and 66% of the potential (handpicked check) yield of lb-solids, (Fig. 6) at the April, May, and June dates. These percentages could undoubtedly be increased with (a) improved shaking modes, (b) trees and fruiting better suited for the foliage shaker, (c) and some degree of mature fruit loosening by an effective abscission chemical.

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FRUIT THINNING OF TANGERINES WITH NAPHTHALENEACETIC ACID

T. A. Wheaton and Ivan Stewart

IFAS Agricultural Research and Education Center
Lake Alfred

Abstract. **Spray applications of naphthaleneacetic acid (NAA) reduced yield, increased fruit size, and reduced the tendency for biennial bearing of 'Dancy' tangerines. The most effective time for spray application was during May. Climatic and physiological factors influenced the amount of thinning obtained and made controlled thinning difficult. Nevertheless, NAA was relatively consistent in thinning and had a fairly wide margin of safety. Used in combination with hedging, topping, and desirable cultural practices, chemical thinning may be an effective way to reduce biennial bearing and provide more uniform crops of high quality fruit.**

Introduction

The 'Dancy' tangerine has a tendency for alternate bearing, resulting in poor fruit size and quality and late maturity during heavy crop years. The goals of a fruit thinning program are to improve fruit size and quality and to control biennial bearing. A great deal of research has been carried out on fruit thinning of deciduous fruits (1). Methods used have included thinning by hand, by mechanical means, and by application of chemicals. Fruit thinning of citrus has received much less attention, although the potential value of thinning for several fresh market varieties appears considerable. At present, there are no chemicals approved for thinning citrus in the USA, but 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) has been used commercially in Australia (9) and NAA in Japan (10).

In Arizona (8) and California (5, 6), NAA has been tested as a thinning agent for mandarins and oranges. NAA applied during the "June drop" period at concentrations of 200 to 1000 ppm resulted in desirable thinning and improved fruit size of several varieties. Fruit quality was improved and no adverse effects on tree condition were observed. In some cases, chemical thinning resulted in significant increases in fruit size with little decrease in yield (8). Some decrease in yield during heavy crop years, however, was necessary to overcome the biennial bearing of mandarins (6). Yield reductions in the range of 20 to 30% during heavy crop years were required to increase yield significantly the following light crop year. Applications of NAA during or shortly after bloom were ineffective (6).

The purpose of this paper is to present the results obtained from experimental applications of NAA to 'Dancy' tangerines in Florida over several years, showing the benefits and problems associated with the use of NAA for fruit thinning.

Materials and Methods

Thinning experiments were carried out in a number of commercial 'Dancy' tangerine plantings

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in the Lake Alfred area. Trees used varied from 5 years of age to mature groves and were mostly on rough lemon rootstock. Hedging, irrigation, and other production practices varied among blocks. Experiments were carried out each season from 1968 to 1972. These included some heavy crop and some light crop years. Groves were selected for thinning experiments only if a moderate to heavy crop was present.

The NAA used was either the NAA-800 potassium salt from Amchem Products, Inc., or the ammonium salt from Thompson Chemicals Co. labeled Fruit Fix Super Concentrate-800. Rates of NAA varied from 100 to 800 ppm in various experiments, and X-77 was added as a surfactant at the rate of 0.05%. Spray was applied with hand guns to provide "outside coverage" and the volume applied varied from 4 to 10 gal depending on tree size.

Replicated single tree plots arranged in a randomized block design were used. Dates of application and NAA concentrations for each experiment are specified in Table 1. In some experiments, applications were made in several different groves on the same day to compare responses among plantings. In other experiments, applications were made on different dates in the same grove to study timing effects. At harvest, fruit samples were taken to provide information on fruit size distribution and juice quality factors.

Results and Discussion

NAA applications in May were generally effective in reducing crop load and improving fruit size at maturity (Table 1). Too little thinning was obtained in some cases, and in a few cases thinning was excessive. Concentration of NAA, time of application, and tree condition at the time of application appeared to be important factors in determining the amount of thinning obtained.

Concentration of NAA. Concentrations of NAA in the 100 to 800 ppm range were generally effective in reducing yield and increasing fruit size (Table 1). The amount of thinning generally increased with increasing levels of NAA, but in experiments A and B similar results were obtained with 400 and 800 ppm. NAA applications in the 100 to 1000 ppm range also proved effective in Arizona (8), California (5, 6), and Japan (10) with concentrations in the 200 to 500 ppm range generally most useful.

