trifluralin are by volatilization, photodecomposition, and chemical and microbial breakdown.

From the residue data presented ,it is clear that the levels of terbacil, bromacil, dichlobenil, and trifluralin were extremely low in the entire 0 to 18 inch layers of the soil types sampled. Although soil samples were not collected on a yearly basis, the data indicates that there is no accumulation which would lead to a toxic buildup at the rates used on the soil types sampled; rather, we should expect a steady rate of dissipation due to several degradation processes. Based on our knowledge of the recommended application rates, the small residues found are well within the tolerance levels of citrus trees in established groves. However, after several years of herbicide applications, it would be to the grower's advantage to determine whether soil residues in the spring are at levels sufficient to afford some degree of commercial weed control before making any further applications at the full rates. Such a practice might lead to satisfactory weed control at reduced rates with consequent dollar savings.

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FOUR YEARS OF ABSCISSION STUDIES ON ORANGES

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ABSTRACT

There are 3 compounds which are known to effectively promote abscission of oranges. Typical results from spraying 'Hamlin' oranges showed that CZ-150 (hexamic acid) or ascorbic (or erythorbic) acid at 1-1/2% reduced the pull force from 14.5 to 7.0 pounds and percent plugs from 90 to 5% within 6 days of application. Cycloheximide at 10 ppm caused a reduction to 5.0 pounds and 0% plugs. Cycloheximide appears to be practical for producing abscission of 'Valencia' oranges, provided application is no earlier than 8 weeks after bloom. Both CZ-150 and ascorbic (or erythorbic) acid effectively loosened mature 'Valencia' oranges, but may cause injury to the young green fruit with subsequent crop reductions as high as 80%. Commercial companies have applied for experimental labels on CZ-150 and cycloheximide. Ascorbic and erythorbic acids are classified as generally recognized as safe, and no USDA registration appears to be necessary for their use as an abscission spray.

Abscission chemicals have been shown to be effective harvesting aids, but the present chemicals have certain drawbacks. Some major problems encountered are reduction in effectiveness due to adverse weather conditions, inability of a chemical to effectively loosen all the fruit on the tree, and inability to loosen fruit without peel injury.

INTRODUCTION

The development of more effective abscission chemicals has progressed greatly in the past 4 years. At the beginning of the period, only iodoacetic acid showed promise of producing useful abscission (4), although considerable defoliation often resulted from the treatments. Still, this compound was a necessary step in the develop-

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ment of these chemicals and served to create interest in this area. Since this time, several compounds have been found to initiate abscission of oranges with little or no defoliation. Ascorbic (AA) or erythorbic (EA) acid combined with other weak acids has proven an effective treatment (2, 6), and CZ-150 (hexamic acid) has also proven to be effective (7). An entirely different type chemical, cycloheximide (CHI), was shown to produce abscission of oranges and, in fact, appeared to have some superior qualities when compared to other chemicals under test (3).

With the citrus labor situation becoming more acute each year, an overall move by the industry toward commercial usage of mechanical harvesting devices appears to be taking place. Therefore, the purpose of this paper is to present information concerning potential commercial performance of these chemicals, with particular emphasis on information relating to their current use by growers.

Materials and Methods

Whole citrus trees were sprayed with various chemicals, and pull tests were made on the fruit as described by Hendershott (4). Fifteen gallons of spray solution per tree was applied to most trees, unless speed-sprayer tests of large numbers of trees were made. In these cases, from 5 to 10 gallons of solution per tree were used. Ortho spray sticker was used with most of the tests with CZ-150 and AA or EA. From 0.0375 to 0.075% spreader, furnished by the Upjohn Company, was used with CHI sprays. Several commercial companies furnished many of the products tested.[1] Ratings of abscission inductiveness were based on the ability of the chemical to reduce the bonding force between the stem and fruit.

The information reported was obtained from the studies on many trees. Often the results of a test involved the collection of information where treatments included spraying from 1 to 30 or more trees. Because of the vast amount of information collected this season, representative results were often taken to illustrate a particular situation. Care was used not to select the very best or worst information available for any one treatment or chemical.

[1]The following commercial companies furnished chemicals reported in this paper: Abbott Laboratories, Chas. Pfizer & Co., Inc., Hoffmann-La Roche, Inc., The Upjohn Co., and Ortho Div. of Chevron Chemical Co. There were many other contributors to the abscission project, but results of their products are not reported here.

Results

CZ-150 produced acceptable loosening of early and midseason oranges as shown in Table 1. As has often been observed in past tests, the 'Pineapple' variety responded to the abscission spray slightly better than 'Hamlin.' The 2 varieties had been interplanted in this test. The 2 lb/15 gal (1.75%) concentration was more effective than the 1 lb/15 gal (0.87%) concentration.

