EFFECTS OF ADDITIVES IN PREHARVEST ETHEPHON APPLICATIONS ON THE DEGREENING AND LOOSENING RESPONSE OF CITRUS FRUIT

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Additional index words. surfactants, buffers, pH, urea, phosphates

Abstract. The addition of several phosphate buffers or urea tended to increase the effectiveness of ethephon in coloring and loosening citrus. Increased responses were equivalent to those caused by about 50 ppm higher ethephon rates. Buffers caused some increases in leaf losses. The addition of surfactants to ethephon increased fruit color and loosening in some tests. Responses varied among cultivars, with differences among surfactants.

Preharvest applications of ethephon (2 chloroethyl) phosphonic acid, cause degreening and loosening of tangerines and tangerine hybrids (4, 5). The addition of surfactants is not recommended, although studies on effectiveness are lacking. Triton X100 was used as a surfactant in earlier studies (4) without causing excessive defoliation. Recently, low ethephon concentrations were found effective

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on pineapple when sprays were adjusted to pH 9 with $CaCO_3$ (2). On olives, adjusting ethephon to pH 7 with potassium phosphate increased the fruit loosening response (1).

The present study was undertaken to determine the effectiveness of several additives for improving the activity of preharvest ethephon applications on citrus fruit.

Materials and Methods

Trees of 'Hamlin' orange (**Citrus sinensis** [L.] Osb.), 'Robinson' (**C. reticulata** Blanco X [**C. paradisi** X **C. reticulata**]) and 'Dancy' (**C. reticulata** Blanco) tangerines, and 'Orlando' tangelo (**C. paradisi** X **C. reticulata**) were used in these studies. Surfactants studied in four tests included Triton X100 and Regulaid at 0.1%, Ag-chem Activator at 0.125%, and γ-butyrolactone at 800 ppm. In six tests, K_2HPO_4, $(NH_4)_2HPO_4$, urea, Ca acetate, Na_2HPO_4 were used as additives in ethephon sprays. Rates for phosphate buffers were between .003 and .008 M concentration and urea was used at rates as high as 3%. Ethephon rates ranged from 150 to 200 ppm on 'Orlando' to as high as 500 ppm on 'Hamlin'.

Fruit samples were taken one and two weeks after treatment. Fruit removal force was measured on 10 randomly selected fruit per plot with a Chatilon tester. An additional 10 fruit were hand pulled so that 20 fruit were available for color measurements. Rind carotenoid levels in fruit were measured with a difference meter and expressed as ΔR540-650 nm (3, 4). All fruit were checked for the degree of separation and plugging (tearing of rind). Leaf losses were determined from leaf counts made on four to six twigs per plot before spraying and after one and two weeks.

Leaf diffusive resistance measurements showed no water stress in test trees at the time the tests were initiated. Treatments were applied to 1/2- or one-tree plots with two to four replicates. All data were analyzed statistically.

Results and Discussion

Preliminary tests of surfactants with ethephon on 'Robinson' tangerines and 'Hamlin' oranges in 1976 showed no effect on color, fruit removal force, or defoliation. In 1977, the fruit removal force of 'Robinson' tangerine treated with 250 ppm ethephon and Triton X100 or γ-butyrolactone was lower than with ethephon alone (Table 1). Defoliation and the frequency of clean abscission (smooth separation at the abscission zone) of fruit tended to be greater with Triton X100.

'Orlando' tangelo color and fruit removal force were improved with the addition of surfactants (Table 1). However, the ΔR of .55 for 200 ppm ethephon is out of line compared to .61 ΔR obtained with 150 ppm ethephon. Although not significant, fruit abscission tended to be greater with surfactants added to ethephon. As with 'Robinson', defoliation of 'Orlando' tended to be greater with Triton X100 than the other surfactants but none of these leaf losses are considered serious.

Buffers applied alone had no effect on fruit or leaf responses. The addition of buffers to 250 or 350 ppm ethephon did not improve carotenoid development in 'Robinson' tangerines in 1977, but did significantly increase leaf and fruit abscission and reduce fruit removal force. On 'Robinson' fruit, combinations of buffers with 250 ppm ethephon gave results similar

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to those from 350 ppm ethephon alone (data not shown). On 'Orlando' tangelo, the addition of buffers increased color development and tended to increase fruit and leaf abscission (Table 2). Higher levels of buffers tended to increase leaf losses.

