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IRRIGATION AND MULCHING MANAGEMENT FOR SWEET PEPPER CROP IN PROTECTED ENVIRONMENT

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1 ABSTRACT

This study was developed over the 1999-2000 agricultural years at the Rural Engineering Department of School of Agronomical Sciences, UNESP, Botucatu, SP, under protected environment. The objective was to evaluate the influence of irrigation and black polyethylene mulch management on the water use and fruit production of sweet pepper crop (Capsicum annuum L., Elisa Hybrid) 230 days after seedling transplant (DAST). The study was divided into two experiments: 1) application of the irrigation at -50 and -1500 kPa minimum soil water potentials with and without mulching on the soil, from 29 to 168 DAST. A randomized experimental design was used with six replications; and 2) severe water deficit in the soil through irrigation suspension and mulching removal (169 to 230 DAST). Drip fertigation was used and soil water was monitored by tensiometers and neutron probe. It was verified that: - the severe drought stress caused leaf senescence and abscission and significantly affected the production and quality of sweet pepper fruits and the Water Use Efficiency (WUE); - the fruit yield and number were higher in the treatments with mulching, therefore polyethylene mulching showed to be an efficient technique to reduce irrigation number and water volume applied. This efficiency was reduced with soil water content decreases based on fruit yield. Pepper plants showed good osmotic adjustment and, consequently, tolerance to water stress.

KEYWORDS: drought stress, polyethylene mulching, soil water potential

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2 RESUMO

O trabalho foi desenvolvido no ano agrícola 1999-2000, em casa de vegetação, no Departamento de Engenharia Rural da Faculdade de Ciências Agronômicas - UNESP, campus de Botucatu, SP. O objetivo foi estudar o efeito de diferentes manejos da água de irrigação e de cobertura de polietileno preto na superfície do solo sobre o consumo de água e produção de frutos da cultura do pimentão (*Capsicum annuum L,* híbrido Elisa), por um período de 230 dias após o transplante das mudas (DAT). O trabalho foi composto por dois experimentos: I) aplicação dos manejos da irrigação a 50 kPa e 1500 kPa, com e sem a presença de cobertura de polietileno preto sobre a superfície do

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solo, para o período de 29 a 168 DAT. O delineamento experimental foi inteiramente casualizado com seis repetições, e II) aplicação de deficiência hídrica severa no solo, através da suspensão das irrigações e retirada da cobertura de polietileno do solo, no período de 169 a 230 DAT. Concluiu-se que a deficiência hídrica afeta a qualidade e a produção dos frutos do pimentão. A utilização de cobertura de polietileno sobre o solo é técnica eficiente para reduzir a necessidade de irrigações e o volume de água a ser aplicado aos cultivos e sua eficiência é reduzida na medida em que diminui o conteúdo de água do solo. Houve significativa influencia no ajuste osmótico pela aplicação dos estresses hídricos nos tratamentos em que o potencial mínimo de água no solo atingiu 1500 kPa.

UNITERMOS: deficiência hídrica, potencial de água do solo, polietileno preto

3 INTRODUCTION

The production of vegetables in protected environments is suffering great transformations in the search for necessary modernization for improved yield and, consequently, the stay farmers in activity, of which requires great effort in the direction of identifying and eliminating the technological shortcomings.

The utilization of greenhouses, principally for vegetables and ornamental plants, increased greatly in the last years in different regions of country. The advantages of this closed or semi-closed systems are the protection against frost, excess of rainfall, continuous fall of temperature during the night; soil protection against lixiviation, cost reduction with fertilizers and defensive materials.

The water consumption inside the greenhouses is less than outside, mainly through the attenuation of incident solar radiation and lower wind speed. Therefore, when the cultivation is been done in the greenhouse, attention must be given to the environmental differences when compared to the cultivation in the open sky with respect to temperature, air relative humidity, solar radiation and, consequently, the evapotranspiration (Klar, 1988).

