the tunnel greenhouses show that temperature varies along the greenhouse (Fig. 1). During the night hours the highest temperature was observed in the central part of both of the tunnels. In the TUN 1 lowest temperature was measured in the north part while in the TUN 2 the lowest temperature was observed in the south part. Statistical analysis of the data showed that temperature differences of 0.83 ° C along the TUN 1 and 1.05 °C in the TUN 2 greenhouse during the night are not significant. Temperature measurements at 7h in the morning also show that there are differences in the air temperature distribution along both of the tunnel greenhouses. In both cases the highest temperature was in the south part of the greenhouse. The lowest temperature in the TUN 1 was measured in the north part while for the TUN 2 the lowest temperature was measured in the central part. Variance analysis confirmed that these differences are not significant for the TUN 1 greenhouse but are very significant in the TUN 2 greenhouse. Based on the LSD test it was concluded that difference of 6.92 °C were very significant (Fig. 1).

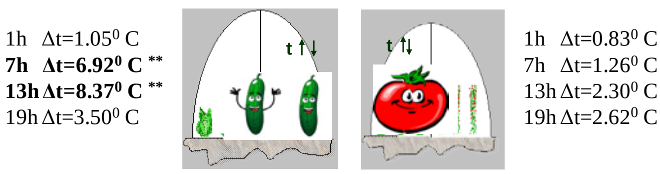

Fig. 1. Temperature variation inside the TUN 2 and TUN 1 tunnel greenhouses

In this way it can be concluded that in the summer tomato production in the tunnel (TUN 1) greenhouse temperature conditions in the greenhouse do not vary much along the greenhouse length. Concerning the temperature values, these oscillations can be considered as acceptable. As for the TUN 2 summer cucumber production temperatures inside the greenhouse are not uniform, especially during the day. There are "hot" spots in the greenhouse and this must be regulated by using the roof openings or introducing the forced ventilation.

Differences between inside and outside temperatures are very important parameter that defines the ventilation system capacity and operation. In the summer production, temperature in the greenhouses is always much higher than the outside. With the appropriate venting system, optimized based on the type of plant species and greenhouse construction, it is possible to regulate these temperature. In the summer greenhouse vegetable production it is important to have good ventilation systems that will lower the temperature in the greenhouses and that will eliminate parts of the greenhouses with high temperature. Table 1 shows the average temperatures inside and outside the greenhouses in the summer vegetable production.

Table 1. Temperature variation inside and outside the greenhouses in the summer production, °C

Time	Greenhouse	Temperature inside the greenhouse	Temperature outside the greenhouse	Inside / outside temperature difference
1 h	TUN 1	16.07	14.93	1.14
	TUN 2	17.16	16.37	0.79
	RND	17.2	17.26	-0.04
7 h	TUN 1	23.32	15.71	7.61
	TUN 2	23.91	15.93	7.98
	RND	22.45	19.45	3.00
13 h	TUN 1	37.36	29.05	8.31
	TUN 2	42.89	32.88	10.01
	RND	33.50	28.44	5.06
19 h	TUN 1	26.51	24.35	2.16
	TUN 2	29.10	28.86	0.01
	RND	31.55	25.32	6.23

Statistical analysis for testing the mean values showed that there are differences between inside and outside temperature in the greenhouses and that these differences are significant in the case of round shape greenhouse and very significant in the case of tunnel structures, in the afternoon hours (Fig. 2). This means that during the evening and night hours one should not expect significantly higher temperatures inside the greenhouse compared to the outside temperatures. In all types of structures statistical analysis showed that temperature in the morning and noon are to be expected significantly higher if compared with the outside temperatures.