When various acidic phosphates were combined with CZ-150, its effectiveness was enhanced (Table 2), with the most striking drop

Table 1.--The effects of CZ-150 (hexamic acid) sprays on the removal (pull) force of interplanted 'Hamlin' (HA) and 'Pineapple' (PA) oranges.[1]

	Pull force (lb)		
Chemical/conc.	3 day post	4 day post	5 day post
1 lb/15 gal HA	8.9*	8.4*	8.8*
2 lb/15 gal HA	8.2*	8.4*	7.2*
Control HA	12.9	12.2	12.0
1 lb/15 gal PA	15.8	14.2	9.7*
2 lb/15 gal PA	7.5*	7.4*	6.3*
Control PA	12.7	14.5	12.0

[1]Sprays were applied February 1, 1969.

*Significant from control at 1% level.

Table 2.--A comparison of the effects of various acidic phosphate additives on CZ-150 (hexamic acid) abscission activity.[1]

Concentration/additive	lb force	% plug
Control	19.01	60
3% CZ-150 only	16.52	50
4% CZ-150 only	11.93	20
3% + .05% phosphoric acid	14.79	35
4% + 0.05% phosphoric acid	11.05	5
3% + 0.1% phosphoric acid	15.60	30
4% + 0.1% phosphoric acid	1.86*	0
3% + 0.13% $(NH_4)_2 H PO_4$	14.29	25
4% + 0.13% $(NH_4)_2 H PO_4$	12.78	30
3% + 0.12% $NH_4 H_2 PO_4$	13.34	25
4% + 0.12% $NH_4 H_2 PO_4$	12.04	20
3% + 0.14% $Na H_2 PO_4$	15.30	20
4% + 0.14% $Na H_2 PO_4$	10.27	10

[1]Branch sprays of 'Valencia' oranges using 10 fruits per sample, 2 replications.

*Significant from control at 1% level.

Table 3.--A comparison of tests made with CZ-150 sprayed at different dates on several varieties of oranges at various locations in the State.

Variety	Date sprayed	Grove location	Concentration (%)	Pull force (lb)	% plug
'Hamlin'	11/25/68	SF	1-3/4%	9.3+	20
'Hamlin'	11/25/68	SF	7/8%	11.8++	80
'Hamlin'	-	SF	Control	15.6	76.6
'Hamlin'	12/8/68	LB	2% (pH 1.5)	5.2+	6.7
'Hamlin'	12/8/68	LB	1% (pH 1.8)	10.2++	68.3
'Hamlin'	-	LB	Control	14.6	100
'Hamlin'	1/6/69	R-1	1-1/2%*	6.9+	-
'Hamlin'	-	R-1	Control*	13.5	-
'Parson Brown'	1/17/69	R-2	1-1/2%*	4.4+	-
'Parson Brown'	-	R-2	Control*	13.0	-
Seedling 'Pineapple'	1/16/69	SF	1-1/2%	4.7+	0
Seedling 'Pineapple'	1/16/69	SF	3/4%	6.9+	6.7
Seedling 'Pineapple'	-	SF	Control	14.5	93.3
'Pineapple'	1/15/69	LB	2%**	10.5++	17.8
'Pineapple'	1/15/69	LB	1%**	13.3	60
'Pineapple'	-	LB	Control**	14.7	88
'Pineapple'	2/1/69	SB	1-3/4%	6.3+	0.0
'Pineapple'	2/1/69	SB	7/8%	9.7++	20
'Pineapple'	-	SB	Control	14.5	80

*Fruit showing slight to moderate freeze injury.

**Residual amounts of synthetic auxin weed killers present in soil.

+Significant from control at 1% level.

++Significant from control at 5% level.

SF = Southern Fruit Distributors (Winter Garden).

LB = Coca Cola Company (Lynchburg block), west of Lake Alfred.

R-1 = Roper grove, Winter Garden (15 miles south).

R-2 = Roper grove, Winter Garden (25 miles south).

SB = Coca Cola Company (Summit block), north of Lake Alfred.

in pull force resulting from the 4% CZ-150+0.1% phosphoric acid applications. In numerous other tests with CZ-150 conducted throughout the fruit season, the inclusion of 0.05 to 0.25% phosphoric acid usually enhanced fruit loosening. Higher concentrations caused excessive leaf drop.

Tests with AA or EA during the 1968-69 fruit season were essentially the same as those of CZ-150, and the results were very similar to those obtained in previous years (6, 7).