Among the difficulties inherent to irrigation products, the adoption of greenhouse presents lack of specific information from plant evapotranspiration in this protected environment. In this manner, in most times, the irrigation in the greenhouse is been done based on the practical sense of the irrigator.

Pepper is a crop very adapted to protect environment (Santos and al., 2003) and Batal and Smitle (1981) emphasize the high sensibility to soil water potential variation, and the water stress produces alterations on plant development with severe fruit yield and quality decreases beyond flower abscission. Buriol et al. (1996) showed that the polyethylene mulching produces evaporation reductions from the soil and better water use by plants. Van Derwerken and Wilcox-Lee (1988) verified reductions on commercial fruit percentages without polyethylene mulching.

This study had the main objective to determine the influence of soil water potentials and polyethylene mulching on the yield and quality of sweet pepper fruits under protected environment.

4 MATERIAL AND METHODS

The experiment was set up at the Agricultural Engineering Department, FCA/UNESP, Botucatu – SP, Brazil, 22º 51’ S Latitude and 786m Altitude. The soil was clay loam, classified as Utisol (Carvalho et al., 1983 and Embrapa, 1999); the bulk density was 1.45 to 1.48 g/cm^3 and the soil water characteristic curves were based on 7 points per depth (Table 1).

The climate, according to Köepen, is Cfa, mesotermic and humid, the rainfall and evapotranspiration averages are 1546.8 mm and 692 mm per year, respectively. The annual temperature average is 20.6 °C, and the maximum and minimum averages are, respectively, 23.5 and 17,4 °C.

An arched roof tunnel (27.5m length, 7.5m width and 3m height in the center) oriented to North/South, covered with polyethylene 150 □m thickness, was constructed. The lateral walls had 2m height and received “sombrite” screen curtains. A mobile transparent polyethylene curtain was placed on the lateral walls only for using during rainfall.

Pepper plants (*Capsicum annuum* L., hybrid Elisa) were sowed on November 03, 1999 and transplanted after 55 days, receiving fertilizers according to recommendations of Dept. of Soil Science – FCA/Unesp. Twenty four plots (2.0 m length x 1.0 m width) were used with plants spaced 0.50 m and 0.60 m between plants and rows, respectively, therefore, eight plants per plot.

Table 1. Soil water potential (Ψm) vs. soil water content at 0-15 and 15-30 cm depth.

	Ψ (kPa						
Depth (cm)	- 5	- 10	- 30	- 50	- 100	- 500	- 1500
a% (0-15)	0.290	0.254	0.212	0.196	0.189	0.168	0.161
a% (15-30)	0.320	0.306	0.265	0.247	0.233	0.190	0.166

In order to estimate the soil water potential, tensiometers were placed at 0.15m and 0.30m depth. Together with the tensiometers, the soil water content was controlled by neutron probe (Jadoski et al., 1999). Drip fertigation was used. A thermo hygrograph and Class A pan were set up in the center of the tunnel. Climatic data were obtained from automatic meteorological station about 400 m from the experiment.

Two experiments were conducted: 1) from 29 to 168 days after seedling transplanting (DAST). A randomized completed block design was used. Four treatments were applied, two minimum soil water potentials, -50 and -1500 kPa □□□with and without black polyethylene mulching on the soil: T_1: - 50 kPa with mulching; T_2: – 50 kPa without mulching; T_3: – 1500 kPa with mulching and T_4: – 1500 kPa without mulching; 2) The experiment 2 was started on June 14, 2000 and finished on August 14, 2000. The management was similar to the previous experiment, but the irrigation was suspended and the mulching was removed. Consequently, the plants were progressively submitted to water stress.

Several plant parameters were observed and measured. Four plants per plot were used for evaluating commercial fruit yield, number of fruits and fruit dimensions (length and width).

These last measurements were based on São Paulo (1998) – Table 2.