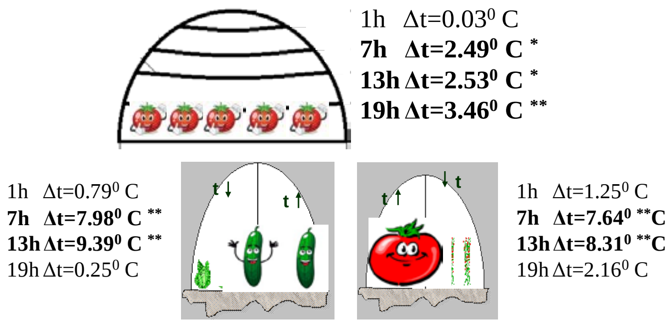

Fig. 2. Temperature inside and outside the TUN 2 and TUN 1 greenhouse

In this way it can be concluded that in the summer tomato production in the tunnel (TUN 1) greenhouse temperature conditions in the greenhouse do not vary much along the greenhouse length. Significant differences were only observed in the inside and outside temperatures in both greenhouses in the early morning hours and at noon. Concerning the temperature values, these oscillations can be considered as acceptable. As for the TUN 2 summer cucumber production temperatures inside the greenhouse are not uniform, especially during the day. There are "hot" spots in the greenhouse and this must be regulated by using the roof openings or introducing the forced ventilation.

Relative humidity

Optimal relative humidity for cucumber is very high (90 – 95 %) while for the tomato it is 50 – 65 %. Literature *(Hanan, 1998; Lazić et al., 2001; Nelson, 2003; Sengar and Kothari, 2008, Singh and Tiwari, 2000)* states that air humidity varies during the day and along the greenhouse length and height. It is stated that the pattern of variation depends on greenhouse type of construction its dimensions, covering material and the plant species that is produced in the greenhouse. Table 2 shows the average air relative humidity values for the three greenhouses in the summer vegetable production.

Table 2. Relative air humidity inside and outside the tunnel greenhouses, %

Time	Greenho.	Air relative humidity inside the greenhouse	Air relative humidity outside the greenhouse	Inside / outside air relative humidity difference
1 h	TUN 1	94.05	64.65	29.40
	TUN 2	85.06	49.02	36.04
	RND	66.84	83.77	-16.93
7 h	TUN 1	88.75	65.94	22.81
	TUN 2	89.83	40.52	49.31
	RND	58.64	77.17	-18.53
13 h	TUN 1	29.99	27.55	2.44
	TUN 2	26.99	24.68	2.31
	RND	27.82	36.96	-9.14
19 h	TUN 1	77.62	46.00	31.62
	TUN 2	31.06	20.04	11.02
	RND	33.68	49.41	-15.74

Measurement of the air relative humidity in both of the tunnel greenhouses show that air relative humidity has the same pattern of change for both of tunnel greenhouses (Fig. 3). It is significantly higher in all periods of the day except in the noon where differences between outside and inside air relative humidity exist but are not significant.

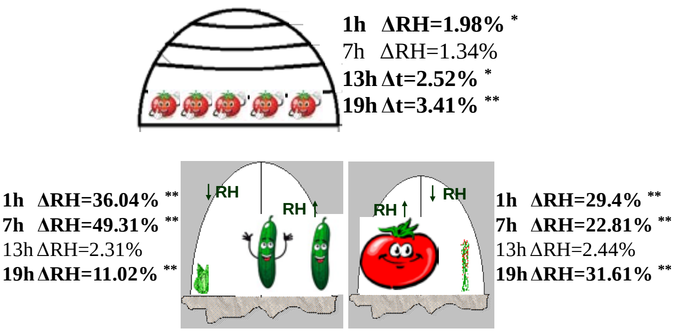

Fig. 3. Outside / inside air relative humidity differences for the TUN 2 and TUN 1 greenhouse

Measurements in the round shape greenhouse show that relative humidity inside the greenhouse was lower compared to the outside relative humidity, which is not typical for the greenhouses. So, in this case, this type of greenhouse structure can be used in the tomato production on the family farms since it has good conditions regarding the air relative humidity. The problem may occur in cucumber production since it is fond of higher air relative humidity.

So, regarding the air relative humidity, the type of tunnel structure does not influence significantly on its behaviour pattern. New type of construction has a different behaviour patter which is suitable for the vegetables that are not fond of higher air relative humidity and are prone to the diseases caused by higher air humidity.

Solar radiation

Solar radiation is one of the most important factors that influences overall energy efficiency of the vegetable production in the greenhouses *(Hanan, 1998; Nelson, 2003; Kozai et al., 1978)*. The solar radiation energy that comes to the plants depends on the greenhouse construction type, greenhouse covering material, greenhouse orientation and the time of the year.

Measurements of the solar radiation outside and inside the tunnel greenhouses showed that there are differences (Tab. 3) and that are not the same in the two types of greenhouse structures.

