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MICROIRRIGATION AND ANTITRANSPIRANT RATES AND CULTIVAR EFFECTS ON TOMATO AND BELL PEPPER YIELDS

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Abstract. **Two tomato, *Lycopersicon esculentum* Mill. cvs. Agriset 761 and Equinox, and two bell pepper, *Capsicum annuum* L., cvs. Jupiter and Whopper Improved, were grown in fall 1995 with two microirrigation rates 1× (HI) and 0.75× (LO) of the open pan evaporation and sprayed either weekly or biweekly with Vapor Gard (di-1p-menthane) antitranspirant at 9.35 liter·ha^{-1} during the first 10 weeks of the season. Tomato yields were similar with HI or LO irrigation rate and with antitranspirant sprays or water control. 'Equinox' had higher extra-large and marketable yields than did 'Agriset 761'. Marketable pepper yields were similar with HI or LO irrigation rates and with antitranspirant sprays or water control. 'Whopper Improved' had better fruit size and higher marketable yields than did 'Jupiter'. Residual soil concentrations of NO_3-N and K were higher ($P \leq 0.05$) with the LO than with HI irrigation rate.**

Antitranspirants are compounds applied to plants for the purpose of reducing transpiration from the stomata. Film forming antitranspirants, when sprayed onto the plants, supposedly form a continuous layer over the leaf surfaces which is penetrable to gases, for example CO_2 and O_2, but is impermeable to water vapor (Gale and Hagan, 1966; Weller and Ferree, 1978). The reduced transpiration enhances plant survival especially under hot climatic conditions and with reduced soil moisture. In laboratory and greenhouse trials, various antitranspirants reduced water use of potted 'Valencia' oranges, *Citrus sinensis* (L.) Osbeck, and 'Golden Delicious' apples, *Malus domestica* Borkh (Albrigo, 1977; Weller and Ferree, 1978).

In a field experiment by Nitzsche et al. (1991), paraffin wax emulsion treated bell pepper, *Capsicum annuum* L. cv. Lady Bell, seedlings had reduced transplant shock due to an increased leaf water potential (ψω) compared to non-treated transplants. The antitranspirant-treated plants had fewer abscised leaves, increased plant growth and higher early yield than non-treated controls. Field trials with antitranspirant products, however, gave inconsistent results due to environmental conditions such as wind speed, water status of soil, solar irradiation, and sprayer efficiency in forming a continuous layer of film with even thickness over the leaf surfaces (Gale and Hagan, 1966; Davenport et al., 1972). For example, Davenport et al. (1972) reported a 6% increase in fruit size from antitranspirant treated peach, *Prunus persica* L., trees compared to non-treated controls, but Weller and Ferree (1978) reported reduced fruit size of 'Golden Delicious' apples when trees were sprayed with 'Vapor Gard' antitranspirants (Miller Chemical and Fertilizer Corp., Hanover, PA). In a previous study by Csizinszky (unpublished) storm-damaged 'Agriset 761' tomatoes in spring 1993, had a higher early, but lower seasonal total yield from plants treated weekly with 'Anti-Stress 500' sprays (Polymer Ag, Inc., Fresno, CA), than on control plants.

There is little or no published information available on the effects of film-forming antitranspirants on yield and quality of fresh-market tomatoes and bell-peppers. The objectives of this study were to investigate the response of tomato and bell pepper cultivars to antitranspirant spray frequencies at two irrigation rates.

Materials and Methods

Tomatoes. The study was conducted in fall (Aug.-Dec.) 1995 at the Gulf Coast Research and Education Center in Bradenton on an EauGallie fine sand. Soil samples prior to land preparation were analyzed at the University of Florida's Analytical Research Laboratory (Hanlon et al., 1990). The soil had a pH of 6.79 and, Mehlich-1 (in mg·kg^{-1}) 28.0 P, 6.0 K, 603.0 Ca and 90.0 Mg. Nitrogen was determined by the Kjeldahl method (Tecator, Inc., 1987) and the concentrations of water extractable NH_4- and NO_3-N were each <1 mg·kg^{-1}.

The production system was the full-bed polyethylene mulch (Geraldson et al., 1965) with microirrigation. Plots were established on 81-cm wide and 20-cm high beds formed on 152 cm centers. Experimental design was a split-split plot,

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Table 1. Main effect of irrigation and antitranspirant rates and cultivars on tomato yields.

