FRUIT THINNING with Chemical Sprays

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Fruit Thinning With Chemical Sprays

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INTRODUCTION

Thinning of certain species and varieties of tree fruits is essential to avoid a tendency toward biennial bearing, especially of most apple varieties, and also to obtain increased fruit size, color, and quality. In some sections, particularly the Western States, hand thinning represents one of the greatest single costs in producing fruit. In a number of apple varieties, adequate thinning by hand cannot be done early enough to curb the tendency of the tree to become alternate in its fruiting habit. Ultimate size of apples and other fruits is also

directly related to the earliness and thoroughness of the fruit-thinning operation.

The application of chemical sprays during the bloom or early postbloom period in order to reduce fruit set, thereby partially or completely overcoming the necessity of hand thinning, is a practice that has received considerable attention in recent years. A wide variety of different materials has been used with varying degrees of success. However, most of the investigational work with chemical thinning, as well as the commercial application of the practice, has centered around the use of the dinitro materials. Considerable attention has also been devoted to the use of naphthaleneacetic acid and its sodium salt. A number of other materials have been under experimentation but are not used commercially to any appreciable extent.

The most extensive experimentation and commercial use of chemical thinning sprays have been with apples, although the possibilities of using such sprays with pears and stone fruits, particularly peaches, have been rather extensively explored.

The extent to which chemical thinning sprays are used in commercial apple areas varies greatly according to the fruit section and varieties grown. In some sections results have been so erratic as to preclude commercial usage. In the New England States and New York chemical thinning sprays are used extensively on the Wealthy and Baldwin varieties. In the Pacific Northwest during the past 3 years, 5 to 20 thousand acres of apples (depending on the season) have been chemically thinned annually. The sprays are applied to all commercial varieties grown in the area.

With the rapid expansion in the use of chemical thinning sprays considerable variations in results have been obtained. The purpose of this circular is to bring together both experimental and observational information that will aid in evaluating the various factors affecting the results with these sprays. This evaluation should help the fruit grower to decide the extent to which he may profitably test or use fruit-thinning sprays.

EFFECTIVENESS OF DINITRO CHEMICALS IN THINNING APPLES

Relative Effectiveness of Different Forms

From 1932 to 1935 Auchter and Roberts *(1, 2)*[1] performed tests with a number of different chemicals to determine their effectiveness in preventing the fruit set on various varieties of apples. Of the several materials tested by these workers, the tar oil distillates were the most effective in killing flower buds when applied in the cluster bud stage.

The primary object of this early work was to find a practical method of entirely preventing fruit set of certain apple varieties. In 1939 Magness, Batjer, and Harley (*31*) and Gardner, Merrill, and Petering (*14*) reported promising results in reducing fruit set with Dow

[1] Italic numbers in parentheses refer to Literature Cited, p. 44.

Dormant, a commercial preparation of dinitro-ortho-cyclo-hexylphenol. This same year MacDaniels and Hildebrand *(28)* found that Elgetol, a commercial preparation containing sodium dinitro-ortho-cresylate, would prevent pollen germination when applied to the stigmatic surface of flowers. Orchard trials with Elgetol indicated that this material had great promise for spraying apple trees in the bloom period to reduce fruit set.

Since 1939 numerous investigators have conducted experiments in order to evaluate the various forms of dinitro chemicals for the purpose of thinning fruit. The different forms that have been tested include sodium dinitro-ortho-cresylate (Elgetol), dinitro-ortho-cresol (DN No. 2), and dinitro-ortho-cyclohexylphenol (DN No. 1). Typical results from the authors' work with these compounds in thinning various apple varieties are presented in table 1.

TABLE 1.—*Effectiveness of different forms of dinitro thinning sprays when applied during the bloom period on certain varieties of apples in certain areas*

Variety	Year	Treatment [1]	Concentration per 100 gallons	Fruits per 100 blossoming spurs [2]	Reduction in fruit set	State and literature reference
			Quantity	*Number*	*Percent*	
Golden Delicious	1944	Check	0	54	--------	West Virginia *(4)*.
		Elgetol	1.0 pt	34	37	
		DN No. 2	.5 lb	29	46	
Grimes Golden	1944	Check	0	49	--------	Do.
		Elgetol	1.2 pt	22	55	
		DN No. 2	.6 lb	24	51	
York Imperial	1944	Check	0	56	--------	Do.
		Elgetol	1.6 pt	32	43	
		DN No. 2	.8 lb	30	46	
Delicious	1946	Check	0	53	--------	New York *(22)*.
		Elgetol	1.0 pt	32	40	
		DN No. 1	.5 lb	29	45	
McIntosh	1946	Check	0	30	--------	Do.
		Elgetol	1.0 pt	10	67	
		DN No. 1	.5 lb	23	23	
Rome Beauty	1946	Check	0	48	--------	Do.
		Elgetol	1.0 pt	38	21	
		DN No. 1	.5 lb	25	48	
		DN No. 2	.5 lb	28	42	
		DN 111	1.0 lb	29	40	
Wealthy	1946	Check	0	60	--------	Do.
		Elgetol	1.5 pt	30	50	
		DN No. 1	.75 lb	28	53	
		DN No. 2	.75 lb	33	45	
Delicious	1947	Check	0	66	--------	Washington *(5)*.
		Elgetol	2.0 pt	53	20	
		DN No. 1	1.0 lb	54	18	
Do	1948	Check	0	59	--------	Washington.
		Elgetol	1.5 pt	25	58	
		DN No. 1	.75 lb	58	2	
Golden Delicious	1945	Check	0	96	--------	Washington *(5)*.
		Elgetol	1.8 pt	73	24	
		DN No. 2	.9 lb	67	30	
Do	1946	Check	0	99	--------	Do.
		Elgetol	2.0 pt	71	28	
		DN No. 2	1.0 lb	65	34	