In 1978, calcium acetate was not effective on 'Robinson' or 'Orlando' (Table 3, 4). Potassium and ammonium phosphate and urea generally increased both fruit and leaf abscission. On 'Robinson', the effects of buffers plus 200 ppm ethephon were similar to those due to 250 ppm ethephon alone. Fruit ringing was increased by buffers with 200 ppm ethephon but not with 250 ppm. (Ringing is a zone where color development is delayed by high levels of ethephon residue [3].) On 'Orlando', defoliation was increased by the buffers, but losses were less than on 'Robinson'. On 'Orlando' additional plots were treated using buffers at .005 M (Ca acetate at .003 M) with results similar to those shown.

'Dancy' tangerines treated on

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Table 1. Response of 'Robinson' tangerines and 'Orlando' tangelos to preharvest applications of combinations of ethephon and surfactants.

Treatment Ethephon	Surfactant	Robinson Color ΔR	Robinson Fruit removal force kg	Robinson Leaf losses %	Robinson Clean abscission %	Orlando Color ΔR	Orlando Fruit removal force kg	Orlando Leaf losses %	Orlando Clean abscission %
0	0	.56	6.8	2	0	.56	11.0	0.3	13
low[Z]	0	.58	6.4	5	17	.61	9.5	1.0	73
	Triton X100	.58	5.4	12	35	.64	6.9	13.0	93
	Regulaid	.60	5.9	4	18	.63	7.8	10.0	97
	A. Activator	.60	6.4	3	25	.59	9.1	2.0	60
	B. Lactone	.59	5.0	2	18	.61	8.2	6.0	80
high	0	.63	5.0	9	60	.55	10.4	5.0	67
	Triton X100	.60	4.5	16	57	.62	7.3	9.0	83
	Regulaid	.63	5.4	9	50	.63	7.4	7.0	80
	A. Activator	.61	5.9	6	32	.61	7.7	3.0	80
	B. Lactone	.61	4.5	3	43	.63	7.3	8.0	90
LSD	A[Y]	ns	0.8**	8*	35*	.03**	1.6**	8.0+	25**
	B	ns	0.8**	8+	ns	.02**	1.7*	ns	ns

[Z]'Robinson' tangerines treated on Oct. 20, 1977, with ethephon at 250 and 350 ppm and 2 replications. 'Orlando' tangelo treated on Nov. 28, 1977, with ethephon at 150 and 200 ppm and 3 replications. All observations at 1 wk, except 'Orlando' leaf losses are for 2 wk from treatment.

[Y]Statistical analyses of all treatments (A) or with untreated check omitted (B). Differences significant at levels shown, 1% (**), 5% (*), 10% (+), or not significant (ns).

Table 2. Response of 'Orlando' tangelo to preharvest applications of combinations of ethephon with buffers. Treated November 28, 1977[Z].

Treatments Ethephon ppm	Additive	Rate	Color ΔR	Fruit removal force kg	Leaf losses %	Clean abscission %
0	0		.56	11.0	0.3	13
200[Y]	0		.55	10.4	5.0	67
200	K_2HPO_4	L[X]	.61	10.3	8.0	65
		M	.63	7.5	5.0	87
		H	.63	8.0	11.0	90
200	$(NH_4)_2HPO_4$	L	.64	7.0	10.0	90
		M	.61	7.4	14.0	93
		H	.62	7.7	15.0	93
200	Urea	L	.61	6.5	7.0	90
		M	.63	6.6	7.0	83
		H	.63	7.6	17.0	87
LSD		A[W]	.04**	3.0**	9.4+	22**
		B	.03**	3.1**	ns	ns

[Z]Measurements obtained 1 wk after treatment, except leaf losses were obtained after 2 wk.
[Y]This test also included ethephon at 150 ppm with medium buffer rate for a total of 15 treatments with 3 replicates.
[X]Additive rates of phosphates were selected to raise the spray to pH 6.5, 7.0 and 7.5, (for 200 ppm ethephon rates were between .003 and .007 M) rates for urea were 1, 2 and 3%.
[W]Statistical analyses of all treatments (A) or with untreated check omitted (B). Differences significant at levels shown, 1% (**), 10% (+), or not significant (ns).

