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THE INFLUENCE OF IRRIGATION AND FERTILIZATION REGIME ON SOME PHENOLOGICAL STAGES AND EARLINESS OF PRUNED PEPPER

SUMMARY

The primary objective of this study was to identify the influence of irrigation and fertilization regime on some phenological stages and earliness of pruned pepper grown in plastic house. We applied four experimental treatments in this study. Three of the treatments were irrigated with drip irrigation and drip fertigation (KK1, KK2, KK3), while the last one was irrigated with furrow irrigation and conventional application of fertilizer ($Ø_B$). From the results obtained during the three years of investigation, we can conclude that treatments with drip fertigation frequency of every 2 and 4 days (KK1 and KK2) and drip fertigation scheduled by tensiometers (KK3) shows from 4 to 10 days earlier initial technological maturity in comparison with $Ø_B$. Results indicate that drip fertigation is an effective practice to achieve earlier yield. Namely, the drip fertigation treatments show from 19.34 to 38.89% higher earliness index compared with $Ø_B$. Similar results were obtained for marketable yield, e.g. the lowest yield was obtained in treatment $Ø_B$, while the highest one in treatment KK1.

Keywords: drip fertigation, furrow irrigation, conventional fertilization, pruned pepper

INTRODUCTION

Pepper is one of the most sensitive vegetables to external factors, especially to light, temperature, soil and air moisture (Bosland and Votava, 2000), as well as cultivation practices (Jovicich et al., 2004; Antony and Singandhupe, 2004; Sezen et al., 2006; Borges et al., 2014). Valšiková et al., (2004) indicate that pepper varieties have influence on duration of vegetation period. Burt et al., (1998) reported similar effect as result of the irrigation techniques. It is well known that vegetables as tomato, pepper and cucumber

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have successive harvest period (Tanaskovik et al., 2014; Đurovka et al., 2006; Lazić et al., 2001; Jankulovski, 1997). Therefore, despite the total yields, earliness has the great importance to obtain better economic effects by the farmers in the country, especially during the early and mid-season production. Till today, different cultivation practice were investigated for shortening the period from transplanting to the first's harvests in some vegetables in our country, as: use different pepper variety (Jankulovski, 1983), inert media combined with drip fertigation in tomato crop (Petrevska, 1999), drip fertigation of tomato crop (Tanaskovic, 2005), pepper pruning technology (Rusevski, 2005).

The official results in the Republic of Macedonia showed that average pepper yield is relatively low, about 18 t/ha (State Statistical Office 2014). Among other, the reasons for low productivity in the country are traditional cultivation practices or just partial use of modern technologies. So, Tanaskovik et al., (2011), reported problems related to wrong irrigation scheduling, as well as conventional use of fertilizers when drip irrigation practice is used. Considering the scarcity of water in many regions in the world, the economic management of water has become essential (Abbasian et al., 2014), so, the primary requirements for a successful water management are to reduce the amount of applied irrigation water (Altinok et al., 2015). Generally, under the present circumstances when the inputs into vegetables production increase more quickly than do the prices of vegetables, it is necessary to pay an extraordinary attention to nutrition (Varga and Ducsay, 2003). Wiertz et al., (1987) reported that water shortage can be more detrimental to pepper than nutrient deficiency.

However, estimates and results for influence of irrigation and fertilization techniques on some phenological stages and pepper yield earliness in our country are limited. Also, as was mentioned above, most of the techniques and production technologies in the country are used separately, even that there is real possibility to combining them and improving the productivity and earliness. Therefore, the main objectives of this research was to evaluate the influence of irrigation and fertilization regime on some phenological stages and earliness of pruned pepper ("V" system) grown in plastic house. Furthermore, the aim of this study is to evaluate the best irrigation and fertilization regime for increasing pepper yield productivity. The obtained results will help to pepper producers in the country and similar regions for higher usage of drip fertigation practice and pepper pruning technology in their fields.

MATERIAL AND METHODS

The field experiment was conducted with pepper (*Capsicum annum L. var. Bela dolga*) pruned at two main shoots ("V" system) and grown in experimental plastic house near by the Faculty of Agricultural Sciences and Food in Skopje (42^{o} 00' N, 21^{o} 27' E), during the period of May to October in 2005, 2006 and 2007. The soil chemical characteristics of the experimental field are presented in Table 1.

