UDC 631.674:635.64

Vjekoslav TANASKOVIKJ, Ordan CUKALIEV, Mile MARKOSKI,
Bojan SRDJEVIC, Velibor SPALEVIC, Ivan SIMUNIC,
Milena MOTEVA and Nevenka DJUROVIC [1]

THE INFLUENCE OF IRRIGATION AND DRIP FERTIGATION REGIME ON SPECIFIC WATER CONSUMPTION AND EVAPOTRANSPIRATION COEFFICIENT IN TOMATO CROP PRODUCTION

SUMMARY

The research experiment aimed at estimation of the influence of irrigation and drip fertigation on the specific water consumption (SWC) and evapotranspiration coefficient (ET_k) of tomato in Skopje region, Macedonia. Different irrigation and fertigation regimes were applied to the tomato hybrid Optima, grown in an open field. Five different irrigation and fertilization regimes were performed. The first three of them were drip fertigation in every 2, 4 and 6 days, respectively (B1, B2 and B3), the fourth one was drip irrigation with conventional application of fertilizers (Ø1), while the last one was furrow irrigation with conventional application of fertilizers (Ø2). Based on the average values of the SWC, a conclusion is derived that there is no significant difference between the treatments B1 and B2. The treatment B3 indicated 12-15% higher SWC in comparison with B2 and B1, i.e. around 38 $l\ kg^{-1}$ more. This result is considered statistically significant. The control treatment Ø1 induced almost 20% higher SWC in comparison with the treatment of the same irrigation regime but with different fertilizer application schedule (B2). In addition, the effect of the irrigation techniques applied on SWC has been analysed by comparing the results from the control treatments Ø1 and Ø2. The use of water per kg of tomato was 46.5% higher in comparison with the one obtained from Ø1. The results are statistically significant at 0.05 level of probability. Similar results were obtained for ET_k, e.g. the lowest value of the average evapotranspiration coefficient was obtained in treatment B1 and the highest one - in the control treatment Ø2; an increase of 84% was in favour of Ø2.

Keywords: drip fertigation, furrow irrigation, conventional application of fertilizers, specific water consumption (SWC), evapotranspiration coefficient (ET_k)

---

[1] Vjekoslav TANASKOVIKJ (corresponding author: vtanaskovic@zf.ukim.edu.mk), Ordan CUKALIEV, Mile MARKOSKI, University St. Cyril and Methodius, Faculty of Agricultural Sciences and Food, Skopje, MACEDONIA; Bojan SRDJEVIC, Faculty of Agriculture, University of Novi Sad, SERBIA; Velibor SPALEVIC, Institute of Forestry, Podgorica, MONTENEGRO; Ivan SIMUNIC, University of Zagreb, Faculty of Agriculture, Zagreb, CROATIA; Milena MOTEVA, University of Architecture, Civil Engineering and Geodesy & Research Institute of Soil Science, Agrotechnologies and Plant Protection "N. Pushkarov", Sofia, BULGARIA; Nevenka DJUROVIC, University of Belgrade, Faculty of Agriculture, Zemun, Beograd, SERBIA.

Note: The author declare that they have no conflicts of interest. Authorship Form signed online.

INTRODUCTION

Specific water consumption (SWC) is defined as the water quantity consumed for producing a unit yield by a crop. This parameter presents the ratio between the total for the vegetation season evapotranspiration (ET) and the obtained fresh yield (fruits). Generally, SWC has great importance in agricultural practice because it indicates the real (in economic terms) value of water while irrigation is applied to the field. In other words, it may help to identify how and when to irrigate and fertilize in order to achieve the highest yield at the lowest water use (Cukaliev, 1996; Tanaskovik, 2005; Tanaskovik et al., 2013). Till today, SWC was estimated in several crops in Republic of Macedonia like: sugar beet (Cukaliev, 1996; Jankuloski, 2000), alfalfa (Iljovski, personal communication, 2001), tomato (Petrevska, 1999; Iljovski, personal communication, 2001; Tanaskovik, 2005), green pepper (Cukaliev, personal communication, 2003; Tanaskovik, 2013), etc. Also, some authors practice water use efficiency (WUE) as a parameter for determination of efficiency of the irrigation and fertilization techniques applied on water consumption by crop (Phene et al., 1989; Papadopoulos 1996; Halitligil et al., 2002; Sagheb et al., 2002; Iljovski et al., 2003; Tanaskovik 2005; Tanaskovik, 2011; Tanaskovik, 2013). The main differences between WUE and SWC concern the parameters used for estimation. Namely, WUE is defined as a ratio between the total fresh or dry biomass (fruit, leaves, stem) and water used by the crop (ET) (Phene et al., 1993; Prihar et al., 2000).

