

ABSCISSION CHEMICALS - AID TO CITRUS FRUIT REMOVAL¹

W. C. WILSON

Research Scientist II,
Florida Department of Citrus, Box 1088,
Lake Alfred, FL 33850

R. E. HOLM

Head of Biological Testing,
Crop Chemicals R&D,
Mobile Chemical Company,
Edison, NJ

R. K. CLARK

Agricultural and Veterinary
Products Division, Abbott Laboratories,
North Chicago, IL 60064

ACTI-AID, while PIK-OFF, RELEASE, and the 2-way tank-mix combination have been granted experimental use permit. Abscission chemicals are subject to variation from adverse environmental factors such as rain and cold temperature. Warm temp, however, may sometimes increase abscissic activity. Judicious use of these growth regulators can benefit harvesting, both with hand picking crews and mechanical equipment.

Within the past 10 years, several new chemicals have become available for use as abscission (loosening) agents for mature citrus fruit. The purpose of this paper is to give a short review of the current status of chemicals which are available in the USA and some of the horticultural aspects of their use in Florida which should be considered.

Additional index words. RELEASE, ACTI-AID, ETHREL (ethephon), SWEEP, PIK-OFF, abscission chemical combinations, growth regulators.

Abstract. Within the past 10 years, several abscission chemicals and tank-mix combinations have been developed to loosen fruit and thus aid in harvesting citrus. ETHREL (ethephon or 2-chloroethyl phosphonic acid) is commercially used in Florida for both color and abscission of tangerine and tangerine hybrids (tangelos) destined for fresh fruit use. Cycloheximide (ACTI-AID), 5-chloro-3-methyl-4-nitro-1H-pyrazole (RELEASE), and glyoxal dioxime (PIK-OFF) produce an abscission response on all orange cultivars destined for processing fruit utilization, although only RELEASE and PIK-OFF can be used in commercial evaluations with the late or 'Valencia' cultivar. ACTI-AID and RELEASE together or with chlorothalonil (SWEEP) have been particularly effective in producing abscission. The 3-way combination generally produces the best fruit loosening with the least side effects. A concn ratio for ACTI-AID:SWEEP of 1:50 to 100 appears best using 1 to 5 ppm ACTI-AID, but the concn of RELEASE in the 3-way combination can be varied substantially as desired. Full clearance has been granted by EPA (Environmental Protection Agency of the U. S. Government) for ETHREL and

Basic Mechanisms of Abscission Action

A great deal of information has been written on this subject, however, it would appear that abscission of fruit and leaves is regulated by a balance of juvenility factors (presumably auxins) which prevent fruit or leaf loosening and cell wall degrading enzymes whose synthesis is controlled by the ethylene level (1). Fruit and leaves require an aging period before ethylene (exogenous or endogenous) is effective in producing abscission, but exogenously applied ethylene can hasten this aging process. There is lack of agreement as to which enzyme(s) is involved in the actual cell wall degradation process, but cellulase synthesized in a response to ethylene appears to be generally accepted as the principal one. To some extent, the cell wall degradation process is reversible. Biggs (2) indicates these findings would appear to apply to citrus as well as to other plants.

The first chemicals found to produce mature citrus fruit abscission (10) were eventually discarded in favor of the newer chemicals which gave overall improved fruit loosening, less phytotoxic effects and, in some cases, could be effectively used on the 'Valencia' orange. Considerable time and effort by the Florida Department of Citrus (FDOC) was devoted to screening for new and better compounds and this cooperative program was at least partially responsible for discovering some of the newer chemicals which

¹Florida Agricultural Experiment Stations Journal Series No. 522.

were submitted by various commercial chemical companies (21, 24).

In all cases, the currently used commercially (or experimentally) available chemicals appear to have mechanisms of action based on production of ethylene. However, there are 2 distinct classes of compounds. The first group, typified by 2-chloroethyl phosphonic acid (ETHREL or ethephon), produces ethylene by degradation of the chemical compound into ethylene and other inert products when absorbed by the plant (25). Other experimental compounds (chemical structures unknown), which produce similar abscission, appear to cause ethylene production in a similar manner. The chief advantage of this type chemical action is citrus fruit abscission with little or no damage to the peel (22, 25). However, they have also shown disadvantages which will be discussed subsequently.

