Effects of Irrigation Rates on Soil Moisture Content, Phytophthora rot, and Fruit Yield and Quality in Seedless Watermelon

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Introduction

Watermelon is an important vegetable in the southeast U.S. as well as other areas of the country. In the southeast, watermelon is typically grown on bare soil and watered by overhead irrigation or on raised beds covered with plastic film mulch and watered with drip irrigation. Due to the occurrence of droughts over the last few years, there is high interest among vegetable growers to increase irrigation water use efficiency. The use of plastic film mulch and drip irrigation has the potential to optimize irrigation water use efficiency. However, over irrigation in many farms is frequent due to inadequate irrigation scheduling. Over irrigation results in water waste and nutrient leaching, and may be conducive to increased incidences of plant diseases such as Phytophthora rot. Phytophthora rot (caused by *Phytophthora capsici* Leonian) is an important disease of several vegetable crops including squash, watermelon, and pepper. This disease can cause complete destruction of an individual crop. The pathogen produces sporangia on roots, stems and fruit of infected plants. These sporangia release zoospores that are dispersed by the rain and irrigation water causing the spread of the disease. Since water is important in the dispersal of the pathogen, the disease is associated with abundant rainfall and high soil moisture conditions.

Objectives

To evaluate the effects of irrigation rates on soil moisture content, incidence of Phytophthora rot, and fruit yield and quality in watermelon.

Materials and Methods

Crop growing conditions. The study will be carried out in the spring season of 2009 in Camilla, Ga. (Stripling Irrigation Research Park, Univ. of Georgia) and Tifton, Ga. (Horticulture Farm, Univ. of Georgia). In Camilla the soil was a loamy sand, while in Tifton it was a sandy loam. The experimental design consisted of a randomized complete block with five treatments [irrigation rates (33%, 67%, 100%, 133%, and 167% the rate of crop evapotranspiration, adjusted by the crop factor)] and four replications. We used a seedless watermelon cultivar (Sakata 'SSX-7401' as female, and '8662' as the pollenizer) that is commonly grown in the southeast U.S. Plants were grown on raised beds (1.8 m from bed center to center), black plastic mulch, and drip irrigation. Plants were planted in April in a single row of plants per bed, with a distance between plants of 0.91 m, placing one pollenizer plant every two female plants. At the time of transplanting, each seedling received about 250 mL of a 2,000 ppm N solution as a starter fertilizer (10-34-00). The experimental plot was 11 m long.

Irrigation. The drip irrigation lines were buried about 5 cm under the soil surface. Fertilization (N-P-K) was performed in accordance to the recommendations of the University of Georgia Extension Service. Crop evapotranspiration was calculated from the reference evapotranspiration data from a nearby weather station and the crop coefficients for watermelon (Univ. of Florida).

Soil moisture. Soil moisture was periodically monitored (every hour) with Time Domain Reflectometry (TDR) sensors (rods 30 cm long, inserted vertically into the soil) connected to a data logger (CR-10, Campbell Sci.).

Leaf gas exchange. Leaf transpiration and stomatal conductance was determined with a photosynthesis analyzer (LI-COR 6400) on four leaves per experimental unit.

Plant diseases. Plants were visually evaluated weekly for incidence of *Phytophthora* rot.

Harvest. Fruit were graded according to USDA standards and individually weighed to determine yields. Fruit were placed in a controlled temperature room (20 ºC; 90% R.H.) immediately after harvest and kept until they were removed, either 1 or 7 days after harvest, for postharvest evaluations.

