Journal of the American Pomological Society 61(4):183-187 2007

Organosilicone Surfactants Sometimes Reduce Corrected Soluble Solids in Processing Oranges Treated with EcoLyst

Ed Stover[1], Frederick S. Davies[2] , Scott Ciliento[3], and Glenn R. Zalman[2]

Abstract

EcoLyst (a formulation of N-N-diethyl-2-(4-methylbenzyloxy) ethylamine hydrochloride, at 0.034 g ml^{-1}), is a plant growth regulator that was reported to increase soluble solids concentration (SSC) in juice oranges by 0.6 to 1.2˚ Brix in initial research and development trials. In our previous report, replicated field experiments largely failed to confirm the excellent early reports, despite numerous trials at different material rates and spray timings conducted over many locations and several years. Based on initial reports, all of these trials had included Silwet L-77 adjuvant at 0.05%. A single trial on 'Valencia' (*Citrus sinensis* L.) in 2000 compared EcoLyst application with numerous surfactants, including a no surfactant treatment and a non-treated control. At harvest, the exclusion of surfactant resulted in significantly higher SSC than in the control and treatments that included surfactants. To test the hypothesis that surfactant use may be compromising EcoLyst efficacy, experiments compared EcoLyst response with and without Silwet L-77 on 6 blocks of 'Hamlin' and 3 blocks of 'Valencia' sweet oranges, all in commercial orchards. Only two trials, one in each year of the study, showed an increase in SSC from EcoLyst treatment relative to non-treated controls. More interestingly, in these two trials and in one additional trial, inclusion of Silwet L-77 with EcoLyst resulted in a significant SSC reduction relative to EcoLyst alone. This suggests that the surfactant was sometimes deleterious to fruit SSC development and/or EcoLyst enhancement of SSC.

Crop value for Florida processed citrus is typically based on the total sugar content of delivered fruit. Since total sugar content is calculated as [adjusted soluble solids content (SSC, total soluble solids corrected for juice acidity, also known as corrected ˚Brix)] × [percent juice] × [total fruit weight], production practices that increase any of these components may increase crop value. EcoLyst, (GMJA Specialties, Bradenton, Fla.), is a tertiary amine plant growth regulator developed by the USDA and Tropicana, Inc. (Bradenton, Fla.) (9), and was reported to increase SSC of juice oranges by as much as 1.2 ˚Brix, with average increases of 0.6 ˚Brix in a Florida trial (2) with similar results also reported from Brazil (3). EcoLyst was labeled for use on juice oranges in 1999 (6), because of its favorable toxicological profile and potential for increasing crop value. In an earlier study (5), we reported that although SSC increases were sometimes observed, replicated field experiments largely failed to confirm the large responses initially reported, despite numerous trials at different material rates and spray timings conducted over many locations and several years. Based on recommendations from initial research and development efforts, all of these trials had included Silwet L-77 adjuvant at 0.05%, as indicated on the EcoLyst label. In this report, we describe experiments in which exclusion of surfactant was evaluated for its potential in improving SSC increase following EcoLyst application.

Materials and Methods

Orchard parameters. Experiments were established using randomized complete block design with ten blocks formed spatially within the field and a single tree for each treatment in each block. Buffer trees within rows and use of alternate rows eliminated the possibility of

[1] USDA, ARS National Clonal Germplasm Repository, One Shields Ave., University of California, Davis, CA 95616
[2] Horticultural Sciences Department, University of Florida, Gainesville, FL 32611
[3] Indian River Research and Education Center, University of Florida, Ft. Pierce, FL 34945

