that populations slowly increase on both old and new flush at this time and generally accelerate in May and June justify chemical control at the time fungicides are applied to fresh market fruit in late-April and early May. Chemical control of citrus rust mite in groves where fruit is to be processed is also justified in view of mite buildup and virtual absence of natural enemies in the spring. If mite populations remain constant in May as occurred in the Lake Alfred grove in 1978, chemical control can be delayed, however a monitoring program would have to be in operation to detect low mite population density. Naturally, justification for a mite monitoring program depends on the characteristics of the grower operation.

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RESULTS OF 5 YEARS' CONTINUED USE OF ABSCISSION-INDUCING CHEMICALS ON 'HAMLIN' ORANGES[1]

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Abstract. **Acti-Aid (cycloheximide), Acti-Aid plus Sweep (chlorothalonil), Pik-Off (glyoxal-dioxime), and Release (5-chloro-3-methyl-4-nitro-1H-pyrazole) were sprayed at several rates onto 'Hamlin'** (Citrus sinensis **(L.) Osb.) orange trees during December, January, and February for 5 years. Fruit quality (as indicated by total soluble solids and acidity), yield, and tree growth were not affected by the abscission-inducing chemicals. Up to 10% defoliation occasionally resulted from sprays, but leaf size and shoot growth were not affected. When applied in February, the chemicals delayed flowering about 1 week in 1976 and 1978. Sweep increased the effectiveness of Acti-Aid in 4 of 5 years when applied in December, but not at other application times. Acti-Aid and Release loosened fruit more consistently than Pik-Off in December. The three sprays were equally effective in January; and Release was the most effective spray in February.**

Acti-Aid (cycloheximide), Pik-Off (glyoxal-dioxime), Release (5-chloro-3-methyl-4-nitro-1H-pyrazole) or certain combinations of these sprays are effective citrus fruit looseners and can be used to facilitate mechanical (2, 3, 4, 6) or hand harvest (1). Sweep (chlorothalonil) may increase the effectiveness of the abscission chemicals by increasing the length of time fruit produce ethylene (5, 6, 7). Acti-Aid is the only chemical that is registered for use as an abscission chemical on oranges.

Data presented in most reports are from one season and show the efficiency of the chemicals in lowering the fruit removal force (FRF) or increasing ethylene production and cellulase activity. The only reported information on fruit quality after the applications of abscission chemicals is on 'Valencia' oranges during one season (5), and the effects on yield of 'Valencia' oranges have been reported after mechanical harvest (9). Some defoliation usually occurs after abscission chemical applications (4, 7). Effects of continued low levels of defoliation on fruit quality, yield, and tree growth have not been reported. Other effects of continued use of these abscission-inducing chemicals on fruit quality, yield, tree growth, and consistency of loosening during several seasons are not known. Abscission chemicals cause tissue damage, as shown by defoliation (4) and fruit rind damage (7). An application of these chemicals could be expected to influence flowering, particularly if they are applied close to the bloom period. Other probable effects are a reduction in acidity because of the ethylene produced, a reduction in ratio of soluble solids to acids in juice, and lower juice content because of increased maturation rate.

The objectives of our study were to determine the effects of continued use of Acti-Aid, Pik-Off, Release, and Acti-Aid plus Sweep on quality, yield, and tree growth of 'Hamlin' oranges, and to determine how consistently these chemicals loosen 'Hamlin' oranges during a 5-year period when applied in early, middle, and late periods of the usual harvest season.

Materials and Methods

For these tests, 'Hamlin' (*Citrus sinensis* (L.) Osb.) 10-year-old orange trees on Carrizo citrange (*C. sinensis* (L.) Osb. X *Poncirus trifoliata* (L.) Raf.) rootstock growing near Lake Butler, Florida, were used. The grove was well irrigated, fertilized, and received adequate pest control measures. Two 2-tree replications were used for each treatment at each application date. Over a 5-year period, the chemicals were applied consistently in December, January,

[1]This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation by the U.S. Department of Agriculture nor does it imply registration under FIFRA.

or February, except in February of 1978, when a freeze in January partially defoliated the trees and loosened the fruit.

The concentrations of Acti-Aid, Pik-Off, Release and Sweep with 0.1% Triton X-100 as a surfactant are shown in the tables. Approximately 5 gal of spray per tree the first year and 8 gal per tree the last year were applied with a handgun sprayer. The amount was increased each year because of tree growth.

Fruit removal force was measured by published methods (4, 7) 3 and 5 days after chemical applications. Data for the 5-day measurements are reported. Fruit quality, as indicated by soluble solids and acidity, was determined the first week of January each year and 7 days after each chemical application. Yields were determined after each harvest, but only averages for each year are reported. Tree height and canopy diameters were measured after 5 years and compared with the size of the trees in 1974 as an index of tree growth. Summer shoot length and number were measured each July; however, only the final measurements are presented in the results because treatment effects were not evident. Soluble solids, acids and solids-acids ratio were determined by reported methods (8).

