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## **The effect of three surfactant formulations in peat-based soilless medium on tomato plant growth and water relations.**

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### **Introduction**

Peat, the major component of most bedding plant media, is essentially a hydrophobic material requiring a surfactant, or wetting agent, to achieve maximum "wettability". In the production of vegetable transplants, the wetting agent most often used is AquaGro 2000, a product of Aquatrols Inc., Cherry Hill, NJ. The purpose of this trial was to test the impact of new formulations of surfactants added to a peat-based medium on tomato plant growth and response to water stress. Several surfactant rates were assessed and results were documented over a six-week time frame.

### **Methods**

A trial was established at the Southwest FI Research and Education Center of the University of Florida in Immokalee, FL to test surfactant formulations. On December 16, 1997 Aquatrols surfactant formulations ACA 1513, ACA 1514, and ACA 1515 were added to Verlite Vegetable Transplant Mix A (Tampa, FL) at rates of 0, 3, 5, or 7 oz/yd<sup>3</sup>. Each surfactant was combined with 500 mls of RO water and sprayed in a fine mist onto a cubic foot of medium, which was constantly stirred to allow for thorough mixing. The appropriately amended medium was then used to fill three, 242 cell flats (i.e. 3 replications) and was seeded with FTE 30 (PetoSeed, Saticoy, CA) tomato. Flats were placed in an unheated greenhouse and grown under standard south FL vegetable transplant cultural procedures for six weeks.

Seedling emergence was monitored for 11 days after seeding to determine surfactant effects on germination. During weeks 4 - 6, five seedlings from each treatment were "pulled" to determine the greenhouse growth parameters of stem length and diameter, leaf area, dry weight of the leaf/stem/root/shoot, leaf:stem ratio, and root:shoot ratio.

Also in weeks 4 - 6, an irrigation stress test was imposed on all treatments to assess surfactant application impact on time to wilt and recovery from wilt. The stress test was begun by bringing all treatments to saturation (i.e., watering to run through), then withholding water until 20% of the plants in a treatment showed signs of wilting. Time to wilt was recorded. Once 20% wilting was achieved in any treatment the plants were

immediately watered to saturation and time to full rehydration (i.e., no sign of wilt apparent) was recorded.

Air temperatures during the trial ranged from the low 50's to high 70's. Manzate and copper were applied (infrequently) to prevent the advancement of fungal diseases and bacterial spot. Various Bt's (insecticide) were also applied to discourage worm pressure. All data were analyzed by ANOVA (SAS) with mean separation via Fisher's Protected LSD at  $p < 0.05$ .

## Results

### Greenhouse Emergence

Main Effects. Tomato seedling emergence was influenced by surfactant and by rate. Surfactant 1513 appeared to have the least and 1515 the greatest effect on seedling emergence (Table 1). ACA 1513-treated medium exhibited a greater number of seedlings on days 8 and 9 compared to 1514, but 1513 treated medium consistently showed more seedlings than 1515-amended medium throughout the 11 days of monitoring.

The major impact of surfactant rate on seedling emergence occurred on day seven, the day on which emergence first began (Table 1). These results were somewhat inconclusive, as emergence did not decline with increasing surfactant rate as might have been expected.

Interaction Effects. The rate effect on delayed germination was most noticeable in 1515 where seemingly all the significance lay (Table 2 – Within Surfactants). When all surfactant-by-rate combinations were compared, the effect of rate was again clearly specific to ACA 1515 (Table 2 – Between Surfactants). All rates of 1515 appeared to delay germination at day seven.

### Seedling Growth Parameters

Main Effects. Seedling growth in week 4 was comparable across the three surfactants used (Table 3). However, the 1515-amended medium produced a plant that had more leaf dry matter per unit of stem than the other treatments. This response disappeared in week 5, but resurfaced in week six.

Surfactant rate, regardless of surfactant used, increased transplant height compared to the untreated medium in each week of the study (Table 3). The 3-oz. surfactant rate showed the least increase in plant height and did not differ from the unamended medium in week five. Total shoot dry matter in week 4 was elevated when surfactant rate was increased above 3 ounces. Leaf dry weight was increased by the 5-oz. surfactant rate in week five and all surfactant rates reduced root:shoot ratio in week six.

Table 3 aptly depicts that plant growth was maximized at the 5-oz. surfactant rate. One notes the greatest value reached in any plant parameter measured (excluding ratio data) generally occurred at 5 ounces of surfactant per cubic yard.

