SOIL OSMOTIC AND MATRIC POTENTIAL IN A TOMATO IRRIGATED WITH AND WITHOUT PLASTIC MULCHING

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ABSTRACT: The aim of this study was to evaluate the soil osmotic potential and productive characteristics in a commercial tomato field irrigated with and without plastic mulch and two water depths. The experiment was developed in a commercial tomato field locate at Ingaí city, MG, Brazil. The experimental design was completely randomized in a 2x2 factorial with two types of soil mulch (without and with plastic mulch) and two water depths (167 mm and 206 mm) with six replications. The irrigation system used was drip and was cultivated salad tomato. The variables evaluated: osmotic potential, total and commercial yield and water use efficiency. Soil matric potential remained within the limits reported in the literature. In treatments with plastic mulch, the osmotic potential always remained higher to treatments without plastic mulch. There was interaction between the water depth applied and the soil mulch for the variables: total and commercial yield and water use efficiency. The largest applied water depth resulted in higher commercial yield of the tomato.
KEYWORDS: Drip irrigation. Water use efficiency. Electrical conductivity.

POTENCIAL OSMÓTICO E MATRICIAL DE ÁGUA NO SOLO DO TOMATEIRO IRRIGADO COM E SEM COBERTURA PLÁSTICA

RESUMO: Objetivou-se com este trabalho avaliar o potencial osmótico e as características produtivas do tomateiro irrigado com cobertura plástica e duas lâminas de irrigação. O experimento foi conduzido em uma lavoura comercial no município de Ingaí-MG. O delineamento experimental utilizado foi inteiramente casualizado, em esquema fatorial 2x2 com dois tipos de cobertura do solo (sem e com cobertura plástica) e duas lâminas de irrigação

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(167 mm e 206 mm) com seis repetições. O sistema de irrigação utilizado foi o gotejamento, sendo cultivado tomate italiano. As variáveis avaliadas: potencial osmótico de água no solo, produtividades total e comercial, número de frutos por planta e eficiência de uso de água. O potencial matricial se manteve dentro dos limites citados na literatura. Nos tratamentos com cobertura plástica, o potencial osmótico sempre se manteve maior nos tratamentos sem cobertura plástica. Houve interação entre a lâmina e a cobertura do solo para as variáveis: produtividades total e comercial e eficiência de uso de água. A maior lâmina aplicada proporcionou a maior produtividade comercial do tomateiro.

PALAVRAS-CHAVE: Gotejamento. Eficiência de uso de água. Condutividade elétrica.

INTRODUCTION

Tomato is the second most cultivated vegetable worldwide. According to the IBGE (2020), in the year 2019, the Brazilian production of tomatoes was over 4.076 million tons and Minas Gerais state was the third national producer with average yield of 74.64 t ha^{-1}.

In order to obtain high productivities and good fruit quality, appropriate technologies are needed, such as the soil mulch with plastic film, since it provides greater weed control, being ideal to be used with drip irrigation.

For vegetables, the use of plastic mulches has presented increase growth and productivity in several crops (CANTU et al., 2013; ALMEIDA et al., 2015; MEDEIROS et al., 2006). The soil mulch with polyethylene films increased the productivity of tomato (CAMPAGNOL et al., 2014; BRANCO et al., 2010), cabbage (BRANCO et al., 2010).

Monitoring the concentration of salts in soil solution is a practical technique that aims to control soil salinity and its interaction with culture development. The contribution of salts in solution to the total potential is quite significant especially in high productivity where we have high requirement of fertilization. These fertilizations make the osmotic potential an important component and cannot be neglected in estimating the total potential (LIMA, 1997).

Therefore, the aim of this study was to evaluate the osmotic potential and productive characteristics of irrigated tomato with and without plastic mulch under two water depths.

MATERIAL AND METHODS

The experiment was conducted from January to May 2017 in a commercial tomato field at Ingaí city, MG, Brazil, (21° 25’ 00.4” S and 44° 59' 14.5" W and 995 m altitude).

Precipitation during the experimental period was 283 mm. The soil of the area was classified as a red yellow latosol of clay texture. Fertilization were performed based on soil chemical analysis, following the recommendations for the crop.