significant overspray from neighbouring treatments. EcoLyst was always applied at 14.8 $g \cdot ha^{-1}$ a.i. and applications were made at early-to mid-bloom (1-50% of flowers open). When surfactants were used they were included at 0.05% (v/v). Every experiment included a non-treated control. In an experiment in 2000, numerous surfactants (Table 1) were compared in a block of 'Valencia' (*Citrus sinensis* L.) on sour orange (*C. aurantium* L.) rootstock near Ft. Pierce, Fla. In this experiment, and except where noted for experiments in 2002, application was made using a three-point hitch airblast sprayer (Rear's Manufacturing. Co. Eugene, Ore.) with application at 935 $L \cdot ha^{-1}$, which was well below the tree-row-volume for the study orchards, and no run-off was observed. At one or two harvest dates, a sample of 50 fruit was randomly collected around each tree at a height of 0.9-1.8 m. In 2002, four blocks of 'Hamlin' and three blocks of 'Valencia' in commercial orchards in the Ft. Pierce, Fla. area were subjected to similar experiments, except that the only surfactant tested was Silwet L-77. Experiments on two additional blocks of 'Hamlin' were also conducted in 2002, with one block near Bartow, Fla. and one near Manatee, Fla. In these two trials, applications were made using a backpack sprayer (Solo, Inc., Newport News, Va.) at 3.8 L per tree. At harvest for these trials, a randomly selected 20 to 50 fruit sample was collected around the tree at a height of 0.9-1.8 m.

Fruit assessments. Fruit were weighed and then juice was extracted using a commercial citrus juicer (for Ft. Pierce sites an FMC State Test juicer was used; for other sites, an FMC Fresh and Squeeze juicer was used; FMC Inc., Lakeland, Fla.), following which juice weight was determined. A hydrometer (for Ft. Pierce sites, FDACS, Winter Haven, Fla.) or refractometer (for other sites, Bellingham and Stanley, Tunbridge Wells, UK) was used to determine uncorrected SSC. Titratable acidity (TA) was determined using an automatic titrator (for Ft. Pierce sites, FDACS, Winter Haven, Fla.; for other sites, Denver Instruments, Denver, Col.) using standard base and endpoint for citrus quality measurements (13). All SSC values presented in this paper have been corrected for TA levels using the method of Wardowski et al. (13) and SSC/TA ratio was calculated.

Statistical analysis. Data were analyzed by ANOVA, using the procedure GLM. Mean separation was performed using Duncan's multiple range test at $P=0.05$ and using contrast analyses (SAS Institute, Cary, N.C.).

Results and Discussion

EcoLyst increased SSC compared to non-treated controls in only two of the ten sites tested, one in each of the two years of this study (Table 1 and orchard 1 in Table 2). This is consistent with the sporadic response reported by Davies et al. (5) but not consistent with other reports (2,3). More interestingly, in these sites, and at one additional site with no significant EcoLyst effect relative to controls, exclusion of surfactant from the EcoLyst application resulted in a statistically significant increase in resultant SSC at harvest. These data suggest that the surfactant was sometimes deleterious to fruit SSC development and/or EcoLyst enhancement of SSC. No other significant effects on fruit quality parameters (such as titratable acidity and mean fruit weight) were observed, except for kg solids per box, which is a function of SSC and was only observed when SSC was significantly affected. These data are shown for the 2000 experiment (Table 1), but not for 2002.

Inclusion of organosilicone surfactants in spray solutions results in a much smaller contact angle for spray droplets than is observed from use of non-ionic surfactants, and there are data indicating that direct entry through stomates may sometimes occur (12). Such potent surfactants sometimes greatly increase effectiveness of plant growth regulators (PGRs) as in published reports on ReTain (1,7,8), presumably by increasing PGR uptake. However, it appears that these compounds may sometimes have deleterious effects that should not be overlooked. Wood (14) reported that many adjuvants suppressed photosynthesis in pecan and that organosilicone surfactants had the greatest effect. Orbovic et al. (11) reported

Table 1. Effects of EcoLyst, with or without surfactant, on internal fruit quality of 'Valencia' oranges in Ft. Pierce, Fla., 2000-01. EcoLyst was applied at 14.83 g.ha^{-1} a.i. and application timing was at 50% bloom. All surfactants were used at 0.05% (v/v). Fruit harvest occurred on 26 March 2001.