When viewed from the perspective of plant response to a particular surfactant, relatively few plant parameters were significantly altered by the application and those parameters that were altered did not show a consistent pattern of change over the

measurement period (Table 4). Four changes were noted in week 4: ACA 1513 rates differed in stem diameter development, ACA 1514 stem length was generally greater than the control, the control tended to have a greater root:shoot ratio than the ACA 1514 treatments, and ACA 1515 at 7 oz. per cubic yd. of medium had a greater leaf dry weight than either the control or the 3 oz. rate. Two changes were noted in week 5, both within ACA 1513 (the 5 oz. rate produced more dry leaf matter and greater overall shoot dry weight than the control and 7 oz. rate.) One change was noted in week 6 where stem diameter was greater for the ACA 1513, 5 oz. rate compared to either the control or 7 oz. rate.

Interaction Effects. A comparison of all surfactants at all rates again showed that most differences occurred during week 4 of the experiment (Table 5.) The three control (zero) rates were averaged for each of the plant parameters shown to allow for the following discussion. Plant height was greater in both ACA 1513 and 1514 at 5 oz. per cubic yd. of medium than in the control (4.95 cm) in week four. Stem diameter was larger in the ACA 1513, 3 oz. treated plants than in the control (1.31 mm), ACA 1513 at 7 oz., or either the ACA 1514 or 1515 at 3 oz. treated plants. Leaf dry weight was greatest in the ACA 1515, 7 oz. treated plants, surpassing several other treatments including the control (0.0226 g). Total shoot dry weight was also greatest for 1515 at 7 oz. surpassing half of all the other treatments including the control (0.0327 g). Finally, plants grown in ACA 1515 at 3 oz. attained a greater leaf-to-stem ratio than most of the treatments in either 1513 or 1514, but not the control (0.2344).

Week 5 exhibited no differences among the treatments or the controls (Table 5). Week 6 showed that the leaf-to-stem ratio was again affected by surfactant. The control had a greater leaf-to-stem ratio (1.552) than ACA 1514 at 7 oz., as did ACA 1513 at 7 oz., and 1515 at 3 and 5 oz. (Table 5 con't).

### Seedling Wilt and Recovery Times

Main Effects. All surfactants behaved similarly with respect to seedling wilt and recovery from wilt (Table 6). No significant differences were recorded between surfactants for either time to 20% wilt or minutes to full recovery. It must be noted here that due to the lack of precision in the 20% wilt determination (i.e., some plants may have had less water initially) the measurement of recovery time was based on those plants that actually returned to full turgidity. Visual observation easily discerned those plants that did not recover from the initial wilt.

Rate of surfactant did impact both wilt and recovery of the tomato seedlings (Table 6). In each of weeks 4 and 5, the untreated control plants wilted earlier than plants raised in medium amended with any rate of surfactant. In week 6 the untreated control wilted earlier than only the medium amended with the 7 oz. of surfactant. Similarly, in weeks 4 and 5, all plants in medium amended with surfactant rehydrated sooner than the untreated controls regardless of rate. In week 6 only plants treated with 3 or 5 oz. of surfactant rehydrated sooner than the control.

The rate within surfactant effect on wilting and rehydration significance (Table 6) was actually one of the presence or absence of surfactant. Essentially all rates of surfactant increased time to wilting and reduced time to rehydration, and these times were not altered by the addition of more (or less) surfactant. In the 5 instances of significance

exhibited among the rates of a particular surfactant, only one (ACA 1513, 5 week time to wilt) showed the 7 oz. rate performed better than the 3 or 5 oz. rate.

Interaction Effects. Time to 20% wilt in week 4 was solely a response to presence of absence of surfactant as no difference between surfactants by rate was shown (Table 7). In week 5, ACA 1513 at 7 oz. increased time to 20% wilt compared to either the ACA 1513-3 or -5 oz. rate and the control, but not to any other surfactant. Time to recovery in week 5 was once again an issue of presence or absence of surfactant only.

## **Discussion**

These data indicate that only minor differences occurred in tomato seedling growth as a result of being grown in media treated with the surfactants tested here. ACA 1515 tended to slow initial emergence, but only by one day in comparison to the other treatments, and surfactant rates did not appear to amplify this effect.