Some variation in responses due to variety, location, and condition of the fruit were noted with CZ-150 (Table 3). Seedling oranges appeared to be more responsive to abscission chemicals than the standard budded varieties tested, and oranges which had been partially frozen appeared to be more sensitive than unfrozen oranges. Fruit maturity seemed to be relatively unimportant provided it was not abnormally green or overly ripe (senescent). The presence of residual amounts of synthetic auxin weed killers in the soil[2] apparently reacted adversely with applied abscission chemicals which reduced the effectiveness of CZ-150 (as well as other compounds which were under test).

Table 4.--A comparison of the abscission-producing ability and related factors of CZ-150 (hexamic acid) and cycloheximide applied as dilute sprays to 'Hamlin' oranges.

	CZ-150	Cycloheximide
Typical pull force at optimum concentration[1]	7.0 lb	5.5 lb
Number of days required to produce loosening	4-6	3-5
Amount of peel injury	Slight to moderate	Moderate to severe
Dry period necessary (no rain)	At least 1 day	Few hours
Effective concentration	1-1/2% (15,000 ppm)	5-20 ppm

[1]Both compounds consistently produced pull force reductions significant from the control at the 1% level.

[2]Evidently, a spray containing 2,4-D or 2,4,5-TP had been applied for vine control during the preceding summer.

CHI produced somewhat better results than AA, EA, or CZ-150. A typical comparison of abscission test results, and other related factors, between CHI and CZ-150 applied to 'Hamlin' oranges is shown in Table 4. At optimum concentration, CHI appeared to produce abscission slightly faster than CZ-150, and observations relating to weather indicate strongly that CHI is less subject to rains following spraying than the weak acids. However, field observations indicated a 24-hour dry period following spraying of all compounds appeared beneficial. CHI caused a moderate to severe pebbling of the fruit peel in contrast to the distinct peel burn caused by the weak acids. None of the chemicals produce abscission suitable for fresh fruit, but the peel injury should not prevent processing the fruit.

CHI was the only acceptable chemical for the 'Valencia' variety according to 1 year's data available with this compound. Eight weeks following full bloom, which occurred about April 3, 1969, and using concentrations of 25 ppm, 'Va-

Table 5.--The results of abscission sprays of cycloheximide on 'Valencia' oranges.

		4 days post		8 days post		12 days post				
Date sprayed	Conc. ppm	Pull psi	Plug %	Pull psi	Plug %	Pull psi	Plug %	Leaf loss %	Flower/young fruit loss %	Remarks
3/28/69	5	12.0	7	10.8	20	12.7	33	1	95	Slight tree injury
3/28/69	15	9.6	0	7.3	13	8.4	13	50	98	Some tree injury
3/28/69	25	3.9	0	3.0	0	3.0	0	90	100	Moderate tree injury
4/3/69*	15	8.4	0	9.1	0	13.0	27	2	98	Most young fruit dropped
4/3/69*	15	9.8	0	10.0	0	11.7	7	2	98	Most young fruit dropped
4/8/69	15	10.1	7	8.6	7	10.2	7	1	98	Light flush burn
4/8/69	15	9.6	0	9.9	0	11.5	20	1	98	Light flush burn
4/21/69	5	13.2	33	15.0	53	17.7	53	1/2	98	Young fruit burned
4/21/69	15	11.6	13	12.7	40	16.2	13	1	98	Young fruit burned
5/6/69	15	13.3	0	11.3	7	9.0	7	4	98	Young fruit burned
5/6/69	25	5.4	0	6.8	0	9.5	0	25	100	Young fruit burned
5/21/69	20	7.3	0	8.1	7	9.6	7	1	70	Some burn on green fruit
5/23/69	20	6.0	7	6.7	0	7.8	0	1/4	50	Light burn on green fruit
6/5/69	25	6.5	0	7.2	5	8.5	5	0	0	No injury to green fruit
Control (Avg.)	-	16.7	66	16.4	64	16.5	57	-	-	Avg. of 14 trees throughout period

*Full bloom.