Statistical analysis showed that in the morning hours the quantity of solar radiation that enters the greenhouses is not significantly lower than the outside solar radiation. So, the properties of the covering material and these types of greenhouse constructions are beneficial for the solar radiation transmission.

Table 3. Solar radiation inside and outside the tunnel greenhouses, W/m^2

Time	Greenho.	Solar radiation inside the greenhouse	Solar radiation outside the greenhouse	Outside / inside solar radiation difference
7 h	TUN 1	61.23	76.09	14.86
	TUN 2	97.56	153.72	56.16
	RND	266.66	288.38	21.72
13 h	TUN 1	357.88	831.69	473.81
	TUN 2	553.08	930.82	377.74
	RND	628.74	821.98	193.244
19 h	TUN 1	31.74	44.47	12.73
	TUN 2	46.69	108.27	58.58
	RND	108.56	48.27	60.28

Measurements in 13h show that solar radiation that has reached the plants inside both of the tunnel greenhouses was significantly lower than the outside solar radiation (Fig. 4). In the TUN1 the losses were 37.71 – 68.44 %. In the TUN 2 structure the losses were lower and were 37.18 – 44.29 %. In the case of round-shape greenhouse solar radiation energy inside the greenhouse was lower but these differences were lower if compared to the tunnel structures.

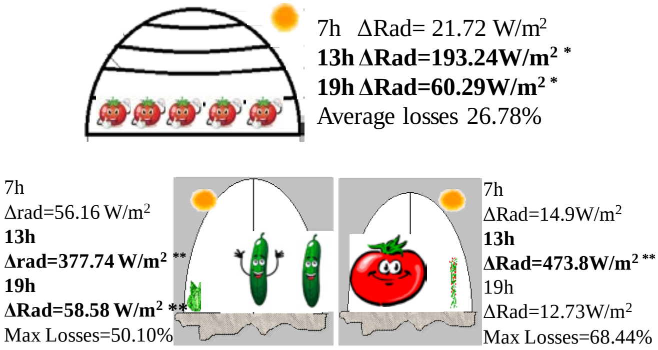

Fig. 4. Outside / inside solar radiation for the TUN 2 and TUN 1 greenhouse

Measurements in the 19h showed that TUN 1 had the better conditions regarding the solar radiation transmittance. The energy that was entering the greenhouse was not significantly lower compared the outside values. The losses were 5.39 – 35.61 %. TUN 2 construction showed higher losses in the solar radiation transmittance (36.18 – 62.70 %). The solar energy that was reaching the plants in the TUN 2 greenhouse was significantly lower compared to values outside. Average losses in the transmitet solar radiation energy were highest for the smaller tunel structure (68.44 %), then in the case of the tunnel with the higher specific volume (50.10 %) and the lowest losses were calculated for the new-proposed round shape greenhouse construcion (26.78 %). It can be concluded that the use of the new proposed round-shape greenhouse construction is benefitial regarding the light conditions in the greenhouse and the transmitet solar energy.

CONSLUSION

Obtained results show that micro-climatic conditions in the greenhouse vary during the day and along the greenhouse length. The variation pattern depends on the greenhouse type of construction. In the TUN 1 structure, with the smaller specific volume, more uniform temperature conditions along the greenhouse were observed. The reason for this can be the size of the TUN 1 and the fact that it was shorter and that ventilation was along the central part of the greenhouse, where data loggers were placed. TUN 2 has the higher specific volume so it is difficult to ventilate the area only with the natural ventilation. In this case either side ventilation must be introduced or forced ventilation since it is 60 m long. Concerning the relative air humidity the type of construction had no influence on the conditions inside both of the tunnel structures. Concerning the solar radiation transmittance the smaller tunnel (TUN 1) had a higher transmittance compared to the TUN 2 structure. Concerning all these differences and unstable production conditions, tunnel structures can not be suggested as a balanced environment for the vegetable summer production. Great care must be taken in order to optimize the venting systems in such greenhouses.

Regarding the new proposed construction results show that, regardless the production surface restrictions, with this type of greenhouse construction energy and financial savings are possible together with the minimization of the plant protection chemical usage due to the favorable production conditions in sense of lower air relative humidity and better solar energy transmittance. If organic fertilizer is used this type of construction can lead to improved food safety production.

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