Determination of proper irrigation scheduling for the agricultural crops has great importance for efficient agricultural production. As it is well known, there are several direct and indirect methods for estimation of evapotranspiration. Some of these methods, such as soil water balance (for direct estimation) and hydro-phyto-termal coefficient (for indirect estimation) were used by some authors from Macedonia for investigations of different crops like: hop (Iljovski, 1982), sugar beet (Cukaliev, 1996; Jankuloski, 2000), tomato (Tanaskovik, 2005), green pepper (Tanaskovik, 2013), etc. In this research, results for tomato crop ET_k, which can be applicable in further estimation of evapotranspiration in similar regions are presented. Otherwise, the evapotranspiration coefficient presents the ratio between the evapotranspiration and the total dry matter yield of the crop (fruit, leaf, stem and root system).

The combination of micro irrigation techniques with application of fertilizers through the system is a common practice in modern agriculture. Recently, the farmers in the Republic of Macedonia widely use the micro irrigation techniques to increase their crop yields. Still, there are problems especially related to the irrigation scheduling, water use efficiency, as well as to the proper use of fertilizers when drip fertigation practice is used (Tanaskovik et al., 2011)

Therefore, the main objective of this study was to determine the specific water consumption and the evapotranspiration coefficient (ET_k) in tomato crop production under different techniques and regimes of irrigation and fertigation, as well as to evaluate the evapotranspiration and the yield as affected by the methods of application of water and fertilizers.

MATERIAL AND METHODS

The field experiment was conducted in the period May-September 2003 and 2004 calendar years. The experiment was carried out in an experimental field near the Faculty of Agricultural Sciences and Food in Skopje (42° 00' N, 21° 27' E). The investigated crop was tomato (*Lycopersicon esculentum* Mill.), hybrid cultivar Optima. The soil type was colluvial (deluvial) soil (FAO Classification). The soil chemical characteristics are presented in Table 1.

Table 1. Soil chemical characteristics of the experimental field

Layer cm	$CaCO_3$ %	Organic matter %	pH		Available N mg/100 g soil	Available forms mg/100 g soil	
			H_2O	**KCl**		**P_2O_5**	**K_2O**
0-20	**3,24**	**0,90**	8,00	7,00	2,80	33,46	30,44
20-40	**3,80**	**0,84**	8,10	6,90	2,07	12,03	14,42
40-60	**3,59**	**0,56**	8,10	7,00	2,41	12,03	9,21

According to the literature data for the region, tomato planted in an open field in similar condition yields up to 80 t ha^{-1} (Tanaskovik, 2011). Tomato crop nutrient uptake for an 80 t ha^{-1} harvest totals approximately: N 260 kg ha^{-1}, P_2O_5 160 kg ha^{-1} and K_2O 320 kg ha^{-1}. The application of the fertilizer for the treatments was done in two portions (before planting and during the growing season), which is a common practice in Macedonia. For all treatments, the first portions of the fertilizers were applied before the planting. The rest quantity of the fertilizers needed for achieving the targeted yield were applied through the fertigation system in the drip fertigation treatments, and by conventional fertilizer application in the control treatments (divided into two portions, given at the flowering stage and at fruit formation). All investigated treatments have received the same quantity of fertilizers but by different methods of application (Table 2). This approach enabled us to quantify the impact of the different irrigation and fertigation regime on SWC and ET_k of the tomato crop.