The experimental design was completely randomized in a 2x2 factorial design with two types of soil mulch (without and with plastic mulch) and two water depths (167 mm and 206 mm) with six replications.

The irrigation used was the drip system with two drip models: first with flow rate of 1.3 $L.h^{-1}$ every 0.30 m and second: 1.6 $L.h^{-1}$ every 0.30 m, providing two different water depths at the end of the crop cycle a 167 mm and 206 mm.

Daily irrigations were performed to ensure the seedlings establishment. Irrigation management was performed using tensiometers installed at 0.20 m deep and the readings were performed by the employees at 7:00 am. The irrigation time was calculated using the average values from the tension (20 kPa).

The salad tomato variety BS II 0020® was used. The tomato seedlings were transplanted in double rows with spacing of 0.35 x 0.90 m and the corridors between the rows are spaced 2.80 m. The drip tubes were installed under the double-sided plastic film (white/black) with the white face upwards in the treatments with mulch.

Four extractors of soil solution were distributed in the plots, by treatment at 0.20 m depth. The soil solution was collected once a week, at the stage of fruit maturation, after 69 days after transplanting. The value of osmotic potential was determined from electrical conductivity of the soil solution (EC), as proposed by Richards (1954):

$$\Psi_{\mathrm{os}} = -36 \cdot \mathrm{EC}$$

where:

Ψ_{os}: osmotic potential, -kPa;

EC: electrical conductivity of the soil solution, dS m^{-1}.

Plants were conducted with single stem, training and sprouting. The control of diseases and pests was done following the conventional recommendations. Harvests started 69 days after transplanting and were performed according to the physiological fruit maturity.

The following variables responses were evaluated: a) soil matric potential (Ψ_m): obtained from the tensiometer readings located at 0.20 m depth in each plot, expressed in -kPa; b) soil osmotic potential (Ψ_{os}): estimated according to equation 1, expressed in -kPa; c) total yield: resulting from the product of the fruit average mass by the number of fruits per plant and the number of plants per hectare, expressed in t ha^{-1}; d) commercial yield: obtained by the difference between total yield and non-commercial yield; damaged fruits, including those with cracks, with blossom end rot or with insect damage were considered non-commercial, expressed in t ha^{-1}; e) water use efficiency: relation between commercial yield and total volume of water applied in each treatment; expressed in kg m^{-3}.

The data were submitted to analysis of variance and, when significant by F test, the means were compared by Tukey teste at the 5% probability level. Statistical analyses were performed using the software SISVAR version 4.6.

RESULTS AND DISCUSSION

The soil matric potential varied throughout the tomato development season (Figure 1A). It has remained within the limits cited in the literature; the recommendation is that irrigation should be started when the soil matric potential reaches between 20 and 40 kPa for tomato (MAROUELLI, 2008; HARTZ & HANSON, 2009; MORREIRA et al., 2012; RODRIGUES et al., 2016).