All surfactants and rates within surfactants tended to increase stem length as would be expected from a material that increases water availability. In general, increasing surfactant rate did not statistically impact plant response, except for ACA 1513, which exhibited a decrease in stem diameter, leaf dry weight, and shoot dry weight when the surfactant rate was increased from 5 to 7 oz. per cubic yd. of medium. Most plant responses maximized at 5 oz. regardless of surfactant used.

These data suggest that plant stems produced in surfactant-treated media support more leaf tissue per unit weight than untreated stems, although it seems to be mostly a response with ACA 1515. This implies better growth as a result of greater water availability, but might suggest greater leaf loss under extreme water stress.

All surfactants tended to increase time to 20% wilt and decrease time to recovery from wilt compared to untreated media. Differences between rates within surfactants with respect to wilt and recovery were not definitive in most cases.

The need for a surfactant when using a peat medium is aptly demonstrated in this study. However, a definitive separation of the pros and cons of ACA 1513, 1514, and 1515 appears to be lacking here. Further studies should be undertaken if the goal of this work is to determine which surfactant chemistry is best suited for vegetable production. This trial was run during the winter (in FL) where evapotranspirational demands are generally the lowest of the year. It would be prudent to run the trial during the summer for comparison.

Table 1. Percentage of tomato seedling emergence in Aquatrols' surfactant-amended media by surfactant and by rate.

		Days after Seeding				
		7	8	9	10	11
<b>Surfactant</b>						
	ACA1513	23	87	93	94	95
	ACA1514	23	84	91	93	94
	ACA1515	17	83	91	92	93
	LSD 5%	4	3	1	1	1
<b>Rate (fluid ounces/yd<sup>3</sup>)</b>						
	0	25	85	91	93	94
	3	17	85	92	94	94
	5	18	85	92	93	94
	7	23	85	92	93	94
	LSD 5%	5	NS	NS	NS	NS

Table 2. Percentage of tomato seedling emergence in Aquatrols' surfactant-amended medium.

		Days after Seeding				
Surfactant	Rate (fl oz/yd <sup>3</sup> )	7	8	9	10	11
<b>Comparisons Within Surfactants by Rate</b>						
<b>ACA1513</b>	0	24	86	93	94	94
	3	21	88	93	94	95
	5	21	86	93	94	94
	7	26	88	94	95	95
	LSD 5%	NS	NS	NS	NS	NS
<b>ACA1514</b>	0	24	84	91	93	93
	3	21	85	92	94	94
	5	21	84	92	93	94
	7	26	82	90	92	93
	LSD 5%	NS	NS	NS	NS	NS
<b>ACA1515</b>	0	27	84	91	92	93
	3	10	81	91	92	93
	5	13	84	91	92	93
	7	17	85	92	93	94
	LSD 5%	7	NS	NS	NS	NS
<b>Comparison Between Surfactants and Rates</b>						
<b>ACA1513</b>	0	24	86	93	94	94
	3	21	88	93	94	95
	5	21	86	93	94	94
	7	26	88	94	95	95
<b>ACA1514</b>	0	24	84	91	93	93
	3	21	85	92	94	94
	5	21	84	92	93	94
	7	26	82	90	92	93
<b>ACA1515</b>	0	27	84	91	92	93
	3	10	81	91	92	93
	5	13	84	91	92	93
	7	17	85	92	93	94
	LSD 5%	9	NS	NS	NS	NS



Table 4. Plant sample parameters from Aquatrols' surfactant-amended medium by surfactant and by rate.