Table 2. Type and amount of fertilizers in drip fertigation, in 2003-2004

N 268	P_2O_5 164	K_2O 320	kg/ha	N:P:K	
50	50	50	330 kg/ha	15:15:15	before replanting
/	93	60	179 kg/ha	0:52:10	drip fertigation
21	21	210	525 kg/ha	4:4:40	drip fertigation
197	/	/	428 kg/ha	46:0:0	drip fertigation
268	164	320			

Note: same amounts and quantity of fertilizers were used in the control treatments Ø1 and Ø2 (spread in 2 portions)

A drip irrigation system with integrated compensating drippers and a discharge of 4 l h^{-1} was installed. The fertigation equipment used for the drip fertigation treatments was Dosatron 16, with a plastic barrel as reservoir for the concentrated fertilizer. The discharge of the stock nutrient solution into the drip irrigation system averaged 1% of the total water discharge. The source of water was of high quality (municipal water supply system for the city of Skopje). The irrigation of the experiment was scheduled according the long-term average daily evapotranspiration of tomato in Skopje area (Table 3). The long-term average evapotranspiration was calculated by FAO software CROPWAT for Windows 4.3 using crop coefficient (K_c) and the stage length adjusted for local condition by the Faculty of Agricultural Sciences and Food. Since the drip irrigation was applied only to a part of the total surface, the daily evapotranspiration of the drip irrigation treatments was 20% decreased (coefficient of the coverage). The furrow irrigation treatment (Ø2) received the full irrigation rate.

Table 3. Daily and monthly crop water requirements for tomato crop for the Skopje region

Months	V	VI	VII	VIII	IX
mm/day	2	4	6	5.0	3
mm/monthly	62	120	186	155	90

The experimental treatments were set up according to the daily evapotranspiration rate. The idea was to investigate irrigation and fertigation regime and their effect on SWC and ET_k, as well as on crop yield and crop potential evapotranspiration (ETP):

Treatment 1 (B1). Drip irrigation according to daily evapotranspiration with fertigation in every 2 days

Treatment 2 (B2). Drip irrigation according to daily evapotranspiration with fertigation in every 4 days

Treatment 3 (B3). Drip irrigation according to daily evapotranspiration with fertigation in every 6 days

Treatment 4 (Ø1). Drip irrigation according to daily evapotranspiration in every four days and conventional fertilization (spreading of fertilizer on soil) (control 1)

Treatment 5 (Ø2). Furrow irrigation according to daily evapotranspiration in every seven days and conventional fertilization (spreading of fertilizer on soil) (control 2)

The size of each plot (replication) was 7.2 m^2 (18 plants in 0.8 m spacing between the rows and 0.5 m plant spacing in the row). Each plot (replication) was designed with three rows of crop. There were six plants in each row. The fresh yield in our investigation was collected from all tomato plants in each treatment and replication, while dry tomato matter was represented by two experimental plants in the middle of the experimental row from each treatment and replication. All the material from these two plants was collected (leaves, steam, fruits and root system) and the yield of the fresh and dry weight (at 70^{o}C for 48 hours, FAO/IAEA sample preparation techniques of biological material for isotope analysis) was measured. These results were used for SWC and ET_k estimation.

The ratio between ETP and the fresh tomato yield (fruits) represents SWC, while the ratio between ETP and the total dry matter (fruit, leaves, steam and root system) represents ET_k. ETP was determined by the soil water balance method using direct measurements of soil moisture in the soil layer 0-100 cm (Cukaliev 1996; Allen et al., 1998; Bošnjak, 1999; Dragović, 2000; Iljovski and Cukaliev 2002; Evett 2007; Tanaskovik, 2013).

The data collected were subjected to statistical analysis of variance and means were compared using the least significant difference (LSD) at the 1 and 5% level of probability ($P<0.01$ and $P<0.05$) test.

RESULTS AND DISCUSSION

The meteorological conditions during the research

The tomato crop needs a lot of heat during the whole growing period. If temperature is below 15°C the flowering stops and if temperature drops below 10°C the growth stops. The optimal temperature for growing tomato is 18-25°C during the day time and 15-16°C during the night. The average seasonal temperature for the experimental site (average in the growing period) during 2003 and 2004 was 22.2°C and 20.5°C respectively (Table 4). During the most intensive fructification period (June-August) the average temperatures over the two experimental seasons were within the optimum values.