Table 2. Classification of pepper fruits according to Agriculture Secretary of S. Paulo State (1998)

Class	Length (cm)	Sub-class	Diameter(cm)
4	4 a 6	4	4 a 6
6	6 a 8	6	6 a 8
8	8 a 10	8	8 a 10
10	10 a 12	10	10 a 12
12	12 a 15	-	-

5 RESULTS AND DISCUSSION

Evapotranspiration

Six irrigations (90 mm water) were applied during 28 DAST. In relation to the experiment 1, the Fig 1 shows that the -1500 kPa treatments used only 48% water compared to – 50 kPa and the evapotranspiration means were 1,56 mm day^{-1} for –1500 kPa and 3,23 mm day^{-1} for –50 kPa treatment. Obviously, the resistances from soil and plants increase, following the soil water potential decreases. These results are similar to those obtained by Caixeta (1984).

The -50 kPa and –1500 kPa treatments with mulching showed 49.11% and 29.9% evapotranspiration reductions in relation to those without mulching, respectively. Obviously, the water economy was very significant because mulching maintains high soil water potentials, close to field capacity, for more time, which decreases the energy spending by plants to get water and nutrients. Rosemberg (1974) reported that black polyethylene mulching is one of the most effective barriers to reduce water losses through soil surface. The Figure 1 shows total water loss from the first experiment (29 to 168 DAST).

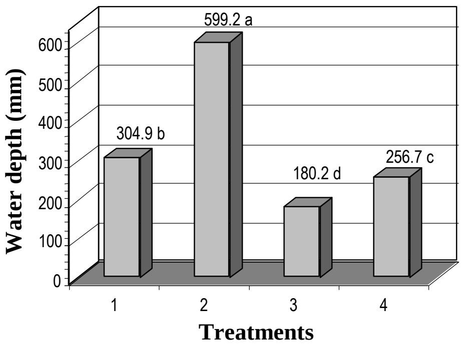

Figure 1. Total water depletion extracted from the different treatments from the experiment 1.

The irrigation was totally suspended in the experiment II (169 to 230 DAST), and the polyethylene mulching was removed. The soil water depletion is showed in the Figure 2. The Characteristic Soil Water Curve determined in the Richard plates showed that at –10 kPa and –1500 kPa, the soil water content was 24.5% and 15.2 % (based on dry soil weight) at 0 to 40 cm layer, respectively. The soil water depletion, in this layer, was started at day zero when the soil water potential was –10 kPa, roughly. After 37 days, it reached 15.2% and was 14.1% at day 63, corresponding to less than –1500 kPa soil water potential. The Characteristic Soil Water Curve showed that at –10 kPa and –1500 kPa, the soil water content was 24.5% and 15.2 % at 0 to 40 cm layer, respectively. The soil water depletion, in this layer, was started at day zero when the soil water potential was –10 kPa, roughly. After 37 days, it reached 15.2% and was 14.1% at day 63, corresponding to less than –1500 kPa soil water potential. Evidently while the soil water is decreasing, the energy expended by plants is increasing, phenomenon that involves stomata movement and other plant defenses. According to Larcher (1995), values lower than -1500 kPa are considered Permanent Wilting Point (PWP) for a great number of crops, and pepper plants are one of them, as this experiment demonstrated here. Several authors contest the PWP, as a rigid value, because several factors are connected to soil-plant-atmosphere system. The same reasoning can be applied to the Field Capacity (FC). However, both parameters, PWP and FC, have not physical significance, but are useful tools as reference points in various occasions (Klar, 1988).

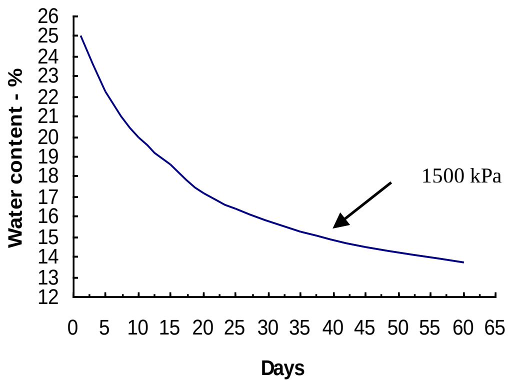

Figure 2. Water depletion from the experiment 2.

