Proc. Fla. State Hort. Soc. 126:155–157. 2013.

Effects of Drip Irrigation Volumes and the Soil Surfactant Integrate™ on Tomato Production

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Additional index words. *Solanum lycopersicum*, water management, wetting agents, cultural practices

A study was conducted to determine the potential of the soil surfactant Integrate (triblock co-polymer 61% and glucoethers 19%) for reducing required drip-irrigation volumes on tomato (*Solanum lycopersicum*) in terms of yield and soil moisture. Integrate is a liquid polymer used to improve soil wetting and reduce surface tension. Drip-irrigation programs were 60%, 80%, and 100% of the potential evapotranspiration (ET_0) (total volume applied three times per day in three equal amounts), whereas Integrate levels were: a) none (control); b) 0.25 gal/acre applied 2 weeks before transplanting plus 0.25 gal/acre weekly from week 1 to 6; c) 0.5 gal/acre at applied 2 weeks before transplanting plus 0.25 gal/acre weekly from week 1 to 6; and d) 1.0 gal/acre applied 2 weeks before transplanting plus 0.25 gal/acre weekly from week 1 to 6. Significant irrigation program by Integrate treatment interactions were observed for early extra-large and total marketable fruit weight. The highest early fruit weights were achieved with 100% ET_0 regardless of Integrate application, and with 80% ET_0 plus any of the Integrate application programs. There were significant increases in yield and in soil volumetric moisture content at the 5-inch depth when Integrate was added to the 80% ET_0 treatment, which suggests that the polymer improved water retention in the soil.

Florida is the second largest tomato (*Solanum lycopersicum*) producer in the United States, with a harvested area of around 31,000 acres and a total value of more than $550 million (U.S. Department of Agriculture, 2012). Most of the tomato production in the state occurs in deep sandy soils, which have low organic matter content, low water retention, and low nutrient holding capacity, as well as high infiltration rates. All these factors increase the risk of nutrient leaching below the root zone.

Informal surveys among growers indicated that tomato production requires between 40 and 50 acre-inches when seepage (subsurface) irrigation is used, and between 14 and 21 acre-inches with drip irrigation. Seepage irrigation is a common method used in south Florida, and is used on approximately 44% of the vegetable and fruit crops acreage in Florida (Smajstrla and Haman, 2005). Seepage irrigation consists of managing a water table perched on an impermeable soil layer through the use of lateral field ditches. The water moves by gravity in the ditches and upward through capillarity above the impermeable layer (Simonne and Morgant, 2005). This irrigation method has a very low efficiency and uses relatively large volumes of water (Bouman et al., 1994; Smajstrla et al., 2002). With drip irrigation, water is pressurized and delivered to the soil through tubes with uniformly spaced emitters, which provide water near the crop root zone. This is a more efficient and uniform (90% to 95%) irrigation method and it allows the delivery of small amounts of water on a frequent basis (Smajstrla et al., 2002). Although establishing drip irrigation is more expensive, it uses one-third of the water volume needed with seepage irrigation (Pitts et al., 2002).

Preliminary studies in Florida showed that a soil surfactant improved water retention in sandy soils, which may result in an increase in water use efficiency (Torres and Santos, 2012). One of the products available today is Integrate 20 (triblock co-polymer 61% and glucoethers 19%), which, according to the manufacturer's label, could "enhance initial wetting and subsequent rewetting of agricultural soils, ensure maximum uptake of water on coarsely textured hydrophobic soils, and provide uniform penetration and lateral movement of water." If these claims are proven correct, growers may have an additional tool to improve water use efficiency in vegetable production. The objective of this study was to determine the effects of Integrate soil surfactant and irrigation programs on tomato yield and soil moisture.

Materials and Methods

A study was conducted between September and December 2012 at the Gulf Coast Research and Education Center of the University of Florida in Wimauma, FL. The soil at the experimental site was classified as a Myakka fine sand (siliceous hyperthermic Oxyaquic Alorthod) with 1.5% organic matter and a pH of 7.3. Planting beds were pre-formed with a standard bedder and were 28 inches wide at the base and 24 inches wide at the top. Bed height was 8 inches. Beds were fumigated using a single-bed rig equipped with three chisels spaced 12 inches apart, which delivered fumigant 6 inches deep. Soil fumigation occurred 3 weeks before transplanting. Within 1 min after fumigation, drip-irrigation tubing (0.45 gal/100 ft per min; T-Tape Systems International, San Diego, CA) was placed in all plots, 1 inch deep in the center of the bed. Beds were covered with black, high-density polyethylene mulch. 'Charger' tomato seedlings at the four true-leaf stage (8 inches tall) were planted 2 ft apart in single rows.

Twelve treatments resulted from combinations of three drip-irrigation volumes and four Integrate 20 (Engage Agro USA, Prescott, AZ) application programs. The drip-irrigation volumes consisted of 60%, 80%, and 100% of the reference evapotranspi-

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ration (ET_0), based on the historical values for the region (3801, 3897, 2172, and 1629 gal/acre/day in September, October, November and December, respectively; Simonne et al., 2012). The Integrate application programs consisted of the combination of two timings of application: a) preplant (0, 0.25, 0.5, and 1.0 gal/acre at 2 weeks before transplanting) and b) weekly application of 0.25 gal/acre from 1 to 6 weeks after transplanting (WAT). Treatments were arranged in a split-plot design with four replications, in which the irrigation volumes were the main plots and the Integrate treatments the sub-plots.