Table 4. Monthly and growing season temperature, precipitation and relative humidity for Skopje region for the period 2003-2004

Year	2003	2004	2003	2004	2003	2004
Month	Average air t (°C)	Average air t (°C)	Precipitation (mm)	Precipitation (mm)	Relative humidity (%)	Relative humidity (%)
V	18.1	15.3	69.0	42.3	60	65
VI	23.8	21.3	62.3	55.2	57	65
VII	25.2	24.1	2.3	61.4	51	56
VIII	26.2	23.0	11.5	16.1	49	57
IX	17.7	18.8	/	14.7	64	62
Total/Average	22.2	20.5	145.1	189.7	56	61

It is well known that tomato is most sensitive to water shortage (drought) during the flowering and fruit formation. In that period, Skopje area has the highest temperatures and insolation, and consequently the evapotranspiration is highest as well. Usually, rainfalls are minimal in that period. Data presented in the Table 4 shows that the year 2004 was very humid with a lot of rainfalls during the growing season (250.3 mm in 2004) which is rather unusual for the Skopje region and the major vegetable production regions in Macedonia. Especially unusual were the rainfalls in the period July 2004. This created favourable conditions for plant diseases. Year 2003 was close to the long-term averages. May and June in 2003 had slightly higher rainfall totals in comparison with the reminder of the growing period. In the period of most active yielding there was a severe shortage of water coupled with very high temperatures, and thus fertigation in 2003 had much higher effect on the measured parameters.

Tomato crop is characterized as a tolerant crop to low relative air humidity, even though the optimal values are of the order of 55-65%. During the research period, the average relative humidity was close to the optimal values.

The influence of irrigation and drip fertigation regime on SWC & ET_k

The main parameters for estimation of SWC and ET_k are ETP and the fresh crop yield (fruits) or total dry matter (fruit, leaves, stem and root system). As was mentioned above, evapotranspiration was determined by direct measurement with soil water balance method over the soil layer 0-100 cm (Cukaliev 1996; Allen et al., 1998; Bošnjak, 1999; Dragović, 2000; Iljovski and Cukaliev 2002; Evett 2007; Tanaskovik, 2013), under permanent content of soil moisture and nutrients, as well as permanent agro-technical measures. Monitoring of soil water income during the vegetation period and the active soil moisture at the end of vegetation period was used in this estimation. The soil water income was determined by estimation of the initial or active soil moisture at the beginning of vegetation (Wi), the irrigation water requirements (I) and the effective precipitation during the vegetation period (P). The initial or active soil moisture at the beginning of vegetation period was calculated as a difference between momentary soil moisture (MSM) and permanent wilting point (PWP). Cukaliev (1996) reported same method for estimation of the initial or active soil moisture at the beginning of vegetation period. Irrigation water requirements (I) for all treatments were read on the volumetric meter; with periodic soil samplings for controlling of momentary soil moisture and irrigation regime. The effective precipitation (P) was calculated as 50% from total precipitation during the vegetation period. The difference between the water contents relevant to MSM and PWP at the end of vegetation is the active soil moisture at the end of the vegetation period (We). The potential evapotranspiration (ETP) was determined by the equation: ETP= (P+I+Wi)-We. The average results for water balance and ETP for period 2003-2004 are presented in Table 5.

Table 5. Water balance and ETP (m^3/ha) for the period 2003-2004

Treatment	Wi	P	I	Total income	We	ETP	Comparison with B1 (%)	Comparison with B2 and Ø1 (%)
B1	679.0	1125.0	3516.0	5320.0	795.5	4524.5^a	100.0	/
B2	679.0	1125.0	3516.0	5320.0	770.5	4549.5^a	100.6	100.0
B3	679.0	1125.0	3516.0	5320.0	650.5	4669.5^b	103.2	102.6
Ø1	679.0	1125.0	3516.0	5320.0	770.5	4549.5^a	100.6	100.0
Ø2	679.0	1125.0	4834.5	6638.5	643.0	5995.5^c	132.5	131.8

*Values in rows followed by the same letter are not significantly different at the 0.05 probability level