A second class of compounds, typified by 3-[2-(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl]-glutarimide (ACTI-AID or cycloheximide), 5-chloro-3-methyl-4-nitro-1H-pyrazole (RELEASE), and glyoxal dioxime (PIK-OFF) cause fruit ethylene production by producing light to moderate peel injury. It is well established that injury to a fruit or leaf will cause substantial increases in ethylene production. For the most part, chemicals of this group injure primarily the outer portion of the peel (flavedo) and sometimes the albedo. The injury rarely penetrates through the entire albedo. The chief disadvantages of these type chemicals are that the fruit cannot be used as fresh fruit, treated fruit must be processed relatively quickly, and sometimes the juice may have a slight but detectable overripe flavor (12). However, the concentrate process appears to remove most off-flavors (3). Further, any blending of this concentrate with concentrate from untreated fruit may effectively eliminate major flavor problems. On the whole, this class of chemicals produces substantially better fruit loosening and usually less leaf drop than those which do not injure the fruit.

Current Status of Abscission Chemicals

1. ETHREL is a product of the Amchem Company, Ambler, PA and is distributed worldwide. It is cleared by the EPA (Environmental Protection Agency of the United States government) for use in Florida on lemons, tangerine hybrids, and tangerines (7). Suggested concns are dilute sprays of 250 ppm for all cultivars except 'Orlando' tangelo where the suggested rate is 200 ppm. This chemical, in addition to producing fruit loosening, also enhances fruit color development (7, 25).

The chief problems with ETHREL are its tendency to cause excessive leaf fall and occasional erratic performance. Although all abscission chemicals are to some extent unpredictable in action, this chemical requires more expertise in its use for it appears to be more subject to the vagaries of the weather than other abscission agents. One special precaution with ETHREL is never to apply it with a surfactant as use of a surfactant can substantially increase the percentage of leaf drop. The chemical should not be applied as a concentrate spray.

Copies of a symposium on the proper use of ETHREL are available on request from the Florida Department of Citrus (20). This edited transcript of a meeting of interested scientists and growers contains information on the practical use of ETHREL.

2. ACTI-AID, a product of the Upjohn Company, Kalamazoo, MI, USA, is cleared by the EPA for use in Florida on oranges intended for processing. This chemical has generally produced good loosening of early and mid-season oranges when applied as dilute sprays of 10-20 ppm

(5, 6, 22). It should not be applied after the spring growth flush begins (22), otherwise, severe phytotoxicity can result. Unfortunately, its performance on 'Valencia' or 1 oranges has been erratic, and few growers attempt to use for this purpose although by 6 weeks following bloom 1 tree (although not necessarily the immature fruit) usually tolerate concns up to 20 ppm. Excessive dropping of immature fruit may also occur from 1 to 6 weeks following bloom (16). ACTI-AID normally causes light to moderate rind pitting, thus eliminating its use for loosening fresh fruit (22). Use of a suitable surfactant is suggested (7).

3. RELEASE is a product of Abbott Laboratories, North Chicago, IL, USA and is approved for experimental use by the EPA (temporary tolerance) on Florida oranges intended for processing. This chemical was the first which showed the ability to loosen mature 'Valencia' oranges without causing virtually no injury to bloom, young fruit or foliage (8, 18) when used as recommended. Higher concns, however, are reported to cause some yield reductions (14). Label recommendations (for dilute sprays) are 75-125 ppm for early and mid-season oranges and 175-250 ppm for late 'Valencia' oranges. The chemical can be applied in concentrate form but should not be used at less than 50 gal/acre. Use of a surfactant is suggested.

RELEASE causes a superficial peel injury which often appears as a distinct ring burn at the blossom-end of the fruit (18). Peel injury tends to be more severe near the beginning of the fruit season (December) on early and mid-season oranges. The 'Valencia' orange is not as subject to injury.

4. PIK-OFF, a product of CIBA-GEIGY Ltd., Basel, Switzerland, is a chemical very similar in action to RELEASE. It differs principally in that it produces slightly more fruit peel injury and may cause injury to immature 'Valencia' fruit which attains a diameter of about 2.5 cm. Label recommended rate is 300 ppm and use of a surfactant is not recommended (15). PIK-OFF is currently available under experimental label (temporary tolerance) granted by the EPA.

5. CHEMICAL COMBINATIONS. Two-way combinations of RELEASE and ACTI-AID have given superior fruit loosening to either chemical used alone (11, 23). The EPA has granted experimental approval to combine (tank mix) these chemicals for limited field testing during the 1976-77 fruit season. Suggested rates (11, 23) for early and mid-season oranges are RELEASE (50-100 ppm) plus ACTI-AID (1-5 ppm). With 'Valencia', the amount of ACTI-AID used should remain quite low (1 ppm) during and shortly after the bloom period, but up to 200 ppm RELEASE can be used in a 2-way combination. Use of a surfactant is suggested with all these combinations.