TABLE 1.—*Effectiveness of different forms of dinitro thinning sprays when applied during the bloom period on certain varieties of apples in certain areas—Continued*

Variety	Year	Treatment [1]	Concentration per 100 gallons	Fruits per 100 blossoming spurs [2]	Reduction in fruit set	State and literature reference
			Quantity	*Number*	*Percent*	
Jonathan	1947	Check	0	54	--------	Washington.
		Elgetol	2.0 pt	49	9	
		DN No. 1	1.0 lb	20	63	
		DN No. 2	1.0 lb	33	39	
Do	1948	Check	0	67	--------	Do.
		Elgetol	2.0 pt	34	49	
		DN No. 1	1.0 lb	49	27	
Winesap	1945	Check	0	42	--------	Washington (*5*).
		Elgetol	1.0 pt	24	43	
		DN No. 2	.5 lb	23	45	
Do	1947	Check	0	30	--------	Do.
		Elgetol	2.0 pt	21	30	
		DN No. 1	1.0 lb	29	3	
Do	1948	Check	0	63	--------	Do.
		Elgetol	1.5 pt	26	59	
		DN No. 1	.75 lb	36	43	

[1] Description of the commercial preparations listed in the treatment column: Elgetol, a slurry containing 20 percent sodium dinitro-ortho-cresylate; DN No. 1, a powder containing 40 percent dinitro-ortho-cyclohexylphenol; DN No. 2, a powder containing 40 percent dinitro-ortho-cresol; DN No. 111, a powder containing 20 percent dicyclohexylamine salt of dinitro-ortho-cyclohexylphenol. In any given experiment the various materials were used at approximately equivalent concentrations of toxicant.

[2] Fruit-set records presented in all tables of this circular were obtained following the June drop.

It seems evident from the data presented in table 1 that no definite conclusion can be drawn as to the relative effectiveness of the various forms of dinitro chemicals as thinning agents for apples. When results are considered on the basis of extent of thinning obtained they are so variable as to preclude the establishment of one form of dinitro as superior to another. In general, the DN No. 2 (used at equivalent toxicant concentration) has resulted in somewhat more thinning than Elgetol in most of the cases where the two materials have been compared. However, DN No. 2 is more prone generally to result in greater foliage injury than Elgetol, particularly when applied under conditions of cool, humid weather. As near as can be judged from the data in table 1, DN No. 1 is about as effective as Elgetol.

Results in New York, where these two materials have been compared (*22*), indicate that DN No. 1 is generally less likely to result in as much foliage injury as Elgetol. For this reason it is sometimes considered preferable to Elgetol in that locality. However, Elgetol or Krenite[2] is used commercially almost exclusively in the fruit areas

[2] Krenite is a commercial preparation similar to Elgetol. It also contains approximately 20 percent sodium dinitro-ortho-cresylate.

of the Northwest. Where DN No. 1 was used in central Washington in 1948 (a cool, humid bloom season) it resulted in rather seriously malformed and russeted fruit. This type of injury with this material had not been observed before or since the 1948 season. Southwick and Weeks (*40*), working in Massachusetts, have also reported fruit russeting with DN No. 1.

The greatest amount of experimental work to date has been performed with Elgetol, and at present (1950) this material is being used commercially more than any other form of dinitro chemical for fruit thinning. Further work may prove other forms of dinitro chemicals preferable to those now being used. Limited work with the triethanolamine salt of dinitro-ortho-sec-butylphenol (DN No. 289) has shown promise as an agent for thinning fruit, but at present this material does not seem to have any advantage over those mentioned above.

Time of Application and Mechanism of Action

MacDaniels and Hildebrand (*28*) found that Elgetol at 0.25 percent (1 quart per 100 gallons) concentration completely prevented pollen

Table 2.—*Effectiveness of Elgetol thinning sprays applied at different stages of bloom development on several varieties of apples in specified areas*

Variety	Amount of Elgetol per 100 gallons	Date sprayed	Bloom stage	Fruits per 100 blossoming spurs	Reduction in fruit set	State and literature reference
	Pints			*Number*	*Percent*	
Wealthy	0			48		Hudson Valley, New York (*20*).
	1.6	April 29, 1941	35 percent open	47	2	
	1.6	April 30, 1941	75 percent open	44	8	
	1.6	May 1, 1941	Full bloom	27	43	
Do	0			52		Western New York (*20*).
	1.6	May 11, 1941	75 percent open	42	19	
	1.6	May 14, 1941	Full bloom	30	42	
York Imperial.	0			26		West Virginia (*4*).
	1.2	May 4, 1943	Full bloom	13	50	
	1.2	May 6, 1943	Early petal fall	10	62	
Do	0			23		Do.
	1.2	May 1, 1943	Full bloom	5	78	
	1.2	May 4, 1943	Early petal fall	5	78	
Yellow Transparent.	0			56		Do.
	1.2	April 29, 1943	Full bloom	34	39	
	1.2	May 2, 1943	Early petal fall	37	34	
Grimes Golden.	0			49		Do.
	1.2	May 2, 1944	Full bloom	22	55	
	1.2	May 4, 1944	Early petal fall	33	33	
Golden Delicious.	0			107		Washington (*5*).
	1.5	May 3, 1945	Full bloom	81	24	
	1.5	May 5, 1945	Early petal fall	87	19	
Winesap	0			73		Do.
	1.4	April 30, 1945	Full bloom	49	33	
	1.4	May 2, 1945	Early petal fall	56	23	
Do	0			42		Do.
	1.0	May 3, 1945	Full bloom	24	43	
	1.0	May 5, 1945	Early petal fall	26	38	
Do	0			42		Do.
	1.33	May 2, 1945	Full bloom	33	21	
	1.33	May 4, 1945	Early petal fall	25	40	

germination when applied to the stigmatic surface of apple flowers. Later MacDaniels and Hoffman (*29*) reported that Elgetol sprays applied at concentrations of 0.1 to 0.2 percent during the bloom period effectively reduced the fruit set of several varieties of apples. From their initial orchard trials these authors concluded that closed blossoms were not killed by the spray, nor were blossoms that had been pollinated sufficiently long to permit fertilization. Hildebrand (*19*) has presented data to indicate that a 0.3 percent concentration of Elgetol applied to open flowers is able to inactivate pollen tubes that have already grown halfway down the style of the pistil. This would approximate the depth of pollen penetration about 1 day after the pollen has been applied to the stigmatic surface.