The results for ETP in Table 5 show negligible differences between the treatments B1, B2 and Ø1, which comes from the closer irrigation intervals of these three treatments. Statistically, there is no significant difference in ETP. On the other hand, as a result of longer application intervals, the treatment B3 (drip fertigation in every 6 days) shows higher ETP in comparison with B1, B2 and Ø1. The results are statistically significant at 0.05 level of probability. The effect of drip fertigation on ETP is presented by the results obtained in treatments B3 in comparison with furrow irrigation and conventional application of fertilizers (Ø2). Namely, in almost the same irrigation intervals, the treatment B3 obtained around 28.4% lower ETP compared with Ø2. The results are statistically significant. The effect of irrigation techniques on ETP is presented by comparison of the results in the control treatments. As a result of the influence of the irrigation techniques, the control treatment Ø1 shows 31.8% lower ETP than the control treatment Ø2. The difference is statistically significant. The ETP results in our investigation are similar to those recommended by Doorenbos et al., (1986) - from 400 to 600 mm. Tanaskovik (2005) and Tanaskovik et al. (2013) reported similar results for the influence of irrigation and fertilization techniques on ETP on tomato hybrid Carla and green pepper crop production. Also, in late tomato production in Strumica region, Cukaliev et al., (2007) reported almost 34% lower ETP in drip fertigation treatment at 4 days in comparison with furrow irrigation treatment at 10 days and conventional application of fertilizers.

The fresh yield in our investigation was collected from all tomato plants in each treatment and replication, while dry tomato matter was represented by two experimental plants in the middle of the experimental row from each treatment and replication. These results were used for estimation of SWC and ET_k. In Table 6 and 7 are presented results for SWC and ET_k of tomato crop.

Table 6. Average results of fresh tomato yield and specific water consumption for Skopje region during the period 2003-2004

Treatment	ETP m^3/ha	Fresh yield-fruits (t/ha)	Specific water consumption (l/kg)	Comparison with B1 (%)	Comparison with B2 (%)
B1	4524.5^a	136.5^a	33.1^a	100.0	
B2	4549.5^a	133.8^a	34.0^a	102.6	100.0
B3	4669.5^b	123.0^b	38.0^b	114.6	111.7
Ø1	4549.5^a	111.5^c	40.8^c	123.1	119.9
Ø2	5995.5^c	100.3^d	59.8^d	180.4	175.8

*Values in rows followed by the same letter are not significantly different at the 0.05 probability level

From the fresh tomato yield (fruits) results presented in Table 6, can be concluded that there is no statistically significant yield difference between treatment B1 (136.5 t ha^{-1}) and treatment B2 (133.8 t ha^{-1}). The yield at the six-day fertigation frequency (B3) is significantly less than those of two- and four-day fertirigation frequencies respectively. Phene et al. (1989) reported better tomato yields at high-frequency subsurface and surface drip irrigation (206 t ha^{-1} and 190 t ha^{-1} respectively) in comparison with low frequency surface drip irrigation (179 t ha^{-1}). Yield difference between treatments with identical irrigation frequency of four days (B2 and Ø1) confirms that, if in the growing season portion of the fertilizer is applied trough the drip irrigation system (B2), the yield is around 20% higher than that obtained by conventional spreading of similar fertilizer quantity (Ø1). A number of other investigators reported higher yields in tomato crop when the fertilizers were injected through the drip system in comparison with the conventional application of the fertilizers (Phene, 1995; Papadopoulos 1996; Pan et al., 1999; Sagheb and Hobbi, 2002; Tanaskovik 2005; Cukaliev et al., 2007; Cukaliev et al., 2008; Tanaskovik et al., 2011). The effects of irrigation techniques on the tomato yield are presented by the yield difference between the control treatments Ø1 and Ø2. Namely, the control treatments Ø1 show a statistically significant yield difference from the treatments Ø2.

According to the average results for SWC of tomato crop presented in Table 6, it can be concluded that the most economical water use or 33.1 litter of water per kilogram produced tomato fruits is obtained in treatment B1. The treatment B2 shows almost 3% higher consumption than treatment B1 or 34 l kg^{-1}, and the results are not statistically significant. Treatment B3 has almost 12 and 15% higher water consumption for producing one kilogram tomato fruits in comparison with B2 and B1. The results are statistically significant at 0.05 level of probability. The control treatment of drip irrigation and conventional application of fertilizers (Ø1) shows 19.9% higher SWC in comparison with the treatment of the same irrigation regime but with different application of fertilizers (B2). Our results show high influence of fertilization techniques on the SWC of tomato crop. The effect of the irrigation techniques on the SWC is presented by the comparison of the results of the control treatments with drip irrigation and conventional application of fertilizers (Ø1) and of furrow irrigation and conventional application of fertilizers (Ø2). Namely, control treatment Ø2 shows almost 60 litter of used water per kilogram tomato yield or 46.6% higher value in comparison with Ø1. The results are statistically significant at 0.05 level of probability.

