DEFICIT IRRIGATION TECHNIQUE FOR REDUCING WATER USE OF TOMATO UNDER POLYTUNNEL CONDITIONS

TEHNIKA REDUKOVANOG NAVODNJAVANJA ZA SMANJENO KORIŠĆENJE VODE KOD PARADAJZA U USLOVIMA PLASTENIKA

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ABSTRACT

The aim of paper was to asses the use of regulated deficit irrigation (RDI) for production of two tomato cultivars (Cedrico and Abellus) in polytunnels in Serbia. RDI plants received 60% of the water that was applied to FI plants and significant saving of water for irrigation and increased in irrigation water use efficiency (IWUE) were achieved. Yield data for Cedrico cultivar showed no differences between RDI and FI, while due to the bigger sensitivity to drought, yield of Abellus was reduced under RDI. In general, fruit quality (soluble solids, titrable acidity) was sustained or improved in both cultivars under RDI. Economic analyses showed that due to the current low prices of water and electricity in Serbia, the profit increase of Cedrico, similarly to the previously trialed cultivar Amati, was not high under RDI comparing to FI. Reduction of yield and consequent profit for Abellus, indicated that for future commercial growing of tomato under RDI should be used drought resistant cultivars.

Keywords: RDI, tomato, yield, IWUE, profit

SAŽETAK

Cilj ovog rada je bio da se ispita mogućnost korišćenje tehnike redukovanog navodnjavanja (RDI) kod dve sorte paradajza (Cedrico and Abellus) gajene u plasteniku. RDI biljke su navodnjavane sa 60% vode koja je primenjena u uslovima punog navodnjavanja (FI), tako da je ostvarena značajna ušteda u količini vode za navodnjavanje i ostvaren porast u efikasnosti usvajanja vode za navodnjavanje (IWUE). Rezultati za sortu Cedrico pokazuju da nije bilo razlike u prinosu između RDI i FI, dok je zbog veće osetljivosti na sušu prinos sorte Abellus bio redukovan.

Generalno, kvalitet plodova (rastvorljivih suvih materija i količina kiselina) se održao ili čak bio bolji pod dejstvom RDI. Ekonomska analiza je pokazala da zbog, trenutno niskih cena vode i električne energije u Srbiji, profit kod sorte Cedrico i prethodne godine gajene sorte Amati, nije toliko veliki u uslovima RDI u poredjenju sa FI. Redukcija prinosa i profit kod sorte Abellus ukazuju da u budućoj komercijalnoj primeni RDI kod paradajza treba koristiti sorte otporne na sušu.