Three-way combinations of RELEASE + ACTI-AID + SWEEP (chlorothalonil or tetrachloroisophthalonitrile) produce better fruit loosening than the 2-way combination (11, 23). With 'Hamlin' oranges, the combination of RELEASE + ACTI-AID + SWEEP (25 + 5 + 250 ppm respectively) was as effective as RELEASE at 100 ppm and ACTI-AID at 20 ppm. With 'Valencia' oranges, a combination of RELEASE + ACTI-AID + SWEEP (100-150 + 5 + 250 ppm, respectively) was as effective as RELEASE at 250 ppm. Use of the 3-way combination has not yet been approved by the EPA. SWEEP is a product of Diamond Shamrock Corp., Cleveland, OH, USA. Combination of ACTI-AID and SWEEP with PIK-OFF appear to be beneficial, but not to the degree noted with RELEASE.

Special Considerations Relating to Abscission Chemicals

As previously stated by Wilson and Coppock (22), fru

acted with abscission chemicals does not loosen even on the tree. Research (18, 19) indicates that when fruit is as loose as theoretically desired for most mechanical harvesters, heavy fruit drops result. This detracts from the efficiency of shaker-catchframe combinations which miss and sometimes run over fallen fruit, but can be handled by harvest systems which remove fruit to the ground for mechanical sweeper-fruit pick-up systems.

Adverse weather can affect abscission chemicals. To be effective, most chemicals must remain on the tree for at least a few hours, and sudden rains within 2 hours usually result in complete loss of activity. Under desert conditions, air humidities are often so low that some abscission chemicals, to be effective at all, must be applied at concns double or triple those applied under humid conditions (17). Tree vigor is also an important consideration with all abscission chemicals and growers should not apply them to trees which are noticeably weakened from such factors as disease, insects, drought or freezing temperatures.

Low temp will delay or lessen the effects of abscission chemicals. Exact temp ranges have not been worked out for all abscission chemicals, but field observations indicate that little loosening takes place at daytime temp below 60°F (16°C). Loosening may subsequently occur with the arrival of warmer weather. Low temp retardation of loosening is sometimes a problem in Florida with winter harvesting of early and midseason oranges. 'Valencia' oranges are normally harvested in spring and summer when such low temp are rarely encountered. High temp have generally not hindered the activity of abscission chemicals.

Under Florida conditions most chemicals which have been useful for fruit loosening also cause peel injury. Because most of the Florida orange crop is utilized for processing, peel injury is inconsequential unless it produces severe damage, such as that caused by certain weak acids which can lead to fruit rot problems (17).

The 'Valencia' orange, in addition to presenting the problem of the presence of both immature and mature fruit crops at the time of harvest, also undergoes a period referred to as "regreening." It has been observed that during this period the mature fruit becomes more difficult to loosen with abscission chemicals, especially if the rootstock is rough lemon (*C. jambhiri* Lush.) (5). In Florida this period usually occurs during May and early June and is probably associated with juvenility factors resulting from active growth of the tree.

Field experience has shown that dilute sprays (applying chemical solution until there is some runoff from foliage and fruit) give the most consistent abscission results. Although concn of some of the currently available abscission chemicals can be made successively, increased leaf drop has sometimes been observed following concentrate sprays.

There are, of course, 3 basic cost factors to be considered in the use of abscission chemicals, namely chemical cost, application cost (equipment and labor), and surfactant cost (if used). These can be a significant portion of the expense of harvesting, but vary according to yield (boxes per tree) (9, 13). The chemical itself is usually the most significant portion of these costs, although even surfactants (which growers often add) have become relatively expensive and can no longer be considered a negligible item.

Abscission chemicals can be used to increase the effectiveness of hand pickers (4). A number of these tests have been conducted in the past and individual picker efficiency increases of 30 to 50% were noted, although these type ex-

periments often produce wide variability and are difficult to control.

Conclusion

The future use of mechanical and chemical aids harvesting depends on a number of factors including cost availability of labor, and ability to achieve the harvest goal desired (percentage fruit removal, reduced tree injury, etc). Many of these factors will be considered in other papers in this section. In addition, national and world events relative to economy and energy may also affect implementation of these programs.