According to the recommendations and literature data for the region (Lazić et al., 2001; Jankulovski, 1997), pepper planted in our conditions and yields up to 60 t/ha need the following amount of nutrients: N 485 kg/ha, P_2O_5 243 kg/ha and K_2O 585 kg/ha.

Table 1. Soil chemical characteristics of the experimental field

Layer cm	$CaCO_3$ %	Organic matter %	pH		ECe dS/m	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	8.02	7.30	2.40	3.10	17.79	32.15
20-40	3.80	0.84	8.08	7.26	2.28	2.47	13.36	19.38
40-60	3.59	0.56	8.03	7.35	2.25	2.80	8.40	16.10

The application of the fertilizer for the treatments was done in two portions, what is common practice in our country. For all treatments, the first portions of the fertilizers was applied before transplanting, while the rest of the fertilizers were applied through the fertigation system for drip fertigation treatments (Table 2) and conventional fertilization of soil for the control treatment (spread in two portions, during the flowering and fruit formation). All investigated treatments have received same amount of fertilizers, but by different methods and frequency of application of water and fertilizers.

Table 2. Type and amount of fertilizers (kg/ha) used during the vegetation period in drip fertigation treatments

Type of fertilizers	Amount of applied fertilizer	Period of application
15:15:15	318 kg/ha	before transplanting
0:52:34	375 kg/ha	drip fertigation during the vegetation
0:0:51+18S	802 kg/ha	drip fertigation during the vegetation
46:0:0	952 kg/ha	drip fertigation during the vegetation

Remark: The same amounts and quantity of fertilizers were used for furrow irrigation treatment

The fertigation equipment for drip fertigation treatments was Dosatron 16, with a plastic reservoir where whole amount of concentrated fertilizer was dissolved. The irrigation of the experiment (treatment KK1, KK2 and $Ø_B$) was scheduled according long-term average (LTA) daily evapotranspiration of pepper in Skopje region (Table 3). The most suitable estimation method of evapotranspiration which could be used for irrigation scheduling of pepper crop is FAO modification of Penman (Orta, 1997). LTA crop evapotranspiration was calculated by FAO software CROPWAT for Windows 4.3 using crop coefficient (K_c) and stage length adjusted for local condition by the Faculty of Agricultural Sciences and Food. The daily evapotranspiration of drip irrigation treatments was decreased by 20% (coefficient of the coverage-application of the water only on part of the total surface).

The irrigation scheme used in the experiment was designed according to randomized block design for experimental purposes with four treatments in three replications. Generally, the experimental treatments were set up according to the daily evapotranspiration rate. The idea was to investigate not only irrigation and fertilization regime, but also irrigation and fertilization frequency and their effect on some phenological stages (initial flowering and initial technology maturity), earliness and pepper yield. Therefore, the follow experimental treatments were applied in this study: Drip fertigation according to daily evapotranspiration with application of water and fertilizer in every two days (KK1); Drip fertigation according to daily evapotranspiration with application of water and fertilizer in every four days (KK2); Drip fertigation with tensiometers (KK3) with recommendations undertaken by Tekinel and Kanber (2002); Furrow irrigation according to daily evapotranspiration with application of water in every seven days and conventional fertilization ($Ø_B$).

Table 3. Long-term average daily and monthly crop water requirements (mm) for pepper in Skopje region calculated by FAO software CROPWAT

Months	V	VI	VII	VIII	IX	X
mm/day	1.9	3.6	5.5	5.0	3.7	1.8
mm/monthly	59	108	171	155	111	54

The size of each plot (replication) was 6.6 m^2 (25 plants in 0.75 m of row spacing and 0.35 m plant spacing in the row). Each plot was designed with 5 rows of crop and 5 plants in each row. The pepper plants from middle row from each plot and treatment were used for determination of initial flowering and initial technology maturity. All plants from each plots and treatments were used for determination of earliness index and marketable pepper yield.

The plant pruning in all three years of investigations started when pepper plants were at least a foot tall. Lateral branch shoots were pruned to form a plant structure of “V” system (two main shoots). According to Jovicich et al., (2004), only flower on the branch node and its adjacent leaf were left when we pruned a main shoot. Therefore, during the vegetation period, every 10 or 15 days, all side shoots were removed on the main shoots similarly to the recommendations of Daşgan and Abak (2003). Tie system was used to support the plants because each shoot was pruned up to 2 m high.