Table 3. Response of 'Robinson' tangerine to preharvest applications of ethephon and buffer combinations.[Z]

Treatment[Y] Ethephon	Buffer	Color ΔR	Fruit removal force kg	Leaf losses %	Clean abscission %	Plugged fruit %	Ringed fruit %
0	0	.53	7.3	9	1	19	0
200	0	.58	6.9	13	11	15	24
200	K_2HPO_4	.61	6.3	14	17	12	34
200	$(NH_4)_2HPO_4$	.61	6.2	15	26	11	61
200	Urea	.60	6.3	12	29	10	50
200	Ca acetate	.57	6.9	7	0	15	0
250	0	.61	6.2	9	24	15	60
250	K_2HPO_4	.62	6.1	26	41	4	64
250	$(NH_4)_2HPO_4$	.62	5.8	16	41	7	75
250	Urea	.60	5.8	17	22	6	57
250	Ca acetate	.58	6.8	9	8	16	0
LSD	A[X]	.03**	ns	8.4**	20**	ns	19**
	B	.03*	ns	8.1**	17**	ns	19**

[Z]Measurements obtained 1 wk after treatment.
[Y]Treated on Oct. 26, 1978, with additives at .005 M concentration and with 4 half tree replicates.
[X]Statistical analysis of all treatments (A) or with untreated check omitted (B). Differences significant at levels shown, 1% (**), 5% (*), 10% (+), or not significant (ns).

Table 4. Response of 'Orlando' tangelo to preharvest applications of ethephon and buffer combinations.[Z]

Treatment[Y] Ethephon	Buffer	Color ΔR	Fruit removal force kg	Leaf losses %	Clean abscission %	Plugged fruit %
0	0	.51	5.1	0.3	5	66
200	0	.53	4.8	1.0	22	50
200	K_2HPO_4	.54	3.7	5.0	50	34
200	$(NH_4)_2HPO_4$	.55	3.7	3.0	71	22
200	Urea	.56	3.8	4.0	61	29
200	Ca acetate	.53	4.8	2.0	24	47
250	Na_2HPO_4	.55	4.2	3.0	50	31
LSD	A[X]	.02**	.77**	3.2*	20**	21**
	B	.02+	.79*	3.3+	21**	ns

[Z]Measurements obtained 1 wk after treatment.
[Y]Treated on Nov. 30, 1978, with additives at .008 M except Ca acetate at .005 M concentration, and with 4 half tree replicates.
[X]Statistical analysis of all treatments (A) or with untreated check omitted (B). Differences significant at levels shown, 1% (**), 5% (*), 10% (+), or not significant (ns).

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Dec. 14, 1978, showed no response to ethephon alone at 250 ppm (data not shown). Buffers, including commercial sodium phosphate, significantly improved carotenoid development and fruit loosening. However, fruit which were past optimum maturity still had 30-40 per cent plugging, indicating inadequate separation. 'Hamlin' oranges sprayed on Jan. 24, 1979, with ethephon at 350 ppm and buffers at .005 or .008 M showed less color and fruit loosening responses (data not shown) than were obtained from ethephon in previous studies (4). Temperatures were low (5-20°C) and this probably reduced the response.

Of the two types of additives tested the surfactants tended to be less effective than the buffers. Differences among the surfactants suggest that other surfactants or different rates may have greater effects. Several phosphate buffers or urea increased the responses to ethephon, frequently at levels comparable to those caused by an increase of 50 ppm ethephon. However, responses to combinations of ethephon and additives varied between cultivars and were reduced by cool weather, patterns which have been noted with ethephon above (4, 5).

To the extent tested all of the buffers appeared to give similar responses, except calcium acetate. The failure of this chemical suggests that tion to pH change. Observations suggest that buffers are effective surfactants on citrus. Attempts to compare several rates indicated that the concentration is not critical. Most of the buffers used in these studies were reagent-grade chemicals. Preliminary work indicates that reagent and commercial grades of sodium phosphate induce similar responses. Commercial grades of ammonium phosphate and urea also should be tested for grove use.