High concentrations of NAA applied to young growth may cause some leaf curling. The spring flush is fully expanded at the time of spray applications for thinning, however, and it is unusual to observe any symptoms of phytotoxicity. NAA appears to have a wider margin of safety than some other potential thinning materials we evaluated on citrus such as 2,4,5-T.

Timing. Applications of NAA during the period of natural fruit drop occurring in May were effective in fruit thinning (Table 1). Timing of applications within this period did not appear to be critical. For example, in 1969 (Table 1, experiment C), applications on May 8 and May 21 were both effective, but an application on June 13 was not effective. During the first applications, there was little rain, natural drop was occuring, and fruit size ranged from ¼ to ¾ inches. On June 13, however, rainfall was plentiful, natural drop had stopped, and fruit was approaching 1-inch diameter. Under these conditions, little thinning was obtained.

Citrus trees produce a large number of flowers each year, only a small percentage of which mature into fruit. Natural reduction of this potential crop usually occurs during 2 periods of flower or fruit abscission (3). These periods may or may not be well separated depending on the time of bloom, weather conditions, etc. The first period involves flowers and very young fruit. The second period takes place later and is commonly referred to as "June drop." During this period, abscission usually occurs at the base of the ovary (the pedicil separates from the small fruit). In Florida, this period of "June drop" usually extends over several weeks beginning in May and terminating with the beginning of summer rains and the summer growth flush. NAA applied during "June drop" is effective as a fruit thinning agent by enhancing the naturally occurring drop during that period.

Tree condition. Variability in the amount of thinning obtained was observed among experiments (Table 1). The amount of thinning was excessive in a few cases and insufficient in some others. Generally, trees under some kind of stress were most easily thinned or tended to be overthinned. Vigorous trees maintained on a regular irrigation program were most difficult to thin. Experiments F1 and F2 provided an excellent example of this effect of tree condition or stress level on NAA-induced thinning. In this experiment, NAA was applied at 3 different rates to 2 plantings on the same day. Trees in F1 were not irrigated and maintained at a relatively low nutritional level. The moderately heavy crop was overthinned by the higher rates of NAA. The vigorous trees in

Table 1. Fruit thinning of 'Dancy' tangerines with NAA.

Experiment NAA concn (ppm)	Date of application	Yield reduced (%)	Fruit size^z (inch)	Percent of fruit in commercial size class 100	120	150	176	210	small	176's and larger (%)
A Control	--	--	2.39a	1	8	22	22	21	26	53
NAA 400	May 24, 1968	28	2.36a	0	6	20	21	22	31	48
NAA 800	May 24, 1968	28	2.41a	1	10	24	22	21	24	56
B Control	--	--	2.37a	1	7	21	21	22	28	50
NAA 400	May 24, 1968	57	2.72b	16	40	29	10	4	2	94
NAA 800	May 24, 1968	50	2.76b	21	42	25	8	3	1	96
C Control	--	--	2.30a	0	4	14	18	23	41	36
NAA 500	May 8, 1969	30	2.42b	1	10	24	22	20	23	57
NAA 500	May 21, 1969	25	2.44b	2	12	26	22	19	19	62
NAA 500	June 3, 1969	23	2.38ab	1	8	21	22	21	27	52
NAA 500	June 13, 1969	9	2.31a	0	4	15	19	22	40	38
D Control	--	--	2.35a	0	6	19	21	23	31	46
NAA 250	May 26, 1969	68	2.67b	11	35	32	13	6	3	91
NAA 500	May 26, 1969	61	2.73b	17	40	28	9	4	2	94
E1 Control	--	--	2.44a	1	12	27	22	19	19	62
NAA 250	May 15, 1970	57	2.56b	4	24	33	19	12	8	80
E2 Control	--	--	2.54a	3	21	32	22	13	9	78
NAA 250	May 15, 1970	26	2.71b	15	39	29	10	4	3	93
E3 Control	--	--	2.15a	0	1	5	10	17	67	16
NAA 250	May 15, 1970	18	2.20a	0	2	7	12	20	59	21
F1 Control	--	--	2.45a	1	12	27	23	19	18	63
NAA 100	May 20, 1970	40	2.60b	6	28	33	17	10	6	84
NAA 200	May 20, 1970	66	2.65b	10	34	32	14	7	3	90
NAA 400	May 20, 1970	79	2.77c	22	42	25	7	3	1	96
F2 Control	--	--	2.21a	0	1	8	14	20	57	23
NAA 100	May 20, 1970	7	2.31b	1	4	15	19	23	38	39
NAA 200	May 20, 1970	10	2.30b	0	3	14	18	23	42	35
NAA 400	May 20, 1970	27	2.43c	1	11	26	22	20	20	60
G Control	--	--	2.26a	0	3	11	16	22	48	30
NAA 250	May 24, 1972	15	2.43ab	1	11	26	22	20	20	60
NAA 500	May 24, 1972	21	2.62bc	7	30	33	16	9	5	86