In subsequent experiments involving chemical thinning attention was directed toward obtaining additional information relative to the length of time during the bloom period that these sprays would effectively reduce fruit set. In table 2 typical results are presented relating to the effectiveness of Elgetol sprays applied at different stages of bloom development. These data show that greater thinning was obtained when the sprays were applied at full bloom as compared with pre-full-bloom when only 35 to 75 percent of the flowers were open. It is interesting to note, however, that about the same amount of thinning resulted when the spray was applied 1 to 3 days following full bloom (early petal fall) as was obtained when applications were made at the full bloom stage.

The fact that appreciable reduction of set is obtained when Elgetol sprays are applied from 1 to 3 days following full bloom would indicate that a large number of flowers already fertilized are prevented from developing fruit by the action of the spray material. It is believed that under many conditions reduction in fruit set is due to the Elgetol acting as a pollinicide or as a direct causal factor (MacDaniels and Hildebrand (*28*) and Hildebrand (*19*)). The spray may also prevent many of the fertilized flowers from setting indirectly through temporary alteration of growth processes resulting from toxicant absorption by both flower and leaf tissue. Although information regarding weather and tree condition under which this type of thinning may take place is lacking, observations indicate that reduction of set is more prevalent during cool, humid bloom periods or when trees are lacking in vigor as a result of imperfect soil drainage, winter injury, inadequate nutrition, and other types of trouble that interfere with normal tree functioning.

For best results Elgetol sprays generally should be applied as near the full-bloom stage as possible. By full bloom is meant that stage at which an occasional petal will fall from the earlier opening blossoms when a small branch is gently shaken but not prior to the opening of approximately 90 percent of the blossoms. At this stage usually most of the center, or "king," blossoms of apples have been open for 12 to 36 hours and under favorable pollinating conditions have been pollinated and fertilized. When the "king" blossom has reached this stage, it has a greater tendency to survive spray treatment than the freshly opened or side blossoms, many of which are killed by the spray. If the spray is applied after the later opening blossoms have become pollinated and fertilized, less thinning may result. As

pointed out above, spray applications as late as 1 to 3 days (normal weather) following full bloom have been (under many conditions) as effective or only slightly less effective than applications at the full-bloom stage. Timing, therefore, is not too critical and allows from 1 to 3 days under most conditions to make applications. This is a sufficient period for most growers to spray a sizable block of a given variety.

Concentration

Since the effective concentration of Elgetol is related to weather conditions, tree vigor, variety, and possibly other factors, no inflexible recommendation is possible. The relationship of these factors to results obtained will be discussed later. The effective concentration of Elgetol for thinning apples will generally vary from 1 pint to 1 quart per 100 gallons. Spray solutions with concentrations much greater than 1 quart per 100 gallons may result in foliage and spur injury

Table 3.—*Effectiveness of different concentrations of Elgetol thinning sprays when applied during the bloom period on certain varieties of apples, 1942-46*

Variety	Year	Concentration of Elgetol per 100 gallons	Fruits per 100 blossoming spurs	Reduction in fruit set	State and literature reference
		Pints	*Number*	*Percent*	
Northwestern Greening	1942	0	38	------	New York (*24*).
		1.0	11	71	
		2.0	1	97	
Cortland	1942	0	34	------	Do.
		1.0	7	79	
		2.0	2	94	
Delicious	1942	0	35	------	Do.
		1.0	8	77	
		2.0	0	100	
McIntosh	1942	0	98	------	Do.
		1.0	76	22	
		2.0	32	67	
Wealthy	1942	0	74	------	Do.
		1.0	45	39	
		2.0	43	42	
Baldwin	1942	0	72	------	Do.
		1.0	51	29	
		2.0	32	55	
Rome Beauty	1942	0	57	------	Do.
		1.0	35	38	
		2.0	15	74	
Yellow Transparent	1942	0	64	------	West Virginia (*3*).
		1.6	22	66	
		2.4	13	80	
Early McIntosh	1943	0	66	------	New York (*25*).
		1.0	40	39	
		2.0	17	74	
Yellow Transparent	1943	0	56	------	West Virginia (*4*).
		1.2	34	39	
		1.7	30	46	

TABLE 3.—*Effectiveness of different concentrations of Elgetol thinning sprays when applied during the bloom period on certain varieties of apples, 1942-46*—Continued

Variety	Year	Concentration of Elgetol per 100 gallons	Fruits per 100 blossoming spurs	Reduction in fruit set	State and literature reference
		Pints	*Number*	*Percent*	
Grimes Golden	1944	0	49	------	Do.
		.8	29	41	
		1.2	24	51	
Golden Delicious	1944	0	54	------	West Virginia (*4*).
		1.0	34	37	
		1.5	29	46	
York Imperial	1944	0	89	------	Virginia (*11*).
		.8	47	47	
		1.2	27	70	
		1.6	27	70	
		2.0	27	70	
		2.4	20	77	
Golden Delicious	1945	0	107	------	Washington (*5*).
		1.5	81	24	
		2.0	83	22	
Winesap	1945	0	58	------	Do.
		.7	42	28	
		1.4	41	29	
Do	1946	0	96	------	Do.
		.7	84	13	
		1.4	73	24	
Delicious	1946	0	61	------	Do.
		.7	61	0	
		1.4	55	9	
Do	1947	0	66	------	Do.
		1.0	50	24	
		2.0	53	20	
Do	1948	0	60	------	Washington.
		1.0	29	52	
		2.0	18	70	
Jonathan	1946	0	97	------	Do.
		1.3	96	1	
		2.0	78	19	

under some conditions, whereas amounts much less than 1 pint in most cases will not result in sufficient thinning.

