THE PREVENTION OF FRUIT FORMATION ON SELECTED WOODY PLANTS

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THESIS

ABSTRACT

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ON SLECTED WOODY PLANTS

By Glen Peirce Lumis

The prevention of fruit formation is in some cases desirable for reasons of: aesthetics, plant vigor and development, lawn maintenance, and attractiveness to birds or insects. Of the many trees used in fruit prevention work the following were used in this study: *Thuja occidentalis*, *Catalpa speciosa*, *Ailanthus altissima*, *Malus zumi calocarpa*, *Malus pumila* '*Jonathan*,' and *Prunus cerasus*. The principal objective was to prevent fruit formation and development by preventing fertilization or causing abscission of the flower or developing fruit. Materials selected were of three types: 1) liquid plastic (Plyac and Wilt-Pruf), 2) caustic (paraquat), and 3) hormone (Naphthylacetamide and 2-(3-chlorophenoxy)-propionic acid). They were applied as sprays at full bloom. Preliminary concentration range trials were conducted in late winter using forced branches of apple, cherry and arborvitae after which field applications were made.

One of the three Plyac formulations (SN2) severely desiccated *Thuja* strobili and thus completely prevented cone formation. The other two Plyac materials were less spectacular but did prevent cone formation or greatly reduced cone size. The Plyac materials were found

to be of little merit on any of the other species treated, however, the Catalpa treatments showed promise. The caustic material was ineffective on all species causing varying degrees of foliage injury with little or no effect on fruit set in most cases. The hormone materials were successful on Malus and Catalpa, but had no effect on the foliage or fruit set of the Thuja or Prunus.

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Glen Peirce Lumis

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PURPOSE

The purpose of this study was to endeavor to prevent fruiting of selected landscape plants. To defruit or not to defruit is a question solely dependent upon ones aesthetic evaluations of the plant in the particular situation in which it is used. What may be unsightly and a nuisance to one is of value and beauty to another. It was with this in mind that a program of study was formulated.

Thuja occidentalis was chosen for extensive investigation. The justification for preventing fruiting of this plant is principally aesthetic. Completely covered with cones it may detract from the harmony of the landscape. Prior to this time no reported work had been undertaken in respect to preventing fruiting of *Thuja*. In order to understand the mechanism by which fruiting was prevented, provided such could be accomplished, it was necessary to become familiar with the morphology of the *Thuja* reproductive parts. *Thuja* flower (strobilus) buds were examined microscopically prior to their opening. Microscopic observations were also made after treatment application in order to determine the mechanism by which the materials did or did not prevent fruiting. Similar studies should be sought or conducted for any plant in respect to fruit prevention work.

In order to adequately study fruit prevention certain other work would be beneficial. Some of which is: 1) studying the physiology of flower and fruit development and the abscission phenomenon, 2) screening various plant growth regulators over a concentration range in order to determine the most active materials and their most effective concentrations, 3) studying combinations of plant growth regulators and certain adjuvants in an effort to inhibit fruiting, and 4) testing various types of physical barriers such as liquid plastics as contraceptives for pollination.

The work here was generally along three lines; 1) using materials which may act as physical barriers to pollination, 2) using certain plant growth regulators over a concentration range and 3) studying flower and fruit morphology.

The following plants were selected for study:

Ailanthus altissima (Mill.) Swingle. (Tree of Heaven)

Catalpa speciosa Warder. (Western Catalpa)

Malus pumila Mill. 'Jonathan' (Jonathan Apple)

Malus zumi calocarpa (Rehd.) Rehd. (Redbud Crabapple)

Prunus cerasus L. (Sour Cherry)

Thuja occidentalis L. (American Arborvitae)

Selected materials for fruit prevention were of three general types: 1) caustic, 2) hormone and 3) liquid plastic. A caustic material was used in an effort to selectively 'burn' the sensitive flower parts and thus prevent fertilization or halt development after fertilization. Hormone materials were employed as agents which would cause flower or developing fruit abscission. The liquid plastics were used as a means of physically preventing pollination and fertilization.

The studies were conducted at the Michigan State University campus, horticulture farm and grounds nursery and at Hidden Lake Gardens in Tipton, Michigan.

INTRODUCTION

Since the beginning of time the production of fruit* by plants has been essential for the existence of man and beast. Man was a wanderer in primitive times, quite dependent on plants for food. Almost every sort of fruit was used in some way. Then, as now, fruit was an integral part of the diet. The production of fruit and seed is the means by which higher life exists. The adaptation of fruit production by plants has not been in vain for it has enabled both the plant and animal kingdoms to advance to the degree at which they now stand.

With the advent of communal living came the art of landscaping and the use of plants for aesthetic appreciation. In many instances the production of fruit is indeed a desirable aspect although sometimes the fruit are unwanted. It is the purpose here to deal with the latter aspect -- that of unwanted fruit.

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*Fruit - a structure consisting of one or more matured ovaries, together with any accessory structures adhering to them (29, p 526).

LITERATURE REVIEW

That vegetative and reproductive growth are antagonistic and that fruiting is an exhaustive process has been recognized ever since man began to observe plants. Theophrastus (60) in the Third Century B.C. observed that some men pluck flowers of the cucumber, which are borne at the ends of the shoots, for these hinder the cucumber's growth. He thought fruiting to be an exhaustive process. Pliny the Elder (50) in the First Century A.D. observed that trees were unproductive as long as they remained growing, presumably in a vigorous state. Flowering and fruiting do indeed occur at the expense of vegetative growth and vice versa.

The need or desire to remove flowers and fruit from plants is by no means a new idea. For as Theophrastus observed, such may be necessary for desirable plant growth. It is a commonly observed fact that plants which have been recently transplanted, injured or are in poor health tend to produce fruit in great abundance. Such fruit production is not advantageous for establishment, recovery or survival of the plant. The developing fruit draw heavily upon the carbohydrate supply which in most cases could better be used for vegetative growth and development. If such a plant was defruited, it could develop more favorably (14, 28, 46, 47).

Certain fruit trees, especially Apple, tend to flower and set fruit* at a very early age. This is often due to the use of a dwarfing root-stock. Some varieties naturally set fruit early. The production of fruit at such an early age is generally not desirable, for the weight of the fruit tends to ruin the structure which should be attained for a well formed tree. Excessive fruit growth also inhibits shoot growth. If the flowers or fruit were removed the young tree could more readily develop a desirable structure (11).

The fruit of numerous landscape trees is often undesirable for one reason or another. The Ginkgo has fruit which produce such an odor that one would think nothing of crossing the street to avoid it (14, 61, 64). Fortunately, most nurseries now sell only the male trees, the species being dioecious, which produce no fruit. A number of street trees such as Elm, Maple and Ash fruit so prolifically that drains are clogged and sewers become blocked. Quite a few trees drop their fruit on lawns and other areas making mowing and maintenance operations difficult. Cleaning up after these trees is expensive and exhaustive (14). Homeowners often have old specimen fruit trees which are valued for shade but whose fruit is of no value, dropping over lawn and walk areas, attracting bees and flies and causing a

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*When successful fertilization occurs there is a burst of growth of the ovary and the fruit begins its development. Simultaneously, there occurs a wilting and even abscission of petals. Such changes mark the transition of the flower into a fruit (37, p 259).

general nuisance. If fruit set could be prevented these trees would be fine landscape specimens. It is also the case that fruit trees would be planted for their profusion of bloom if there were means to prevent fruiting. Trees such as Mulberry produce fruit which stain autos and driveways. The fruit also attract birds which are nuisances in other ways (14). Certain landscape plants are very unattractive when covered with fruit. The Arborvitae (Thuja) is a good example. Some individual specimens of the genus become so covered with small cones that some people imagine the plant has succumbed to some sort of strange infestation. If fruit development could be prevented the plant would be held in greater esteem as a landscape specimen. In public, even private places, children will sometimes use fruit as projectiles, climb trees for access to the fruit and in the process break branches.