Postharvest. Upon removal from storage, fruit were first evaluated for disorders, such as stem-end rots, discoloration, soft spots, or other quality factors such as cracking. Fruit were then cut equatorially, and analyzed for color using a Konica-Minolta CR-400 colorimeter (Ramsey, NJ), fitted with an 8 mm aperture and set for D65 illuminant and CIE *L*a*b** color space. Hue and chroma were determined using the standard formulas {arctan(b/a] x 57.3 and $(a^2 + b^2)^{½}$, respectively. Six flesh color measurements were taken per fruit (three heart samples and three locular samples), all taken equidistant from each other and from the center of the fruit. A representative sample of flesh tissue was then pressed through 4 layers of cheesecloth, and the resulting juice was used for determination of total soluble solids (TSS) using a handheld digital refractometer, and pH and acidity (expressed as percentage of citric acid equivalents) using a Mettler-Toledo automatic titrator (DL 15).

Results

Phytophthora rot. There was negligible incidence of Phytophthora rot (natural infection) in the plants in both Camilla and Tifton. Thus, it was not possible to evaluate the effect of irrigation rate on the incidence of the disease.

Soil Moisture. The volumetric soil moisture content at a soil depth of 10 cm increased with the irrigation rate. The average soil moisture content over the season for the irrigation rates were: 8.5% (33% ET), 10.7% (67% ET), 9.3% (100% ET), 13.1% (133% ET), and 13.6% (ET).

Gas exchange. Irrigation rate had no effect on stomatal conductance (mean = 118 mmol m^{-2} m^{-1}) or leaf net photosynthesis (mean = 23 µmol m^{-2} m^{-1}), suggesting that differences in soil moisture as a result of the irrigation treatments had no significant effect in plant function.

Yield. Location had a stronger effect on watermelon fruit yields than irrigation rate. Fruit yields and the average fruit weight were higher in Tifton than in Camilla, although the percentage of marketable fruit was higher in Camilla than in Tifton (Table 1). Fruit yields and average fruit weight were not significantly affected by irrigation rate; however, they tended to be lowest at the lowest irrigation rate (33% ET). These results suggest that watermelon plants irrigated with 67% ET may produce satisfactory yields and that higher rates of irrigation do not increase yields. These results, however, are not conclusive. It is recommended to repeat the study at least another year in order to confirm the results of the 2009 trials.

Postharvest. The effects of location, harvest, shelf period after harvest, and irrigation rate on fruit quality characteristics are shown in Table 2. There was a significant effect of harvest date, with the second harvest having substantially smaller fruit than the first harvest. Fruit weight and total soluble solids were higher and pH was lower in the first harvest than in the second harvest in both locations. These differences suggest that fruit from the first harvest were more mature than those of the second harvest. Fruit flesh pH was lowest and TSS was highest at the lowest irrigation rate. The pH and acidity were not significantly affected by irrigation rate, although pH tended to increase and acidity to decrease with irrigation rate. The TSS was highest (10.3%) at 33% ET and lowest (9.4%) at 166% ET. Thus, there appears to be a slight delay in maturity as a result of increased irrigation, as suggested by lower TSS and higher acidities under higher irrigation rates. There was no relationship between irrigation rates and flesh color (Hue). There were, however, color differences between the two harvests, with fruit from the second harvest having higher L* (locular and heart tissues were lighter in color) and Hue values and lower a*, b* (flesh less red), and chroma values (depth or saturation of color). Across all treatment effects, there were significant differences in the color between the heart and locular tissues, with the latter often being lighter and having less saturated red color, suggesting the lycopene biosynthesis (and ripening) is not uniform throughout the entire cross-section of the fruit.

Conclusions

The results suggest that there is potential to reduce the current rates of watermelon irrigation and thus increase the water use efficiency without significantly affecting fruit marketable yields and quality. Fruit yield and quality of watermelon plants irrigated with 67% ET were similar to those of plants irrigated at higher irrigation rates. It was not possible to evaluate the effects of irrigation rates on the incidence and severity of Phytophthora rot, since there was negligible presence of the disease in the trials. The results of this first year, however, are not conclusive. It is recommended to repeat the study at least another year.