Treatment	Early yield		Season's total yield	
	Extra-large	Marketable	Extra-large	Marketable
Irrigation[z]		$t \cdot ha^{-1}$ [y]		
HI	14.8	21.2	38.0	71.0
LO	12.0	17.8	32.0	63.4
F-test[x]	ns	ns	ns	ns
Antitranspirant[w]				
Control	14.2	19.7	39.7	71.4
5×	12.6	18.8	32.1	66.1
10×	13.4	19.9	33.2	64.0
LSD 0.05[v]	ns	ns	4.4	5.2
Cultivar				
Agriset 761	11.3	5.7	31.4	59.5
Equinox	15.4	23.3	38.6	74.8
F-test[x]	*	*	*	*

[z]Irrigation: HI = 1× pan evaporation; LO = 0.75× pan evaporation.
[y]ha = 6557 linear meters of mulched bed; 14,254 plants.
[x]F-test is significant at $P \leq 0.05$ (*) or non-significant (ns).
[v]LSD is significant at $P \leq 0.05$ or nonsignificant (ns).
[w]Antitranspirant: 5× = 'Vapor Gard' five times per season every other week; 10× = weekly for 10 consecutive weeks.

arranged in three randomized complete blocks. Main plots, each 41 m long and 1.52 m wide were two irrigation rates: high (HI) and low (LO). Sub-plots, each 13.66 m long and 1.52 m wide, were two antitranspirant spray treatments 1× per week for 10 consecutive weeks and 5× per season, every other week for 10 consecutive weeks. In the control plots, plants were sprayed with water. Sub-sub plots, each 6.83 m long and 1.52 m wide, were two tomato, *Lycopersicon esculentum* Mill. cvs. Agriset 761 and Equinox.

In the main plots, irrigation from a T-tape (T-Systems International, San Diego, CA) (20 cm emitter spacing, 2.5 liter·min^{-1}· 30.5 m^{-1} at 0.56 Pa) was applied at the previous day's open pan evaporation (HI) or at 75% of that amount (LO). In the sub-plots, plants were sprayed with 'Vapor Gard' (di-1p-menthane, Miller Chemical and Fertilizer Corp., Hanover, PA) antitranspirant at 9.35 liter·ha^{-1} per application. Sprays were applied at 9 am by a portable backpack sprayer operated at 2.81 kg·cm^{-2} pressure and equipped with a hollow-cone nozzle. The 'Vapor Gard' was diluted in 187 to 374 liters of water to allow for plant growth during the season. In the sub-sub plots, 5 week old 'Agriset 761' and 'Equinox' tomato seedlings were transplanted on 22 Aug. at 46 cm within-row spacing, 13 plants per sub-sub plot.

Thirty percent of the total N (88 kg·ha^{-1}) and 23% of K (101 kg·ha^{-1}) and all of the P (38 kg·ha^{-1}) and micronutrients (16 kg·ha^{-1}) were applied pre-plant from a 18-0-20.75 and from a 0-8.74-0 (N-P-K) source. Micronutrient source was an F503 oxide (Frit Industries, Inc., Ozark. AL). The remainders of the N (205 kg·ha^{-1}) and K (340 kg·ha $^{-1}$) were applied from a liquid 8-0-6.64 (N-P-K) and KNO_3 injected with the irrigation through the drip tube during the season for a total of 293 N and 441 K kg·ha^{-1} from dry and liquid fertilizer sources.

Soil was fumigated with 66.6% methylbromide and 33.3% chloropicrin at 239 kg·ha^{-1} (6,557 linear m·ha^{-1} mulched bed). Beds were covered with a 0.38 μm thick white-on-black polyethylene film. Pesticides, labeled for tomatoes against insect pests and plant pathogens were applied weekly. Soil moisture tension at 15 cm in the beds was monitored by tensiometers (Irrometer Co., Riverside, CA). Leaf samples, young mature leaves for determination of dry matter and elemental concentrations, were taken at 76 and 119 days after planting (DAP) (Hanlon and deVore, 1988). Soil samples for macro and microelement analyses were taken at 3 and 120 DAP.

Fruits were harvested on 8, 15, 22, 30 Nov., and 6 and 18 Dec. Fruits were separated into marketable and cull (United States Department of Agriculture, 1981), then marketable fruits were size graded as extra large (xlg): ≥ 70 mm; large (lge): 63.5-70.6 mm; and medium (med): 57.2-64.3 mm in diameter by a machine. Number and weight of fruit in each grade were recorded. Data were analyzed by ANOVA (SAS Institute, Inc., 1988).