Ključne reči: RDI, paradajz, prinos, IWUE, profit

DETALJAN SAŽETAK

Tehnika redukovanog navodnjavanja (RDI) se u svetu veoma mnogo primenjuje sa ciljem uštede vode kod različitih poljoprivrednih kultura, dok je za uslove Jugoistočne Evrope relativno nova. Metoda je malo primenjivana i u plasteničkoj proizvodnji. Cilj rada je bio da se ispita efekat primene RDI tehnike na prinos, kvalitet prinosa i efikasnost usvajanja vode za navodnjavanje (IWUE) i ostvareni profit kod dve sorte paradajza (Cedrico i Abellus) gajene u plasteniku. RDI je započeto u fazi prve cvetne grane i trajalo je 4 meseca. Na osnovu sadržaja vode u zemljištu (merenja Delta-T probom), RDI biljke su zalivane sa 60% od norme punog navodnjavanja (FI). Na kraju ogleda izmerena je suva masa nadzemnog dela, broj plodova po biljci, njihov dijametar, sveža i suva masa, °Brix vrednosti (refraktometrijskom metodom) i sadržaj kiselina (titracijom sa NAOH). Efikasnost korišćenja vode za navodnjavanje (IWUE) je izračunat iz odnosa ostvarenog prinosa i količine utrošene vode za navodnjavanje biljaka. Ekonomska analiza je izvršena na osnovu fiksnih (priprema za sađenje, sadni materijal, đubriva, sredstva za zaštitu bilja i troškovi rada) i varijabilnih (cene utrošene vode i električne energije za rad pumpi) troškova. Na osnovu prinosa i cene paradajza izvršen obračun prihoda, a po odbitku troškova i profit. Ekonomska analiza je obuhvatila i sortu Amati koja je u istim uslovima gajena prethodne godine. Rezultati su pokazali da primena RDI kod sorte Cedrico nije dovela do redukcije rastenja biljaka ili plodova (njihovog broja i mase). Kod RDI biljaka sorte Abellus došlo je do redukcije u suvoj masi nadzemnog dela, dijametra i sveže mase plodova, kao i ukupnog prinosa i to za 6% u odnosu na FI. To ukazuje da je sorta Abellus osetljivija na sušu od sorte Cedrico. RDI je dovelo i do povećanja sadržaj kiselina u plodovima sorte Cedrico i °Brix vrednosti kod sorte Abellus. RDI je kod obe sorte doveo do porasta IWUE (kod Cedrico za 75% a Abellus za 33%). Ekonomska analiza je pokazala da profit pri primeni RN kod sorte Cedrico (720 € ha^{-1}) i Amati (759 € ha^{-1}) nije toliko veliki koliko se moglo očekivati u odnosu na uštedu vode i električne energije (za 38%) u ovom sistemu u odnosu na FI. Kod sorte Abellus zbog redukcije prinosa profit nije ostvaren. Osnovni razlog ovako malog profita je u tome što su trenutno cene vode i električne energije u Srbiji veoma niske. Međutim, uzimajući u obzir klimatske promene i sve više izražen efekat suše, kao i to da će cene vode i električne energije porasti, za očekivati je da će ova tehnika navodnjavanja naći svoju primenu u proizvodnji paradajza u Srbiji, kao i u drugim zemljama Jugoistočne Evrope. Preporuka je da se koriste sorte paradajza otporne na sušu.

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L) is the most widely grown vegetables in the world. Present world production of tomato is about 100 million tonnes fresh fruit from 3.7 million hectares. In the European Union, 17 millions tons fresh fruit are produced on 300,000 ha [5]. Tomato is also one of the most widely grown vegetable in the South East European region and production varied from 1.464.844 t in Greece and 640.785 t in Romania to 152.052 t in Serbia and 48076 in Croatia [6]. Water supply is essential for successful production of this culture, but the water requirement depends of environmental conditions and soil type, phase of ontogenesis etc. However, in many countries including these of South East European region, as a consequence of global climate changes and environmental pollution, water use in agriculture is reduced.

Use of deficit irrigation strategies, especially regulated deficit irrigation (RDI) is one of the actions that were suggested to save water for irrigation [4, 2]. RDI is a method that irrigates the entire root zone with an amount of water less than the potential evapotranspiration during whole or specific periods of the crop cycle [3]. RDI can also reduce yield and for optimal application of RDI plant and soil water status must be monitored in order to maintain plant water regime within the certain degree of water stress that could not limit yield. This is the major difficulty when RDI is applied in the field conditions [20]. However, if RDI is managed carefully the negative impact on yield could be avoided, WUE increased and farmer's profit maintained or even increased [7].

The aim of presented paper was to investigate the effects of RDI on yield, yield quality and irrigation water use efficiency (IWUE) of tomato grown polytunnel conditions. The potential of RDI for saving water in commercial polytunnel or glasshouse conditions has been relatively unexplored so far. To avoid drought effect on yield, tomato growers often over-irrigate plants and they receive much more water that they need. This could have damaging effects on crop development and yield and also increase risks of pests and diseases development. In such scenario the RDI strategy could be a viable practice to control damaging effects and to save water for irrigation. RDI studies also demonstrated that responses to this technique vary significantly among crop species and cultivars [2]

and therefore in presented paper we compared the reaction of two tomato cultivars to RDI under polytunnel conditions. Although RDI application for tomato irrigation has been widely studied, mainly in the controlled and field conditions, the profitability of RDI technique in commercial condition of tomato growing is largely unknown. Thus, the objective of our paper was also to investigate the economic implication of RDI method in polytunnels.