Treatment [z]	Adjusted SSC	Titratable acidity (%)	Ratio SSC/TA	% juice	Juice per box (kg)[x]	Solids per box (kg)
Control	13.6 b[y]	1.04	13.19	60.1	24.8	3.36
EcoLyst only	14.2 a	1.06	13.34	62.0	25.2	3.58
EcoLyst + Break-Thru	13.8 b	1.06	13.04	62.1	25.4	3.49
EcoLyst + Kinetic	13.8 b	1.03	13.41	62.3	25.4	3.54
EcoLyst + Silken	13.8 b	1.04	13.31	62.4	25.4	3.54
EcoLyst + Silwet L-77	13.8 b	1.03	13.45	61.5	25.1	3.45
Probability of difference from contrast analyses						
all EcoLyst vs. control	0.0342	0.5676	0.5884	0.0679	0.1096	0.0087
all Eco+surf vs. Eco no surf	0.0127	0.2312	0.9194	0.8243	0.6064	0.2838

[z] Identity of surfactants: Break-Thru (Goldschmidt Chemical Co., Hopewell, Virg.), Kinetic (Helena Chemicals, Memphis, Tenn.), Silken (Agriliance Chemicals, Memphis, Tenn.), and Silwet L-77 (Loveland Industries, Greeley, CO).

[y] SSC values are corrected for titratable acidity. Means within columns followed by the same letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$. Means presented are for 10 trees per treatment and a 50 fruit sample per tree.

[x] Values are per 90 lb Florida field box = 40.8 kg.

that Silwet L-77 significantly suppressed photosynthesis (by as much as 80%) for more than 24 hours following application to potted grapefruit trees. Even more moderate surfactants such as Regulaid (Kalo Inc., Overland Park, Kan.) may sometimes have potentially adverse effects, such as reduction in return bloom (10). There is also a recent report of serious yield loss in blueberry which was ascribed to surfactant-induced phytotoxicity (4). Is it possible that less severe physiological or morphological changes might sometimes occur which influence plant function without overt evidence of damage?

In the recent past there have been several new PGRs that entered into research trials on tree fruits with recommendations for surfactant use already established, which then receive little further scrutiny. Data reported in this study, and the several studies cited, suggest that initial replicated trials should always include treatments without surfactants and possibly surfactant-only treatments.

Despite the deleterious effect of surfactants on SSC in 30% of the trials in this study, recognition of this phenomenon does not increase efficacy of EcoLyst to a commercially useful level. It is clear that EcoLyst does have PGR activity, but it is apparently relatively weak or interacts strongly with other unidentified factors. The mode of action of EcoLyst and other tertiary amine PGRs is not known, and such understanding may permit commercial utility of these compounds in the future.

Literature Cited

1. Byers, R.E. 1997. Effects of aminoethoxyvinylglycine (AVG) on preharvest fruit drop, maturity, and cracking of several apple cultivars. J. Tree Fruit Prod. 2:77-97.

2. Campbell, C.A., T. Taggert and J. Keithly. 1999. A novel plant growth regulator, MBTA, increases soluble solids (Brix) of 'Valencia' orange. Proc. Fla. State Hort. Soc. 112:25-28.

3. Castro, P.R.C., I.A. Alvarez, G. Maturana, S. Tavares, S.C.M. Sereiloto, C.L. Medina and J.H. Keithly. 2004. Effects of MBTA on soluble solids and acidity of Pera sweet orange. Acta Hort. 653:163-166.

Table 2. Effects of EcoLyst, with or without Silwet L-77 surfactant, on internal fruit quality of juice oranges in 2002-03. EcoLyst was applied at 14.83 g.ha^{-1} a.i. and application timing was at 1-50% bloom. Silwet L-77 was used at 0.05% (v/v).