In connection with defruiting, people often ask "Why?" Haskell (28) put it well when he said "While most of us think very highly of trees, like to have them around, and readily forgive them their little failings and drawbacks, sometimes it seems that when the fruit is formed certain of our leafy friends strain this forgiveness until it wears thin."

A partial list of landscape trees which produce "objectionable" fruit is given in Table 1.

In early times defruiting, generally thinning, if practiced at all was done by hand, primarily in the orchards where it was practical.

Table 1. Trees which produce objectionable fruit and the criteria for the objection.

Species	Criteria for Objection
Arborvitae	aesthetic, drain clogging
Ash	drain clogging
Black Locust	lawn maintenance
Catalpa	lawn maintenance, aesthetic
Cherry	lawn maintenance, birds
Crabapple	lawn maintenance, insects
Elm	drain clogging
Ginkgo	odor, lawn maintenance
Honey Locust	lawn maintenance
Horsechestnut	lawn maintenance
Kentucky Coffee	lawn maintenance
Maple	drain clogging
Mulberry	staining, lawn maintenance, birds
Pear	lawn maintenance, insects
Persimon	lawn maintenance
Poplar	drain clogging, lawn maintenance
Sweetgum	lawn maintenance
Tree of Heaven	aesthetic, drain clogging

This method has its advantages for one can be very selective, leaving only a certain number of fruit per limb or leaf area. Fruit size is directly related to leaf area (24, 41, 42). Aldrich (2) observed that a larger leaf area per fruit increased growth rate of the fruit. Thinning increases the size of the remaining fruit and reduces biennial bearing (1, 26, 34, 59). The need for thinning arose from the problem of biennial bearing.

It soon became apparent that hand defruiting was costly and slow so workers began the search for compounds which would accomplish this task. Some of the first chemical defruiting or thinning work was begun in the 1930's using inorganic compounds. During the middle 1930's to early 1940's many growers wanted to completely eliminate a fruit crop. Because of the depression and war they could not afford to spray and continue normal orchard operations. The growers wanted some material to inhibit fruit set or defruit without permanently injuring the trees. If fruit were left to mature without cultural practices or picking, insects and diseases would have an ideal refuge and build up drastically. Early workers who concerned themselves with finding defruiting compounds and techniques were: Auchter and Roberts (4) 1933, Cole (16) 1942, and Schneider and Enzie (56) 1943. They used such things as copper sulfate, lime sulfur, sodium nitrate, zinc sulfate, Bordeaux, tar oils and cresylic acid. The oils seemed to be most effective. The results showed none to be completely satisfactory and in almost all cases were variable, leading them and others to search for new and better compounds. One material, Elgetol (Sodium dinitro-ortho-cresylate) which was reported by MacDaniels, et al. (38) in 1939, was used to a great extent. Later work again showed that when used at about 2,000 ppm. Elgetol destroyed the receptive nature of the stigma and inhibited pollen germination, thus proving to be a good thinner or defruiter (6, 30, 31, 48, 57, 59, 63).

During the early 1930's the question arose as to what effect materials which were being used for control of fire blight and scab had on fruit set. MacDaniels, et al. (39, 40) carried out some of the first work. It was found that sulfur used in scab control sometimes reduced fruit set by preventing pollen germination. Some of their other work showed no reduction in set.

In 1937 Gardner, et al. (21) found that a hormone type material, Naphthylacetic acid (NAA) reduced abscission of parthenocarpically induced holly fruit. The observation led workers to the realization that fruit which tended to drop just prior to harvest might be held on the tree until picking. Gardner and co-worker (22) in 1939 showed a reduction in pre-harvest fruit drop with NAA and Naphthylacetamide (NAD) applied at about 2.5 ppm. The following year Burkholder and McCown (12) pointed out that if NAA and NAD were applied at or shortly after bloom there was a reduction in number of clusters setting fruit. They observed some leaf injury when using the acid form of NAA but very little injury when the amide form was used. At 50 ppm. NAA there was a 77 percent reduction in fruit set but serious injury occurred on young leaves, which scorched and dropped. With NAD at 50 ppm. a reduction in set of 34 percent and no leaf injury were observed. Thus, when NAA and NAD were used at the same concentrations, NAA was the more effective as a defruiting agent but caused leaf injury.

Starting in about the mid 1950's hormone type sprays and Elgetol began to be applied on a commercial basis in orchards. In northwestern United States the caustic sprays became and still are widely used while the hormone type were and are commonly used in eastern United States (62). Various carbamate formulations have been used in thinning work but with no great success (32). In the late 1950's the insecticide Sevin (1-naphthyl N-methylcarbamate) came into use in orchards. It was soon observed that this material caused thinning (7, 10).

Workers have tried various materials in an effort to find better deflowering, thinning and defruiting compounds. White and Kennard (67) in 1950 reported the use of maleic hydrazide on Apples. Applications at concentrations of 1,000 - 3,000 ppm. to buds in the pink stage were used in an effort to delay flowering. They found little vegetative or floral retardation but abscission of the fruit occurred at an early stage of development. Maleic hydrazide was applied to plants such as tobacco, corn and cocklebur in order to observe effects on flowering. Treated tobacco plants produced no new flowers and all those initiated at the time of treatment were dead (49). Flowering of certain azaleas was inhibited by maleic hydrazide (13). Gibberellic acid has been used by a number of workers (9, 23, 43, 45, 54). Bradley and Crane (9) showed that gibberellic acid inhibited the development of lateral meristems in several Prunus species, thus, reducing bud development. Working with Apple, Marcelle and Siroval (43) concluded that flowering was decreased corresponding to an increase in shoot growth. A latex type material when combined with certain insecticides was also found to have a thinning effect (20). A material called DCIB (Sodium dichlor-oisobutyrate) has been found to reduce subsequent fruit set in tomato (35).

When thinning or defruiting work is undertaken a great number of factors are encountered which can and will vary the results. For this reason results from year to year, tree to tree and region to region differ. "There will probably never be an ideal thinner that will give satisfactory results in all varieties, in all years under all conditions. The factors involved in fruit set are too many and too complex to hope for such (62)." Continued research is the only means toward this goal.

A very excellent discussion of the many factors affecting thinning can be found in Fruit Thinning With Chemicals (5). The bulletin also reviews the history of thinning and discusses thinning of stone fruits in detail.