Bell peppers. Growing season, soil type, production system, experimental design, and irrigation and antitranspirant treatments were similar to those described above for tomatoes. Main plots (irrigation rates) were 33 m long and 1.52 m wide; sub-plots (antitranspirants sprays) were 11 m long and 1.52 m wide and sub-sub plots (pepper cvs.) were 5.5 m long and 1.52 m wide. In the sub-sub plots, 5-week-old 'Jupiter' and 'Whopper Improved' seedlings were planted on 28 Aug. in double rows at 30.5 cm between and 28 cm within-row spacing (33 plants per sub-sub plot). Twenty-three % (70.6 kg·ha^{-1}) of the total N and 30% (81 kg·ha^{-1}) of the K and all of the P (30 kg·ha^{-1}) and the micronutrients (12.8 kg·ha $^{-1}$) were applied pre-plant from an 18-0-20.75 and from a 0-8.74-0 (N-P-K) sources. Micronutrient source was an F503 oxide. The remainder of the N (230 kg·ha^{-1}) and K (191 kg·ha^{-1}) were applied from a liquid 8-0-6.64 (N-P-K) fertilizer injected through the drip tube during the season for a total of 300 N and 271 K kg·ha^{-1} from dry and liquid fertilizer sources.

Pesticides labeled for peppers against insects and plant pathogens, were applied weekly. Soil samples for macro and microelement analyses were taken at 3, 50, and 121 DAP. Leaf samples were taken for determination of dry matter and elemental concentrations at 77 and 127 DAP.

Table 2. Interaction of irrigation and antitranspirant rates on tomato yields.

Irrigation[z]	Antitranspirant[y]	Early yield: Extra-large	Early yield: Marketable	Season's total yield: Extra-large	Season's total yield: Marketable
			t·ha^{-1}[x]		
HI	0	13.4	18.6	38.5	71.7
	5×	15.1	21.4	39.5	71.9
	10×	15.8	23.5	35.9	69.4
LO	0	14.9	20.8	40.9	71.1
	5×	11.7	18.3	26.9	56.2
	10×	9.3	14.2	28.2	62.8
	$LSD_{0.05}$[w]	ns	7.3	10.0	14.8

[z]Irrigation: HI = 1× pan evaporation; LO = 0.75× pan evaporation.
[y]Antitranspirant: 5× = 'Vapor Gard' five times per season every other week; 10× = weekly for 10 consecutive weeks.
[x]ha = 6557 linear meters of mulched bed; 14,254 plants.
[w]LSD is significant at P ≤ 0.05 or nonsignificant (ns).

Fruits were harvested four times, on 13, 28 Nov., and 13 and 27 Dec. Fruits were graded according to USDA standards (United States Department of Agriculture, 1981).

Results and Discussion

Tomatoes. During the 119-day-long season (22 Aug.-18 Dec.), the open pan (PE) at the GCREC-Bradenton was 342 mm and the rainfall was 595 mm. At the HI (1 × PE) irrigation rate, the crop received 348 mm and, at the LO (0.75 × PE) rate, 262 mm of water. Rainfall was particularly heavy during September and during the first two weeks of October, when 331 mm of rain was recorded during the 6-week-long period. Due to the high rainfall, early and seasonal total yields of extra-large and marketable fruits were similar with the HI or LO irrigation treatments (Table 1). The early yields of extra-large and marketable fruits were also similar with antitranspirant sprays. For the season, both extra-large and marketable total yields were higher with water control than with antitranspirants. Of the two cultivars, early and seasonal total yields of 'Equinox' were higher than 'Agriset 761' yields (Table 1). Among the interactions, only the irrigation × antitranspirant treatments had a significant effect on fruit yields (Table 2). Early marketable yields were higher (23.5 t·ha^{-1}) at the HI irrigation rate with 10× antitranspirant sprays than at the LO irrigation rate with 10× antitranspirant sprays (14.2 t·ha^{-1}). For the season, both extra-large and marketable fruit yields were lower at the LO irrigation rate and 5× antitranspirant treatment than at the HI irrigation rate and 5× antitranspirant treatment (P ≤ 0.05). Extra-large yields with the LO irrigation rate and water control and marketable total yields with the HI irrigation rate and water control were also higher than yields with the LO irrigation rate and 5× antitranspirant treatment (Table 2). A closer examination of the data on the two-way interaction revealed that with the LO irrigation rate, the antitranspirant treatments tended to reduce tomato yields compared to water control or compared to the antitranspirant treatments with the HI irrigation rate.

Irrigation and antitranspirant rates had little effect on dry matter and macronutrient concentrations in shoots at 77 days after planting (DAP) (Table 3). Nitrogen concentration was higher with LO than with HI irrigation, and dry matter and K

Table 3. Main effects of irrigation and antitranspirant rates and cultivars on dry matter and macroelement concentrations in tomato shoots at 76 DAP.