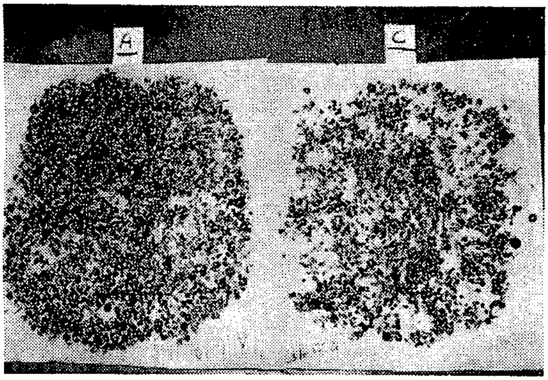

Figure 1.—A comparison of the amount of immature 'Valencia' orange fruit removed with an inertia shaker following a spray application of cycloheximide (15 ppm). "A" was chemically treated (April 21, 1969); "C" was control. Both trees were harvested April 21, 1969. (Photograph courtesy of Mr. G. E. Coppock.)

lencia' oranges loosened with little or no leaf drop and no injury to the immature, green fruit (Table 5). Prior to this time, extensive injury to the young, green fruit occurred; and heavy foliage loss often resulted. Spraying 'Valencia' oranges before blooms opened also caused extensive leaf and blossom shedding.

The increase in young fruit loss following a spray of 15 ppm CHI applied April 28, 1969, is graphically shown in Figure 1. Mechanical shaking of the treated and control trees produced much more young fruit drop with the former.

The weak acids AA, EA, and CZ-150 successfully loosened mature 'Valencia' oranges in tests made this season and in past seasons (7); but severe pitting and development of necrotic (dead) areas on young, green fruit was always noted. Although young fruit did not fall immediately, in every case it was obvious by the following spring (when the crop had matured) that trees sprayed with these compounds had markedly reduced crops. Reductions occurred whether the trees were sprayed in March (before bloom) or as late as early June.

Major problems relating to weather conditions were noted occasionally in past years, but were particularly acute during portions of the 1968-69 fruit season. Specific reasons for failures due to weather were difficult to document as specific instrumentation for this purpose was not attempted. However, a comparison of Weather Bureau records and test results obtained indicated that, in general, periods of cold tempera-

Table 6.--A comparison of the effects of temperature and relative humidity on the performance of abscission compounds CZ-150 (hexamic acid) and cycloheximide on 'Pineapple' oranges. (Computed temperatures and relative humidities are the averages of highs and lows during the first 3 days following spraying.)

Chemical/concentration and date sprayed	Days post spray	Pull force lb	Temperature (F) during 3-day period		Relative humidity during 3-day period	
			Avg. high	Avg. low	Avg. high	Avg. low
CZ-150 2 lb/15 gal February 1, 1969	6	7.0*	77.7°	54.3°	92.3%	55.7%
CZ-150 2 lb/15 gal February 20, 1969	11	13.0	66.7°	47.3°	77.0%	49.0%
CHI 10 ppm February 1, 1969	6	5.3*	77.7°	54.3°	92.3%	55.7%
CHI 10 ppm February 20, 1969	11	10.67	66.7°	47.3°	77.0%	49.0%
Control February 7, 1969	-	13.0	-	-	-	-
Control March 3, 1969	-	15.26	-	-	-	-

*Significant from control at 1% level.

tures (night temperatures in the 30 to 40°F range, day temperatures not exceeding 65°F) and dry conditions caused an overall delay in abscission-producing effects of all chemicals, but usually did not otherwise prevent obtaining good fruit abscission. Typical delays ranged from a few days to up to 2 weeks longer than the normal abscission-induction period of 4 to 6 days. Cold, relatively rainy periods often resulted in failures of all compounds tested. The weak acids appeared to be more subject to losses due to adverse weather conditions than CHI (Table 6).

Discussion

Although CHI appeared to be somewhat more effective in producing fruit loosening than AA, EA, or CZ-150, the later compounds produced acceptable results. Field experience has shown that reduction of the pull force of the fruit below 6.0 pounds, measured by the standard pull tester (4), may cause excessive fruit drop which could interfere with mechanical harvester operations. Therefore, pull force reduction by a chemical to the range of 5.5 to 7.5 pounds force would appear to be sufficient.

In other areas of comparison, CHI is advantageous in that a very small concentration is necessary to produce abscission, thus eliminating the logistics problem created by using large quantities of chemicals. Although the compound is relatively toxic, residue studies made by the Upjohn Company (5) on citrus products, manufactured at the Florida Citrus Experiment Station from fruit sprayed with CHI, indicated no detectable amounts of the chemical should remain when the fruit is processed. Because of the recent ban on the use of cyclamates by FDA, the question of issuance of residue tolerances for CZ-150 (hexamic acid) is now very much in doubt. However, AA and EA are safe and evidently no USDA registration is necessary for their use. Experimental labels have been requested from FDA by the respective manufacturers of CZ-150 and CHI.