Results and Discussion

Fruit quality. The 5-year averages of total soluble solids (TSS) in fruit from sprayed trees did not differ from the average for unsprayed fruit (Table 1). In fact, the 5-year averages were unusually uniform. However, if seasonal data are considered, TSS varied considerably, and generally increased during the experimental period. In some cases, TSS of treated fruit differed from TSS of untreated fruit, but the differences were probably due to tree-to-tree variation for no chemical consistently increased or decreased TSS. The acidity of the juice also varied from season to season but not consistently according to chemical treatment (Table 2). The acidity of all the fruit was slightly lower in the 1978-79 season than in previous seasons. The fruit were coarse and large—typical fruit from trees with a small crop. Fruit size, juice content, and TSS-acids ratio were not affected by any of the treatments within any year or after 5 years.

Table 1. Soluble solids of 'Hamlin' orange sprayed with abscission-inducing chemicals for 5 years.

Treatment (ppm)	Season[z] 1974	1975	1976	1977	1978	Avg.
10 Acti-Aid	10.4	10.7	11.3 ab	11.7 ab	12.2 b	11.3
75 Release	10.4	10.2	10.4 a	11.3 a	11.8 ab	10.8
125 Release	10.9	10.8	12.0 b	12.6 b	12.4 b	11.7
75 Pik-Off	10.1	11.0	12.1 b	12.2 b	11.6 a	11.6
150 Pik-Off	10.2	10.1	12.0 b	11.6 a	12.0 b	11.2
10 Acti-Aid + 125 Sweep	11.4	10.4	10.8 a	11.3 a	12.3 b	11.2
Unsprayed	11.4	11.0	10.7 a	11.0 a	12.5 b	11.3

[z]Percent total soluble solids in fruit harvested the first week of January each season.
[y]Means followed by a different letter are significantly different at 5% level.

Although no data are presented, the chemicals had no effect on fruit quality within 7 days as has been reported for 'Valencias' (5). The only visible or measurable change in fruit quality was the damage to the rind.

Fruit yield. The total 5-year yields (90-lb field boxes) from the treated trees did not differ significantly from the yield for the untreated trees (Table 3). Some differences occurred between seasons and within seasons, but none could be attributed to treatment. The decreased yields in 1978-79 resulted from freeze damage in January 1978 and a short bloom period in March 1978. The yield increases over the 5 years were nearly the same for all trees, whether sprayed or unsprayed. Also, the differences in time of chemical application (i.e., December, January, or February) had no effect on yield.

Table 2. Juice acidity of 'Hamlin' oranges sprayed with abscission-inducing chemicals for 5 years.

Treatment (ppm)	Season[z] 1974	1975	1976	1977	1978	Avg.
10 Acti-Aid	1.15 b[y]	1.10	0.96 a	0.95 a	0.81	0.99
75 Release	0.96 a	1.04	1.06 b	1.03 b	0.92	1.00
125 Release	0.86 a	0.97	1.02 ab	1.07 b	0.84	0.95
75 Pik-Off	1.10 b	1.02	1.04 b	0.93 a	0.92	1.00
150 Pik-Off	0.99 a	0.99	0.94 a	0.92 a	0.90	0.95
10 Acti-Aid + 125 Sweep	0.97 a	1.04	0.94 a	0.89 a	0.89	0.95
Unsprayed	0.95 a	1.03	1.06 b	1.01 b	0.84	0.98

[z]Percent total acids in fruit harvested the first week of January each season.
[y]Means followed by a different letter are significantly different at 5% level.

Table 3. Yield of 'Hamlin' oranges from trees sprayed with abscission-inducing chemicals for 5 years (90-lb field boxes).

Treatment (ppm)	Season[z] 1974	1975	1976	1977[y]	1978	5-yr total
10 Acti-Aid	4.2 a	4.7 a	6.5	6.2	4.4 a	26.0
75 Release	4.8 a	4.7 a	5.9	6.1	4.2 a	25.7
125 Release	4.9 a	5.8 b	6.2	6.7	4.0 a	27.6
75 Pik-Off	5.0 a	4.8 a	7.1	6.8	4.7 ab	28.4
150 Pik-Off	5.1 a	5.7 a	6.5	7.0	5.6 b	29.9
10 Acti-Aid + 125 Sweep	5.8 b	6.7 b	6.9	7.0	3.7 a	30.1
Unsprayed	4.9 a	5.2 a	6.8	6.1	3.9 a	26.9

[z]Means followed by a different letter are significantly different at 5% level.
[y]Averages for trees sprayed in December only because of January 1978 freeze.