The factors affecting fruit thinning include: a) concentration, b) timing, c) weather, d) additives, e) species or variety, f) tree vigor, g) number of applications, and h) amount of bloom.

a) The concentration range is a factor of prime importance. NAD, for example, is used at 10 to 20 ppm. for thinning and 40 to 60 ppm. for defruiting while higher concentrations cause leaf "burn". Since many factors affect the performance of a chemical, it is particularly difficult to recommend an inflexible rate of application.

b) Time of application appears to be less critical than some of the other factors. Davidson, et al. (18) showed that most successful thinning could be accomplished with NAA from full bloom to about two weeks after. If applied much beyond one month after full bloom, thinning could not be accomplished. The dinitro compounds have little latitude due to their mechanism of action. It has been found that thinning is best done at or shortly after petal fall, while defruiting is best accomplished at full bloom (14, 19, 27, 28, 44, 58, 62).

c) One of the most variable factors is the weather. In the case of hormone and caustic type materials unfavorable conditions such as cool temperatures, low light intensity and rain at time of application result in heavy thinning (5). It was shown by Westwood (66) that when under very high humidity, leaf cuticle was altered in respect to the spreading and absorption of Elgetol.

d) It has been observed that certain materials used as surfactants will in themselves act as mild fruit thinners and when used with thinning materials such as NAA will increase the thinning effect of that chemical (25, 65). Horsfall and Moore (33) tried various inorganic salts as adjuvants with NAA. Of all the ones used only ammonium possessed thinning activity.

e) Certain varieties of Apple are thinned more easily than others. Those considered hard to thin are Golden Delicious, Yellow Transparent, Rome Beauty and Baldwin. Red Delicious, McIntosh, Jonathan and Northern Spy are easy to thin, while Grimes Golden is considered intermediate. It has been observed that varieties which set heavier fruit loads, being partially self-fruitful, are harder to thin (5).

f) Tree vigor is another factor affecting thinning. Heavy thinning usually occurs on trees that are low in vigor because of low fertility, winter injury, low food reserve, light pruning, low light intensity or other factors. Such trees tend to have few fruit and the fruit are easily thinned.

g) Other factors which influence the effect of thinning sprays are the number of applications, bee activity and amount of bloom.

As early as 1914 it was observed that dust from cement mills inhibited pollen germination of certain fruit trees. The dust contained alkali and calcium salts which went into solution on the stigmatic surface (3). Attempts to prevent fruit set are directed at the gynoecium rather than the androecium. The gynoecium appears to be more sensitive to injury and exposed in such a condition for a greater period of time. If only the local pollen source is controlled, pollination may still occur from a source far remote from the controlled area. The stigma and petals are the most sensitive parts of a flower. Caustic materials must be used within a critical concentration range so that the stigma or other flower parts are "burned" while the leaves are not adversely effected. A material which only destroys the receptivity of the stigma would have to be applied before pollination. If the material progressed to injure the ovary, it could be applied well after pollination. NAA and related compounds have been found most effective for deciduous trees. These materials can generally be applied over a wide time period, generally within a seven to ten day period after full bloom. For defruiting purposes, the materials are best applied at full bloom.

The material to be found in the literature concerning thinning is almost infinite but references to actual defruiting are few. Most of the latter work has been conducted by city maintenance workers and landscape horticulturists concerned with specific problems.

The first defruiting work was done by hand. Murneek and Hibbard (48) had good results by using Elm switches to thin or defruit Peach trees. Needless to say, hand defruiting was slow, tedious and not very efficient. Some of the early work was supported in connection with the National Shade Tree Conference in an attempt to find methods and materials for economically preventing fruit formation on numerous landscape trees. Miller and Erskine (44) in 1949 conducted tests on over a dozen tree species. They showed that materials such as NAA, NAD, dinitros and maleic hydrazide could be used for defruiting purposes on some trees. Very good elimination of fruit was observed on Ash, Catalpa, Crabapple, Elm, Horsechestnut, Norway Maple, Tree of Heaven and Poplar. Haskell (28) in 1953 reported good success in preventing fruit set on Catalpa, American and English Elm, and Horsechestnut. NAA and Elgetol (a dinitro) were found to be the most effective. The caustic dinitro type materials were only practical when flowering preceeds leaf emergence as in Populus. Table 2 summarizes the work which has been reported in connection with fruit prevention work.

In past years the defruiting of Ginkgo has received some attention because of the obnoxious odor of the ripened fruit. Turner (61) in 1953 had little success with chemicals because of leaf burn so he experimented with other methods. Sending men into the trees armed with spiked poles was not too successful. It took four to six

Table 2. Review of fruit prevention studies on woody plants.

Species	Material	Concentration	Time	Remarks & Results	Work By
Apple *Malus sp.*	Na NAA	40-50 ppm.	Full bloom	Satisfactory (50-75%) elimination, although variable	28, 53
	NAD	50-60 ppm.			
Ash *Fraxinus*	DN 289	1 qt./100 gal.	Flower clusters 2 1/2 - 3 " long	Complete elimination but slight burning of opened foliage	28, 44, 53
Catalpa *Catalpa*	Na NAA	60 ppm.	Full bloom	Complete elimination	28, 44, 53
	NAA	1 1/3 oz./100 gal.			
Crabapple *Malus sp.*	Na NAA	40-60 ppm.	Full bloom	Practically complete elimination although variable	53
	Parmone	7 oz./100 gal.	After petal fall	Complete elimination	28
Elm *Ulmus*	Na NAA	40-60 ppm.	Full bloom	Practically complete elimination	28, 53
Ginkgo *Ginkgo*	Chloro IPC	500 ppm.	12 days after full bloom	Results variable	53
	Chloro IPC	150, 500 and 1,000 ppm.	12 days after full bloom	Complete inhibition of further developments	64
			37 days after full bloom	0%, 20% & 34% elimination, respectively	
	MH	750 ppm.	Full bloom	Practically complete elimination, some leaf injury	28, 53
	Silicate Soda	1:10 or 1:20 with H_2O	Full bloom	Partial prevention, prevented pollination	44

Honey Locust *Gleditsia*	Na NAA	60-100 ppm.	Full bloom	Unsuccessful	28, 44, 53
			Fruit 1-2" long	Satisfactory elimination	
	NAA	1 1/3/100 gal.	Full bloom	Satisfactory elimination	44
			Fruit 1-2" long	Satisfactory elimination	
	Parmone	13.25 & 26.4 oz. /100 gal.	Prior to full bloom	Unsatisfactory, leaflet abscission	44
			Full bloom	Complete elimination	
Horsechestnut *Aesculus*	Na NAA	30-60 ppm.	Full bloom	Complete elimination	28, 44, 53
			Fruit 3/8" dia.	Complete elimination	44
Kentucky Coffee *Gymnocladus*	Dinitrol	1 1/2 lb./ gal.	Small developing fruit	Satisfactory elimination, slight foliage injury	28, 44, 53
	Elgetol	2 qts./100 gal.	Small developing fruit	Satisfactory elimination	28, 44, 53
Maple, Norway *Acer platenoides*	Na NAA	40-60 ppm.	Full bloom prior to leafing	Satisfactory elimination, results variable	28, 44, 53
Maple, Red *Acer rubrum* and Maple, Silver *Acer saccharinum*	Na NAA	40 ppm.	Full bloom	Fair to poor elimination, results variable	28, 53
Maple, Sugar *Acer saccharum*	Na NAA	60 ppm.	Full bloom	Fair to poor elimination, results quite variable	28, 53
Mulberry, Red White *Morus sp.*	Na NAA	50-60 ppm.	Full bloom	Fair to poor elimination, results variable	28, 44, 53
	Elgetol	2 qts./100 gal.	Full bloom	Unsatisfactory	28
Poplar *Populus sp.*	DN 289	1 qt. & 1 qt. summer oil/100 gal.	Full bloom	Complete elimination	28, 44, 53
	Elgetol	2 qts./100 gal.	Full bloom		
Tree of Heaven *Ailanthus*	Na NAA	200 ppm.	Full bloom	Practically complete elimination	28
		5 lbs./100 gal.			

Table 3. Materials used for fruit prevention.