MATERIAL AND METHODS

Polytunnel experiment

Two tomato experiments were carried out during 2006 and 2007 in a commercial polytunnels, located 10 km north of Belgrade. Planted tomato (*Solanum lycopersicum* L.) cultivars were Cedrico F1 and Abellus F1 (Rijk Zwaan, Netherland). Polytunnel design was typical for Serbia with the size of 400 m^2 (width 8 m and length 50 m), covered with polyethylene folia and unheated. Tomatoes were grown on loam-clay soil with field water capacity of 0.356 $m^3 m^{-3}$ and a wilting point of 0.188 $m^3 m^{-3}$. Seeds were sown at the end of February and uniform tomato plants were transplanted into polytunnel soil at the end of April. Plants were planted in single rows each having 90 plants of 50 cm spacing in rows. When plants were in the phenological phase of the first truss formed (middle of May), FI and RDI were applied. The irrigation was done by the drip system between the middle of May and the end of August, when plants were in the growth stage 88 [8]. Plants in FI treatment were irrigated every two or three days and RDI plants received 60% of the water that was applied to FI. Irrigation timing and the amount of supplied water in FI and RDI treatments were calculated in accordance to the SWC measured by the profile probe (PR2/6, Delta-T Device, Ltd, UK).

Measured parameters

From both investigated species yield and yield quality data were collected at harvest as well as data for calculation of irrigation water use efficiency (IWUE). Tomato fruits were harvested when the stage of ripeness had been reached. Their diameter was measured using digital vernier callipers (Digimatic ABSolute Caliper Series 500, Mitutoyo Ltd., UK). Soluble solids, expressed as °Brix, were measured by using a Reichert hand-held refractometer (Reichert Analytical Instruments, Depew NY). Titrable acidity was determined by titration with NaOH [12] and expressed as µmol citric acid.

The irrigation water use efficiency (IWUE), was used to evaluate comparative benefits of the irrigation treatments. IWUE was calculated as the ratio between yield (expressed as FW of fruits) and the amount of water used for irrigation. During investigated season for irrigation of Cedrico plants under FI it was used 1,566 m^3 ha^{-1} H_2O, while for RDI 823, 5 m^3 ha^{-1} H_2O. The amounts of water for irrigation of Abellus were smaller (1,350 and 795 m^3 ha^{-1} for FI and RDI, respectively).

Economic evaluation

The economic evaluation included the results for cultivars Cedrico and Abellus, and also results for trialed in the similar experimental conditions cultivar Amati during 2006 year [17]. Economic evaluation was similar to the analyses done by Romero et al. [16] and Perez-Perez et al. [14]. Costs were divided into fixed operational costs and variable costs. Fixed costs consisted of: preparation and planting in polytunnel, tomato seeds, application of fertilizers and phytosanitary products, herbicides and labor payment (staff). Variable costs included cost of water for irrigation and cost of electricity for irrigation pumps. Cost of the initial investment in construction of polytunnel, overhead cost, cost for irrigation equipment (drip lines, tank for fertilizer and irrigation pump) and machinery for carrying out related agricultural tasks were not taken into consideration. Labour cost was 1.50 € h^{-1} and the price of the water was 0.33 € m^{-3} [19]. The cost of electricity for pumping water (0.043 € m^{-3}) was according to Ørum et al. [22] calculated on the basis of total energy use (0.36 kW m^{-3}) and the cost of energy in Serbia (0.12 € kW h^{-1}). Calculation of the energy use for irrigation involved several components as operating time, the water flow in drip systems, efficiency of motor and pump and distance from water source to the field or to the polytunnel. The tomato price used for calculation was 0.54 € kg^{-1} for Cedrico and Abellus and 0.57 € kg^{-1} for Amati [19]. Profit was calculated by subtracting the total production costs (fixed and variable) from total income.