Orchard Identification	Cultivar	Location	Rootstock[z]	Date applied	Soil Type	Harvest date	TA adjusted SSC[y]		
							Control	EcoLyst only	Ecolyst+ Silwet
1	Hamlin	Ft. Pierce	Swingle	20 Feb. 2002	Winder/ Wabasso	5 Dec. 2002	9.7	10.1	9.7
1	Hamlin	Ft. Pierce	Swingle	20 Feb. 2002	Winder/ Wabasso	29 Dec. 2002	10.3 b	10.7 a	10.3 b
2	Hamlin	Ft. Pierce	Swingle	20 Feb. 2002	Lawnwood	5 Dec. 2002	9.3	9.4	9.3
2	Hamlin	Ft. Pierce	Swingle	20 Feb. 2002	Lawnwood	29 Dec. 2002	10.1	10.1	10.2
3	Hamlin	Ft. Pierce	Carrizo	22 Feb. 2002	Pineda	11 Nov. 2002	10.7	10.8	10.5
4	Hamlin	Ft. Pierce	Sour orange	22 Feb. 2002	Pineda	11 Nov. 2002	10.8	10.8	10.8
5	Hamlin	Manatee	Carrizo	22 Feb. 2002	Immokalee	22 Oct. 2002	9.0	9.1	9.0
5	Hamlin	Manatee	Carrizo	22 Feb. 2002	Immokalee	31 Oct. 2002	10.3 ab	10.6 a	10.3 b
6	Hamlin	Bartow	Carrizo	22 Feb. 2002	Candler	5 Nov. 2002	9.2	9.3	9.2
7	Valencia	Ft. Pierce	Carrizo	25 Feb. 2002	Winder	15 Apr. 2003	12.4	12.3	12.2
8	Valencia	Ft. Pierce	Swingle	25 Feb. 2002	Wabasso	15 Apr. 2003	11.9	11.7	11.7
9	Valencia	Ft. Pierce	Sour orange	8 Mar. 2002	Riviera	15 Apr. 2003	13.2	13.0	13.0

[z] Identity of rootstocks: Swingle citrumelo (*C. paradis*i Macf.*x P. trifoliata* (L.) Raf.), sour orange (*C. aurantium* L.), and Carrizo citrange (*C. sinensis* L.*x P. trifoliate* (L.) Raf.)

[y] SSC values are corrected for titratable acidity. Means within rows followed by the same letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$. Means presented are for 10 trees per treatment and a 50 fruit sample per tree except for Manatee and Bartow orchards which are means for 20 fruit samples per tree.

4. Cline, W.O. and P.V. Oudemans. 2002. Diagnosis and description of widespread surfactant injury on blueberries in North Carolina. Acta Hort. 574:95-99.

5. Davies, F.S., E. Stover, G.R. Zalman, and S. Ciliento. 2004. EcoLyst application timing and juice soluble solids content of processing oranges and grapefruit in Florida. HortTechnology 14:282-289.

6. Environmental Protection Agency. 1999. Pesticide fact sheet, Ecolyst. http://www.epa.gov/opprd001/factsheets/ecolyst.pdf <August 2007>.

7. Greene, D.W. 2006. An update on preharvest drop control of apples with aminoethoxyvinylglycine (ReTain). Acta Hort. 727:311-319.

8. Greene, D.W. and J. Krupa. 2000. Influence of surfactants on the performance of ReTain as a harvest-management tool on Marshall McIntosh apple. Fruit Notes 65:54-56.

9. Keithly, J.H. ,T.A. Taggart, and C.A Campbell. 2000. Ecolyst: a new plant growth regulator for sweet orange [*Citrus sinensis* (L.) Osb.]. Proc. Intl. Soc. Citricult. 9:668-669.

10. McArtney, S.J. and S.H. Li. 1998. Selective inhibition of flowering on 'Braeburn' apple trees with gibberellins. HortScience 33:699-700.

11. Orbovic, V., J.L. Jifon and J.M. Syvertsen. 2001. Foliar-applied surfactants and urea temporarily reduce carbon assimilation of grapefruit leaves. J. Amer. Soc. Hort. Sci. 126:486-490.

12. Stevens, P.J.G. 1993. Organosilicone surfactants as adjuvants for agrochemicals. Pestic. Sci. 38:103-122.

13. Wardowski, W., J. Soule, W. Grierson and G. Westbrook. 1995. Florida citrus quality tests. SP99. Inst. Food and Agr. Sci., Univ. of Fla., Gainesville.

14. Wood, B.W. 1997. Impact of adjuvants on pecan foliage. HortTechnology 7:182-186.