Initial flowering was determined as period (days) from pepper transplanting to setting flowers at first four nodes, while initial technology maturity is period from transplanting to fruits formation at same nodes. In order to identify pepper yield earliness, the earliness index was determined. The earliness index was calculated as a ratio between the yields from the first four harvests of drip fertigation treatments and control treatment separately. Also, to present the effect of drip fertigation frequency on pepper yield earliness, the drip fertigation treatments were compared between them. Pepper fruits were harvested in technological maturity (physiologically immature) during the vegetation period. Generally, this is the main practice in the country, especially for pepper used for fresh consumption. Non marketable fruits (with defects or to small) were not taken in calculation of marketable yields.

Collected data of the earliness index and marketable yield were subjected to statistical analysis of variance and means were compared by using the least significant difference (LSD) at the 5% level of probability (P<0.05) test.

RESULTS AND DISCUSSION

The meteorological conditions during the research. The optimal temperature for growing of pepper in controlled environment is 21-30^{o}C during the day time and 17-18^{o}C during the night (Rylski and Spigelman, 1982).

The average seasonal temperature in the experimental plastic house during 2005, 2006 and 2007 was 22.83^{o}C, 22.95^{o}C and 24.1^{o}C respectively (Table 4). During the period of the biggest fructification (June-August) the average temperature in all three years was in the frame of the optimum values.

Table 4. Monthly average air temperature (^{o}C) for Skopje region (by National Hydro-meteorological Service) and in the experimental plastic house (by own measurements)

Year / Months	Average temperature (^{o}C) in Skopje region			Average temperature (^{o}C) in the experimental plastic house		
	2005	2006	2007	2005	2006	2007
V	18.0	17.8	18.6	20.9	20.5	21.6
VI	20.9	20.6	23.9	24.1	23.6	27.1
VII	24.1	23.4	27.1	28.2	27.2	31.0
VIII	22.1	23.3	25.1	26.1	26.9	28.9
IX	19.1	19.5	17.7	22.2	22.7	20.6
X	12.7	14.0	12.7	15.5	16.8	15.4
Average	19.48	19.77	20.85	22.83	22.95	24.10

Generally, the pepper water requirements during the vegetation period is quite big compared to other crops, what is result of the poorly developed root system (Bosland and Votava, 2000), large transpiring leaf surface and high stomata conductance of water vapour (Delfine et al., 2002). Also, it is well known that water deficit during the period between flowering and fruit development reduced the final productivity of pepper (Jaimez et al., 2000).

The Skopje region during the period flowering-fruit development is characterized with the highest temperatures and insolation, so the evapotranspiration has the highest rate.

As was mentioned above, the field experiment was conducted in plastic house, where precipitation does not have any influence on the crop water supply, which means that the total water income was presented by irrigation water.

Data for relative air humidity during the investigation are shown in Table 5.

Table 5. Monthly average relative humidity (%) for Skopje region (by National Hydro-meteorological Service) and in the experimental plastic house (by own measurements)

Year/ Months	Average relative humidity (%) in Skopje region			Average relative humidity (%) in the experimental plastic house		
	2005	2006	2007	2005	2006	2007
V	63	59	65	72	74	73
VI	56	64	56	63	71	61
VII	55	59	38	60	63	53
VIII	65	57	51	71	60	60
IX	68	60	58	74	66	68
X	71	70	75	81	80	83
Average	63	61.5	57.2	70.2	69	66.3

The influence of irrigation and fertilization regime on some phenological stages. It is well known that pepper crop set flowers throughout the whole vegetation period. When the plant has set several fruits, the rate of flower production decreases (Bosland and Votava, 2000). If pepper is harvested often in technological maturity, it can form more flowers in comparison to harvesting once or twice (Jankulovski, 1983). According to Rusevski (2005), pruned pepper has possibility for re-flowering, it means that pepper can form fruits and flowers again; even that harvest is previously done from the same nodes. Drip irrigation pepper had more number of branches, new nodes for flower and fruit development compared with surface irrigated (Antony and Singandhupe, 2004). According to the experiences from above mentioned authors, we have decided to observe only appearance of initial flowering and initial technology maturity in our investigation.