Comparative effectiveness of different concentrations of Elgetol sprays is presented in table 3. Reduction in set is usually greater with the stronger spray, but there are numerous exceptions. Under New York conditions, apparently a more direct relationship between concentration and reduction in fruit set is obtained than under conditions prevailing in Washington. Repeated observations in Washington indicate that an increase in concentration will frequently result in significantly greater thinning under conditions unfavorable for fruit set.

When cool, humid weather prevails during the bloom period it is believed that a greater amount of thinning of the indirect type results from the stronger sprays. Under Northwest conditions if the bloom period is characterized by rather warm weather with low

humidity, little or no difference is obtained on normal healthy trees with concentrations varying from 1 pint to 1 quart per 100 gallons. Thus, during the latter type of bloom period set reduction may be largely a result of the toxicant acting as a pollinicide or causing injury to the stylar tissue within a short time after pollination ensues. Supporting this premise MacDaniels and Hildebrand (*28*) have shown that pollen germination is completely inhibited at concentrations well below 0.1 percent (0.8 pint per 100 gallons) Elgetol.

Aside from weather conditions, concentration may play a role in results, depending on such factors as variety and tree condition. As Verner and Franklin (*42*) have pointed out, concentration may prove to be of greater consequence as it approaches critical limits beyond which overthinning results. With a given variety the critical limit of concentration varies greatly, depending upon tree condition and environmental factors. In order to obtain any appreciable indirect effect of the thinning sprays during seasons of warm, dry weather, it may be necessary under many conditions to use concentrations higher than the conventional range.

Under Northwest conditions Elgetol sprays are generally used at higher concentrations with a greater margin of safety than under most eastern conditions (*5*, *42*). The probable reason is due to the uniformly greater vigor of the trees and usually more favorable weather during the bloom period.

Varietal Response

In general, chemical thinning can be used with greater safety and dependability with varieties that tend to set heavy crops. With a moderately heavy bloom, under conditions prevailing in the Northwest, production of a commercial crop usually requires about 35 to 40 apples per 100 blossoming spurs. It is necessary to remove fruit in excess of this amount if satisfactory fruit size and annual bearing habits are to be obtained.

In this fruit area the partially self-fruitful varieties, such as Golden Delicious, Yellow Newtown, Jonathan, and Rome Beauty, usually set from 70 to 100 fruits per 100 blossoming spurs when carrying a heavy bloom. Thus one may expect a fruit set on these varieties of at least double the number considered desirable for a satisfactory crop. Therefore, under Northwest conditions the varieties listed above can be chemically thinned with little or no likelihood of overthinning. On the other hand, Delicious and Winesap in the Northwest may or may not set heavily, depending upon the season and provisions for pollination. If these self-unfruitful varieties are adequately pollinized, fruit set is usually about 50 to 60 fruits per 100 blossoming spurs. Thinning sprays are safely used in the Northwest on these varieties when weather conditions and cross-pollination are favorable.

In fruit sections other than the Northwest, varieties considered best adapted for chemical thinning include Duchess, Early McIntosh, Wealthy, Baldwin, Yellow Transparent, Wagener, and Golden Delicious. These varieties are partially self-fruitful (or at least they set fruits with a few seeds) and tend to set heavily even under rather

adverse weather conditions, which may prevail during the bloom period. They are also fairly resistant to the action of Elgetol sprays, and if in good vigor there is little likelihood that overthinning will result. On heavily blooming trees under Eastern conditions, 20 to 30 fruits per 100 blossoming spurs constitute a commercial crop. The most satisfactory number varies somewhat with the variety, its season of maturity, and orchard conditions. With reasonably good bloom weather, trees of the above varieties receiving good care may set 50 to 60 fruits per 100 blossoming spurs.

Whether or not such varieties as Jonathan, York Imperial, Rome Beauty, and Grimes Golden can be safely sprayed in East and Midwest fruit sections will depend largely upon tree vigor and weather conditions prevailing during the bloom period. In these fruit areas such wholly self-unfruitful varieties as McIntosh, Delicious, Northern Spy, Winesap, and Stayman are generally not considered adapted for chemical thinning with dinitro sprays. Fruit set on these varieties in East and Midwest fruit areas is frequently unpredictable, and even though a heavy set is expected to occur Elgetol may overthin, par-

TABLE 4.—*Comparison of effectiveness of 1 and 2 applications of Elgetol thinning sprays applied to certain varieties of apples in certain areas*