Table 7. Average results of total dry matter of tomato crop and evapotranspiration coefficient for Skopje region, during the period 2003-2004

Treatment	ETP m^3/ha	Total dry matter yield (t/ha)	ETk	Comparison with B1 (%)	Comparison with B2 (%)
B1	4524.5^a	11.8^a	383.4^a	100.0	
B2	4549.5^a	11.3^a	402.6^a	105.0	100.0
B3	4669.5^b	10.2^b	457.8^b	119.4	112.7
Ø1	4549.5^a	9.4^c	484.0^c	126.2	119.1
Ø2	5995.5^c	8.5^d	705.4^d	184.0	173.6

*Values in rows followed by the same letter are not significantly different at the 0.05 probability level

Petrevska (1999) in a three-year investigation of tomato crop proved that the treatments with drip fertigation have the lowest and the most economical SWC, while the treatment with furrow irrigation and classical fertilization have the highest value. Tanaskovik (2005) also presented high positive effect of drip fertigation on SWC, while the most economical treatments are those of 2- and 4-day drip fertigation. Similar to our results are presented for green pepper crop by Cukaliev (personal communication, 2003) and Tanaskovik (2013).

From the results in Table 7 can be concluded that the total dry matter yield under drip fertigation (B1, B2 and B3) shows a statistically significant difference from those of the control treatments Ø1 and Ø2. The total dry matter yield shows the same pattern as a fresh fruit yield, which would once again indicate yield increase with simultaneous application of water and nutrients through the drip irrigation system. Sagheb and Hobbi (2002) reported that with the same quantity of fertilizer but different methods of application, drip fertigation shows about 2.7 times more total dry matter in comparison with treatment with furrow irrigation and conventional spreading of fertilizers on soil.

The obtained results for evapotranspiration coefficient (ET_k) were 383.4, 402.6, 457.8, 484 and 705.4 respectively. Treatments B1 and B2 show statistically significant difference from treatment B3. The differences can be considered as a result from the drip fertigation frequencies. Tanaskovik (2013) in his three-year investigation with green pepper crop, reported lower ET_k in treatments with 2- and 4-day drip irrigation and fertigation frequency in comparison with lower drip irrigation and fertigation frequency (irrigation scheduled by tensiometers or approximate at 6-8 days). The influence of drip fertigation on ET_k varies from 54% in treatment B3 up to 84% in treatment B1. The results are statistically significant at 0.05 level of probability. This can be attributed to the wasteful water application and lower yield obtained by the conventional irrigation (Tanaskovik et al., 2011). The effect of irrigation techniques on ET_k is presented by the comparison of the results from the control treatments Ø1 and Ø2. Namely, the control treatment Ø2 shows almost 48.7% higher ET_k in comparison with Ø1. Petrevska (1999) and Tanaskovik (2005) reported similar results in drip fertigation tomato crop in comparison with furrow irrigation and conventional application of fertilizers.

CONCLUSION

The results for ETP showed negligible differences between the treatments B1, B2 and Ø1. Statistically, there is no significant difference in ETP. On the other hand, as a result of longer application intervals, the treatment B3 (drip fertigation in every 6 days) showed higher ETP in comparison with B1, B2 and Ø1. The results are statistically significant at 0.05 level of probability. In almost the same irrigation intervals, the treatment B3 obtained around 28.4% lower ETP compared to Ø2, which is as a result of the influence of the fertilizer application by drip fertigation. The results are statistically significant. The effect of irrigation techniques on ETP is presented by comparison of the results of the control treatments. As a result of the influence of the irrigation techniques, control treatment Ø1 showed 31.8% lower ETP, which is statistically significant than control treatment Ø2.