From the data presented in Table 6, it can be concluded that there are very small differences in initial flowering stage between the treatments in each investigation year, which may be related to the fact that all treatments were under same conditions until the beginning of the irrigation and fertilization regime (end of May). However, beside these small differences, treatments KK1 and KK2 show from 1 in 2006 to 3 days earlier initial flowering in 2005 and 2007 in comparison with $Ø_B$. As result of lower irrigation frequency (period between two consecutive irrigations is very similar and sometimes a bit longer compared with the control treatment), treatment KK3 show only 1 day difference in 2005 and 2007 in comparison with treatment $Ø_B$, while in 2006 there was no differences. Sezen et al., (2006) reported earlier date of occurrence of flowering, first fruit set and 50% flowering stages in lower than in higher irrigation frequencies of bell pepper. The statistically significant effect of drip fertigation treatments compared with furrow irrigation and conventional fertilization treatment was determined in initial technological maturity, where results show differences between 4 days in 2006 and 10 days in 2007.

Table 6. Transplanting date and appearance of some phenologycal stages (initial flowering and technology maturity) in pepper in 2005, 2006 and 2007

	KK1	KK2	KK3	$Ø_B$
Transplanting date in 2005	30.04.2005	30.04.2005	30.04.2005	30.04.2005
Initial flowering (in days after transplanting)	44^a	44^a	46^b	47^b
Technology maturity (in days after transplanting)	65^a	65^a	68^b	73^c
Transplanting date in 2006	28.04.2006	28.04.2006	28.04.2006	28.04.2006
Initial flowering (in days after transplanting)	44^a	44^a	45^a	45^a
Technology maturity (in days after transplanting)	66^a	66^a	69^b	73^c
Transplanting date in 2007	26.04.2007	26.04.2007	26.04.2007	26.04.2007
Initial flowering (in days after transplanting)	42^a	42^a	44^b	45^b
Technology maturity (in days after transplanting)	61^a	63^b	67^c	71^d

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

Burt et al., (1998) reported that drip irrigated peppers do not experience the moisture stress that furrow irrigated peppers experience between irrigations. This seems to allow more uniform growth rates without periods of starting and stopping. González-Dugo et al., (2007) reported that water stress delayed pepper fruit ripening. Similar results of ours, when drip fertigation indicated shortest periods of passing from one to another phenological stage in comparison with furrow irrigation and conventional fertilization of tomato crop are presented in studies of Petrevska (1999) and Tanaskovic (2005). Iljovski et al., (1996) indicated the positive effect of drip irrigation on initial ripening of tomatoes. When we compared drip fertigation treatments among them, we concluded that treatment KK3 shows delay by 3 days in 2005 and 2006 and by 4 to 6 days in 2007 compared with KK2 and KK1. The results are statistically significant at 0.05 level of probability.

The influence of irrigation and fertilization regime on earliness and marketable yield. The results of influence of irrigation and fertilization regime on pepper yield earliness are presented in Table 7. From the data presented in Table 7, it can be concluded that treatment KK1 achieved almost 39.00% higher yield during the same period compared with the treatment $Ø_B$. Slightly lower earliness index or nearly 7% compared with KK1 show treatment KK2. Anyhow, treatment KK2 achieves by 31% higher earliness index in comparison with $Ø_B$. In addition, we have found that treatments KK1 and KK2 are statistically significant at 0.05 level of probability in comparison with $Ø_B$. A positive effect of drip fertigation on pepper yield earliness is presented by comparison of the results of the treatments KK3 and $Ø_B$.

Table 7. Average pepper earliness index for the period 2005-2007

	KK1	KK2	KK3	$Ø_B$
Yield from first 4 harvests in t/ha	18.82[a]	17.75[a]	16.17[b]	13.55[c]
Yields from first 4 harvests compared with treatment $Ø_B$ (earliness index) in %	138.89	130.99	119.34	100
Yields from first 4 harvests compared with treatment KK3 (earliness index) in %	116.39	109.77	100	

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

Namely, drip fertigation treatment according to tensiometers measurements has realized 19.34% higher earliness index in comparison with control treatment. The results are statistically significant at 0.05 level of probability. This positive effect of KK1, KK2, and KK3 can be attributed of the strong influence of combined water and fertilizer application, with quantities and dosages according to the growth and development stages.