Surfactant/Rate (fl oz/yd <sup>3</sup> )	Stem Length (cm)	Stem Dia. (mm)	Leaf Area (cm <sup>2</sup> )	Dry Leaf (g)	Dry Stem (g)	Dry Root (g)	Dry Top (g)	Leaf Stem Ratio	Root Shoot Ratio
<b>Plant Samples After 4 Weeks of Growth in Aquatrols' Amended Medium</b>									
<b>ACA1513</b> 0	5.0	1.33	7.09	0.0231	0.0099	0.0099	0.0330	2.365	0.301
3	5.7	1.42	8.08	0.0259	0.0116	0.0108	0.0376	2.251	0.293
5	5.6	1.39	7.93	0.0252	0.0116	0.0108	0.0368	2.230	0.295
7	5.1	1.26	6.29	0.0223	0.0096	0.0093	0.0320	2.331	0.296
LSD 5%	NS	0.11	NS	NS	NS	NS	NS	NS	NS
<b>ACA1514</b> 0	4.7	1.25	6.04	0.0209	0.0090	0.0093	0.0299	2.350	0.315
3	5.3	1.32	6.90	0.0239	0.0107	0.0101	0.0346	2.265	0.291
5	5.6	1.36	7.62	0.0262	0.0119	0.0104	0.0380	2.212	0.276
7	5.5	1.34	7.35	0.0260	0.0113	0.0104	0.0373	2.310	0.281
LSD 5%	0.6	NS	NS	NS	NS	NS	NS	NS	0.024
<b>ACA1515</b> 0	5.2	1.36	7.41	0.0238	0.0104	0.0099	0.0342	2.316	0.292
3	4.9	1.31	6.93	0.0232	0.0093	0.0101	0.0325	2.505	0.313
5	5.4	1.34	7.80	0.0261	0.0107	0.0106	0.0368	2.476	0.289
7	5.5	1.35	8.59	0.0284	0.0120	0.0114	0.0405	2.401	0.281
LSD 5%	NS	NS	NS	0.0039	NS	NS	NS	NS	NS
<b>Plant Samples After 5 Weeks of Growth in Aquatrols' Amended Medium</b>									
<b>ACA1513</b> 0	6.0	1.52	7.94	0.0313	0.0156	0.0147	0.0469	2.027	0.317
3	6.7	1.60	9.70	0.0359	0.0191	0.0167	0.0550	1.921	0.307
5	7.5	1.62	10.39	0.0402	0.0216	0.0162	0.0618	1.920	0.268
7	6.4	1.45	8.03	0.0323	0.0159	0.0142	0.0482	2.043	0.294
LSD 5%	NS	NS	NS	0.0057	NS	NS	0.0110	NS	NS
<b>ACA1514</b> 0	6.3	1.59	8.23	0.0336	0.0169	0.0151	0.0505	2.003	0.302
3	7.0	1.57	9.51	0.0365	0.0208	0.0161	0.0573	1.793	0.284
5	6.8	1.55	8.88	0.0358	0.0193	0.0155	0.0551	1.885	0.283
7	6.9	1.57	9.38	0.0383	0.0200	0.0164	0.0583	1.928	0.286
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>ACA1515</b> 0	6.7	1.61	9.36	0.0357	0.0192	0.0159	0.0550	1.890	0.292
3	6.4	1.59	9.13	0.0354	0.0179	0.0162	0.0532	1.999	0.306
5	6.9	1.62	10.21	0.0401	0.0196	0.0168	0.0597	2.063	0.284
7	7.1	1.57	10.02	0.0380	0.0202	0.0176	0.0582	1.895	0.304
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. (Con't.)

Surfactant/Rate (fl oz/yd <sup>3</sup> )	Stem Length (cm)	Stem Dia. (mm)	Leaf Area (cm <sup>2</sup> )	Dry Leaf (g)	Dry Stem (g)	Dry Root (g)	Dry Top (g)	Leaf Stem Ratio	Root Shoot Ratio
<b>Plant Samples After 6 Weeks of Growth in Aquatrols' Amended Medium</b>									
<b>ACA1513</b> 0	7.7	1.81	10.46	0.0458	0.0309	0.0233	0.0767	1.499	0.305
3	8.3	1.87	11.86	0.0477	0.0322	0.0231	0.0799	1.502	0.293
5	8.8	1.91	12.44	0.0522	0.0370	0.0244	0.0892	1.433	0.275
7	8.0	1.76	10.21	0.0445	0.0295	0.0221	0.0740	1.533	0.303
LSD 5%	NS	0.09	NS	NS	NS	NS	NS	NS	NS
<b>ACA1514</b> 0	7.6	1.80	10.61	0.0457	0.0293	0.0224	0.0750	1.575	0.303
3	8.3	1.82	10.84	0.0472	0.0327	0.0236	0.0799	1.469	0.300
5	8.4	1.85	10.69	0.0462	0.0315	0.0228	0.0777	1.487	0.298
7	9.0	1.83	11.34	0.0490	0.0348	0.0234	0.0838	1.414	0.283
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>ACA1515</b> 0	7.8	1.80	10.45	0.0441	0.0285	0.0222	0.0726	1.582	0.313
3	8.3	1.86	11.81	0.0482	0.0310	0.0230	0.0792	1.571	0.294
5	8.4	1.87	11.80	0.0515	0.0334	0.0231	0.0849	1.558	0.274
7	9.1	1.87	13.08	0.0549	0.0374	0.0251	0.0923	1.488	0.274
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS



Table 5. Plant sample parameters from Aquatrols' surfactant-amended medium for all surfactants and rates.