The highest average yields are achieved in treatment B1 (136.5 t ha^{-1}) and treatment B2 (133.8 t ha^{-1}), while the average yield in treatment B3 was almost 10.8 - 13.5 t ha^{-1} lower (123 t ha^{-1}). The results are statistically significant at 0.05 level of probability. The effect of drip fertigation is up to 36%. The treatments with drip fertigation show statistically significantly higher yield compared to furrow irrigation with conventional spreading of the fertilizer. The effect of drip irrigation on yield production is 11.2%. The results are statistically significant. The total dry matter yield shows the same pattern as a fresh fruit yield, which once again indicates yield increases due to simultaneous application of water and nutrients through the drip irrigation system.

The treatment B1 shows the most economical water use or 33.1 litter of water per kilogram produced tomato fruits, while the treatment B2 shows almost 3% higher water consumption than treatment B1 or 34 l kg^{-1}. The results are not statistically significant. The treatment B3 has almost 12 and 15% higher water consumption in comparison with B2 and B1. The effect of drip fertigation on the specific water consumption is up to 80%, while the effect of irrigation techniques is almost 47%. The results are statistically significant at 0.05 level of probability.

The treatments B1 and B2 show the best ET_k or 393 in average. The highest ET_k was achieved in treatment Ø2 - almost 706, which is a result of the improper irrigation and fertilization techniques. The effect of drip fertigation on ET_k is up to 84%, while the effect of irrigation techniques is almost 46%. Statistically, the results are significant at a 0.05 level of probability.

REFERENCES

Allen, G.R., Pereira S. L., Raes, D., & Smith, M. (1998): Crop Evapotranspiration (Guidelines for Computing Crop Water Requirements). *FAO Irrigation and Drainage Paper No.56,* 300 pp.

Bošnjak, Đ. (1999): *Irrigation of Agricultural Crops*. University of Novi Sad, Faculty for Agriculture, Novi Sad.

Cukaliev, O. (1996). *The Effect of Pulse Irrigation on Sugar Beet Yield and Quality in the Skopje Area*. Ss. Cyril and Methodius University, Faculty of Agriculture, Skopje. (Ph.D. thesis)

Cukaliev, O., Iljovski, I., & Tanaskovikj, V. (2007): *Application of drip fertigation in vegetable production and possibility for automation.* Ministry of Agriculture, Forestry and Water Management of the Republic of Macedonia and International Fund for Agricultural Development, Skopje, Macedonia.

Cukaliev, O., Tanaskovik, V., Kanwar, R. S., Heng Kheng Lee., & Mukaetov, D. (2008): Irrigation and fertigation effects on nitrogen use efficiency & tomato yield. *International Agricultural Engineering Journal* 17 (1-4), pp.19-26.

Doorenbos J., Kassam, A.H., Bentvelsen, C.L.M., Branscheid, V., Plusje, J.M.G.A., Smith, M., Uittenbogaard, G.O., & Van Der Wal, H.K. (1986): Yield response to water. *FAO Irrigation and Drainage Paper 33*, FAO/UN, Rome.

Dragović, S. (2000): *Irrigation*. The research Institute for Field and Vegetable Crops, Novi Sad.

Evett, S. (2007): Soil Water and Monitoring Technology. *Irrigation of Agricultural Crops*. Agronomy Monograph No.30. *In* Lascano, R. J., & Sojka, R. E. Eds. Second Edition, Madison, Wisconsin, USA.664 pp.

Halitligil, M.B., Akin, A.I., Kislal, H., Ozturk, A., & Deviren, A. (2002): Yield, nitrogen uptake and nitrogen use efficiency by tomato, pepper, cucumber, melon and eggplant as affected by nitrogen rates applied with drip-irrigation under greenhouse conditions. Fertirigation for improved water use efficiency and crop yield, IAEA-TECDOC-1266. *Water balance and fertigation for crop improvement in West Asia*. *In* Results of a technical co-operation project organized by the Joint FAO/IAEA/ Division of Nuclear Techniques in Food and Agriculture, pp. 99-110.

Iljovski, I. (1982): *The influence of irrigation at different soil moisture contents on yield and quality of hop in Pelagonija region*. Ss. Cyril and Methodius University, Faculty of Agriculture, Skopje. (Ph.D. thesis).

Iljovski I., & Cukaliev O. (2002): *Irrigation practice.* Faculty of Agriculture, Skopje, Macedonia, 166 pp.