Treatment	DM	Element: N	P	K	Ca	Mg
Irrigation[z]				g·100 g^{-1}		
HI	11.7	4.01	0.28	4.93	1.89	0.61
LO	11.4	4.11	0.29	5.04	1.98	0.60
F-test[y]	ns	*	ns	ns	ns	ns
Antitranspirant[x]						
0	11.5	3.98	0.27	4.95	2.06	0.62
5×	11.8	4.06	0.29	5.17	1.86	0.59
10×	11.4	4.14	0.29	4.85	1.88	0.60
$LSD_{0.05}$[y]	0.3	ns	ns	0.31	ns	ns
Cultivar						
Agriset 761	11.7	4.00	0.28	4.74	1.90	0.61
Equinox	11.4	4.12	0.29	5.24	1.97	0.60
F-test[y]	*	*	ns	**	ns	ns

[z]Irrigation: HI = 1× pan evaporation; LO = 0.75× pan evaporation.
[y]F-test is significant at P ≤ 0.05 (*) or non-significant (ns).
[x]Antitranspirant: 5× = 'Vapor Gard' five times per season every other week; 10× weekly for 10 consecutive weeks.
[w]Mean difference is significant at P ≤ 0.05 (*), or nonsignificant (ns).

Table 4. pH and elemental concentrations in soil of the tomato field on 3 and 120 days after planting (DAP).

			Water extractable		Mehlich-1 extractable			
			NH_4-N	NO_3-N	P	K	Ca	Mg
		pH	g·100 g^{-1}					
3 DAP		6.34	13.6	24.9	69.1	109.0	595.0	81.0
120 DAP	HI[z]	6.67	0.63	1.45	38.2	18.6	605.0	281.0
	LO	6.70	0.66	2.96	37.8	37.2	619.0	281.0
F-test[y]		ns	ns	***	ns	*	ns	ns

[z]HI = Irrigation at 1× of the pan evaporation; L0 = 0.75× of the pan evaporation.
[y]F-test at 120 DAP is significant at $P \leq 0.05$ (*); 0.001 (***), or nonsignificant (ns).

concentrations were higher with 5× than with 10× antitranspirant sprays or with water control. Among the cvs., 'Equinox' had a higher shoot concentration of N and K and a lower concentration of dry matter than 'Agriset 761'. Macronutrient concentrations with all treatments were in the sufficiency ranges, however, and deficiency symptoms were not observed on the plants during the season.

In the soil, residual concentrations of NO_3-N and K at 120 DAP were higher with the LO, than with the HI irrigation rate (Table 4). The residual concentrations of all other macronutrients and pH were similar with HI or LO irrigation rates. Antitranspirant rates and cultivars had no effect on residual concentrations of nutrients or pH in the soil (data not presented).

Since fruit size or yields in this study were not better with antitranspirant sprays than with water control, the application of antitranspirant sprays can not be recommended for tomatoes. Early and total yields and fruit size were also similar with HI (1 × PE) or with LO (0.75 × PE) treatments. Consequently, microirrigation applied at 75% of the open pan evaporation will not reduce fruit size or marketable yields and will save irrigation water. Furthermore, at the LO irrigation rate, lower N and K rates may be used for the crop than at the HI irrigation rate because twice as much NO_3-N and K remained in the soil after harvest at the LO, than at the HI irrigation rate. Under the experimental conditions, 'Equinox' proved to be a better cultivar with the microirrigated production system than 'Agriset 761'.

Bell peppers. During the 120-day- long season (28 Aug.-27 Dec.) the crop received 372 mm irrigation at the HI (1 × PE) and 286 mm at the LO (0.75 × PE) rate. For the same period, 348 mm PE and 452 mm rainfall was recorded at the GCREC-Bradenton. Yields were affected by the interaction of the three experimental factors (Table 5). Early yield of U.S. Fancy grade fruit of 'Whopper Improved' with the HI irrigation rate and with 10 antitranspirant applications was higher ($P \leq 0.05$) than the yield with the same (HI) irrigation rate and with water control, but similar to 'Whopper Improved' yield with LO irrigation and water control and with HI irrigation rate and 5 antitranspirant applications. Early yields of marketable fruits and yields of U.S. Fancy grade fruits in the total harvest of 'Whopper Improved' were similar with antitranspirant treatments or with water control. The seasonal total yields of marketable fruits were higher, or similar with water control, than with antitranspirant sprays.

In general, irrigation and antitranspirant rates had less effect on bell pepper yields than did cultivars. 'Whopper Improved' yields, except with the LO irrigation and 10× antitranspirant spray were higher than 'Jupiter' yields. A large number of the 'Jupiter' fruits were shorter than the required length of 9 cm for U.S. Fancy grade (USDA, 1981).

