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Yellow bell pepper production in greenhouse with mulching and irrigation

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ABSTRACT

Different irrigation depths and cover crops were compared in yellow bell pepper production, in order to establish a rational amount of water and suitable soil cover for yield and quality of bell peppers grown in a greenhouse. The experiment was conducted in Sao Manuel, SP, from May to December. The experimental design was randomized blocks with treatments in subdivided parcels, with four repetitions. In the parcels, it were analyzed the water depths, and in the sub-parcels the soil covers. Four water depth were utilized consisting of 120, 100, 80 and 50% of the volume of water transpired for the respective treatments. The irrigation control was made based on the evapotranspiration of class A tank. Soil crops cover were: C1 bare soil (control); C2 Soil coverage with cane bagasse; C3 ground cover with black polyethylene film; C4 ground cover with silver polyethylene film; C5 - ground cover with orange polyethylene film; and C6 - ground cover with green polyethylene film. Black and green plastic films provided higher soil temperatures, higher weed control, higher plant growth and increased productivity. Using plastic films to cover the ground water depths with 80% and 100% of water replacement had the highest yield.

Keywords: Solanaceae; *Capsicum annum*; irrigation; greenhouse; evapotranspiration.

INTRODUCTION

Bell pepper cultivation in the field is subject to adverse environmental conditions, especially the variation in rainfall, which can cause major losses of productivity and thus, cause a variation in prices at certain times of year.

Different methods can be used to irrigate a culture. However, the selection and use of a particular method is conditional on environmental and soil factors, the crop characteristics, the availability of water for irrigation, as well as ease of management, cost, and operation of the selected irrigation system.

For the management of irrigation water to proceed in a rational manner, it is necessary to monitor soil moisture and/or evapotranspiration throughout the crop development cycle. It is also indispensable to know the characteristics of related plant, soil, and climate to determine the appropriate time to irrigate and the amount of water to be applied (Marouelli et al. 1994).

Abou-Hadid et al. (1994) recommended the use of class A tank as a method for the determination of water consumption for pepper culture. The authors compared the class A tank with the radiation method in the Chili culture, and observed greater efficiency in water use and less nutrient loss were obtained using the Class A tank method.

The combined use of mulch and irrigation in a protected environment yields satisfactory results, as the soil cover has certain advantages such as: influences early development and productivity, reduces evaporation, nutrient leaching, promotes limited soil compaction, lower stress to the roots, and weed control (Marouelli & Silva 2012). Pakyürek et al. (1994) observed an increase in yield of 21% in tomato, 19% in chili, and 16% in eggplant using soil cover when compared to no cover. In addition, an early development of 28% in tomato, pepper 39% and 32% in eggplant was observed.

Siwek et al. (1994) and Cebula (1995) tested plastic films of different colors in the soil covered cultivation of pepper and found that black polyethylene led to an increase in fruit weight and size. Decoteauet al. (1990) and Castellane (1995) observed higher growth rates in peppers grown with (red and black) plastic soil cover associated with an increase in soil temperature. VanderWerken & Wilcox-Lee (1988) compared the influence of the plastic film and different irrigation methods in pepper cultivation, and observed that the combination of plastic and drip irrigation led to higher yields.

The objective of this work was to compare the combined application of water depths with plastic soil cover in Chili cultivation in order to determine the amount of water and optimum plastic cover for increased productivity and quality of sweet peppers in greenhouse cultivation.

MATERIAL AND METHODS

The experiment was conducted in the Sao Manuel Experimental Farm, belonging to UNESP-FCA in Sao Manuel, SP. According to Espindola et al. (1974) local climate is mesothermal type Cwa, humid subtropical, with dry spells in the winter. The soil was classified as sandy Yellow Red Latosol. The 0-20 cm depth had the following chemical characteristics: pH = 6.3 $CaCl_2$; Organic matter = 9 g dm^{-3}; P = 80 mg dm^{-3}; H + Al = 11 mmol dm^{-3}; K = 1.4 mmol dm^{-3}; Ca = 31 mmol dm^{-3}; Mg = 10 mmol dm^{-3}; total exchangeable bases (TEB) = 43 mmol dm^{-3}; cation exchange capacity (CEC) = 54 mmol dm^{-3}; Percent base saturation = 80 mmol dm^{-3}; Cu = 1.5 mg dm^{-3}; Fe = 11 mg dm^{-3}; Mn = 5.5 mg dm^{-3}; Zn = 3.4 mg dm^{-3} and B = 0.18 mg dm^{-3}.

