LITERATURE CITED

1. Coppock, G .E. 1969. Unpublished data. State of Fla., Dept. of Citrus.
2. Cooper, W. C., and W. H. Henry. 1967. The acceleration of abscission and coloring of citrus fruits. Proc. Fla. State Hort. Soc. 80: 7-14.
3. Cooper, W. C., and W. H. Henry. 1968. Field trials with potential abscission chemicals as an aid to mechanical harvesting of citrus in Florida. Proc. Fla. State Hort. Soc. 81: 62-68.
4. Hendershott, C. H. 1964. The effect of various chemicals on the induction of fruit abscission in 'Pineapple' oranges. Proc. Amer. Soc. Hort. Sci. 85: 201-209.
5. Personal communication.
6. Wilson, W. C., and G. E. Coppock. 1968. Chemical stimulation of fruit abscission. Proc. Int. Citrus Symp., Riverside, Calif. (In Press).
7. Wilson, W. C., and G. E. Coppock. 1968. Chemical abscission studies of oranges and trials with mechanical harvesters. Proc. Fla. State Hort. Soc. 81: 39-43.

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-low humidity; 3) low temperature-high humidity; or 4) low temperature-low humidity. High temperature was 90° day-70° night; low temperature was 60° day-40° night; high humidity was 80% day-100% night and low humidity 40%-day-60% night. Under the high humidity conditions a fine mist came on a 1 AM and 5 AM, for 30 seconds, to simulate a heavy dew with no water runoff from the trees. We programmed the temperatures for 12-hour days.

We sprayed the trees with 5, 25 and 50 ppm cycloheximide. Trees sprayed with H_2O were controls. All sprays contained 0.01% triton x-100 as a wetting agent. The trees sprayed with cycloheximide grew in these conditions an additional 4 days, then we measured the pull force and ethylene content of the fruit by previously described methods (7). The data in the tables show average measurements of the number of fruit left on the trees at harvest. The number varied from six to 20 depending on number of drops.

Calamondin fruit test. — We dipped 10 calamondin fruit in either H_2O, 5, 10 or 25 ppm cycloheximide for 1 minute, dried, then placed them in 1-liter jars for 12 hours at 40°, 50° and 70°. We used four replications of each treatment.

Field tests. — Temperature records during two field tests show the relation of air temperatures to ethylene production and pull force of Hamlin oranges. The average maximum and minimum temperatures in one test were 70°/54° and during the other 63°/37°. We applied 10 gal of spray with 0,5,10 or 25 ppm cycloheximide and 0.1% triton x-100 to single trees. Data represent the average ethylene content of five fruit from each of four replications, and the pull force of 10 fruit from each replication 5 days after spray application (Fig. 2).

Results and Discussion

Effect of temperature and humidity in controlled conditions. — Ethylene in the fruit increased at nearly the same rate as cycloheximide concentration increased under high temperature. The humidity ranges used had no effect on ethylene production by Hamlin oranges (Table 1). The pull force required to remove the fruit from their stems decreased as ethylene increased up to about 0.77 ppm. Above that level, the pull force remained nearly constant but more fruit dropped prematurely than at the lower ethylene levels when the humidity was high. In low humidity even the highest ethylene concentration had little effect on the number of fruit drops.

Table 1. Ethylene content, pull force of fruit and fruit drop of Hamlin oranges sprayed with cycloheximide and grown in high temperatures1/

Cycloheximide ppm	C_2H_4 2/ ppm	Pull force lbs	Drops3/ number
	High humidity (80/100%)		
0 (H_2O)	0.02	16	0
5	0.34	12	0
25	0.77	2	6
50	2.59	3	10
	Low humidity (40/60%)		
0 (H_2O)	0.03	16	0
5	0.28	14	1
25	0.85	5	4
50	2.75	4	3

1/ 90°/70° day-night.
2/ Ethylene under rind of fruit.
3/ Number of fruit drops out of 20 original fruit.

In the low temperature test on Hamlin oranges (Table 2), cycloheximide did not increase ethylene production as much as in the high temperature. The maximum amount in low temperature was 1.42 ppm compared to 2.75 ppm in high temperature. Under the high humidity the pull force decreased as cycloheximide concentration increased but when the humidity was low (40/60% RH), the treatments affected the pull force very little. Only the 50 ppm treatment in high humidity increased the number of premature drops.