Variety	Concentration of Elgetol per 100 gallons	Date sprayed	Year	Full bloom	Fruits per 100 blossoming spurs	Reduction in fruit set	State and literature reference
	Pints			*Percent*	*Number*	*Percent*	
Wealthy	0		1940		45		New York (*29*).
	.8	May 27	1940	65	15	67	
	.8	May 27; May 29	1940	65; 100	5	89	
Do	0		1941		47		New York (*20*).
	1.6	May 1	1941	100	27	43	
	1.6	April 20; May 1	1941	75; 100	22	53	
Do	0		1941		52		Do.
	1.6	May 11	1941	75	42	19	
	1.6	May 11; May 14	1941	75; 100	13	75	
Golden Delicious	0		1946		100		Washington (*5*).
	2.0	April 26	1946	75	83	17	
	2.0	April 26; April 29	1946	75; 100	77	23	
Do	0		1946		99		Do.
	2.0	May 3	1946	100	71	28	
	2.0	May 1; May 3	1946	65; 100	57	42	
Do	0		1948		97		Washington.
	2.0	May 17	1948	100	35	64	
	2.0	May 15; May 17	1948	75; 100	16	84	
Jonathan	0		1946		97		Do.
	1.3	May 1	1946	75	96	1	
	1.3	May 1; May 3	1946	75; 100	63	34	
Do	0		1947		95		Do.
	2.0	April 21	1947	100	82	14	
	2.0	April 20; April 21	1947	75; 100	79	17	
Do	0		1948		67		Do
	2.0	May 12	1948	75	34	49	
	2.0	May 11; May 14	1948	75; 100	10	85	

ticularly if applied to trees of low vigor or when adverse weather conditions prevail during the bloom period.

Number of Spray Applications

One application of an Elgetol spray is not usually sufficient to approach the desired amount of thinning on some apple varieties when grown under conditions conducive to a heavy fruit set. In the Northwest Golden Delicious, Yellow Newtown, and Jonathan frequently require two sprays. It is also desirable in some instances to apply two sprays to Wealthy in the Northeast. This is especially true for vigorous "on-year" trees that produce considerable lateral bloom on the past season's terminal growth. This bloom opens several days after the spur bloom, and a second application is required for adequate thinning. Table 4 summarizes some of the results, comparing the effectiveness of one and two applications of an Elgetol spray applied to three varieties of apples. As might be expected in most of the experiments, two sprays resulted in appreciably more thinning than a single application. Overthinning resulted in two of the three experiments (table 4) in New York with the Wealthy variety. In those instances of overthinning following two sprays, the trees were of relatively low vigor, caused in one case by a low nitrogen level and in the other by imperfect soil drainage.

In Washington the double Elgetol spray treatment overthinned both Jonathan and Golden Delicious in 1948, while the same treatment, though significantly reducing fruit set, failed to thin sufficiently these varieties in other years. It is believed that weather conditions in 1948 during the bloom period (cool and humid) caused a greater indirect action of the spray. This point will be discussed in a subsequent section.

Whether or not heavy-setting varieties will require two sprays to approach the desired amount of thinning depends upon locality, tree condition, and the type of weather prevailing during the bloom period. Under Northwest conditions it is a general commercial practice during seasons of favorable weather to apply two sprays on Golden Delicious, Yellow Newtown, and Jonathan. In this area Winesap and Delicious under favorable conditions are sometimes sprayed twice. Since conditions, particularly tree vigor and pollination, vary from orchard to orchard it remains for individual fruit growers to determine under their own particular conditions the advisability of applying a second spray. When two sprays are used it is preferable to apply the first one about 1 or 2 days ahead of full bloom, when approximately 50 to 75 percent of the flowers are open. The second application should be made from 1 to 3 days later when most of the remaining flowers have opened.

Pollination and Bee Activity

As stated previously successful use of thinning sprays is predicated on the assumption that fruit set will be heavy. Weather conditions during the bloom season is an important factor in determining the adequacy of pollinizers and number of bees needed to insure a heavy

set of fruit. Self-unfruitful varieties, such as Winesap and Delicious, with favorable weather during the bloom period normally set heavily at least three tree spaces away from a pollinating variety, provided there are adequate bees or other pollinating insects. Under cool, rainy, or windy conditions pollination may become a limiting factor when these varieties are located more than one tree space from a pollinizer. In fruit sections where such varieties are adapted for chemical thinning it would seem advisable, for greatest safety in seasons of adverse weather, to apply thinning sprays only if adjacent to pollinizers, or at the most two tree spaces distant.

Weather Conditions During Blossoming Period

In the preceding discussion frequent reference has been made to weather conditions as they are related to various factors influencing the effectiveness of dinitro sprays. During the past several years it has become increasingly evident that weather conditions existing during the bloom period are perhaps the most important factors in the success of thinning sprays.

Working with Elgetol sprays in West Virginia in 1943 and 1944, Batjer, Moon, and Kinman (*4*), obtained results that were in decided contrast during the 2 years. The weather in the 1943 bloom period was cool and windy (mean minimum 43° F.; mean maximum 69°), with frequent showers. The weather the following year was much warmer (mean minimum 54°; mean maximum 78°) and relatively dry. In 1943 the application of Elgetol sprays on York Imperial and Grimes Golden seriously overthinned, principally because fruit set on unsprayed trees during that year was less than one-half that which occurred in the more favorable year (1944).

Dinitro sprays in the Northwest are more likely to thin heavily during a cool, humid bloom period (as in 1948), even though a heavy

Table 5.—*Effectiveness of Elgetol thinning sprays at Wenatchee, Wash., during 2 years of widely different weather* [1]

Orchard and variety	Fruits per 100 blossoming spurs in—			
	1947		1948	
	Unsprayed	Sprayed	Unsprayed	Sprayed
	Number	*Number*	*Number*	*Number*
Birchmount orchard:				
Winesap	54	40	50	25
Bond orchard:				
Delicious	65	50	66	35
Winesap	70	52	75	30
Golden Delicious	95	70	90	45
Ox Team orchard:				
Winesap	50	35	23	3

[1] During a 7-day bloom period at Wenatchee, Wash., in 1947 and 1948, there were 108 degree-hours and 65 degree-hours (daily average), respectively, above 50° F.

set is likely to occur, than in seasons when generally warm, dry conditions prevail (as in 1947). The data presented in table 5 illustrates this point. In the Bond and Birchmount orchards Delicious and Winesap trees were within one tree space of a pollinizer (Golden Delicious and Jonathan) and fruit set on unsprayed trees was approximately the same for the 2 years in both orchards. However, it is evident from the data in table 5 that the Elgetol sprays were much more effective in reducing fruit set in 1948 than in 1947. In 1948 the sprays prevented many of the flowers from setting fruit even though pollination and fertilization had apparently taken place prior to treatment.