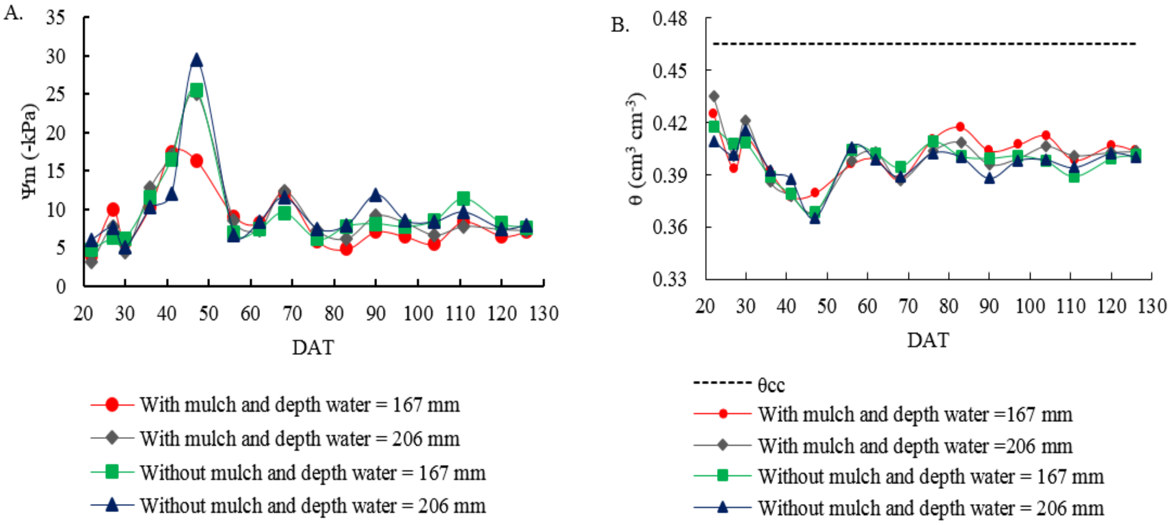

Figure 1. Soil matric potential (A) and soil moisture (B) observed during the experimental period.

The tomato is a vegetable with high water requirement, and soil moisture should vary slightly to avoid fruit cracking, apical rot, flower fall and occurrence of hollow fruits (ALVARENGA et al., 2013). It is observed that the water crop water requirement was supplied without great variations in the soil water content (Figure 1B).

Table 1. Summary of the analysis of variance for osmotic potential (-kPa) in 69, 77, 83, 90, 97, 104, 111, 120 e 126 days after transplant (DAT) of tomato

Source of variation	G.L	Mean squares								
		69 DAT	77 DAT	83 DAT	90 DAT	97 DAT	104 DAT	111 DAT	120 DAT	126 DAT
Soil mulch (SM)	1	105.06^{ns}	4924.88**	2426.55**	2141.52**	4604.98**	1191.46^{ns}	6376.42**	4996.02**	4896.85**

Depth water (DW)	1	0.17^{ns}	121.72^{ns}	622.75^{ns}	765.21^{ns}	129.56^{ns}	1188.01^{ns}	57.04^{ns}	0.18^{ns}	20.86^{ns}
SM x DW	1	764.25^{ns}	349.60^{ns}	11.73^{ns}	2243.68**	315.42^{ns}	385.63^{ns}	0.83^{ns}	154.32^{ns}	119.08^{ns}
SM x DW = 167 mm	1	-	-	-	4367.39**	-	-	-	-	-
SM x DW = 206 mm	1	-	-	-	0.81^{ns}	-	-	-	-	-
DW x With mulch	1	-	-	-	2814.75**	-	-	-	-	-
DW x Without mulch	1	-	-	-	194.14^{ns}	-	-	-	-	-
Error	12	201.443	80.235	154.856	167.415	317.767	515.329	199.320	345.889	224.094
Grand means		43.14	39.9	39.65	46.62	40.26	44.63	50.9631	55.4	64.56
C. V. (%)		32.9	22.45	31.38	27.75	44.28	50.87	27.7	33.57	23.19

**; * Significant at 1% and 5%, respectively, by the F test; ^{ns} = non-significant.

The osmotic potential was affected by the plastic mulch (Table 1). In the treatments with plastic mulch the osmotic potential always remained higher to treatments without plastic mulch (Table 2). The plastic mulch shows low permeability to the gases and vapors of water; hence the evaporation is almost null, disfavoring the ascending flow, which reduces the risk of salinization in the soil.

Table 2. Means for soil osmotic potential (-kPa) in maturation stage of the tomato in the soil without and with plastic mulch

Days after transplant	Without mulch	With mulch
69	45.70 a	40.58 a
77	57.45 a	22.36 b
83	51.97 a	27.34 b
97	57.23 a	23.30 b
104	53.26 a	35.00 a
111	70.93 a	31.00 b
120	73.07 a	37.73 b
126	82.05 a	47.06 b
90 DAT	Without mulch	With mulch
Water depth = 167 mm	63.07 aA	16.34 bB
Water depth = 206 mm	53.22 aA	53.86 aA

Averages followed by the lowercase latters in the columns and uppercase in lines not differ by F test ($p \leq 0.05$).

The tomato is a plant classified as moderately sensitive to salinity. The salinity effect in the tomato is characterized initially by leaf wilting in the hotter periods of the day, even when the soil with proper moisture (ALVARENGA et al., 2013).

There was also interaction between soil mulch and applied water depth in the total yield (Table 3). The highest yield was obtained when 206 mm of water was applied (Table 4).