Production

Experiment 1

The production results are in the Table 3. The first harvest was done at 119 DAST and the last one, the ninth, occurred at 230 DAST. The final yield average of the treatment T_3 (-1500 kPa, with mulching) was 219% higher than T_4 (-1500 kPa, without mulching), 28,283 and 12,943 kg ha^{-1}, respectively. This last treatment was watered six times, while T_3, only four. Consequently, T_4 reached - 1500 kPa soil water potential two times more and expended more energy during the period studied to obtain water from the soil, therefore affecting the results. For the same reason, both treatments –50 kPa did not show statistical differences between them. A conclusion can be inferred: the higher temperature promoted by black mulching did not affect the production. However, the influence of high soil water potential was important factor to increase fruit yield; the –50 kPa treatments produced 118% more than the – 1500 kPa treatments.

Table 3. Production results for the experiments 1 and 2.

				Means of Treatments							
DAT	Total		CV%	T_1		T_2		T_3		T_4	
	Fruit number means										
		Exp 1									
119	1	1	50.76	0.900	A	0.3667	b	0.455	b	0.1467	b
133	2	2	36.28	1.171	Ab	1.4300	a	1.266	ab	0.5483	b
147	3	3	16.92	2.868	B	2.9167	b	3.853	a	1.5283	c
161	4	4	20.25	3.043	A	2.6767	ab	2.053	b	0.9450	c
175	5	5	8.99	2.901	B	2.9967	b	3.607	a	2.3233	c
	TOTAL		12.31	10.88	A	10.386	a	11.20	a	5.488	b
		Exp. 2									
189	6	1	6.25	1.400	B	2.6633	a	2.416	a	1.508	b
203	7	2	26.34	3.016	Ab	2.5600	b	4.205	a	3.288	ab
217	8	3	1024	2.216	A	1.200	a	1.333	a	1.233	A
230	9	4	95.07	0.450	B	0.1617	b	0.300	b	1.660	A
	TOTAL		24.54	7.083	A	6.582	a	8.255	a	7.690	A
	Fruit weight means										
		Exp 1									
119	1	1	34.72	120.3	A	103.19	a	72.26	ab	45.71	B
133	2	2	25.56	125.1	A	126.31	a	77.92	b	82.99	Ab
147	3	3	11.33	168.7	A	179.03	a	104.40	b	87.50	B
161	4	4	7.70	183.8	A	176.02	a	91.98	b	97.82	B
175	5	5	9.69	135.7	B	156.93	a	91.31	c	85.52	C
	TOTAL		10.61	146.7	A	148.29	a	87.57	b	79.90	B
		Exp. 2									
189	6	1	11.14	85.69	Bc	102.76	a	75.69	c	96.35	Ab
203	7	2	16.49	64.36	A	77.31	a	61.27	a	66.89	A
217	8	3	60.54	23.87	Ab	26.03	ab	18.67	b	52.81	A
230	9	4	101.2	14.16	Ab	4.33	a	1256	ab	33.13	A
	TOTAL		14.23	47.02	B	52.61	ab	42.21	b	62.30	A
	Yield ha^{-1} means										
		Exp 1									
119	1	1	67.25	3034	A	957	b	874	b	272	B
133	2	2	43.23	39556	A	4454	a	2707	ab	1183	B
147	3	3	23.17	12911	A	14018	a	10759	a	3631	B
161	4	4	18.14	14937	A	12545	a	5023	b	2490	B
175	5	5	11.79	10480	B	12524	a	8793	b	5365	C
	TOTAL		9.57	45324	A	44500	a	28183	b	12943	C
		Exp 2									
189	6	1	30.44	3265	B	7433	a	4870	b	3852	B
203	7	2	31.69	5334	A	5168	a	6862	a	5742	A
217	8	3	102.1	1718	A	1165	a	1357	a	1615	A
230	9	4	106.6	295	B	53	b	221	b	1730	A
	TOTAL		22.69	10614	A	13860	a	13311	a	12329	A
			Total yield in both experiments								
			6.81	55938	A	58361	a	41194	b	25272	C