The same general trends exist when cycloheximide is sprayed on Orlando tangelos in the same growing conditions (Tables 3 & 4). However, the ethylene content was never as high in Orlando tangelos as in the Hamlin oranges under similar conditions. Untreated Orlando tangelos, contained slightly more ethylene than the untreated Hamlin oranges, and they sep-

Table 2. Ethylene content, pull force of fruit and fruit drop of Hamlin oranges sprayed with cycloheximide and grown in low temperatures1/

Cycloheximide ppm	C_2H_4 ppm	Pull force lbs	Drops number
	High humidity1/		
0 (H_2O)	0.05	12	0
5	0.24	13	0
25	0.78	9	0
50	1.42	5	4
	Low humidity		
0 (H_2O)	0.03	19	0
5	0.23	18	0
25	0.36	18	0
50	0.89	16	0

1/ 60°/40° day - night.
2/ See Table 1.

Table 3. Ethylene content, pull force and drop of Orlando tangelo fruit of trees sprayed with cycloheximide and grown in high temperatures1/

Cycloheximide ppm2/	C_2H_4 ppm	Pull force lbs	Drops number
	high humidity2/		
0 (H_2O)	0.06	9	0
5	0.44	6	3
25	0.87	2	8
50	1.97	4	14
	low humidity		
0 (H_2O)	0.05	12	0
5	0.48	8	0
25	0.97	2	1
50	1.72	3	2

1/ 90°/70° F day - night.
2/ See Table 1.

arated from their stems with less force than did the Hamlins. This observation is expected since low pull force is generally correlated with high ethylene levels.

In high temperature, even though ethylene was lower, the pull force of the Orlandos was reduced to nearly the same level as that of the Hamlin oranges. Seventy per cent of the fruit dropped in the high humidity-high temperature treatment as compared to about 10% in low humidity.

Cycloheximide increased the ethylene least of all in Orlando tangelos in the 60°/40° regime (Table 4). The treatments did not reduce the pull force in these environmental conditions, even though ethylene increased up to .64 ppm. No increase in drops occurred under these conditions.

Ethylene evolution from calamondin fruit. — To further test the effect of temperature on the efficiency of cycloheximide, we dipped calamondin fruit in solutions of cycloheximide as described. Cycloheximide at 5 and 10 ppm stimulated ethylene production in these conditions at 50° and

Table 4. Ethylene content, pull force of fruit and fruit drop of Orlando tangelos sprayed with cycloheximide and grown in low temperatures1/

Cycloheximide ppm	C_2H_4 ppm	Pull force lbs	Drops number
	High humidity2/		
0 (H_2O)	0.04	10	0
5	0.29	10	0
25	0.62	10	0
50	0.54	11	2
	Low humidity		
0 (H_2O)	0.05	11	0
5	0.28	10	0
25	0.58	11	1
50	0.64	9	0

1/ 60°/40° F day - night.
2/ See Table 1.

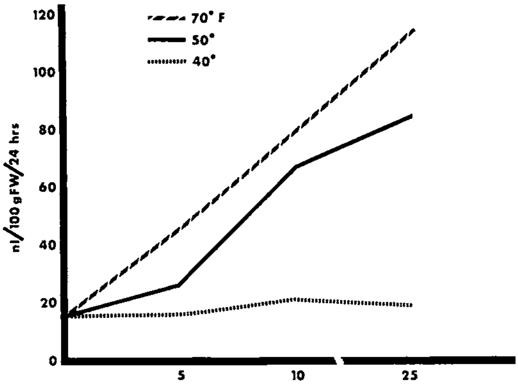

Figure 1.—The effect of cycloheximide on ethylene production by calamondin fruit at 40, 50, and 70°F.

70° but not at 40° F (Fig. 1). The rate of ethylene production increased rapidly in the 5 and 10 ppm treatments at 50° and 70°. Higher temperatures may have increased it even more, since field and greenhouse data indicate increased ethylene production by other citrus varieties up to 90° F. Also, ascorbic acid increased ethylene production more at 80° than at lower temperature under similar conditions (unpublished data).

Field tests. — Cycloheximide stimulated ethylene production by Hamlin orcnges more when the average temperatures were 74°/52° day-night than when they were 63°/37° day-night. Almost five times as much ethylene was produced by 5 ppm cycloheximide in the higher temperatures. The fruit sprayed with 25 ppm cycloheximide contained about two times as much ethylene in the higher temperatures (Fig. 2).

The pull force decreased more rapidly in the high temperature test. The 5 ppm treatment reduced the pull force to about 9 lbs compared to 14.5 lbs in the low temperature. The pull force did not go below 10 lbs during the cold temperatures regardless of cycloheximide treatment, while it went down to about 8 lbs in the warmer temperature when 25 ppm cycloheximide was used.