The soil was initially plowed and harrowed, and fertilized with 9 g m^{-2} triple superphosphate, 3.1 g m^{-2} potassium chloride and 2.0 kg m^{-2} of organic compost Biomix®. Topdressing fertilizer formulas used were: 5-15-45 + 0,004B and 05-15-30 + 2 Mg, 350 g once a week, alternating formulas until the beginning of growth. After flowering were applied twice a week 588 g monoammonium phosphate (11.0% N and 60% P_2O_5 and 377.3 g of special calcium nitrate (11.5% N and 19 % Ca). Dosmatic (model: DP 30-2) fertilizer injector pump was used for fertilizer appliction. Sowing of yellow pepper hybrid Zarco ocurred on March, in plastic trays with 128 cells using Plantmax® substrate. Within 3 months seedlings were transplanted. Arch greenhouses with closed sides, 4 m in height, with two modules of 6.40 m wide by 49.5 m, covered with low density polyethylene (LDPE) of 150 uM. A drip irrigation system with an eletric pump with disk filters, pressure regulator, chemical injectors and drip line able to pressure compensate.

Irrigation water management was based on the daily evaporation and the coefficient (Kp) Tank class A located in the greenhouse. The experiment was irrigated twice a week and the amount of water was calculated based evaporation measured between each application and the tank coefficient was assigned according to the wind speed, relative humidity, and the spacing surrounding the tank as described by Doorenbos and Pruitt (1977).

Eto = Eca x Kp; Etc = Eto x Kc; L = Etc / Ea

In which: Eto - reference evapotranspiration (mm day^{-1}); Eca - evaporation from class A tank (mm day^{-1}); Etc – crop evapotranspiration (mm day^{-1}); Kp - Tank coefficient. L – water depths to be applied; Ea - water application efficiency of the system (assigned as 90%). Kc - crop coefficient, considering a Kc 0.65 at the stage of transplantation until flowering and fruit formation and Kc 1.00 from flowering and fruit formation until the end of the cycle, according to Marouelli et al. (1994).

The different irrigation levels for each treatment were applied by different operating times of the drip tube lines in each plot, according to the mean discharge and the spacing between them.

T = (L x Sg x Sl)/q

In which: T - irrigation time for each treatment (m); L - depths to be applied in per treatment (mm); Sg - spacing between drip points in the irrigation line (m); Ls - lateral spacing (0.30 m); q - average flow rate (1.49 L h^{-1} with a pressure of 1.4 meter water column).

The experiment was set in a randomized block design with treatments in a split plot with four replications, plots were represented by the four water depths, and the subplots by the six soil covers. Each subplot occupied an area of 1.00 m x 5.0 m, consisting of single rows of 15 plants spaced at 34 cm.

Evaluated water depths were: L1, soil irrigated with 120% of the calculated depth; L2, soil irrigated with 100% of the calculated depth; L3, soil irrigated with 80% of the calculated depth; and L4, soil irrigated with 50% of the calculated depth.

An adaptation of Marouelli et al. (1994) study was performed, and the experiment was divided into two crop development stages: Stage I – from transplanting until the beginning of flowering using a Kc (crop coefficient) of 0.65; and Stage II - from the flowering and fruit formation to harvest, using a Kc of 1.00 to 1.10.

Table 1 presents the class A tank evaporation, crop evapotranspiration and water depth applied during the experiment. Class A tank evaporation averaged 2.4 mm day $^{-1}$.

Soil covers evaluated were: C1, bare soil (control); C2, soil covered with cane bagasse (5cm thick); C3, soil covered with black polyethylene film; C4, soil covered with silver colored polyethylene film; C5, soil covered with orange polyethylene film; C6, soil covered with green polyethylene film.

Soil temperatures were measured daily at 5.0 and 15.0 cm depths, at 8AM, 12PM and 4 PM, with portable digital thermometers Hanna Hi 93530, and relative humidity was measured using Davis Weather Monitor II - Weather Link EC 95.