Statistical analyses

Mean values of investigated traits were compared between the two irrigation treatments with the Student's t-test (Sigma Plot 6.0 for Windows - SPW 6.0, Jandel Scientific, Erckhart, Germany) and differences have been deemed statistically significant at 5 and 1 % probability level.

RESULTS

In presented experiments the significant saving of water for irrigation of both cultivars was achieved under RDI comparing to FI (743 and 555 m^3H_2O ha^{-1} for Cedrico and Abellus, respectively). Comparison between investigated cultivars showed differences in both treatment. Under both FI and RDI, Abellus cultivar had a higher shoot dry weight, while the number of fruits and fruit fresh weight and final yield were significantly lower comparing to the Cedrico (Table 1 and 2).

Table 1. Investigated traits in tomato cultivar Cedrico grown in polytunnel under full irrigation (FI) and deficit irrigation (RDI)
Tabela 1. Ispitivani parametri kod sorte Cedrico gajene u uslovima plastenika i navodnjavane sa punom normom (FI) i redukovanim navodnjavanjem (RDI)

Traits	FI	RDI
Shoot DW per plant	78.0	84.5
Number of fruits per plant	40.45	37.45
Average fruit diameter (mm)	60.39	60.23
Fruit FW (kg per plant)	5.52	5.30
Fruit DW (g per plant)	212.8	214.6
Soluble solids (^{o}Brix)	5.44	5.40
Titrable acidity (citric acid μmol g^{-1} FW)	31.70a	41.80b
IWUE (kg $m^{-3}H_2O$ ha^{-1})	47.6a	83.6b

Means bearing uncommon letter(s) in a column varied significantly at 5 % level

The effects of RDI on plant growth, yield and fruit characteristics also differed between investigated cultivars. Results for Cedrico showed that RDI irrigation did not have a significant effect on both shoot growth or fruit growth (Table 1). Shoot dry weight, the number of harvested fruits per plant, fruit diameter, fruit FW and DW mass and final yield has not been significantly different from FI treatment. On the contrary, in Abellus shoot growth was significantly reduced under RDI, as well as fruit diameter and fresh weight. Fruit number and fruit dry weight was not significantly reduced under RDI (Table 2).

Table 2. Investigated traits in tomato cultivar Abellus grown in polytunnel under full irrigation (FI) and deficit irrigation (RDI)
Tabela 2. Ispitivani parametri kod sorte Cedrico gajene u uslovima plastenika i navodnjavane sa punom normom (FI) i redukovanim navodnjavanjem (RDI)

Traits	FI	RDI
Shoot DW per plant	182. 5a	133.1b
Number of fruits per plant	35.3	34.2
Average fruit diameter (mm)	65.2a	57.7b
Fruit FW (kg per plant)	4.10a	3.70b
Fruit DW (g per plant)	214.1	199.0
Soluble solids (^{o}Brix)	5.5a	7.7b
Titrable acidity (citric acid μmol g^{-1} FW)	30.5	26.0
IWUE (kg $m^{-3} H_2O$ ha^{-1})	47.4a	63.2b

Means bearing uncommon letter(s) in a column varied significantly at 5 % level

The fruit quality data for Cedrico did not show significant differences between RDI and FI plants in total soluble solids content, but TA was increased under RDI (Table 1). Fruit quality results for Abellus plants showed an opposite change. The TA activity was similar in both treatments, although soluble solids were significantly increased under RDI (Table 2). In both cultivars, the IWUE was significantly increased under RDI comparing to FI (by 75% and 33% for Cedrico and Abellus, respectively).