Chemical Compound	Type Spray	Trade Name
Maleic hydrazide	Hormone	MH-30
Naphthylacetic acid (NAA)	Hormone	
Naphthylacetic acid preparation by E. I. DuPont Company	Hormone	Parmone
Naphthylacetic acid - sodium salt of (Na NAA)	Hormone	APP-L-Set
Naphthylacetamide (NAD)	Hormone	Amid-Thin
Dinitro-o-secbutylphenol	Caustic	DN-289
Isopropyl-N-(3-chlorophenyl) carbamate	Caustic	Chloro IPC
Sodium dinitro ortho cresolate	Caustic	Elgetol
4,6-dinitro-o-cresol	Caustic	Dinitrol (DNC)

hours to defruit a large tree and needless to say the men disliked the work. Blasts of air from a mist blower were then tried. This was unsuccessful for the 150 to 250 mile per hour winds only blew off the leaves. Turner (61) found that water blasts from fire hoses was at best 85% successful in defruiting. Other workers (64) used Isopropyl-N-(3-chlorophenyl) carbamate (CIPC) at 250 ppm. on Ginkgo. If the material was applied about two weeks after flowering further fruit development was completely arrested. If applied a month after flowering 250 ppm. caused no fruit abscission, 500 ppm. removed 20% of the fruit and 1,000 ppm. removed only 34%. Fruit drop usually occurred three to five weeks after spraying.

Haskell (28) and Fenner (19) merely mention the use of "mechanical sprays."

> "These sprays put a film over the stigma and style of the flower so as to keep the pollen grains from contacting and fertilizing the ovary. This is done either by excluding moisture or placing an actual barrier over the end of the pistil, blocking the pollen tube, preventing pollination or pollen germination. Dowax and other antidessication compounds used in transplanting are of this type (28)."

In 1959, Reisch (52) reviewed the information on preventing fruiting up to that time. He indicated that 100 arborists were asked about defruiting work. Only nine indicated any work along this line. As a result, Reisch was lead to conclude: "At the present time the commercial use of chemicals to eliminate fruit on trees appears to be limited."

Defruiting or inhibiting fruit set is merely the ultimate degree of thinning. Most of the principles and practices used for thinning are applicable to fruit elimination. It must also be understood that much work has been done in connection with thinning rather than defruiting.

EXPERIMENTAL PROCEDURE

Greenhouse Studies

In order to obtain an idea of the concentration range necessary for fruit prevention, branches of Cherry, Apple and Arborvitae were forced in the greenhouse in late winter of 1965. Arborvitae was sprayed and observations made as to the amount of foliage injury. Cherry and Apple branches were forced at a temperature of 70^{o}F in order to determine the effects of spray materials on the flowers and foliage. Materials were of three types: caustic, hormone and liquid plastic. Of the caustic types, 1,1'-dimethyl-4, 4' dipyridylium cation (paraquat) and isoprophyl-N-(3-chlorophenyl)-carbamate (CIPC) were used. Naphthylacetamide (NAD) and 2-(3-chlorophenoxy)-propionic acid (3-CP) were the hormone types used. "Plyac"* is used commercially as a spray adjuvant to reduce the water surface tension and to increase chemical adhesion to plant surfaces. Three experimental Plyac formulations were used: SN1 (Plyac 'O' SN-1-10597-10), SN2 (Plyac 'M' SN-2-10597-10)** and SN7 (Plyac SN-7-10453-11). The branches

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*Plyac as commercially produced consists of emulsifiable polyethylene and actyl phenoxy polyethoxy ethanol. Previous commercial formulations consisted of emulsifiable polyethylene, fatty acidamide concentrade and alkyl aryl sulfonate. The material is produced by Allied Chemical Corp. - General Chemical Division.

**This consists of a 20% solution of alkanol amide in water.

were kept in crocks of water. The Apple and Cherry branches were sprayed when the flowers were fully open. Observations were made at periodic intervals.

Thuja branches were treated as follows:

paraquat 25, 50, 100 and 200 ppm.

NAD 50, 125, 250, 500 ppm.

3-CP 50, 125, 250, 500, 1,000 ppm.

Prunus branches were treated as follows:

Plyac SN1 20 and 50 percent

Plyac SN2 5 and 7 percent

Plyac SN7 20 and 50 percent

paraquat 30, 60 and 120 ppm.

Malus branches were treated as follows:

Plyac SN2 5, 7 and 10 percent

CIPC 50, 125, 250 and 500 ppm.

paraquat 25, 50, 125, 250 ppm.

3-CP 50, 125, 250, 500 and 1,000 ppm.

Field Studies

Study I

Prior to field spraying of *Thuja occidentalis*, branches were selected which were as uniform as possible and contained approximately the same number of flower buds. Plyac and Wilt-Pruf (WP)* treatments

*Wilt-Pruf is marketed as a 49% poly vinyl chloride complex by Nursery Specialty Products, Inc.

were applied to plants in the horticulture gardens at the time of flower (strobilus) opening and anthesis, which occurred on April 12, 1965. Paraquat, NAD and 3-CP treatments were applied to plants at the horticulture farm. Strobili opening and anthesis of these plants occurred on April 13, 1965. SN1 was applied at the following concentrations: 17, 50 and 100 percent. SN2 was applied at 10, 25 and 50 percent; SN7 at 17, 50 and 100 percent. Wilt-Pruf was applied at concentrations of 10, 50 and 100 percent. Paraquat was applied at 50, 100 and 200 ppm.; NAD at 100, 200 and 400 ppm.; 3-CP being applied at 100, 200 and 400 ppm. All treatments were randomized and replicated three times. Observations were made daily for the week following spraying and weekly thereafter until June 25, 1965. Measurements of cone diameters were recorded weekly from April 25 until June 25, 1965. Calipers were used for all measurements. On June 25 the number of cones on each branch under observation were counted.

Study II

Branches of full grown Sour Cherry trees at the horticulture farm were selected for their uniformity and similar numbers of buds. SN2, SN7, paraquat, NAD and 3-CP randomized treatments were applied May 11, 1965 at full bloom. The following concentrations were used: SN2 - 3.3, 5 and 10 percent; SN7 - 3.3, 5 and 10 percent; paraquat - 15, 60 and 120 ppm.; NAD - 60, 90 and 120 ppm.; 3-CP - 60, 90 and 120 ppm.

Observations were made daily for the first week after treatment applications, thereafter weekly, until June 22, 1965.

Study III

Prior to spraying young Jonathan Apple trees at the horticulture farm, branches were selected which had approximately the same number of spurs. The following materials were used: SN2 - 2, 2.5 and 3.3 percent; SN7 - 2.5, 3.3 and 5 percent; paraquat - 15, 45 and 75 ppm.; NAD - 60, 90 and 120 ppm.; 3-CP - 60, 90 and 120 ppm. The randomized treatments were applied May 15, 1965 at full bloom. Observations were made weekly for five weeks. At the end of six weeks, fruit counts were made.

Study IV

Selected branches of Redbud Crabapple (*Malus zumi calocarpa*) were sprayed with SN2 and SN7 in efforts to prevent fruiting. SN2 was applied at 2.5, 3.3, 5 and 10 percent; SN7 at 3.3, 5 and 10 percent. Very limited SN2 (2.5 percent) and SN7 (2.5 percent) treatments were applied to two other Crabapples, Scheidecker Crab (*Malus scheideckeri*) and Red Jade Crab (*Malus* 'Red Jade'). All Crabapple treatments were applied on May 14, 1965 at full bloom to trees in the grounds nursery. Periodic observations were made.