(Values with the same letter are not statistically different by Tukey test – 5% probability)

The final average of fruit number also showed the same variation of fruit yield. The treatments – 50 kPa had similar behavior (10.88 and 10.39), but the treatment T_3 showed values

104% higher than T_4 (11.20 and 5.48 fruits, respectively). It was observed that a lot fruits fell from plants of treatment T_3 and T_4 promoted by water deficit, which is another form of plant defense against stress.

The fruit weight average did not show statistical difference between T_1 and T_2 and between T_3 and T_4. However, there was a tendency of T_3 to produce fruits 9.6% more weighed than T_4 (87.575 and 79.90 g per fruit, respectively), following the tendency of the yield and the fruit number. But both –50 kPa treatments produced 76% larger fruits than the –1500 kPa treatments. But, as occurred with these last treatments, also there were not significant differences between T_1 and T_2 (146.77 and 148.29 g per fruit, respectively).

Experiment 2

The Experiment 2 had the irrigation suspended and the mulching was removed at the end of the Experiment 1. Consequently, plants were progressively submitted to water stress until 230 DAST and the Table 3 shows no statistical variation among the treatments in relation to the fruit number and yield for this part of the study. The Table 3 shows an adaptation of plants from T_3 and T_4 to water stress. This behavior comes from the effort of plants to maintain the specie through osmotic adjustment, stomata mechanisms, etc. when submitted to water deficit (Klar, 1988). On the other hand, T_4 (-1500 kPa with mulching) presented significantly larger fruits than the treatments with mulching, which can be explained by the flower abscissions under water stress, according to Casali and Couto (1984).The total fruit number from T_3 and T_4 showed a tendency to produce higher values than T_1 and T_2, probably because the higher drought resistance acquired along the first experiment.

The total yield was not statistically significant among the treatments, but plants from T_1 showed a tendency to yield the lowest production, probably because the lowest osmotic adjustment and, consequently, lower drought resistance. This treatment always received all best watering and nutrition for the best development and was not morphologic and anatomic prepared to adverse conditions promoted by stresses, like water deficit.

The total fruit production from both experiments showed statistically similar values in T_1 (55,938 kg ha^{-1}) and T_2 (58,361 kg.ha^{-1}) and the smallest yield for T_3 (41,194 kg.ha^{-1}) and T_4 (25,2722 kg.ha^{-1}). The significant difference between these last two values (63%) showed the importance of the mulching use for this crop under stress conditions.

The Table 4 shows fruit classification, according to Table 2. The dimensions followed the same tendency of the observed results of fruit weight, consequently, plants from T_1 and T_2 showed higher weights and dimensions with classification 10 and subclass 6, one superior position in relation to plants from T_3 and T_4, which are classified as 8 and 4, respectively, showing that irrigation also influenced the fruit quality.

The results showed that the irrigation management affected the fruit yield and quality, according to Batal and Smittle (1991). O'Sullivan (1979) observed the sensibility of pepper to water deficit which reduces nutrient translocation to fruits, affecting the form and the size and, consequently, the fruit quality. Levitt (1972) and Heitholt et al. (1991) describe the productive process of plants in conditions of soil water deficit in connection to physiological activity, mainly related to osmotic adjustment.