This greater indirect action of the Elgetol when applied during a cool, humid bloom season may be a result of a greater amount of the toxicant being absorbed. An alternate possibility is that many of the fruits may have been "weak," due to imperfect fertilization or low seed content per fruit. It would seem reasonable to expect that such fruits would be more susceptible to the indirect action of the toxicant. Extensive observations indicate that the tendency toward the "indirect" type of thinning is greater with weak trees or parts of trees with weak fruiting wood. When a combination of both weak trees and cool, humid weather occurs, thinning sprays used at conventional concentrations may result in almost complete defruiting.

It should be emphasized that in orchards where pollination is a limiting factor in years of adverse weather, dinitro sprays usually result in serious overthinning (table 5, Ox Team orchard, 1948). In such instances a combination of both a light set and a greater than average killing power of the spray frequently results in a greater set reduction than desired. Since dinitro sprays are applied at full bloom or later, it is fortunate that weather conditions influencing fruit set from the earlier opening blossoms are largely known before it becomes necessary to determine the desirability of using these sprays.

Failure to obtain sufficient thinning is often associated with weather conditions that are conducive to heavy fruit set. During bloom periods of moderately high temperature, fertilization processes proceed at a very rapid rate. Under such conditions most of the thinning with dinitro chemicals is of the direct type, and consequently the sprays should be accurately timed to coincide with full bloom. Even with the best timing possible, less thinning than desired may be realized. During the 1950 season approximately 20,000 acres of apples received dinitro sprays in central Washington without a single instance of overthinning. Practically all growers using the sprays obtained substantial benefits, but many were disappointed because of insufficient thinning. The 1950 season was characterized by warm, dry weather with a daily accumulation during the bloom period of 230 degree-hours above 50° F., i.e., the sum of the hourly degrees above 50° during which such temperatures prevailed. During this type of season the possibility of using higher concentrations of Elgetol to obtain greater thinning has not been sufficiently explored. By doubling the conventional concentration in a favorable bloom period it may be possible to obtain a substantial amount of thinning of the indirect type.

Dinitro sprays may cause considerable scorching of the young developing leaves if applied during rainy periods. This type of injury is not too harmful, because the growing points are not usually damaged and the tree recovers rapidly. Slight mottling and crinkling of some leaves may result if cool, humid weather prevails at the time and following the spray application. In Eastern fruit sections, particularly the Northeast, DN No. 1 is frequently preferred to Elgetol, because there is less likelihood of serious foliage injury resulting under conditions prevailing in these fruit areas. In the Pacific Northwest foliage injury from the use of dinitro sprays is rarely a problem.

Tree Vigor

Overthinning is less likely to occur when dinitro sprays are applied to trees in a normal to above-average state of vigor. Trees are more susceptible to the action of these sprays when suffering from effects brought about by imperfectly drained soil, various types of root trouble, winter injury, low nitrogen level, or any condition that may affect normal functioning of growth and fruit-setting processes. Fruit set on trees suffering from the effects of any of the above conditions is frequently lower than on normal trees. Experimental evidence and repeated observations with trees of this type indicate that use of dinitro sprays may result in reduction of fruit set beyond the point of an adequate commercial crop. Overthinning is probably a result of a much greater indirect effect of the toxicant than usually occurs on normally vigorous trees. It should not be concluded that weak trees preclude the possibility of using dinitro sprays. If heavy fruit set can be depended upon, it is likely that lower than standard concentrations (one-half to two-thirds pint of Elgetol per 100 gallons) might prove safe and effective. In order to proceed safely, however, it would be necessary to conduct trial tests.

In certain situations high tree vigor is not necessarily associated with less effectiveness of dinitro sprays. Under West Virginia conditions (*4*) trees moderately low in nitrogen, but not low enough to limit fruit set, were no more susceptible to thinning sprays than trees of the same variety maintained at a much higher level of vigor. It therefore might be concluded that the conditions or causes responsible for a particular state of vigor may be important factors in determining the response of trees to dinitro sprays.

Technique in Applying Sprays

The amount of bloom below which dinitro thinning sprays are not advisable varies so greatly as to preclude any specific recommendation. Usually the heavier the bloom the greater is the total fruit set. When using these sprays a general rule is to avoid spraying trees or portions of trees with less than about a 50-percent bloom. With some varieties a bloom of considerably less than 50 percent can be safely sprayed. With a majority of apple varieties the less the bloom the greater the percentage set and the more resistant the blossoms are to the action of the thinning sprays. This safeguard will prevent overthinning if sound judgment is used in avoiding trees that have such

a sparse bloom that no thinning would be needed. A thorough knowledge of the fruit-setting characteristics of a variety under a particular set of conditions is the best guide in determining the amount of bloom below which spray thinning is inadvisable.

Thoroughness of application is essential for effectiveness. Failure to thin sufficiently is often a result of applying the spray material too lightly. At Wenatchee, Wash., 15 to 20 percent more thinning was obtained when the amount of spray material applied was increased from 20 to 32 gallons per tree on 20-year-old Golden Delicious, Winesap, and Delicious.

In many orchards, particularly the older and more crowded ones, the lower limbs are likely to be weak and blossoms fail to set as heavily as on the more vigorous and well-exposed branches. Depending upon weather and pollination, these lower weak limbs should be sprayed lightly or not at all.