Study V

Branches within ground reach of Catalpa (Catalpa speciosa) were selected. Part of this study was carried out at Hidden Lake Gardens. Two groups of Catalpa were used on the campus, one flowering two weeks before the other. SN1 - 10 and 25 percent; and 3-CP - 120 ppm. treatments were applied to the trees in full bloom on June 18, 1965. SN1 - 5 percent, SN7 - 5 percent and 3-CP - 240 ppm. were applied to the trees in full bloom on July 1, 1965. At Hidden Lake Gardens the following treatments were applied at full bloom on June 21, 1965: SN1 - 5 percent; SN7 - 10 percent; 3-CP - 120 and 240 ppm. Observations were made periodically.

Study VI

Limited treatments were applied to Tree of Heaven (Ailanthus altissima) on June 24, 1965 at full bloom as follows: SN7 - 5 and 10 percent; 3-CP - 120 ppm. Periodic observations were made.

Two types of sprayers were used. Plyac and Wilt-Pruf treatments were applied with a small 300 milliliter plunger action sprayer. Paraquat, NAD and 3-CP were applied using a 3 liter sprayer at 4 kg. per sq. cm. of air pressure. Distilled water was used in the treatments. A very small amount of surfactant was used with paraquat, NAD and 3-CP.

Morphological Studies

Samples were taken of check and Plyac SN2 treated strobili and developing cones. Sampling of SN2 treated strobili was done at 3, 6, 12 and 24 hours; 3 days; and 1 and 3 weeks after spraying. Check samples were taken weekly until July 12, 1965. The samples were placed in killing solution after which they were prepared for mounting on microscope slides. Sections were stained for 1 1/2 minutes in Delafield's hematoxylin staining solution. Photomicrographs were then made from selected sections in an effort to determine the mechanism of action of the Plyac SN2 material, and also to follow cone and seed development of untreated fruit.

RESULTS

Greenhouse Studies

Preliminary greenhouse study provided a base from which larger field experiments could be developed. It is interesting to note the effects of the Plyac (SN) materials on flower parts, especially petals. Within a very short period of time, petals were completely browned and desiccated.* At the higher concentrations the leaves were adversely affected also. SN1 at 20 and 50 percent completely desiccated petals of Prunus within 18 hours. SN2 at 5 and 7 percent caused moderate browning of Prunus and Malus foliage, and moderate to severe desiccation of the petals. The effect of the SN7 was similar to the other two materials.

Paraquat proved to be of questionable value for fruit prevention. On Thuja 25 ppm. caused slight browning of the foliage; 50, 100 and 200 ppm. caused considerable browning after two weeks. At 25 and 50 ppm. Malus foliage and flowers were considerably browned; while at 125 and 250 ppm. the foliage and flowers were completely "killed." When used on Prunus paraquat at 60 and 120 ppm. showed slight to moderate browning of the foliage and moderate to severe browning and "kill" of the flowers.

CIPC showed somewhat less injury than paraquat. After 2 weeks

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*Desiccated will be used for lack of a more thoroughly descriptive term.

foliage and flowers of Malus were moderately injured with 50 and 125 ppm. while severe browning occurred at 500 ppm.

Both NAD and 3-CP had little or no effect on the foliage of Thuja at the concentrations used. Slight yellowing occurred at 1,000 ppm. of 3-CP. NAD at 500 ppm. caused some wilting and browning.

Field Studies

Study I

Field spraying of Thuja with Plyac SN1, SN2, SN7 and Wilt-Pruf brought some very interesting results. Branches which were treated with 1) SN1 - 50 and 100 percent, 2) SN2 at all concentrations, and 3) SN7 at 100 percent formed no cones whatsoever. The SN1 treatment at 17 percent was less effective than higher concentrations but produced fewer and smaller fruit than check branches. The same was true for SN7 at 17 and 50 percent. The Wilt-Pruf treatments were rather ineffective in preventing fruit set.

Almost immediately after applying the SN1 and SN2 materials, the strobili became blackened and shrunken; the effect being less pronounced at the lowest concentrations. After spraying there was no visible coating or residue on the strobili or foliage.

Wilt-Pruf applications formed a thick, caked coating over the strobili and foliage, which soon cracked and broke away.

Neither the Plyac nor Wilt-Pruf treatments had any effect on the *Thuja* foliage present at the time of spraying or on new growth which resulted some time after spraying.

Cones which were not completely inhibited from developing were of three types: 1) undeveloped since pollination but green, whereas "burned" strobili were black and shrunken, 2) approximately one-half the size of check cones and 3) fully developed, similar to checks. In Table 4 the number of cones of each type are recorded. In Table 5 the cone diameter resulting from the liquid plastic treatments are recorded. Figure 1 shows cone development graphically.

Paraquat was not successful in preventing fruit set on *Thuja*. Moderate to severe leaf injury occurred with no effect on the strobili or resulting cones.

Both NAD and 3-CP showed no effect on cone size, cone number or foliage of *Thuja*.

Study II

The results of all treatments on Sour Cherry were negative. None showed any degree of fruit prevention or thinning. SN2 and SN7 were observed to cause flower browning and desiccation, but fruit size, number and quality were not different from the checks. The SN2, SN7, NAD and 3-CP treatments had no effect on the foliage. SN7 did not form a crystalized coating as it did in the treatments of

Table 4. Number of fruit formed on liquid plastic treated <u>Thuja occidentalis</u>.*

	Concentration in Percent	A	B	C
SN1	17	2.3	11.7	6.3
	50	0	.3	0
	100	0	2.3	0
SN2	10	0	0	0
	25	0	0	0
	50	0	0	0
SN7	17	7.3	2.0	3.0
	50	0	12.7	.7
	100	0	0	0
WP	10	35.3	0	42.7
	50	24.7	9.0	33.0
	100	68.7	21.7	0
CHECK		0	0	101

A = Not developed since pollination, but green.

B = Half normal size.

C = Fully developed.