In other field tests during cold weather we found that the temperature at the time of application was as important as temperatures after application. Usually a warm day soon after spray application had more effect on cycloheximide than one closer to harvest date. Both pull force and ethylene production by the fruit indicated this. The most likely reason is that the

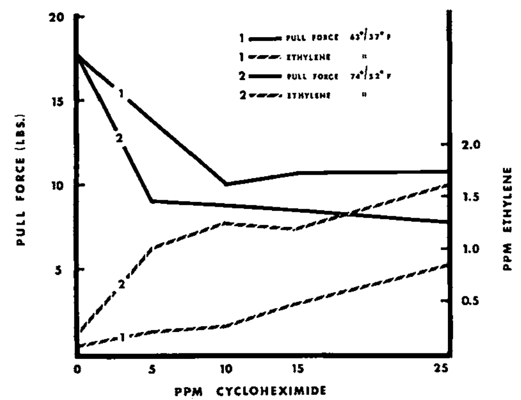

Figure 2.—Pull force and ethylene content of Hamlin oranges from trees sprayed with cycloheximide in two temperature ranges. Ethylene and pull force determinations 5 days after spray application.

half-life of cycloheximide is relatively short in these conditions, so that the temperature soon after application is more important than that closer to harvest.

LITERATURE CITED

1. Abeles, F. B., and R. E. Holm. 1967. Abscission; Role of protein synthesis. Ann. N. Y. Acad. Sci. 144: 367-373.
2. Cooper, W. C., and W. H. Henry. 1968. Field trials with potential abscission chemicals as an aid to mechanical harvesting of citrus in Florida. Proc. Fla. State Hort. Soc. 81: 62-68.
3. Cooper, W. C., G. K. Rasmussen and D. J. Hutchison. 1969. Promotion of abscission of orange fruits by cycloheximide as related to site of treatments. Bioscience 19: 443-444.
4. Cooper, W .C., G. K. Rasmussen, B. J. Rogers, P. C. Reece and W. H. Henry. 1968. Control of abscission in agricultural crops and its physiological basis. Plant Physiol. 43: 1560-1576.
5. Hartman, H. T., M. Fadl and S. Whisler. 1966. Induction of abscission of olive fruits by sprays with ascorbic acid and iodoacetic acid. Olive Industry News 20(3): 2-5.
6. Possingham, J. V., and P. E. Kriedemann. 1969. Environmental effects on the formation and distribution of photosynthetic assimilates in citrus. Proc. 1st Int. Citrus Symp. I. 325-332.
7. Rasmussen, G. K., and W. C. Cooper. 1968. Abscission of citrus fruits induced by ethylene-producing chemicals. Proc. Amer. Soc. Hort. Sci. 93: 191-198.
8. Rasmussen, G. K., and J. W. Jones. 1968. Abscission of calamondin fruit as influenced by humidity, ascorbic acid and copper. Proc. Fla. State Hort. Soc. 81: 36-39.
9. Vaadia, Y., F. C. Raney and R. M. Hagan. 1961. Plant water deficits and physiological processes. Ann. Rev. Plant Physiol. 12: 265-292.
10. Wilson, W. C., and G. E. Coppock. 1968. Chemical abscission studies of oranges and trials with mechanical harvesters. Proc. Fla. State Hort. Soc. 81: 39-43.

PERFORMANCE AND COMPARATIVE COST OF TREE SHAKER HARVEST SYSTEMS[1]

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ABSTRACT

Several citrus harvest systems were operated and evaluated under near-commercial field conditions during the 1968-69 season. These systems all utilized the hydraulic operated, inertia-type tree shaker for fruit removal. The fruit handling equipment included a catching frame, 2 pick-up machines, and 2 methods of windrowing the fruit for pick up.

Field performance, equipment and labor requirements, and costs are presented and compared for the various harvest systems.

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[1]Cooperative research by the University of Florida, Citrus Experiment Station; State of Florida, Department of Citrus; and U. S. Department of Agriculture.

INTRODUCTION

The inertia-type tree shaked for citrus has been under development in Florida for the past 12 years as a method of removing fruit from the tree. Catching frames for handling citrus after removal from the tree have been developed along with the tree shaker. This work has been reported to this Society on several occasions. (1, 2, 3, 4).

Many citrus industry people have objected to the size and cost of the catching frame equipment for fruit handling and expressed an interest in pick-up machines as an alternate method of handling fruit in the grove. The State of Florida, Department of Citrus, contracted with a machinery company to build a citrus pick-up machine to their specifications. In addition, a machine was designed and built at the Citrus Experiment Station employing a different pick-up principle (5). Both machines were built to pick up a windrow of fruit, and it was necessary to