^z Mean separation between averages by Duncan's multiple range test, 5% level. Each experiment analyzed separately.

F2 were irrigated frequently with a permanent overhead system and maintained at a higher nutritional level. This block had an excessive crop and thinning was minimal even at the highest level of NAA. Only a fraction of the crop reached marketable size.

Variability in response to chemical fruit thinning has been a problem with both deciduous fruits and citrus. Many factors such as tree age and vigor, time and amount of bloom, weather conditions, nutritional levels, water potential, and other unrecognized factors undoubtedly influence the amount of thinning obtained. Some of these factors have been mentioned in previous studies with NAA-induced thinning of citrus (6, 7). This variability of response emphasizes the need for caution in chemical fruit thinning with due recognition of the importance of environmental stresses and production practices on the results obtained with thinning sprays.

Fruit size and quality. Large increases in average fruit diameter and percent of fruit in the larger commercial sizes were obtained by effective thinning treatments, particularly in cases of heavy crop loads (experiments B, D, F1, G). In cases of moderate crops or limited thinning (experiments A, C, F2), effects on fruit size were less marked.

Fruit size on 'Dancy' trees was inversely related to crop load. In one experiment, yield from large 'Dancy' trees varied from 5 to 14 boxes per tree as a result of various thinning treatments. The increase in average fruit size with decreasing yield is shown in Fig. 1. Over 95% of the fruit from the lowest yielding trees was commercial size 176 and larger, but less than 50% of the fruit from the heavily loaded trees attained this size. Similar relationships between crop load and fruit size were found in several of the thinning experiments shown in Table 1 and have been observed elsewhere (2).

In addition to improved fruit size, beneficial effects of thinning on external color and juice characteristics were observed in some of our experiments. It is unlikely that these were direct effects of NAA on fruit quality (6). The observed benefits probably resulted from the reduced crop load, less competition among fruits, and the earlier maturity normally associated with light to moderate crops.

Biennial bearing. Thinning treatments that reduced yield by 20% or more generally resulted in a higher yield the following "light crop" year.

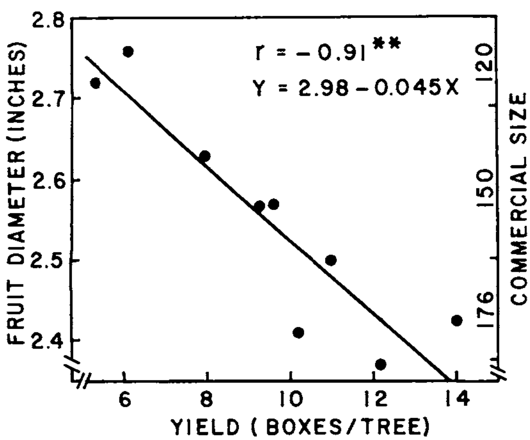

Fig. 1. The relationship between fruit size and yield of individual 'Dancy' trees in a chemical thinning experiment.

Yield records on experiment B showed that the thinning sprays applied only in 1968 provided fairly uniform cropping over a 3-year period while the yield of control trees fluctuated widely (Table 2). Total yields over the 3-year period were slightly lower for the thinned trees, but improved size and packout resulted from the thinning treatments. Similarly, NAA reduced yield of trees in experiments E1 and E2 by 25 to 50% in 1970 (Table 1). These trees bloomed more heavily and produced more fruit than controls in 1971. On the other hand, trees in experiment E3 with a very heavy crop in 1970 were not thinned satisfactorily by NAA that year and produced a very small 1971 crop.