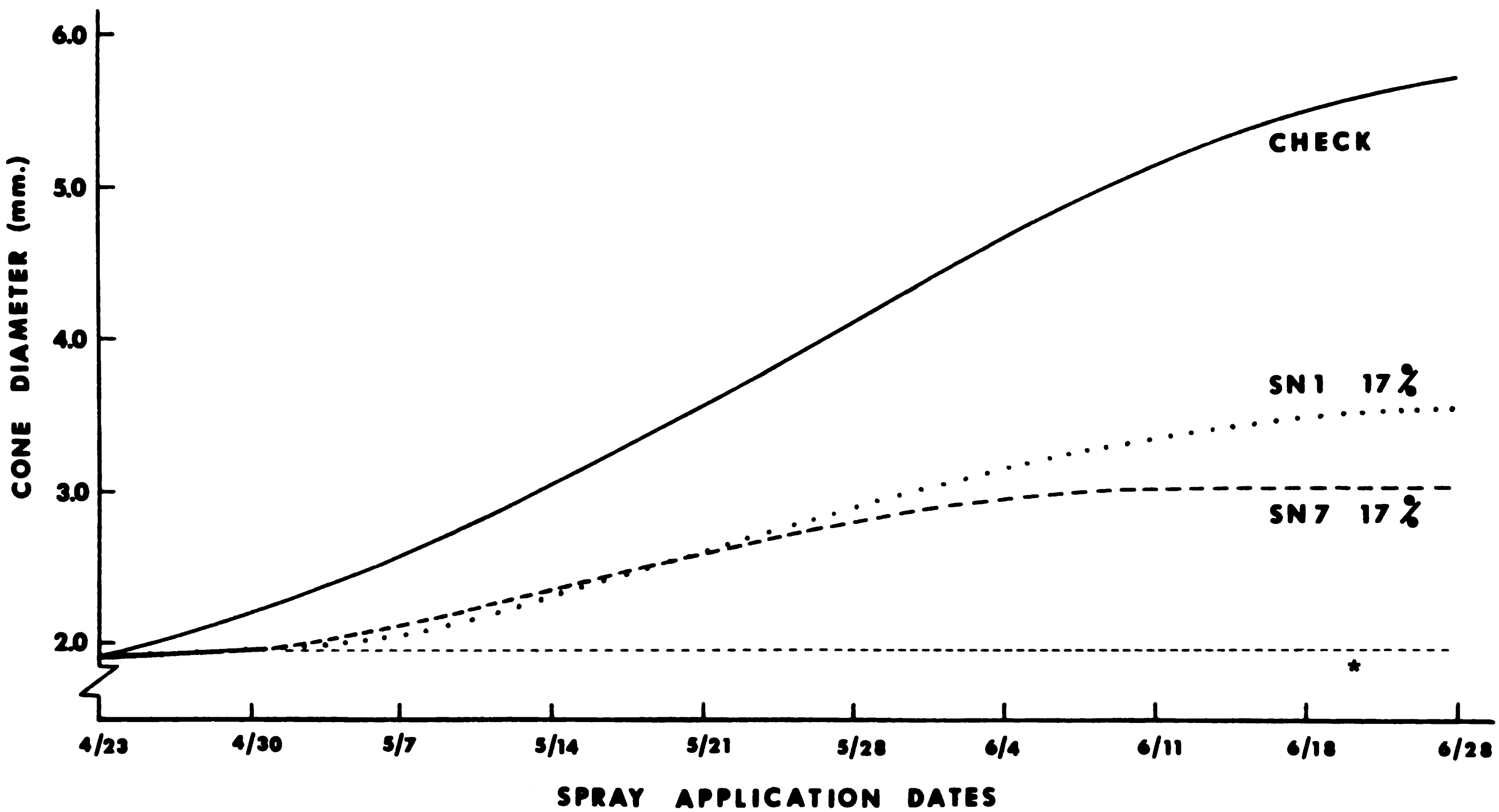
*Mean values of three replications.

Table 5. Cone diameters in millimeters of liquid plastic treated <u>Thuja</u> <u>occidentalis</u>.

Check			SN1 Treatments				SN2 Treatments		
Date		Date	17%	50%	100%	Date	10%	25%	50%
4-23-65	1.77	4-23-65	1.95	1.89	1.85	4-23-65	1.84	1.92	1.75
4-30-65	2.25	4-30-65	2.03	1.90	1.97	4-30-65	1.89	1.98	1.89
5-7-65	2.61	5-7-65	2.05	No development		5-7-65	No development		
5-14-65	3.09	5-14-65	2.31			5-14-65			
5-21-65	3.60	5-21-65	2.61			5-21-65			
5-28-65	4.11	5-28-65	2.87			5-28-65			
6-4-65	4.70	6-4-65	3.13			6-4-65			
6-11-65	5.11	6-11-65	3.30			6-11-65			
6-18-65	5.45	6-18-65	3.44			6-18-65			
6-25-65	5.70	6-25-65	3.51			6-25-65			

	SN7 Treatments				WP Treatments		
Date	17%	50%	100%	Date	10%	50%	100%
4-23-65	1.88	1.90	1.92	4-23-65	1.89	1.89	1.90
4-30-65	1.92	2.08	1.92	4-30-65	2.22	2.20	2.12
5-7-65	2.13	No Development		5-7-65	2.84	2.61	2.40
5-14-65	2.44			5-14-65	Similar to Check		
5-21-65	2.63			5-21-65			
5-28-65	2.79			5-28-65			
6-4-65	2.94			6-4-65			
6-11-65	2.96			6-11-65			
6-18-65	2.96			6-18-65			
6-25-65	2.96			6-25-65			

FIG. 1 Cone diameters of *Thuja occidentalis* treatments



* SN 1 50,100%; SN 2 10,25,50%; SN7 100%

Thuja (Study I). Paraquat caused slight to moderate leaf chlorosis and "burn" depending on the concentration used.

Study III

The degree to which the treatments accomplished the desired results on Jonathan Apple trees is shown in Table 6. Defruiting and thinning (mature fruit prevention) were noted. 3-CP for example caused all or nearly all fruit to abscise. NAD was less effective than 3-CP in causing abscission. Paraquat at all concentrations was detrimental to vegetative growth even though some mature fruit prevention was accomplished. Leaves showed varying degrees of chlorosis, "burn" and abscission, being rather severe at 75 ppm. SN2 and SN7 caused slight leaf injury at the highest concentrations. The injury occurred on the youngest leaves. Considerable fruit prevention and thinning were accomplished. The SN2 and SN7 treatments caused immediate browning of the flower petals. It is interesting to note that the materials, especially SN2, had both a floricidal and a thinning effect. Some of the "burned" flowers formed no fruit. Others of the developing fruit abscised similarly to and at about the same time as hormone treated fruit. No crystalization of the SN7 was noted as on Thuja (Study I).

A Chi-Square statistical analysis of the data presented in Table 5 revealed with 95 percent confidence that: 1) A difference exists between treatments and check, and 2) 3-CP is the most successful defruiting compound, as used in this study. In the case of paraquat, significant

Table 6. Number of fruit formed on treated Jonathan apple.*

	Treatment	Concentration in Percent	Mean Number
SN1	A	2.0	4.25
	B	2.5	3.00
	C	3.3	.50
SN2	D	2.5	6.75
	E	3.3	3.50
	F	5.0	2.25
		ppm.	
Paraquat	G	15	9.00
	H	45	7.75
	I	75	1.25
NAD	J	60	3.50
	K	90	4.25
	L	120	3.50
3-CP	M	60	.75
	N	90	.75
	O	120	.00
CHECK	P		12.00

*Mean values of four replications.

differences are nullified by the leaf injury which occurred.

Study IV

The SN2 and SN7 treatments were unsuccessful in desirably preventing fruit set on Redbud Crabapple. SN2 at 5 and 10 percent caused complete defoliation and fruit formation was completely inhibited. At the two lower concentrations SN2 caused moderate to slight leaf epinasty and "burn". The fruit that formed at the two lower concentrations were severely russeted, being somewhat smaller than check fruit. The SN7 material caused moderate leaf injury at the two higher concentrations and no leaf injury at the lowest. No fruit inhibition was noted except that sprayed fruit were slightly smaller than the checks and quite russeted. Flowers which had not opened at the time of spraying failed to open, especially at the higher concentrations.

SN2 at 2.5 percent which was applied on a very limited scale to Scheidecker and Red Jade Crabapple was observed to cause only slight leaf "burn." The Red Jade foliage seemed more resistant to the spray. It is of interest to note that by three weeks after spraying all the treated fruit had abscised.

Study V

Of the three parts in the Catalpa study only one was successful in accomplishing fruit prevention. Unfortunately, the trees used for the treatments of June 21 at Hidden Lake Gardens and of July 1 on the campus set no fruit. Check branches as well as other unsprayed branches were without fruit. However, of the treatments applied June 18, all were successful in preventing fruit set. SN1 at the higher concentration caused a certain amount of leaf "burn," the lower concentration causing only slight injury. The flower parts were desiccated by the SN1 as in treatments of the other deciduous species. The 3-CP treatment had no effect on the foliage. Within one week after spraying, all the SN1 treated flowers had abscised. Abscission of the 3-CP treated flowers did not occur completely until after nearly two weeks. The 3-CP treated flower parts were distinctly disiccated and "burned." Check flowers, it was noted, abscised their petal structure soon after pollination, during and after which the fertilized ovary develops rapidly. Treated flowers abscised cleanly below the ovary without necessarily losing the petal structure first.