There were small but significant differences between cultivars in dry matter and all macroelement concentrations except Mg in the shoots at 77 DAP (Table 6). At 127 DAP significant differences were found only in P and Ca concentrations between the two cultivars. At both sampling dates,

Table 5. Interaction of irrigation and antitranspirant rates and cultivars on bell pepper yields.

			Early yield		Season's total yield	
Irrigation[z]	Antitranspirant[y]	Cultivar[x]	U.S. fancy	Marketable total	U.S. fancy	Marketable total
			t·ha^{-1}[w]			
HI	Control	JR	0.1 c[v]	4.0 def	0.2 c	15.1 cd
		WI	0.6 b	7.2 a	2.0 a	17.5 abc
	5×	JR	0.1 c	3.0 f	0.3 c	13.9 d
		WI	1.0 ab	6.8 abc	1.4 ab	16.8 bc
	10×	JR	0.4 c	4.0 def	0.7 bc	16.1 bcd
		WI	1.4 a	7.9 a	2.2 a	19.2 ab
LO	Control	JR	0.2 c	5.6 bcd	0.4 bc	15.6 cd
		WI	1.0 ab	7.1 ab	2.1 a	20.6 a
	5×	JR	0.2 c	4.9 de	0.4 bc	14.8 cd
		WI	0.9 b	6.8 abc	1.9 a	16.6 bcd
	10×	JR	0.3 c	3.7 ef	0.5 bc	14.0 cd
		WI	0.3 c	5.1 cde	0.6 bc	16.0 bcd

[z]Irrigation: HI = 1× pan evaporation; LO = 0.75× pan evaporation.
[y]Antitranspirant: 5× = 'Vapor Gard' five times per season every other week; 10× = weekly for 10 consecutive weeks.
[x]Cultivar: JR = Jupiter; WI = Whopper Improved.
[w]ha = 6557 linear meters of mulched bed; 42,996 plants.
[v]Mean separation within column by Duncan's Multiple Range Test; $P \leq 0.05$.

Table 6. Dry matter and macroelement concentrations in bell pepper shoots on 77 and 127 days after planting (DAP).

Cultivar	DM	N	P	K	Ca	Mg
			g·100 g[1]			
77 DAP						
Jupiter	16.48	4.36	0.26	3.60	1.66	0.99
Whopper Improved	17.19	4.06	0.23	3.35	1.79	1.00
F-test[z]	*	*	*	*	*	ns
127 DAP						
Jupiter	17.54	3.93	0.22	2.92	2.81	1.40
Whopper Improved	17.42	3.81	0.20	3.07	3.02	1.45
F-test[z]	ns	ns	*	ns	*	ns

[z]F-test is significant at P ≤ 0.05 (*), or nonsignificant (ns).

Table 7. pH and elemental concentrations in soil of the pepper field on 3 and 121 days after planting (DAP).

			Water extractable		Mehlich-1 extractable			
			NH_4-N	NO_3-N	P	K	Ca	Mg
		pH			g·100 g[1]			
3 DAP		6.41	8.97	10.27	76.8	41.3	659.0	93.0
121 DAP	HI[z]	6.19	0.82	1.96	60.5	16.4	665.0	90.4
	LO	6.28	0.78	3.62	57.7	19.2	680.0	96.6
F-test[y]		ns	ns	*	ns	*	ns	ns

[z]HI = Irrigation at 1× and L0 = 0.75× of the pan evaporation.
[y]F-test at 121 DAP is significant at P ≤ 0.05 (*) or nonsignificant (ns).

however, elemental concentrations in shoots were within the sufficiency range. Dry matter and macroelement concentrations in shoots were similar with irrigation and antitranspirant rates at both sampling dates (data not presented).

In the soil, residual concentrations of NO_3-N and K were higher ($P \leq 0.05$) with the LO, than with the HI irrigation rate, but the pH and the concentrations of NH_4-N, P, Ca, and Mg were similar with both irrigation rates (Table 7).

As in tomatoes, bell pepper yields with the HI irrigation rate were not better than with the LO irrigation rate. Therefore, an irrigation program based on the application of 75% of the open pan evaporation should result in similar or better yields than irrigation at a higher rate. Furthermore, the higher residual soil concentrations of NO_3-N and K with the LO than with the HI irrigation also indicated that both N and K fertilizer rates could be reduced for bell peppers with the LO irrigation rate without reducing fruit size or marketable yields. Antitranspirant applications did not result in an increased fruit size or marketable total yields. Both early and total yields of 'Whopper Improved' bell peppers were far greater than that of cv. Jupiter with the microirrigation system.

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