This study showed the possibility to evaluate the Water Use Efficiency (WUE) by pepper plants through drip irrigation for the different treatments (Fig.3). T_1 presented the best WUE based on L/kg fruit for both experiments. The 90 mm of water applied during the first 28 DAST also were considered in the calculation. The WUE for the experiment 1 were 91, 161, 101 and 280 L/kg fruit and for the full cycle of the crop were: 74, 123, 69 and 140 L/kg for the treatments T_1, T_2, T_3 and T_4, respectively. However, the results showed that T4 had the greatest water use decrease on the experiment II which demonstrated significative osmotic adjustment of pepper plants utilized.

Table 4. Fruit classification for both experiments.

Harvests			Treatment averages							
DAT	Total	CV%	**T1**		**T2**		**T3**		**T4**	
Exp 1	*Fruit length*									
119	1	12,83	**10,5	a	**10,3	ab	*9,0	ab	* 8,5	B
133	2	11,47	** 11,7	a	**10,3	a	* 9,4	b	* 9,2	B
147	3	10,10	** 11,8	a	**11,6	a	* 9,2	b	* 9,2	B
161	4	19,54	***12,5	a	**12,0	a	* 8,3	b	* 9,9	ab
175	5	11,92	** 1,4	a	**11,5	a	* 9,0	b	* 9,1	B
Exp.2										
189	6	10,48	*9,4	a	*10,3	a	* 9,1	a	* 8,8	A
203	7	17,86	xx 7,9	a	*8,9	a	* 8,6	a	* 8,7	A
217	8	17,95	x 4,6	b	x 4,1	b	x5,1	b	* 8,0	A
230	9	13,04	x 4,3	b	x 4,2	b	x4,8	b	x 5,9	A
Exp. 1 *Fruit Diameter*										
119	1	12,83	5,8	a	5,2	ab	4,5	bc	4,1	C
133	2	11,47	4,9	ab	5,4	a	4,3	ab	4,2	B
147	3	10,10	6,5	a	6,7	a	4,3	b	4,0	B
161	4	19,54	6,5	ab	6,85	a	5,22	bc	4,87	C
175	5	11,92	6,0	a	6,42	a	4,17	b	4,90	B
Exp.2										
189	6	10,48	4,5	a	5,2	a	4,5	a	4,2	A
203	7	17,86	4,0	a	4,0	a	4,1	a	4,1	A
217	8	17,95	2,2	b	1,8	b	2,4	b	3,9	A
230	9	13,04	2,0	b	2,0	b	2,3	ab	2,7	A

10 (**); 12 (***) and subclasses 4 and 6 (S. PAULO , 1998).

However, these results, in isolate form, must be use with caution, including all factors involving fruit production and quality. Caixeta (1984) presented similar results for WUE: from 58 to 298 liters per kg of pepper fruit.

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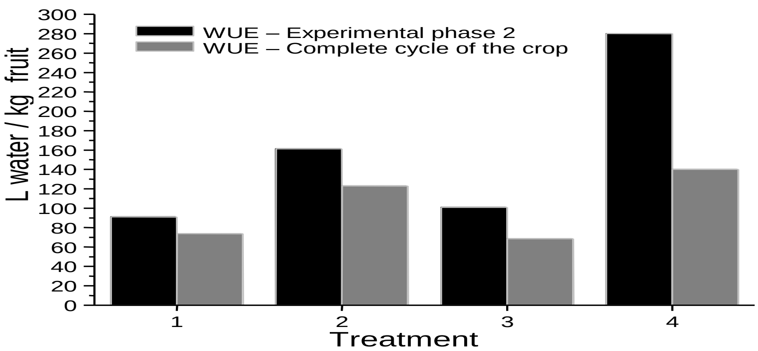

Figure 3. Water Use Efficiency (WUE) for both experiments

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6 CONCLUSIONS

The results allowed concluding: the Water Use Efficiency (WUE), the fruit yield and number were higher in the treatments with mulching; therefore polyethylene mulching showed to be an efficient technique to reduce irrigation number and water volume applied. This efficiency, based on water applied per fruit yield, is reduced with soil water content decreases. Pepper plants showed good osmotic adjustment and consequently tolerance to water stress.

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