Table 1. Evaporation (mm) class A tank - (ECA) evapotranspiration (mm) culture (ETc) and depths (mm) applied in yellow bell pepper hybrid 'Zarco'

	DAT	ECA (mm)		Etc (mm)		Depths applied (mm)	
		Period	Day	Períod	Day	Period	Day
May	Up to 35	63	1.8	29.7	0.8	33.0	0.94
June	36 – 63	29.7	1.1	29.1	1.0	32.4	1.2
July	64 – 91	48.6	1.8	37.8	1.4	40.5	1.5
August	92 - 126	56.6	1.6	44.0	1.3	48.9	1.4
September	127 - 157	85.0	2.7	75.3	2.4	83.7	2.7
October	158 - 186	79.8	2.7	72.4	2.5	80.5	2.7
November	187 - 217	101.2	3.3	89.0	2.8	98.9	3.2
December	218 - 238	84.6	4.0	74.4	3.5	82.7	3.9
	Total	568.1		453.1		503.4	

Crop parameters evaluated were: fresh fruit weight, fruit number and yield, measured at every harvest, in three plants per plot. Diseased or injuried fruit were discarded.

For statistical analysis, data were subjected to analysis of variance, using the F test at 5% probability. Means comparison was performed using Tukey's test at 5% probability.

RESULTS AND DISCUSSION

Air relative humidity ranged from 58.9 to 71.9%, air temperature varied between 18.7 and 24.2 °C, and wind speed was below 1.0 m s^{-1}.

Soil temperature at 8AM in the depth of 5 cm was lower than the temperature at 15 cm depth. However, at 12PM and 4PM, the soil temperature at 5 cm depth were greater. The average soil temperature in the control plot (bare soil) was lower than the temperatures of the film covered treatments at 5cm depth. The highest difference occurred in the month of May, in which treatments covered with green and black films were 1.5 °C and 1 °C respectively higher than the control. In the following months the temperature difference narrowed, perhaps, due to the growth of plants and shading promoted by them. These results are in agreement with those found by Ashrafuzzaman et al. (2011) who tested blue and black plastic films and used bare soil as a control in pepper cultivation, and observed that under the plastic films the temperature was greater than the bare soil. At 15 cm depth, the temperature difference was even smaller and in within a few months the soil temperature in the control plots did not vary from the film covered treatments. Cane bagasse treatment had the lowest average soil temperature during the experimental period at both, 5 and 15 cm soil depth, as a result of the low thermal conductivity of this plant material. As for the low-density polyethylene film used as soil cover, green and black films promoted higher soil temperatures when compared to orange and silver colored films. Diáz-Perez (2010) in an experiment with different films achieved the highest temperatures in the root zone with black plastic film while the reflected photosynthetically active radiation was higher in silver colored film.

According to Lamont Jr. (1993), the difference in soil temperatures under different plastic films depends on the thermal properties such as reflection, absorption or transmission of solar radiation waves. The color of the plastic film determines the radiant energy and influences on the microclimate around the crop, according to its color, opacity or transparency, plastic films exert different impact on the transmission of short and long radiation waves (Robledo and Martin, 1981; Farias et al., 1993). In some instances in order to decrease the penetrating radiation, colored or painted plastic are utilized to increase the reflection and / or absorption. Ham et al. (1993) reported that the efficiency of black and opaque plastic to increase soil temperature can be attributed to the optimized heat transfer conditions from the plastic to the soil.

In the current study pepper plants performed differently according to the amount of irrigation water and the use of plastic cover. It was observed that plants receiving 80% of the amount of transpired water and covered with green plastic film had a larger number of fruit per plant (15.3) (Table 2). The lowest number of fruit per plant (4.8) was observed in the plots which received 50% of the evapotranspired and covered with cane bagacilho. On the other had, this treatment had highest fruit mass.

The highest yield (6274.02 g m^{-2}) was achieved by the plants in the soil covered with green plastic film that received 100% of the evapotranspired water, and did not differ statistically from the plots in which irrigation was 120 and 80% of evapotranspired of water (Table 3). The lowest yield was observed in the irrigated plot with 50% of the evapotranspired water and covered with cane bagasse (2218.90 g m^{-2}).