Experience has shown that dinitro sprays are usually more effective in reducing fruit set on young trees. Trees under 10 to 12 years of age are likely to be more vigorous and frequently fail to set fruit in proportion to the amount of bloom they produce. Only by trial under one's own conditions can it be determined whether these sprays can be safely used on such trees. There seems to be less risk involved on young trees of the Golden Delicious, Duchess, Wealthy, and other heavy-setting varieties than with Winesap and Delicious of comparable age.

Thinning sprays are best applied with manually operated "guns" or "brooms" that deliver the spray material under high pressure from either portable or stationary spray equipment. Portable spray equipment that applies the spray through fixed outlets is not too well adapted for use with thinning sprays, except under conditions of uniformly good vigor and heavy bloom. Frequently the use of such equipment results in overspraying the low or weaker wood, which in many cases should be sprayed lightly if at all. It is also difficult to avoid spraying trees or parts of trees that do not have a sufficient amount of bloom.

EFFECTIVENESS OF GROWTH-REGULATING CHEMICALS IN THINNING APPLES

Effectiveness of Different Chemicals

Most of the work and experience with hormone or growth-regulating chemicals for thinning apples has involved the use of preparations containing naphthaleneacetic acid or the sodium salt of naphthaleneacetic acid as the active ingredient. These are the same preparations that have come into general use as harvest sprays for the control of fruit drop.

In attempting to increase the set of the Starking apple, Burkholder and McCown (*6*) sprayed halves of Starking apple trees during the bloom with naphthaleneacetic acid at concentrations of 10 parts per million (p. p. m.), or 0.001 percent, and 50 p. p. m., or 0.005 percent. The number of blossoming spurs setting fruit on the sprayed parts of the trees as compared with the unsprayed parts was reduced 15

percent by the weaker concentration and 77 percent by the stronger concentration. Naphthaleneacetamide at a concentration of 50 p. p. m. used in a similar way reduced the number of spurs setting by 34 percent. Slight injury of the young foliage was caused by the naphthaleneacetic acid at 10 p. p. m., while more severe injury in the form of epinasty, scorching, and leaf drop resulted from the stronger concentration of 50 p. p. m. No visible foliage injury followed the naphthaleneacetamide spray. These results indicated that naphthaleneacetamide was effective in reducing the set of Starking but was less effective than naphthaleneacetic acid when used at the same concentration.

Schneider and Enzie (*34*), employing the branch-unit method, found that bloom sprays of naphthaleneacetic acid at concentrations of 100 to 300 p. p. m. seriously overthinned Delicious and Gano and deformed the leaves. Similar results were obtained on Arkansas Black with the same concentrations of naphthaleneacetic acid and naphthaleneacetamide. The acid was more potent than the acetamide in reducing set and causing leaf injury.

In a second paper, Schneider and Enzie (*35*) reported that the limbs of Delicious and Gano sprayed with these high concentrations of naphthaleneacetic acid, which almost eliminated the crop, failed to produce any more flowers the following year than untreated check limbs, which had practically no bloom. Apparently this was due to the dwarfing of leaves caused by the spray. In the case of the Arkansas Black, which was a more annual blossoming variety under their conditions, the percentage of flowering points in 1943 based on the number of flowering points in 1942, the year of treatment, was as follows: Naphthaleneacetic acid 100 p. p. m., 39 percent; naphthaleneacetic acid 300 p. p. m., 12 percent; napthaleneacetamide 100 p. p. m., 73 percent; naphthaleneacetamide 300 p. p. m., 84 percent; and check limbs, 67 percent.

In another test on Arkansas Black (limb-unit method) these investigators employed sprays of naphthaleneacetic acid during the bloom at weaker concentrations, ranging from 10 to 40 p. p. m. These treatments resulted in less reduction in set than the stronger concentrations, and the data indicate that the degree of thinning was associated with concentration. Leaf injury was recorded as none to slight, following the use of these concentrations. Naphthaleneacetic acid at 40 p. p. m. reduced fruit set approximately twice as much as naphthaleneacetamide at 80 p. p. m. concentration. The 40 p. p. m. spray of naphthaleneacetic acid caused slight leaf injury, while the 80 p. p. m. of naphthaleneacetamide caused none.

Other growth-regulating chemicals used in these tests, at a wide range in concentrations, included indolebutyric acid, indoleacetic acid, and indoleproprionic acid. None of these chemicals significantly reduced the set of Stayman, nor did indoleacetic acid or indolebutyric acid affect the set of Arkansas Black.

In studying the effect of growth-regulating chemicals on the set of the Starking apple (limb-unit method), Greene (*16*) used sprays of naphthaleneacetic acid at concentrations of 10, 50, and 100 p. p. m. in a 0.1 percent polyvinyl alcohol-water solution. The set of fruit was reduced in all cases, with the greater reductions occurring at the

higher concentrations. Indolebutyric acid at 10 and 50 p. p. m. in the same alcohol-water carrier had no significant effect on set.

Davidson, Hammer, Reimer, and Dutton *(8)* included the sodium salt of naphthaleneacetic acid at a concentration of 10 p. p. m. in the regular insecticide and fungicide applications during the 1941 growing season on trees of the following varieties: Stark, Grimes Golden, McIntosh, Jonathan, and Golden Delicious. Similar plots of these varieties received only the normal insecticide and fungicide applications. Since the addition of the hormone was for purposes other than thinning, no fruit-set records were made. However, counts at harvest-time showed a large reduction in the number of fruits borne per tree where the sodium salt of naphthaleneacetic acid had been included in the spray schedule. The reduction in the number of apples harvested per tree was as follows: Stark, 90 percent; Grimes Golden, 85; McIntosh, 64; Jonathan, 70; and Golden Delicious, 85. Thus, a very significant thinning effect was obtained from repeated applications of the sodium salt of naphthaleneacetic acid, none of which were applied in the blossoming stage.