Experimental units were 28 ft long, equivalent to 14 tomato plants per plot. Plant nutrients were injected using recommended rates during the last irrigation cycle each day (between 1 and 3 PM) three times per week with a hydraulic injector (Dosatron, Clearwater, FL). The crop was staked at 3 WAT and tied at 3, 5, and 7 WAT. Irrigation was provided three times per day with cycles between 15 and 45 min long (after 5 min of line pressurization), depending on the crop growth stage. Current recommendations for insect and disease control were followed (Olson et al., 2012). Soil moisture was measured using a 5-inch-long time-domain reflectometry probe inserted at the center of the bed. Readings were collected 10 times per month between 7 and 8 AM and before the first drip irrigation cycle. Plant height was measured at 4 and 8 WAT. Marketable tomato fruit were harvested twice (early at 10 WAT and seasonal at 10 and 12 WAT) at the mature-green stage and were graded following current market standards of extra-large and total marketable fruit (Sargent et al., 2005). Fresh shoot weight was measured at 13 WAT (at the end of the season). Data were analyzed by ANOVA to determine the significance ($P < 0.05$) of the individual factors and their interactions.

Results and Discussion

The interaction between drip-irrigation volumes and preplant Integrate application rates was not significant for soil moisture and fresh shoot weight. Drip-irrigation volumes affected only soil moisture and fresh shoot weight (Table 1). None of the factors affected plant height at 4 and 8 WAT. Plots that received 100% ET_0 had the highest soil moisture (16.3%) among all treatments. There was no soil moisture difference between plots treated with either 80% or 60% ET_0, averaging 14.8%, possibly due to soil moisture being measured at the center of the beds. For fresh shoot weight at the end of the season, plants growing with 100% ET_0 had the highest biomass weight (554 g/plant), while the fresh shoot weights of plants irrigated with the other two drip irrigation volumes dropped below 500 g/plant.

Early and total fruit weights were determined by the interaction between drip irrigation volumes and preplant Integrate rates (Table 2). In all cases, early and total fruit weights were not influenced by preplant Integrate rates when irrigation at 100% ET_0 was applied, regardless of fruit grading. There were significant early fruit weight differences among plots treated with different preplant rates of Integrate at 60% and 80% ET_0 for extra-large and total fruit weights. In plots treated with 80% ET_0, extra-large fruit weight was higher in all plots treated with Integrate independently of the rates applied, averaging 8.8 ton/acre in comparison with 7.6 ton/acre of extra-large fruit obtained in plots not treated with Integrate. However, total early fruit weight was higher with drip irrigation at 80% ET_0 when plots were treated with preplant rates of 0.5 or 1.0 gal/acre of Integrate than without injection of the soil surfactant. Drip irrigation with 60% ET_0 severely reduced early

Table 1. Effects of drip irrigation volumes based on the reference evapotranspiration (ET_0) on soil moisture, and on tomato shoot weight and plant height at 4 and 8 weeks after transplanting (WAT). Balm, FL, Fall 2012.

Irrigation programs	Soil moisture (%)	Fresh shoot wt (g/plant)	Plant ht 4 WAT (cm)	Plant ht 8 WAT (cm)
100% ET_0	16.3 a[z]	554 a	79	118
80% ET_0	14.7 b	490 b	80	123
60% ET_0	14.8 b	490 b	80	121
Significance ($P < 0.05$)	*	*	NS	NS

[z]Values followed by the same letters do not differ at the 5% significance level. NS, *Nonsignificant and significant at the 5% level, respectively. ET_0 = 3801 gal/acre/day in September, 3897 gal/acre/day in October, 2172 gal/acre/day in November, and 1629 gal/acre/day in December.

Table 2. Effects of drip irrigation volumes based on the reference evapotranspiration (ET_0) and pretransplant Integrate rates on early and seasonal marketable tomato fruit weight. Balm, FL, 2012.

Pretransplant Integrate rates	Early fruit wt 100% ET_0 Extra-large	100% ET_0 Total	80% ET_0 Extra-large	80% ET_0 Total	60% ET_0 Extra-large	60% ET_0 Total
--- *(gal/acre)* ---	*(ton/acre)*					
0	10.7	11.1	7.6 b	8.8 b	7.1 c	7.8 b
0.25	10.1	10.7	8.6 a	9.0 b	9.7 a	10.1 a
0.5	11.1	11.6	8.8 a	10.1 a	8.4 ab	9.0 ab
1.0	10.3	10.7	8.4 a	10.1 a	9.0 ab	9.9 a
Significance ($P < 0.05$)	NS	NS	*	*	*	*

Values followed by the same letters do not differ at the 5% significance level. NS, *Nonsignificant and significant at the 5% level, respectively. ET_0 = 3801 gal/acre/day in September, 3897 gal/acre/day in October, 2172 gal/acre/day in November, and 1629 gal/acre/day in December.

extra-large and total fruit weights. Nevertheless, when preplant Integrate was applied to plots irrigated with only 60% ET_0, early extra-large and total fruit weights were enhanced, regardless of Integrate rates. Seasonal fruit weight, which combined the two harvests at 10 and 12 WAT, followed the same patterns as for early fruit weight in both extra-large and total fruit categories when using irrigation volumes equivalent to 60% and 80% ET_0 (Table 2).

In summary, the results of this study suggest that the application of Integrate likely ameliorated water stress when there was reduced irrigation rate (i.e., 60% or 80% ET_0). With the application of this soil surfactant and a water deficit of 20% (i.e., 80% ET_0), it may be possible to produce the same early and seasonal fruit weights as for tomato plants grown with a drip irrigation volume of 100% ET_0. This suggests that the polymer was increasing water retention in the soil. However, more research is needed to confirm these results.

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