Ngouajio et al. (2007) obtained a yield of 106.5 t ha^{-1} for tomato cultivated with irrigation under black plastic film. Branco et al. (2010) evaluated the productive performance of the tomato in different environments and observed that the tomato was more productive with mulching, regardless of irrigation method use. Campagnol et al. (2014) verified that the use of plastic mulch increased tomato yield by 11.75%.

According to Yuri et al. (2014), the use of soil plastic mulch maintains constant moisture content, favoring the microbial activity and greater mineralization of organic nitrogen, increasing the availability of this nutrient to the plants in the superficial layers of the soil, which may have contributed to the greater total yield in treatments with plastic mulch and higher applied water depth.

Table 3. Summary of the analysis of variance for the total yield (t ha^{-1}), commercial yield (t ha^{-1}) and water use efficiency (kg m^{-3}) for tomato

Source of variation	G.L.	Mean squares		
		Total yield	Commercial yield	Water use efficiency
Soil mulch (SM)	1	57.6290 ^{ns}	22.0992 ^{ns}	9.1390 ^{ns}
Depth water (DW)	1	400.7385 **	561.3435 **	0.1457 ^{ns}
SM x DW	1	81.5859 *	71.3805 *	23.4630 *
SM x DW = 167 mm	1	138.1765 **	86.4570 *	30.9444 *
SM x DW = 206 mm	1	1.0384 ^{ns}	7.0227 ^{ns}	1.6576 ^{ns}
DW x With mulch	1	421.9788 **	516.5344 **	9.9554 ^{ns}
DW x Without mulch	1	60.3457 ^{ns}	116.1896 *	13.6533 ^{ns}
Error	20	14.7499	16.4733	4.4867
Grand means		59.1	48.16	25.82
C. V. (%)		6.5	8.43	8.2

**; * Significant at 1% and 5%, respectively, by the F test; ^{ns} = non-significant.

Table 4. Averages of total and commercial productivity, and water use efficiency of tomato in the soil with and without mulch and under two water depths

	Total productivity (t ha^{-1})	
	Water depth = 167 mm	Water depth = 206 mm
With mulch	51.62 bB	63.48 aA
Without mulch	58.40 aA	62.89 aA
	Commercial productivity (t ha^{-1})	
	Water depth = 167 mm	Water depth = 206 mm
With mulch	40.64 bB	53.76 aA
Without mulch	46.01 aB	52.23 aA
	Water use efficiency (kg m^{-3})	
	Water depth = 167 mm	Water depth = 206 mm
With mulch	24.30 bA	26.12 aA
Without mulch	27.51 aA	25.37 aA

Means followed by the lowercase letters in the columns and uppercase in lines not differ by F test ($p \leq 0.05$).

There was interaction among the sources of variation in commercial yield (Table 3). Observing the 167 mm water depth, the soil without mulch produced higher commercial yield (Table 4).

In a study performed by Bogiani et al. (2008), the soil mulch with both white and black plastic did not affect the average yield of "Duradoro" tomato.

The increase in commercial yield due to higher water depths applied was also observed by Macêdo and Alvarenga (2005). The authors verified that the increase in the irrigation depth increased the yield of healthy and total fruits of "Bonus" tomato cultivated in a greenhouse environment. On the other hand, in a study developed by Monte et al. (2013), who studied cv. Débora under different water depths, no difference was observed in the commercial yield of tomato, with an average of 32.17 t ha^{-1}.

There was interaction among the factors in the water use efficiency (Table 3) being the largest WUE observed in the soil without mulch and 167 mm of water depth. The water depth variation did not interfere with the WUE (Table 4).

This result is not in agreement with Campagnol et al. (2014) study. They observed that the reduction of the irrigation depth associated to the use of black plastic film increased the water use efficiency in the tomato. Kalangu et al. (2012) also observed higher water use efficiency when smaller water depths were applied in the tomato.

CONCLUSION

The osmotic potential was higher in the treatments with plastic soil mulch. There was interaction between the water depths applied and the soil mulch for the variables: total and commercial yield and water use efficiency. The 206 mm of water depth resulted the highest commercial yield of tomato.

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