Tanaskovic (2005) emphasized the positive influence of drip fertigation on tomato earliness in comparison with conventional irrigation and fertilization. Daşgan and Abak (2003) indicated better early yield when combining drip fertigation and pruning pepper at 2 or 3 main shoots with 4.16 plants m^{-2} density in comparison with 3 or 4 main shoots and 2.78 plants m^{-2}. Also, proper substrate media combined with proper drip fertigation has a great importance on earliness of tomato crop (Petrevska 1999; Tzortzakis et al., 2008).

Furthermore, in the present study we have found that drip fertigation frequency affects earliness too. Namely, the treatments KK1 and KK2 show 16.39 and 9.77% % higher yield in first four harvests than KK3. The results are statistically significant at 0.05 level of probability.

The results in Table 8 show that the highest average marketable pepper yield of 71.11 t/ha has been realized in the treatment KK1, then comes the treatment KK2 with 68.40 t/ha or 2.71 t/ha less yield, and then comes the treatment KK3 with 62.61 t/ha or 8.5 i.e. 5.79 t/ha less yield when compared to KK1 and KK2. The lowest yield from 54.74 t/ha was noted in the control treatment ($Ø_B$).

Table 8. Average marketable pepper yields (t/ha) for the period 2005-2007

	KK1	KK2	KK3	$Ø_B$
Yield t/ha	71,11[a]	68,40[a]	62,61[b]	54,74[c]
Comparison with treatment $Ø_B$ in %	129,9	125,0	114,4	100
Comparison with treatment KK3 in %	113,6	109,3	100	

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

According to the data from Table 8, it can be seen that all three treatments with drip fertigation show statistically significant differences at 0.05 level of probability when compared to the control treatment. The effect of drip fertigation on better pepper yield is due to the continuous intake of the readily available water and nutrients in the small volume of soil, from where they are actively extracted by the plant. Haynes (1985) reported that if nutrients are applied outside the wetted soil volume they are generally not available for crop use. Antony and Singandhupe (2004) reported better yield in drip irrigated pepper crop than in surface irrigated.

Generally, our results for pepper yields are consistent with a number of other investigations with different vegetable crops and where fertilizers were injected through the drip system in comparison with conventional application (Tanaskovik et al., 2011; Cukaliev et al., 2008; Halitligil et al., 2002; Al-Wabel et al., 2002; Castellanos et al., 1999; Petrevska 1999; Papadopoulos, 1996). In similar growing density (3.8 plants m^{-2}) with those in our investigation, but same drip fertigation regime in all investigated treatments, Jovicich et al., (2004) reported higher yield of pruned pepper in 4 compared with 2 main shoots.

In other investigation, when same drip fertigation regime was applied in all treatments, Daşgan and Abak (2003) reported better total yield in pruned pepper with 2 or 3 main shoots and 4.16 plants m^{-2} density in comparison with 3 or 4 main shoots with 2.78 plants m^{-2}. Furthermore, our results show that if frequency between two applications of drip fertigation is higher than four days, the yield will significantly decrease, as result of decreased amount of readily available water in the soil. Sezen et al., (2006) in investigations with different irrigation regime in pepper reported the highest yield in treatment with drip irrigation frequency of 3 to 6 days, while in drip irrigation frequency from 6 to 11 days and 9-15 days yield decrease. Various researches reported better yields in pepper and other crops by using of high-frequency surface drip fertigation in comparison with low frequency drip fertigation (Tanaskovik et al., 2011; Tekinel and Kanber 2002; Oğuzer et al., 1991; Topçu 1988).

CONCLUSIONS

The results in this study clearly showed that when pepper is irrigated and fertigated with same amount of water and fertilizers, drip fertigation created better environment for initial flowering and initial technological maturity, yield earliness and increasing of marketable pepper yield than did furrow irrigation and conventional application of fertilizers. Also, the results in this study indicate that high frequency drip fertigation resulted in better initial flowering and technological maturity, higher earliness index and higher yielding compared with low frequency drip fertigation. Therefore, under similar pepper growing condition, drip fertigation of two to four days combined with two main shoots pruned pepper is the best option to achieve early and higher yield in order to increase farmer's income.

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