Surfactant/Rate		Stem Length (cm)	Stem Diameter (mm)	Leaf Area (cm <sup>2</sup> )	Dry Leaf (g)	Dry Stem (g)	Dry Root (g)	Dry Top (g)	Leaf Stem Ratio	Root Shoot Ratio
<b>Plant Sample at 4 Weeks After Seeding</b>										
<b>ACA1513</b>	0	5.0	1.33	7.09	0.0231	0.0099	0.0099	0.0330	2.365	0.301
	3	5.7	1.42	8.08	0.0259	0.0116	0.0108	0.0376	2.251	0.293
	5	5.6	1.39	7.93	0.0252	0.0116	0.0108	0.0368	2.230	0.295
	7	5.1	1.26	6.29	0.0223	0.0096	0.0093	0.0320	2.331	0.296
<b>ACA1514</b>	0	4.7	1.25	6.04	0.0209	0.0090	0.0093	0.0299	2.350	0.315
	3	5.3	1.32	6.90	0.0239	0.0107	0.0101	0.0346	2.265	0.291
	5	5.6	1.36	7.62	0.0262	0.0119	0.0104	0.0380	2.212	0.276
	7	5.5	1.34	7.35	0.0260	0.0113	0.0104	0.0373	2.310	0.281
<b>ACA1515</b>	0	5.2	1.36	7.41	0.0238	0.0104	0.0099	0.0342	2.316	0.292
	3	4.9	1.31	6.93	0.0232	0.0093	0.0101	0.0325	2.505	0.313
	5	5.4	1.34	7.80	0.0261	0.0107	0.0106	0.0368	2.476	0.289
	7	5.5	1.35	8.59	0.0284	0.0120	0.0114	0.0405	2.401	0.281
<b>LSD 5%</b>	0.6	0.09	NS	0.0035	NS	NS	0.0055	0.176	NS	
<b>Plant Sample at 5 Weeks After Seeding</b>										
<b>ACA1513</b>	0	6.0	1.52	7.94	0.0313	0.0156	0.0147	0.0469	2.027	0.317
	3	6.7	1.60	9.70	0.0359	0.0191	0.0167	0.0550	1.921	0.307
	5	7.5	1.62	10.39	0.0402	0.0216	0.0162	0.0618	1.920	0.268
	7	6.4	1.45	8.03	0.0323	0.0159	0.0142	0.0482	2.043	0.294
<b>ACA1514</b>	0	6.3	1.59	8.23	0.0336	0.0169	0.0151	0.0505	2.003	0.302
	3	7.0	1.57	9.51	0.0365	0.0208	0.0161	0.0573	1.793	0.284
	5	6.8	1.55	8.88	0.0358	0.0193	0.0155	0.0551	1.885	0.282
	7	6.9	1.57	9.38	0.0383	0.0200	0.0164	0.0583	1.928	0.286
<b>ACA1515</b>	0	6.7	1.61	9.36	0.0357	0.0192	0.0159	0.0550	1.890	0.292
	3	6.4	1.59	9.13	0.0354	0.0179	0.0162	0.0532	1.999	0.306
	5	6.9	1.62	10.21	0.0401	0.0196	0.0168	0.0597	2.063	0.284
	7	7.1	1.57	10.02	0.0380	0.0202	0.0176	0.0582	1.895	0.304
<b>LSD 5%</b>	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table 5. (con't)

Surfactant/Rate		Stem Length (cm)	Stem Diameter (mm)	Leaf Area (cm <sup>2</sup> )	Dry Leaf (g)	Dry Stem (g)	Dry Root (g)	Dry Top (g)	Leaf Stem Ratio	Root Shoot Ratio
<b>Plant Sample at 6 Weeks After Seeding</b>										
<b>ACA1513</b>	0	7.7	1.81	10.46	0.0458	0.0309	0.0233	0.0767	1.499	0.305
	3	8.3	1.87	11.86	0.0477	0.0322	0.0231	0.0799	1.502	0.293
	5	8.8	1.91	12.44	0.0522	0.0370	0.0244	0.0892	1.433	0.275
	7	8.0	1.76	10.21	0.0445	0.0295	0.0221	0.0740	1.533	0.303
<b>ACA1514</b>	0	7.6	1.80	10.61	0.0457	0.0293	0.0224	0.0750	1.575	0.303
	3	8.3	1.82	10.84	0.0472	0.0327	0.0236	0.0799	1.469	0.300
	5	8.4	1.85	10.69	0.0462	0.0315	0.0228	0.0777	1.487	0.298
	7	9.0	1.83	11.34	0.0490	0.0348	0.0234	0.0838	1.414	0.283
<b>ACA1515</b>	0	7.8	1.80	10.45	0.0441	0.0285	0.0222	0.0726	1.582	0.313
	3	8.3	1.86	11.81	0.0482	0.0310	0.0230	0.0792	1.571	0.294
	5	8.4	1.87	11.80	0.0515	0.0334	0.0231	0.0849	1.558	0.274
	7	9.1	1.87	13.08	0.0549	0.0374	0.0251	0.0923	1.488	0.274
<b>LSD 5%</b>	NS	NS	NS	NS	NS	NS	NS	NS	0.102	NS