Tree size and shoot growth. Tree height did not differ significantly with treatment, and only those trees sprayed with 10 ppm Acti-Aid plus 125 ppm Sweep had canopy diameters significantly larger than those of the untreated trees (Table 4). The increased canopy diameter was most likely due to the location of the trees in the field. Three of the trees had no adjacent trees on two sides, and therefore, less competition for nutrients; thus, they could expand more into the space than the other trees. The sprays had no effect on yearly growth rates, as measured by increases in height and diameter of the canopy (data not presented). Similar chemical applications to other citrus cultivars ('Pineapple' and 'Valencia') had no effect on tree size (unpublished data) during a 5-year period.

Shoot growth of the summer flush was measured each year. Only those measurements of the 1979 flush are presented, since growth on all treated trees was nearly the same as that on the untreated trees (Table 4). In a 2- x 2-ft square frame, the number of new shoots varied from 5 to 14 and showed no treatment effect. The spring flush growth did not differ between treatments, and growth was more variable because of unequal numbers of flushes with and without flowers.

Table 4. Tree height, canopy diameter and shoot growth of 'Hamlin' orange trees sprayed with abscission-inducing chemicals.[z]

Treatment (ppm)	Height (ft) 1974	Height (ft) 1979	Diameter[y] (ft) 1974	Diameter[y] (ft) 1979	Shoot[x] growth (in.) 1979
10 Acti-Aid	11.0	14.4	9.4 b	16.5 a	4.4
75 Release	10.8	14.8	9.6 b	16.8 a	5.1
125 Release	10.4	15.3	9.3 ab	16.4 a	4.4
75 Pik-Off	10.6	14.9	8.8 a	15.4 a	5.3
150 Pik-Off	11.6	16.6	8.8 a	17.8 ab	5.4
10 Acti-Aid + 125 Sweep	11.4	16.5	9.0 ab	18.4 b	4.7
Unsprayed	10.8	14.6	8.0 a	15.7 a	4.8
	N.S.	N.S.			N.S.

[z]Means followed by a different letter are significantly different at 5% level.
[y]Average of north-south and east-west diameters at 4-ft height.
[x]Summer flush, length in inches, average of 10 shoots/tree.

Fruit removal force. Release at 125 ppm was the most consistent of the chemicals in loosening fruit (Table 5). Acti-Aid or Acti-Aid plus 125 ppm Sweep was nearly as

Table 5. Average fruit removal force 5 days after abscission-inducing chemical application in December, January and February.[z]

Treatment (ppm)	Fruit removal force (lb) December	January	February
10 Acti-Aid	6.1 a[y]	3.9 a	5.3 b
75 Release	7.7 b	4.6 a	7.1 c
125 Release	6.0 a	4.0 a	2.0 a
75 Pik-Off	10.0 c	7.9 b	9.7 c
150 Pik-Off	8.8 bc	4.8 a	5.9 b
10 Acti-Aid + 125 Sweep	6.3 a	4.0 a	5.2 b
Unsprayed	21.0 d	17.3 c	13.9 d

[z]Averages for 5 years.
[y]Means followed by a different letter are significantly different at 5% level.

effective as Release, except in February when temperatures averaged several degrees below those recorded during the January tests. In 2 of the 5 years, 125 ppm Release caused all the fruit to drop within 5 days of application in January or February. Because of the preharvest drop, either Release at a lower rate or Acti-Aid at 10 ppm may be better for efficient harvest. A FRF of about 5 lb is generally considered to be low enough for good mechanical harvest.

The overall FRF averages do not indicate that Sweep was beneficial when applied with Acti-Aid; however, in 4 of the 5 years the FRF was lower for the Acti-Aid plus Sweep combination than for Acti-Aid alone in December. In January and February, no difference existed.

Fruit loosening was more variable from the 150 ppm Pik-Off treatment than from other treatments, but if the maximum temperatures were above 55°F, loosening was generally good with this treatment in January and February. Ethylene production rind injury, and fruit loosening for Pik-Off in December were lower than those for any other combination of treatment and time of application. The reason for the low response of fruit to Pik-Off early in the season is being investigated to determine whether absorption, condition of the rind, or some other factor limits its effectiveness.

Release and Pik-Off at 75 ppm were generally not satisfactory because they inconsistently lowered FRF. The average FRF resulting from these treatments were not low enough for efficient harvest.

Miscellaneous observations. In 2 of the 5 years, the date of full bloom was delayed 5 to 7 days by the February applications of Acti-Aid, 125 ppm Release, and 150 ppm Pik-Off. The lower rates of Release and Pik-Off had no effect on bloom date.

The chemicals, even though causing as much as 10% defoliation, did not affect cold hardiness of the trees, as indicated by the amount of damage resulting from freezes in January 1977 and January 1978. Fruit damage and defoliation of sprayed trees were no different from those of the nonsprayed trees. The January 1977 freeze caused the FRF to drop to less than 5 lb with about 5% defoliation. However, a freeze within a week after spray application may cause more damage than recorded in these tests (personal communication, W. C. Wilson).

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