The treatments with green and black film soil cover had higher average production per area and higher average soil temperatures at 5.0 and 15.0 cm deep. Gough (2001) observed that approximately 50% of chili roots are in the range of 20 cm depth and also noted that the amount of lateral and adventitious roots varied depending on plastic color. Gosselin and Trudel (1986) found that higher soil temperatures in the root region yielded smaller fruit, however, higher production per hectare when compared to lower temperatures.

Table 2. Average number of fruits per plant of pepper hybrid Zarco under different water irrigation depths and cover crops

Treatment	L1	L2	L3	L4	Means
bare soil(control)	11.17 abA	11.90 abA	9.17 Ba	10.5 aA	10.67
Cane Bagasse	9.42 bA	12.25 abA	11.35 abA	4.8 bB	9.45
Black	10.67 abA	12.42 aA	10.90 bA	9.85 aA	10.95
Silver	10.82 abA	11.97 abA	10.60 bA	13.1 aA	11.62
Orange	10.82 abAB	8.00 bB	6.90 bB	13.1 aA	9.70
Green	14.75 aA	13.42 aAB	15.32 aA	9.7 bA	13.31
Means	11.27	11.66	10.71	10.2	
C.V. %			27.99		

Means followed by the same lowercase letters in columns and capitals in the rowns, do not differ by Tukey's test (p≤0.05)

Table 3. Fruit yield (g m^{-2}) of pepper hybrid Zarco Zarco under different water irrigation depths and cover crops

Treatment	L1	L2	L3	L4	Means
Bare soil-control	4951.87 abA	4796.87 abA	3500.42 bA	3814.85 abA	4266.0
Cane Bagasse	3750.07 bAB	5412.19 abA	4709.87 abA	2218.90 bB	4022.7
Black	4409.62 abA	5693.77 aA	4226.50 bAB	3605.62 abB	4483.9
Silver	3821.82 abA	4403.70 bA	4162.85 bA	5184.20 aA	4393.1
Orange	4447.85 bAB	3517.07 bAB	3007.22 bB	4996.40 aA	3992.1
Green	5685.4 aA	6275.02 a A	6084.70 a A	3433.65 abB	5369.7
Means	4511.11	5016.44	4281.93	3875.60	
C.V. %			29.15		

Means followed by the same lowercase letters in columns and capitals in the rows, do not differ by Tukey's test (p≤0.05)

Some authors studying bell pepper cultivation suggested that the envinronment change induced by the colors of film surfaces influences pepper growth. Siwek et al. (1994) and Cebula (1995) tested different film colors for growing bell pepper over covered soil and observed that the black polyethylene film resulted in an increase in fruit weight and size. Decoteau al. (1990) and Castellane (1995) observed higher pepper plant growth when cultivated with red and black plastic, compared to white and yellow plastic films. The color of the plastic film determines the radiant energy and influences the microclimate around the crop. According to its color, opacity or transparency, plastic films behave differently regarding the transmission ofshort and long wave radiation (Díaz-Perez, 2010 Robledo and Martin, 1981 Farias et al., 1993). Mulch color affects pepper plant development, due to the quantity and quality of the reflected light and also due to soil temperature.

Irrigated plots with 80, 100, and 120% of evapotranspired water did not present statistical differences, corroborating the results obtained by Gadissa and Chemeda (2009) and Carrijo et al. (1997) who stated that the amount of water replenished to the plant must be equal to that lost by evaporation. However, when using soil cover water saving is possible, as observed by Garcia and Stewart (2004), which observed 30% savings in water consumption when using green plastic and black film as soil cover when compared to bare soil. Lima et al (2006) and Sharma et al. (2004), cultivating pepper, obtained higher yields and water savings when used ground cover compared to bare soil.

Experiments with chili have shown improved production when water replenishment was 125% of the evapotranspiration in the absence of soil cover (Sirjacobs and Dada Ould, 1983). Carvalho et al. (2011) also obtained the an increased fruit number and yield with replacement of 125% of evapotranspired water.

CONCLUSIONS

Under the experimental conditions black and green colored mulch provided the best plant development and the highest yield. Using soil cover water depths calculated to replenish from 80 to 120% water lost by evapotranspiraton provided the highest fruit and crop yield.

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