The biggest problem with the weak acids has been the cost of the compounds. Tests at the Citrus Experiment Station indicate that $1 per tree, for one which has at least 5 boxes, is the maximum allowable cost for chemical and spray application where the purpose is to augment operation of an inertia shaker (1). For use in increasing the efficiency of picking crews, such sprays might have to be substantially lower in price to justify their use. It is hoped that all these compounds can be marketed below the $1 per tree level. Anticipated large increases in production of AA should bring about a substantial price reduction in this compound, making it useable economically. Indeed, the weak-acid type compounds, though slightly inferior to CHI, could well-establish themselves in the abscission chemical market if a very inexpensive chemical or combination could be found.

Much research remains to be done with the 'Valencia' variety. Although CHI appears to be effective approximately 8 weeks following full bloom, often this is relatively late in the harvest season. By this time, the young fruit would normally achieve sufficient size and weight so that it, as well as the mature fruit, would be susceptible to removal by mechanical shaking. However, results of tests with the inertia shaker (1) indicate mature 'Valencia' oranges can be effectively removed, with negligible loss of young fruit, until about the 15th of May each year. Perhaps CHI sprays will allow extension of this period somewhat.

Field observations indicate one problem of using abscission chemicals is lack of uniformity in loosening all fruit, e.g., some are too loose and some never seem to loosen at all.

The first commercial purchase and use of abscission chemicals to aid harvesting will probably occur during the 1969-70 fruit harvesting season. Although these chemicals greatly aid mechanical harvesting, they are not a "cure all" in themselves. Judicious management will be required in their use, otherwise the operation may be uneconomical. Abscission chemicals appear to work satisfactorily provided certain precautions are met:

1. Do not apply them when probability of rain is high, or during cold periods interspersed with frequent rains.
2. Thorough spray coverage is necessary for optimium results. The weak acids have little, if any, systematic action. Although information concerning CHI indicates it may have some systemic action (3), field results indicate thorough spray is desirable.
3. Avoid over concentration of the sprays. Relatively dilute sprays of the weak acids appear to be necessary, but some concentration of the CHI is probably possible.

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INFLUENCE OF TEMPERATURE AND HUMIDITY ON CYCLOHEXIMIDE-INDUCED ABSCISSION AND ETHYLENE CONTENT OF CITRUS

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Abstract

Cycloheximide stimulated ethylene production in Hamlin oranges and Orlando tangelos more in 90°/70° than 60°/40° day-night controlled greenhouse conditions. Pull force generally decreased as the ethylene content increased, except for Orlando tangelos at low temperatures with both high and low humidity. Excessive premature fruit drop from the trees sprayed with 25 and 50 ppm cycloheximide occurred in the high temperature-high humidity conditions. Ethylene production in calamondin fruit was stimulated by cycloheximide at 50° and 70° but not at 40° F. Warm air temperatures in the field also increased the efficiency of cycloheximide in stimulating ethylene production and reducing the pull force of Hamlin oranges.

Introduction

Temperature and humidity influence many physiological processes in plants (6,9); among these are absorption and translocation of chemicals applied to the surface of leaves and fruit. More ethylene is produced by 'calamondin' fruit (*Citrus reticulata* var. *austera* ? X *Fortunella* sp ?) sprayed with ascorbic acid and grown in high humidity than when grown in low humidity (8). Pull force of the fruit is closely related to the amount of ethylene produced. Also, olive fruit abscise with less pull force after ascorbic acid treatment in humid conditions than dry (5).

The response of citrus fruits to ethylene producing chemicals under field conditions is variable (2,3,4,10). Usually, temperatures, humidity, soil moisture, etc., were different in each test. Therefore, an understanding of the environmental conditions that affect the efficiency of these abscission chemicals is desirable, so that they may be applied at the best time.

Cycloheximide (3[2-(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl] glutarimide) stimulates ethylene production by a number of plants (1,2,4) including citrus. It is one of the most promising chemicals to induce abscission of citrus fruit. However, the pull force of fruit from their stems after cycloheximide application is variable, depending on environmental conditions.

We grew small citrus trees in cans in a greenhouse with temperature and humidity control to determine how these two factors affect ethylene production and pull force of fruit after they are treated with cycloheximide. To determine whether the temperature effect was the same in the field, we monitored temperatures during several tests. We also report the results of several 24-hour temperature tests with calamondin fruit dipped in cycloheximide.

Methods and Materials

Greenhouse tests. — We placed 2-year-old 'Hamlin' orange (*Citrus sinensis* [L.] Osbeck) and 'Orlando' tangelo (*C. paradisi Macf.* x *C. reticulata* Blanco) trees in an air-conditioned greenhouse for 5 days at either 1) high temperature-high humidity; 2) high temperature-