Table 6. Time to 20% wilt and rehydration time of tomato seedlings grown in media treated with surfactants.

Treatment	Week 4 Hours to 20% Wilt	Week 4 Recovery in Minutes	Week 5 Hours to 20% Wilt	Week 5 Recovery in Minutes	Week 6 Hours to 20% Wilt	Week 6 Recovery in Minutes
<b>Surfactant</b>						
ACA1513	158.1	49.6	154.8	49.6	126.4	41.4
ACA1514	156.8	50.9	157.8	48.6	128.5	42.1
ACA1515	158.2	46.0	156.1	45.8	124.7	45.1
LSD 5%	NS	NS	NS	NS	NS	NS
<b>Rate</b> (fl oz/yd <sup>3</sup> )						
0	147.3	67.2	142.5	81.9	121.2	55.9
3	159.9	42.9	157.5	38.5	128.2	36.8
5	161.8	48.8	159.5	39.2	124.3	37.2
7	161.9	36.4	165.3	32.3	132.5	41.4
LSD 5%	8.4	16.7	8.4	14.9	7.9	14.9
<b>ACA1513</b>						
0	147.0	57.8	140.8	73.0	121.6	46.2
3	154.1	44.2	153.2	52.0	126.9	42.2
5	165.8	52.2	153.5	45.0	121.9	33.5
7	165.5	44.0	171.6	28.2	135.0	43.5
LSD 5%	12.1	NS	12.9	NS	NS	NS
<b>ACA1514</b>						
0	147.2	66.2	140.5	86.5	121.6	47.2
3	159.8	46.8	159.4	35.8	129.2	28.0
5	154.2	51.5	165.7	40.2	129.0	42.0
7	166.0	39.2	165.7	31.8	134.2	51.2
LSD 5%	NS	NS	17.8	20.5	NS	NS
<b>ACA1515</b>						
0	147.7	77.5	146.3	86.2	120.4	74.2
3	165.8	37.8	160.0	27.8	128.4	40.2
5	165.4	42.8	159.4	32.2	121.8	36.2
7	154.1	26.0	158.6	37.0	128.3	29.5
LSD 5%	NS	NS	NS	28.1	NS	NS

Table 7. Time to 20% wilt and rehydration of tomato seedlings grown in media treated with surfactants.

Surfactant Rate (fl oz/yd <sup>3</sup> )	Week 4 Hours to 20% Wilt	Week 4 Recovery in Minutes	Week 5 Hours to 20% Wilt	Week 5 Recovery in Minutes	Week 6 Hours to 20% Wilt	Week 6 Recovery in Minutes
<b>ACA1513</b>						
0	147.0	57.8	140.8	73.0	121.6	46.2
3	154.1	44.2	153.2	52.0	126.9	42.2
5	165.8	52.2	153.5	45.0	121.9	33.5
7	165.5	44.0	171.6	28.2	135.0	43.5
<b>ACA1514</b>						
0	147.2	66.2	140.5	86.5	121.6	47.2
3	159.8	46.8	159.4	35.8	129.2	28.0
5	154.2	51.5	165.7	40.2	129.0	42.0
7	166.0	39.2	165.7	31.8	134.2	51.2
<b>ACA1515</b>						
0	147.7	77.5	146.3	86.2	120.4	74.2
3	165.8	37.8	160.0	27.8	128.4	40.2
5	165.4	42.8	159.4	32.2	121.8	36.2
7	154.1	26.0	158.6	37.0	128.3	29.5
<b>LSD 5%</b>	14.5	NS	14.5	25.8	NS	NS