In order to relate the financial requirements of the RDI and FI techniques to a production basis and profit, the economic analyses were done for Cedrico and Abellus, and also for previously trialed cultivar Amati [17]. Fixed and variable costs of both techniques and final profit were compared to justify profit of RDI technique for three tomato cultivars (Table 3). Comparison between RDI and FI showed that the biggest reduction of the fixed operating costs under RDI treatment for all investigated cultivars was for labour (*ca.* by 16%) and fertilizers and phytosanitars (*ca.* by 28%). In all experiments variable costs under RDI were significantly reduced comparing to FI due to the saving of about 38% of the costs for irrigation water and electricity. However, the variable costs were a small proportion of total production costs under RDI, and therefore, comparison between FI and RDI did not show a big reduction of total production costs under RDI comparing to FI (only by 16% for Cedrico and 13% for Abellus and Amati). This could explain the small profit under RDI production for Cedrico (720 € ha^{-1}) and Amati (759 € ha^{-1}). Due to the yield reduction in Abellus, the profit under RDI was not achieved.

Table 3. Economic analyses for tomato cultivars Cedrico, Abellus and Amati production under full irrigation (FI) and deficit irrigation (RDI)
Tabela 3. Ekonomska analiza proizvodnje sorti Cedrico, Abellus i Amati u uslovima navodnjavanja sa punom normom (FI) i redukovanim navodnjavanjem (RDI)

Cost explanation	Cedrico		Abellus		Amati	
	FI	RDI	FI	RDI	FI	RDI
Fixed cost						
Preparation and planting (€ ha^{-1})	500	500	500	500	500	500
Seed (€ ha^{-1})	1,500	1,500	1,300	1,300	1,400	1,400
Fertilizers and phytosanitary products (€ ha^{-1})	1,500	1,080	1,500	1,080	1,500	1,080
Herbicides (€ ha^{-1})	600	600	600	600	600	600
Labour (€ ha^{-1})	1,861	1,568	1,600	1,505	1,656	1,489
Total fixed costs (€ ha^{-1})	5,961	5,248	5,500	4,985	5,656	5,069
Variable costs						
Irrigation - total water costs (€ ha^{-1})	517	272	445	262	460	258
Irrigation - total energy costs (€ ha^{-1})	67	35	58	34	60	33
Total variable costs (€ ha^{-1})	584	307	503	296	520	291
Total production costs (€ ha^{-1})	6,545	5,555	6,003	5,281	6,176	5,360
Income						
Yield (t ha^{-1})	74.5	74.0	59.00	55.9	48.7	48.6
Price (€ kg^{-1})	0.54	0.54	0.54	0.54	0.57	0.57
Total income (€ ha^{-1})	40,230	39,960	31,860	30,186	27,759	27,702
Profit (€ ha^{-1})	33 ,685	34,405	25,857	24,905	21,583	22,342

DISCUSSION

Our results confirm that with RDI strategy it is possible to save water for irrigation and increase IWUE without significant reduction of yield (Table 4). Such significant increase in IWUE is in line with RDI studies for tomato cultivars [10, 21]. However, there is some discrepancy concerning the results about RDI effects on tomato yield. Results of Jensen et al. [9] for fresh tomato grown in field conditions, showed similarly to our results for Cedrico, and earlier for Amati [17], that under RDI yield and yield quality might be sustained. Similarly to our results for Abellus, in the literature, there are also results showing that RDI reduced yield of tomato [15, 10, 21]. According to the Polupol et al. [15] drought during tomato flowering or fruit-set phases may induce abortion of flowers. Consequently, the lower number of fruits is produced and the tomato yield is reduced.

The key to the RDI strategy is the timing of the application that depends on the phenological stage and on the severity of the stress imposed. Recently, Jensen et al. [9] suggested new RDI irrigation guidelines for tomato. For fresh tomato grown in the field full irrigation is needed until the crops are well established (until the first truces are developed), and then RDI should start. In the first two weeks RDI should be applied to save 15-20% of FI, then water saving by RDI could increase to 30% of FI and, finally, in the last 14 days of the tomato growth period RDI could be applied to save 50% of FI irrigation. For processing tomato RDI should be applied later (at the 4-5th cluster). Similar RDI scheduling for irrigation of field grown processing tomato was also suggested by Patane and Cosentino [13].