Study VI

Treatments applied to Tree of Heaven were unsuccessful. Of the two trees used in the study, neither set any fruit whatsoever.

Morphological Studies

In order to more correctly evaluate the effects of the various spray materials on Thuja, it is desirable to look closely at the strobili. The ovulate strobili are borne at the tips of practically all branchlets, the staminate strobili being borne further back on the branchlet. With a certain amount of experience the male and female buds can be distinguished in advance of their opening. Fertilization in Thuja is accomplished soon after anthesis. Mature cones are produced and seed is shed within seven months after fertilization. For thorough discussions of gametaphytic development of Coniferales, see (15, 17). A morphological study of Thuja has been prepared by Land (36). Several excellent line drawings of Thuja are given by Sargent (55).

The ovulate strobilus with its "naked" ovaries is very succulent when fully expanded. Cells of the entire structure are fully turgid, liberating a semi-viscous water-like fluid when crushed. When any part is placed under direct heat as from an incandescent light, it is quickly desiccated and subsequently becomes darkened. The cells and cellular organelles are extremely delicate and sensitive. Since the ovaries are exposed in a "naked" condition, they are succeptable to injury. Photographs of normal and partially desiccated strobili are shown in Figure 2: a-g.

Microscopic observations of the SN2, 25% treatment revealed large amounts of darkly stained areas on the strobili scales, considerably more than on check strobili. The darkly stained cells had some appearance of being plasmolyzed or desiccated. Affected cells seemed more rectangular than normal cells of the scale tip area. Cellular content was not discernible. See Figures 2:h-k and 3:b-d.

Photomicrographs of normally developing Thuja cones are shown in Figure 3:e-f.

Figure 2. _Thuja occidentalis_ treatments.

a. ovulate strobili; 10X

b. ovulate strobilus; 25X

c. staminate strobilus; 10X

d. ovary; 20X

e. ovary; 30X

f. ovulate strobilus and twig treated with Plyac SN2;10X

g. ovulate strobilus and twig treated with Plyac SN7; 10X

h. Plyac (SN2) treated strobilus showing cellular injury; 30X

i. Plyac (SN2) treated strobilus showing cellular injury; 300X

j. Plyac (SN2) treated strobilus scale tip showing cellular injury; 65X

k. Plyac (SN2) treated strobilus showing cellular shrinking; 125X.

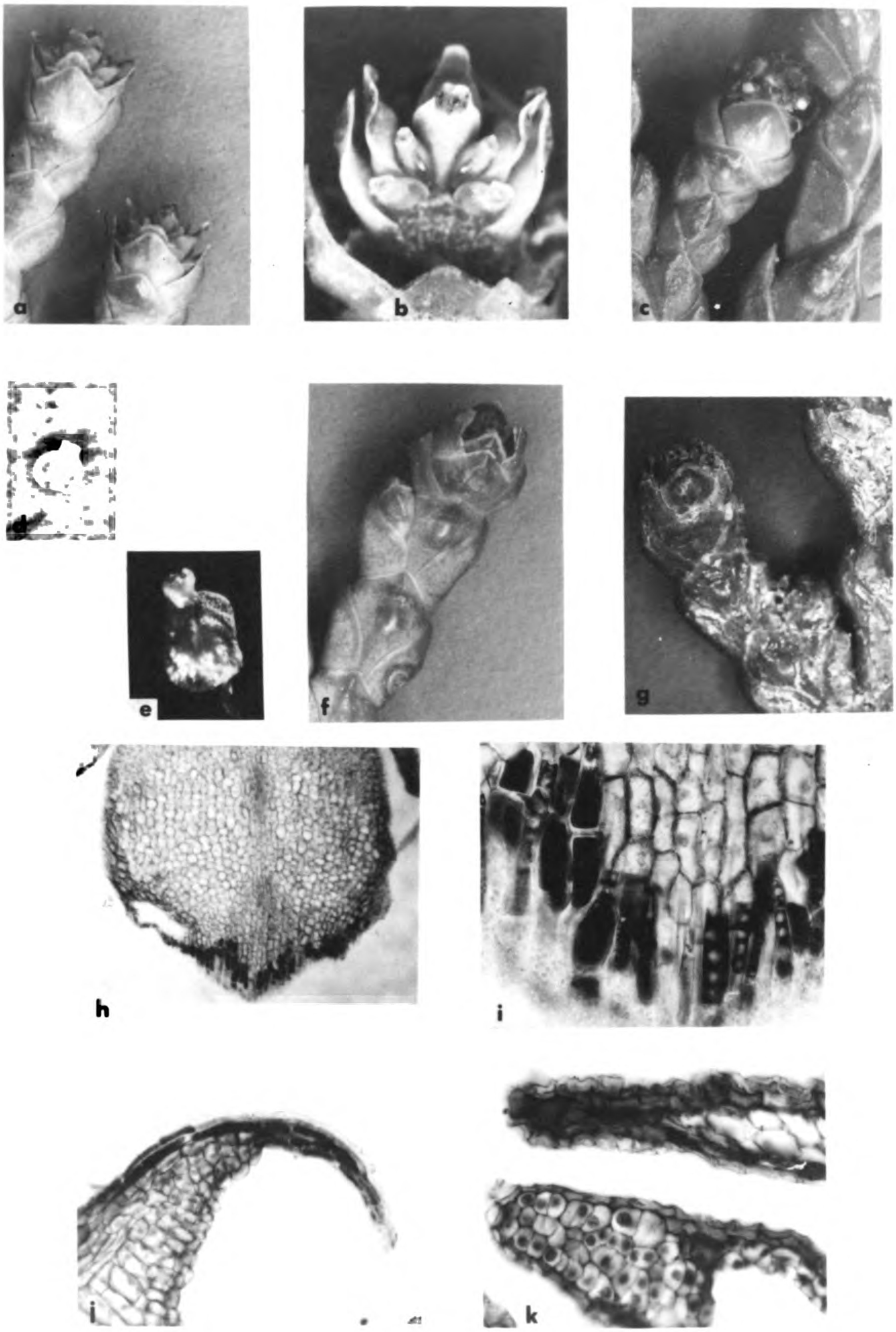

a
b
c
d
e
f
g
h
i
j
k

Figure 3. <u>Thuja</u> <u>occidentalis</u> treatments.