Iljovski, I., Cukaliev, O., Mukaetov, D., Tanaskovik, V., & Jankuloski, Z. (2003): Application of fertigation for improved crop production and environment protection. In *Proceedings of the Ninth Symposium of Water Economy of the Republic of Macedonia*. Ohrid, R. Macedonia, pp. 235-242.

Jankuloski, Z., (2000): *The influence of irrigation and fertilization regime on evapotranspiration, yield and quality of sugar beet in Pelagonia region*. Ss. Cyril and Methodius University, Faculty of Agriculture, Skopje. (Ph.D. thesis)

Pan H.Y., Fisher K.J., & Nichols M.A. (1999): Fruit yield and maturity characteristics of processing tomatoes in response to drip irrigation. *Journ. Veget. Crop. Prod.* 5, pp. 13-29.

Papadopoulos, I. (1996): Micro-irrigation systems and fertigation. In *Sustainability of Irrigated Agriculture*. *In* L. S. Pereira *et al.*, eds. Kluwer Academic Publishers, pp. 309-322.

Petrevska, K. J. (1999): *Cultivation of tomato on inert substrates in protected area*. Ss. Cyril and Methodius University, Faculty of Agriculture, Skopje, Macedonia. (Ph.D. thesis)

Phene C.J., Davis K.R., McCormick R. L., Hutmatcher R. B., & Pierro J.D. (1989): Water-fertility Management for Subsurface Drip Irrigated Tomatoes. *Tomato and Pepper Production in the Tropics, International Symposium on Integrated Management Practices*, Tainan, Taiwan, pp. 323-338.

Phene, C. J., Hutmacher, R. B., Ayars, J. E. & Ben-Asher, J. (1993): Subsurface drip irrigation, A BMP for controlling drainage outflow and reducing groundwater contamination. Industrial and Agricultural Impact on the Hydrologic Environment. *In Proc. Second USA/CIS Conference on Environmental Hydrology and Hydrogeology*. *In* Y. Eckstein & A Zaporazec, Eds. Water Environment Federation, Alexandria, Virginia, pp. 51-69.

Phene, C. J., & Lamm, F.R. (1995): The sustainability and potential of subsurface drip irrigation. Microirrigation for a changing world conserving resources-preserving the environment. In *Proc. 5th Int. Microirrig. Congr.*, Orlando, Florida ASAE Publ 4, pp. 359-367.

Prihar, S. S., Gajri, P. R., Benbi, D. K., & Arora, V. K., (2000): *Intensive Cropping, Efficient Use of Water, Nutrients, and Tillage*. Haworth Press, Inc

Sagheb N., & Hobbi M.S. (2002): Field evaluation of urea fertilizer and water use efficiency by tomato under trickle fertigation and furrow irrigation in Iran. Fertirigation for improved water use efficiency and crop yield, IAEA-TECDOC-1266. *Water balance and fertigation for crop improvement in West Asia*. *In* Results of a technical co-operation project organized by the Joint FAO/IAEA/ Division of Nuclear Techniques in Food and Agriculture, pp. 3-13.

Tanaskovik, V. (2005): *The Effect of Drip Fertigation on Increasing of Tomato Yield*. University St's. Cyril and Methodius, Faculty of Agricultural Sciences and Food, Skopje, Macedonia. (MA thesis), pp. 103.

Tanaskovik, V., Cukaliev, O., D, Romić., & G., Ondrasek, (2011): The Influence of Drip Fertigation on Water Use Efficiency in Tomato Crop Production. *Agriculture Conspectus Scientificus, Vol.76*, No. 1, pp. 57-63.

Tanaskovik, V., Cukaliev, O., Jankuloski, Z., Markoski M., Iljovski, I., & Nechkovski, S. (2013): Determination of evapotranspiration under different irrigation and fertilization techniques in green pepper crop production. *In Proceedings of International Symposium for Agriculture and Food*, Skopje, Macedonia, pp.755-768.

Tanaskovik, V., Cukaliev, O., Spalevic, V., Markoski, Mile., & Nechkovski, S. (2013): The effect of irrigation and fertilization techniques on specific water consumption of green pepper. *In Proceedings of the* 1^{st} *International Congress on Soil Science, XIII National Congres in Soil Science, Soil-Water-Plant*, Belgrade, Serbia pp. 409-423.