In both of our experiments the irrigation started in the vegetative phase of tomato growth that is according to Srinivasa et al. [18] less sensitive to water stress than the reproductive phase. Thus, different reaction of our investigated cultivars to RDI might be explained by different sensitivity of these cultivars to drought. Such conclusion is supported by data which showed that under RDI the shoot DW in Abellus was reduced by *ca*. 30 %, as well as the number and FW of fruits (*ca.* 12%) comparing to FI (Table 2). Such tendency of growth reduction under RDI was not asserted for Cedrico cultivar (Table 1), as well as for Amati [17]. These results indicated that cultivar Abellus is more susceptible to drought than Cedrico and Amati.

In general, yield quality data of our experiments showed that under RDI the fruit quality parameters were sustained or even increased comparing to FI treatments (Table 1 and 2). Under RDI the TA was increased in the fruits of Cedrico, while the soluble solids were increased in Abellus fruits. Similar results were also obtained in other experiments [11, 17].

In literature, there are a lot of reports concerning the economics of managing RDI to different agricultural crops but mainly for semiarid regions [16, 14]. According to Ali et al. [1] economic benefit of RDI is derived from three factors: increased irrigation efficiency, reduced cost of irrigation and the opportunity costs of water. Our results showed under RDI a significant reduction in the costs of water and electricity used for irrigation comparing to FI (Table 3). However, due to the relatively low prices of water for irrigation and electricity in Serbia, the reduction in total production costs under was not big. For comparison the prices of water were by 10%, 44% and 90% higher in Montenegro, FYR Macedonia and Bosnia & Herzegovina, respectively. Similar differences between Serbia and these South East European countries were also for electricity prices. The profit depends also on yield prices that are among lowest in South Eastern Europe. The low price of agricultural products in Serbia is also the result of low labour cost (1.50 € h^{-1}). This could allow Serbian farmers to sell their products at a more competitive market price. Product prices also varied within the year or year to year. The prices of tomato used in this study were the average for July and August 2007 (for Cedrico and Abellus) and 2006 (for cultivar Amati), but in October and November of the both years the prices were 66% higher. If tomato growing under RDI would be prolonged to longer period than four months, it will further increase profit and reduce irrigation costs.

CONCLUSION

Greater savings of water for irrigation, the increase in IWUE and the maintenance of yield in cultivars Cedrico, and earlier Amati indicate that RDI could be the more promising strategy for future irrigations of tomato than classical FI approaches. Results for Abellus cultivar indicated for tomato production under RDI should be used drought resistant tomato cultivars. Adoption of RDI technique would be especially helpful for tomato growers which often over-irrigate plants to avoid reduction of yield induced by increased temperature and evaporatranspiration in polytunnels during summer months. Due to the relatively low prices of water for irrigation and electricity in Serbia, the RDI strategy is not yet as profitable as it is in other countries. However, with the prediction of the more prevalent drought in Serbia and the whole South East European region, it could be expected that soon the pressure on limited water resources will be increased and consequently, water will become a more highly valued and accordingly priced resource. Under this concept, it could be expected that deficit irrigation will become an efficient alternative to classical irrigation for commercial tomato growing not only in polytunnels or glasshouses, but also in the field conditions.

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REFERENCES

[1] Ali M.H., Hoque M.R., Hassan A.A., Khair, A., Effects of deficit irrigation on yield, water productivity and economic returns of wheat. Agric. Water Manage. (2007) 92: 151-161.

[2] Costa M., Ortuno M.F., Chaves M.M., Deficit Irrigation as a Strategy to Save Water: Physiology and Potential Application to Horticulture. J. Integ. Plant Biol. (2007) 49 (10): 1421–1434.

[3] English M.J., Raja S.N., Perspectives on deficit irrigation. Agric. Water Manage. (1996) 32: 1-14.

[4] FAO, Deficit Irrigation Practices. FAO, Rome, Italy., Water Reports (2002): No. 22.

[5] FAO, FAO statistical databases. Agriculture Data Collection. FAO, Rome, Italy., http://faostat.fao.org, 2006.