Literature Cited

1. Abeles, F. B., G. R. Leather, L. E. Forrenee and L. E. Crake. 1971. Abscission: Regulation of senescence, protein synthesis, and enzyme secretion by ethylene. *HortScience* 6(4):371-376.
2. Biggs, R. H. 1971. Citrus abscission. *HortScience* 6(4):288-292.
3. Carter, R. D. 1977. Personal communication.
4. Clark, R. K., Jr. and M. T. Ellis. 1976. The use of RELEASE, a abscission agent, to increase the productivity of pickers on processing oranges. *Proc. Fla. State Hort. Soc.* 89:72-73.
5. Cooper, W. C. and W. H. Henry. 1973. Influence of rootstock on citrus fruit abscission response to cycloheximide treatment. *Proc. Fla. State Hort. Soc.* 86:52-55.
6. Davies, F. S., W. C. Cooper, and F. E. Galena. 1975. A comparison of four abscission compounds for use on 'Hamlin,' 'Pineapple,' and 'Valencia' oranges. *Proc. Fla. State Hort. Soc.* 88:107-113.
7. Florida Citrus Spray and Dust Schedule 1977. *Fla. Coop. Ext. Sci. Cir.* 393-C, Jan. 1977.
8. Kenney, D. S., R. K. Clark and W. C. Wilson. 1974. ABG-3030 an abscission chemical for processing oranges: Biological activity. *Proc. Fla. State Hort. Soc.* 87:34-36.
9. Hedden, S. L., H. R. Sumner, G. E. Coppock, J. G. Blair, W. C. Wilson, D. L. Deason, and C. L. Anderson. 1972. Shaker-pickup harvest system for early and midseason oranges. *Proc. Fla. State Hort. Soc.* 85:245-249.
10. 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.
11. Holm, R. E. and W. C. Wilson. 1976. Loss in the capacity of 'Valencia' oranges treated with abscission chemicals to produce ethylene and fruit loosening during the regreening period. *Proc. Fla. State Hort. Soc.* 89:35-38.
12. Moshonas, M. G., P. E. Shaw and D. A. Sims. 1976. Abscission agent effects on orange juice flavor. *Jour. Food Sci.* 41:809-811.
13. Wardowski, W. F. and W. C. Wilson. 1971. Observations on early and midseason orange abscission demonstrations using cycloheximide. *Proc. Fla. State Hort. Soc.* 84:81-84.
14. Whitney, J. D. 1976. Air shaker trials in Valencia oranges with two rates of abscission chemical. *Proc. Fla. State Hort. Soc.* 89:41-43.
15. Wilcox, J., J. B. Taylor, W. C. Wilson and I. Y. Chen. 1974. Chemical abscission of 'Valencia' oranges by glyoxime (CGA 22911). *Proc. Fla. State Hort. Soc.* 87:22-24.
16. Wilson, W. C. 1969. Four years of abscission studies on orange. *Proc. Fla. State Hort. Soc.* 82:75-81.
17. ————. 1972. Field testing of weak acids for facilitating citrus fruit harvest under Florida conditions. *HortScience* 7(1):31-33.
18. ————. 1973. A comparison of cycloheximide with a new abscission chemical. *Proc. Fla. State Hort. Soc.* 86:56-60.
19. ————. 1973. Problems encountered using cycloheximide to produce abscission of oranges. *HortScience* 8(4):323-324.
20. ————, Editor. 1976. Conference on the proper use of Ethrel on citrus. Sponsored by the Florida Department of Citrus, Lakeland, FL and the Amchem Company, Ambler, PA.
21. ————, and J. A. Attaway. 1974. The Florida Department of Citrus Program for Plant Growth Regulation. *PCR Bull.* 2(2):18-19.
22. ———— and G. E. Coppock. 1975. Citrus harvesting. *CIBA GEIGY Ltd. Technical Monograph* No. 4. Citrus pp. 67-71.
23. ————, and R. E. Holm. 1976. Combinations of RELEASE, ACTI-AID and SWEEP for abscission of oranges. *Proc. Fla. State Hort. Soc.* 89:32-34.
24. ————, D. S. Kenney and R. E. Holm. 1977. The Florida Department of Citrus cooperative screening program for citrus. *Proc. 1977 Int. Soc. Citriculture.*
25. Young, R. H., O. J. Jahn, and J. J. Smoot. 1974. Coloring and loosening of citrus fruit with ethephon. *Proc. Fla. State Hort. Soc.* 87:24-28.