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Table 1. Watermelon yield as affected by irrigation rate and location. Camilla, Ga. (Stripling Irrigation Farm) and Tifton, Ga. (Horticulture Farm), spring of 2009.[z,y]

Factor		Marketable yield		Total yield		Marketable fruit	Fruit weight
		Fruit (#/ha)	Weight (kg/ha)	Fruit (#/ha)	Weight (kg/ha)	(%)	(kg/fruit)
Location	Camilla	2,653 b	19,553 b	3,058 b	21,355 b	87 a	7.5 b
	Tifton	3,898 a	32,048 a	5,031 a	39,603 a	77 b	8.2 a
Irrigation rate	33	2,802	20,914 b	3,767	26,952	77	7.4
	67	3,238	24,683 ab	3,985	29,549	84	7.6
	100	3,518	28,431 ab	4,078	32,541	85	8.0
	133	3,144	25,309 ab	3,860	29,271	82	8.2
	167	3,674	29,666 a	4,483	34,083	82	8.1
Significance							
Location (L)		***	***	***	***	*	*
Irrigation (I)		NS	NS	NS	NS	NS	NS
L x I		NS	NS	NS	NS	NS	NS

[z] Mean values in each column followed by different letter are significantly different by Duncan's Multiple Range Test at $P \leq 0.05$.

[y] Irrigation rates are the amount of water equivalent to the percentages of crop evapotranspiration (ET). Crop evapotranspiration was calculated as the product of reference evapotranspiration and crop coefficient.

Table 2. Comparisons of postharvest watermelon quality characteristics over numerous location, harvest, shelf period, and irrigation rate (% ET)[a].

Factor		pH	TSS (%)	acid (%)	L*	a*	b*	Hue	Chroma
Location	Camilla	6.07 a	10.0 a	0.198 a	37.56 a	23.50 a	14.94 a	32.92 a	27.92 a
	Hort Farm	6.19 b	9.7 a	0.176 b	36.23 b	23.17 a	14.78 a	32.77 a	27.53 a
Harvest	1	5.97 a	10.2 a	0.205 a	36.28 a	24.81 a	15.29 a	31.35 a	29.17 a
	2	6.29 b	9.5 b	0.169 b	37.51 b	21.86 b	14.43 b	34.34 b	26.28 b
Shelf	+1 (days)	5.93 a	9.8 a	0.200 a	37.69 a	23.04 a	14.36 a	32.86 a	27.23 a
	+7	6.34 b	9.9 a	0.174 b	36.10 b	23.63 b	15.35 b	32.83 a	28.21 b
Irrigation rate	33%	6.06 a	10.3 a	0.191 a	37.63 a	23.09 a	14.69 a	33.51 a	27.46 a
	66%	6.07 a	9.8 b	0.190 a	38.17 a	22.67 a	14.56 a	33.15 a	27.04 a
	100%	6.21 b	9.8 b	0.191 a	35.61 b	24.05 b	15.21 b	32.37 a	28.48 b
	133%	6.15 b	10.0 b	0.174 b	35.80 b	23.59 ab	15.10 b	32.79 a	28.06 b
	166%	6.17 b	9.4 c	0.189 ab	37.28 a	23.28 ab	14.73 a	32.41 a	27.57 ab
Source	Heart				37.71 a	26.86	16.70 a	31.90 a	31.66 a
	Locular				36.08 b	19.81	13.02 b	33.79 b	23.79 b
Significance [b]									
Location (LOC)		***	NS	**	***	NS	NS	NS	NS
Harvest (HAR)		***	***	***	***	***	***	***	***
Shelf (SHL)		***	NS	**	***	*	***	NS	**
Irrigation rate (I)		NS	*	NS	***	*	NS	NS	*
Source (SRC)					***	***	***	***	***
I X LOC		NS	NS	NS	NS	***	***	**	***
I X HAR		NS	NS	**	**	***	***	***	***
I X SHL		*	NS	*	NS	NS	NS	***	NS
I X SRC					NS	NS	NS	NS	NS

[a] NS; * ; ** ; *** , not significant and significant at $P = 0.05$, 0.01 and 0.001, respectively. Means followed by the same letter within a factor are not significantly different ($P < 0.05$)