[6] FAOSTAT, Food and Agriculture Organization of the United Nations. Commodity trade by country., http://faostat.fao.org/site/339/default.aspx, 2007.

[7] Fereres E., Soriano M.A., Deficit irrigation for reducing agricultural water use. J. Exp. Bot. (2007) : 58, 147–159.

[8] Hack H., Gall, H. Klemke Th.,. Klose, R Meier U., Stauss R., and Witzenberger A., The BBCH scale for phonological growth stages of tomato (*Solanum lycopersicum* L), in: Meier, U. (Eds.), Growth Stages of Mono and Dicotyledonous Plants. BBCH Monograph, Federal Biological Research Centre for Agriculture and Forestry, 2001.

[9] Jensen C.R., Battilani A., Plauborg F., Psarras G., Kostas C., Janowiak F., Stikic R., Jovanovic Z., Li G., Qi X., Liu F., Jacobsen S.E., Andersen M.N., Deficit irrigation based on drought tolerance and root signalling in potatoes and tomatoes. Agric. Water. Manage. (2010): 98, 403–413.

[10] Kirda C., Cetin M., Dasgan H.Y., Topcu S., Kaman H., Ekici B., Derici M.R., Ozguven A.L., Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation. Agric. Water Manage. (2004): 69, 191-201.

[11] Mitchell J.P., Shennan C., Grattan S.R., May D.M., Tomato fruit yields and quality under water deficit and salinity. J. Am. Soc. Hort. Sci. (1991): 16, 215-221.

[12] OIV, Compendium of international methods of wine and must analyses. OIV, Paris. 1992.

[13] Patane S., Cosentino S.L., Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. Agri. Water Manage. (2010): 97, 131-138.

[14] Perez-Perez J.G., Garcıa J., Robles J.M., Botıa P., Economic analysis of navel orange cv. ‘Lane late’ grown on two different drought-tolerant rootstocks under deficit irrigation in South-eastern Spain. Agric. Water Manage. (2010): 97, 157-164.

[15] Pulupol L.U., Behboudian M.H., Fisher K.J., Growth, yield and post harvest attributes of glasshouse tomatoes produced under deficit irrigation. Hort Sci. (1996): 31, 926–929.

[16] Romero P., Garcıa J., Botia P., Cost–benefit analysis of a regulated deficit-irrigated almond orchard under subsurface drip irrigation conditions in Southeastern Spain. Irrig. Sci. (2006): 24, 175-184.

[17] Savic S., Stikic R., Jovanovic Z., Vucelic-Radovic B., Paukovic M., Djordjevic S., Deficit irrigation strategies for production of tomato in greenhouse conditions. Proceedings of the 46th Croatian and 6th International Symposium on Agriculture, Opatia, Croatia (2011): pp. 567-570.

[18] Srinivasa R.N.K., Bhatt R.M., Sadashiva A.T., Tolerance to water stress in tomato cultivars. Photosynthetica (2000): 38, 465–467.

[19] Statistical Office of the Republic of Serbia., http://webrzs.stat.gov.rs/axd/en/index.php, 2007.

[20] Stikic R., Savic S., Jovanovic Z., Jacobsen S.E., Liu F., Jensen C.R., Deficit irrigation strategies: use of stress physiology knowledge to increase water use efficency in tomato and potato, in: Sampson, A.N. (Eds.), Horticulture in 21st Century. Series: Botanical Research and Practices, Nova Science, Publishers, NY, USA, 2010, pp. 161-178.

[21] Zegbe-Domínguez J.A., Behboudian M.H., Lang A., Clothier B.E., Deficit irrigation and partial rootzone drying maintain fruit dry mass and enhance fruit quality in “Petopride” processing tomato (*Lycopersicon esculentum,* Mill.). Sci. Hort. (2003): 98, 505-510.

[22] Ørum J.E., Boesen M.V., Jovanovic Z., Pedersen S.M., Farmers’ incentives to save water with new irrigation systems and water taxation-A case study of Serbian potato production. Agric. Water Manage. (2010): 98, 465-471.