a. longitudinal section of untreated ovary, 5/3/65; 65X

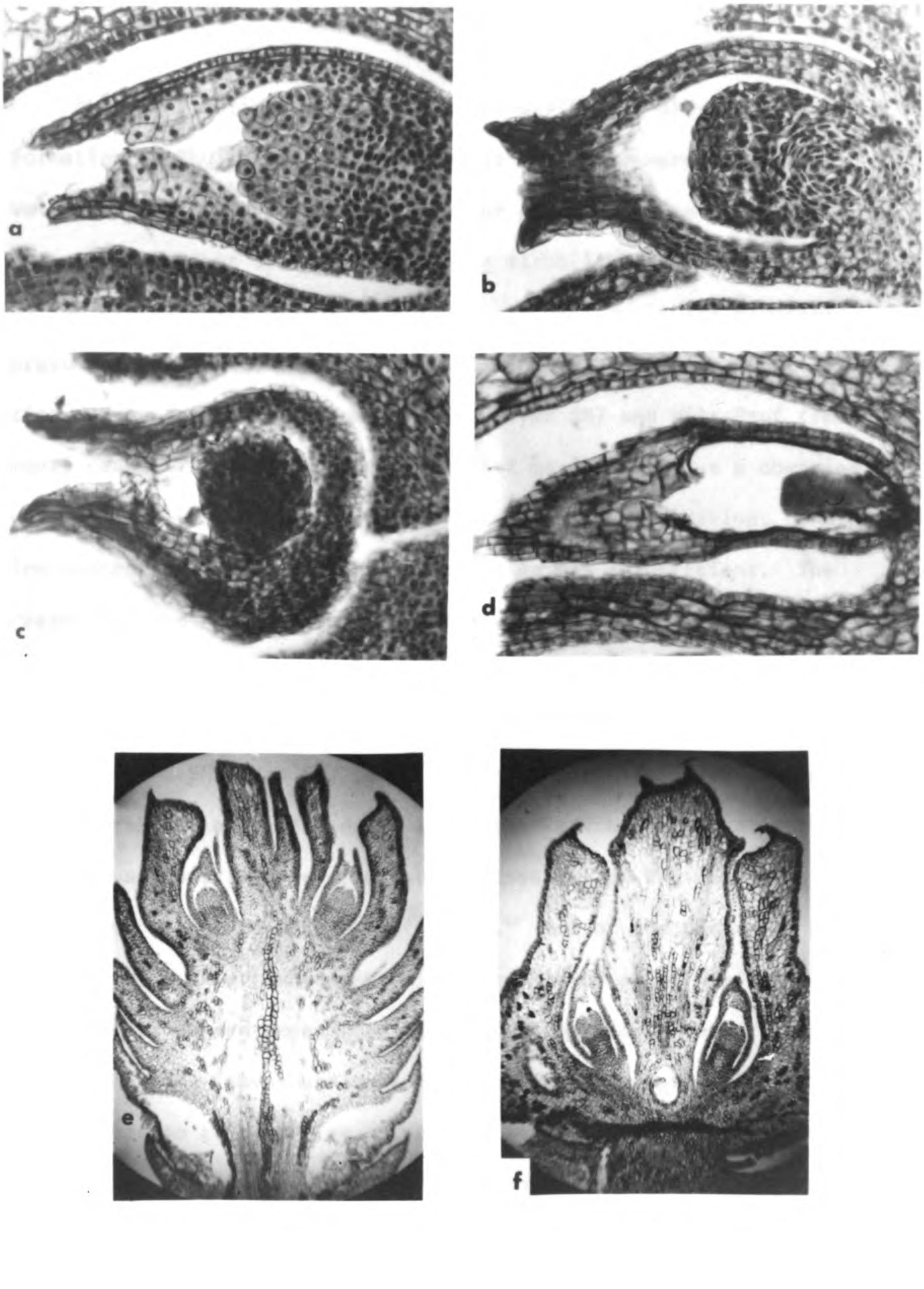
b. longitudinal section of Plyac (SN2) treated ovary, 24 hours after application; 65X

c. longitudinal section of Plyac (SN2) treated ovary, 4 days after application; 65X

d. longitudinal section of underdeveloped ovary, 6/30/65; 65X

e. developing cone, 5/3/65; 30X

f. developing cone, 5/10/65; 30X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f

DISCUSSION

Liquid plastic spray applications strikingly prevented fruit formation on Thuja occidentalis. These materials were of limited value for fruit prevention of the other plants used in the study. The very succulent tissue of the Thuja strobili was easily injuryed by the Plyac (SN1 and SN2) materials. The injury to the strobili presumably affected receptivity and prevented or hindered fertilization and subsequent development. The Plyac SN7 and Wilt-Pruf treatments caused little or no shrinking, but merely acted as a covering which possibly prevented pollin germination and penetration. Where low concentrations were used, the covering was insufficient. The reason for one-half developed cones may have been delayed fertilization due to the material or a physical restriction of cone growth.

The explanation for the difference in mechanism of action between SN1 and SN2, and SN7 is at present unknown for little information is readily available as to their chemical and physical differences.

Plyac materials were not very successful on the deciduous species because of slight to severe leaf "burn." All of the deciduous species used in these experiments, except Catalpa, flower at or near the time when the leaves are expanding. Since Catalpa flowers open later in the season when the leaves are more mature, the Plyac material was least detrimental to this species. Leaf surfaces which are glabrous such as Sour Cherry are injured to a much less degree than ones covered by pubescence such as Redbud Crabapple. The pubescence aids the retention of the spray material.

If the set of fruit can be reduced or prevented with little or no adverse effect on the foliage, a material would be said to be desirable. As shown in this study, certain materials significantly reduce the number of fruit set, but leaf injury occurred which was detrimental to the tree. This fact should be kept in mind when evaluating materials.

Microscopic observations of Plyac SN2 treated ovulate strobili revealed some cellular desiccation. The dark color of cells of the scale tips was due in part to the accumulation of natural products associated with the drying of these cells rather than entirely due to the hematoxylin histological stain. Checks were noted to have similar darkly stained areas but were much less extensive than on treated strobili and developing cones. The exposed scale tip cells are very succulent and succeptable to dehydration. The dark color of both treated and check cells may be due to an oxidation of cellular material.

Hormone materials, Naphthylacetamide (NAD) and 2-(3-chlorophenoxy)-propionic acid (3-CP), were used in an effort to cause flower or fruit abscission. Such was accomplished on Jonathan Apple and Catalpa, which is in agreement with previous work reported in the literature. The failure of Sour Cherry to respond may have been due to insufficient spreading and sticking of the materials on the glabrous young leaves. Hormone materials had no influence on _Thuja_ cone abscission. Mature cones do not abscise easily. The cones are often seen remaining one or two years after their formation. It is possible that hormone materials do not induce formation of an abscission layer in early cone development at the concentrations used. Due to the rather thick and coreacious character of the leaves, the materials may not have been absorbed in sufficient quantities to affect abscission.

The caustic material, paraquat, was completely unsuccessful for fruit prevention. Generally used as a contact herbicide, it seemed to have little effect on floral parts but adverse effects on foliage. Its mode of action as a herbicide is not entirely known but it has some effect on photosynthetic and enzymatic processes.

Failure of the _Ailanthus_ and some of the _Catalpa_ trees to set fruit was presumably due to insufficient pollination. Both species generally fruit prolifically.

SUMMARY

The prevention of fruit formation is in some cases desirable. Unfortunately, information concerning the means by which to do so on landscape trees is not overly abundant. In an effort to shed more light on this area, the present study was undertaken.

Thuja occidentalis may be treated with Plyac as indicated in order to prevent fruit formation. This is accomplished without injury to the plant. Plyac materials may be used on _Catalpa_ as indicated, but at somewhat lower concentrations, with some reservation. To be effective, especially on _Thuja_, the Plyac must be used in relatively high concentrations, possibly making this material less desirable because of the amount of material needed. Plyac should be used on a small scale prior to any extensive applications.

Hormone materials may be used on a number of deciduous species. The only danger seems to be high concentrations which will cause leaf wilting. Further study should be continued with 3-CP.

Fruit prevention with the use of caustic sprays seems to be of limited value. The concentration range necessary is quite critical. CIPC should be tried further on _Thuja_.

The most desirable materials for fruit prevention would be specific for reproductive or floral tissue. To date none have been successful without causing injury to other plant parts.

With the increased selective use of landscape plants, fruit

prevention may become more important in the future. Selected studies will need to be undertaken in order to find the most desirable materials and their critical concentration range. Unfortunately, there is no ideal material that is effective in all situations.

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