Reports from California (6) also suggest that a decrease in yield of 20% or more was required to give a significant increase in yield the following year.

Alternate years of heavy and light crops may create production and marketing problems. An excessively heavy crop of 'Murcotts,' for example, may effectively eliminate production for the following 1 or 2 years, and in severe cases results in death of the tree. Preliminary experiments indicate that NAA may be useful for fruit thinning of 'Murcotts' as well as 'Dancy' tangerines. Thinning may control alternate bearing of individual trees or blocks, and also may help avoid marketing problems created by alternate years of heavy and light crops over the whole state, perhaps triggered by some unusual climatic disturbance such as a freeze.

Economics. Profits from tangerines are related to packout even more closely than with other types of fresh citrus fruits because pick and haul costs are high and prices for packinghouse eliminations

Table 2. Control of biennial bearing in 'Dancy' tangerines. Thinning treatments were applied only in 1968 (experiment B, Table 1).

NAA concn (ppm)	Yield boxes per tree 1968	1969	1970	Total
Control	12.2	3.1	9.5	24.8
NAA 400	5.3	5.8	8.0	19.1
NAA 800	6.1	7.0	7.5	21.6

are frequently low (4). Furthermore, the prices for larger sizes are generally higher than for smaller sizes. Thus, net return per acre depends not only on overall packout but also on the actual size distribution of the fruit.

Many factors influence the costs of chemical thinning and the returns expected. More important than the actual cost of material probably will be the confidence with which NAA can be used and the ease with which it can be incorporated into the overall spray program. Returns from thinning will depend on the improved packout achieved, the relationship between fruit size and market prices, the presence of market size restrictions, and the value of eliminations.

General comment. Application of NAA to 'Dancy' tangerines during years of excessive crops shows promise for improving fruit size and reducing alternation of heavy and light crops. However, many factors influence both the amount of natural abscission and the influence of NAA, making it difficult to predict accurately the amount of thinning that will be achieved. Practical implementation will require careful integration of chemical fruit thinning with existing hedging and topping programs, irrigation, and other management practices. Careful analysis of relative costs and benefits will be required.

Performance and residue data for NAA have been obtained in both California and Florida and registration is being sought. At present, however, it is illegal to apply NAA to citrus.

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INFLUENCE OF ROOTSTOCK ON CITRUS FRUIT ABSCISSION RESPONSE TO CYCLOHEXIMIDE TREATMENT

W. C. Cooper and W. H. Henry
Agricultural Research Service, USDA
Orlando

Abstract. **Experiments were conducted during April and May at a location in Clermont, Fla., where 'Valencia' orange, Citrus sinensis (L.) Osbeck, trees on rough lemon, C. limon (L.) Burm. f.; 'Cleopatra' mandarin, C. reticulata Blanco; and sour orange, C. aurantium L., rootstocks were sprayed with cycloheximide (CHI) for stimulating fruit abscission. Fruit on trees on sour orange and 'Cleopatra' mandarin rootstocks loosened much more readily than fruit on trees on rough lemon rootstock. Fruit on 'Valencia' orange trees on 'Carrizo' citrange, C. sinensis X Poncirus trifoliata (L.) Raf., rootstock at a nearby location were also readily loosened by cycloheximide treatment. A survey revealed that CHI-induced fruit abscission was always greater on trees on sour orange rootstock than on those on rough lemon.**

When 10 to 20 ppm cycloheximide (CHI) is sprayed on citrus trees, it reacts with the flavedo sufficiently to stimulate the fruit to generate ethylene at rates of 0.5 to 5.0 ppm, which loosens the fruit (1). Treated 'Hamlin' and 'Pineapple', *Citrus sinensis* (L.) Osbeck, oranges are usually more responsive than 'Valencia' oranges, *C. sinensis*, (3) in both ethylene production and fruit loosening. Also, considerable variability in the responsiveness of any cultivar to CHI treat-

[1]This is a report on the current status of research involving use of certain chemicals that require registration under the Federal Environmental Pesticide Control Act (FEPCA). This report does not contain recommendations for the use of such chemicals, nor does it imply that the uses discussed have been registered. All uses of these chemicals must be registered by the appropriate State and Federal agencies before they can be recommended.