Following these observations Davidson and coworkers *(8)* conducted experiments in 1942, 1943, and 1944 to evaluate the sodium salt of naphthaleneacetic acid as an agent for thinning apples. Concentrations of 10 and 20 p. p. m. were used, and single applications were made at different stages of development, starting at the pink or open cluster stage and extending up to and including the second cover spray, 4 weeks after bloom. In most cases the hormone was applied alone as a special application. In these tests, which included six varieties, a concentration of 20 p. p. m. was more effective in reducing set than 10 p. p. m. The greatest thinning, in some cases too severe, occurred when the application was made at full bloom. Sprays applied just before or just after bloom were less effective than at full bloom but were often adequate. Treatments made 2 and 3 weeks after petal fall were less effective than at petal fall, and when the spray was delayed until 4 weeks after petal fall there was little or no effect. There was considerable variation in the response of different varieties, and the same variety did not respond the same each year. Foliage injury was reported as not being a factor in these experiments.

Timing of Sprays and Mechanism of Action

In most of the recent experiments involving the use of hormone sprays for thinning apples, the application has been made at the calyx stage. Beneficial results have also been reported from later treatments by Hoffman, Southwick, and Edgerton (*22*) and Southwick and Weeks (*40*).

From the standpoint of obtaining maximum benefits in fruit size and annual bearing of biennial varieties, the earlier the thinning can be accomplished the better will be the results. However, with many varieties in certain seasons, it is just as difficult to appraise the need for thinning at the calyx as at an earlier bloom stage. Since naphthaleneacetic acid preparations are effective in reducing the set of apples for several weeks following the bloom, there is considerable leeway in timing the spray. This offers definite advantages for those

areas where variable weather conditions may occur during or immediately following the bloom period. For example, apple bloom occurred relatively early in 1949 throughout fruit sections of the Northeast and excellent conditions for fruit setting prevailed for several days. About petal fall a prolonged period of cool weather set in and some frost damage occurred in localized areas. Two weeks after bloom, with the advent of warm weather, a number of varieties that had overset were successfully thinned with the hormone spray.

Working with the variety Early McIntosh, Southwick and Weeks (*40*) reported that a calyx spray of the sodium salt of naphthaleneacetic acid at 20 p. p. m. caused considerable permanent curling and dwarfing of the spur leaves, while a concentration of 50 p. p. m. applied 3 weeks after the calyx formed did not produce any appreciable extent of this type of injury. These investigators also observed that calyx applications on McIntosh were definitely more harmful to foliage than those applied 2 to 4 weeks later.

Although much of the emphasis has been placed on a late bloom or calyx spray in order to obtain the benefits of early thinning, this early application has in many cases caused rather serious foliage dwarfing. This spray usually causes a temporary "flagged" or wilted appearance of the foliage for several days, with a gradual return to normal. However, under some conditions and especially with some varieties, a serious dwarfing and curling of the leaves may result and persist throughout the season. This type of injury has occurred most frequently on Duchess, Yellow Transparent, Early McIntosh, Delicious, and Winesap. Severe dwarfing of the foliage of these varieties by naphthaleneacetic acid sprays has been observed to interfere with proper sizing of the fruit and to prevent fruit-bud formation, even though adequate thinning was accomplished. While the varieties Wealthy, Jonathan, Grimes, Baldwin, and Golden Delicious appear to be less susceptible, moderate leaf dwarfing from calyx sprays has been observed on these varieties in some seasons.

Experience during the past several years indicates that leaf dwarfing from naphthaleneacetic acid sprays can be largely or entirely avoided by delaying the application until 2 to 3 weeks after the calyx stage. The lack of injury at this stage is probably due to the completion by the spur leaves of certain growth processes such as cell division, cell expansion, and cuticle formation. A prolonged period of cloudy, rainy weather during the calyx and early postbloom period has often been associated with severe dwarfing. Such weather conditions might tend to delay temporarily the development of the leaves to a stage at which they are resistant to dwarfing.

Varieties that have shown susceptibility to serious leaf dwarfing from calyx sprays of the hormone should not receive this treatment until approximately 2 weeks after petal fall. This includes some of the heavier setting summer varieties such as Yellow Transparent, Duchess, and Early McIntosh. Even though some of the benefits from the earliest possible thinning may be sacrificed by delaying the spray, a normal healthy leaf surface as compared with dwarfed foliage will more than compensate for the loss of 2 weeks in the time of thinning.

Apples are more subject to abscission from any cause prior to the

June drop than they are after this drop is over. From the limited data available it seems doubtful that any appreciable thinning could be accomplished with a hormone spray after the June drop unless abnormally high concentrations were used, which might result in some form of injury to either leaves or fruit.

No definite explanation of the physiological effect of naphthaleneacetic acid in reducing the set of apples has as yet been offered. However, there is a limited amount of information that seems to indicate the possible mechanism of action. In thinning experiments it has been frequently observed that naphthaleneacetic acid sprays result in heavier thinning on weak spurs located in shaded parts of the tree than on the more vigorous spurs of well-exposed wood. An experiment conducted by Southwick and Weeks (*40*) confirms these observations. Their data show that dormant flower buds of "on-year" Wealthy trees having a diameter of only 4.7 millimeters or less were more severely thinned by postbloom sprays than those buds having a diameter of 4.8 millimeters or more.

It has long been recognized that a good supply of reserve food is essential for fruit setting. Heinicke (*18*) has emphasized the importance of the vigor of individual spurs as a factor in fruit setting. His work shows that when the seed number is constant, the vigorous spurs that can supply adequate food and water exhibit a greater capacity for fruit setting than weaker spurs. If the seed content is low the spur must be vigorous, else the young fruits will likely shed. On the other hand, fruits having a high number of seeds may develop on relatively weak spurs.

When naphthaleneacetic acid is used as a harvest spray to delay fruit drop, Smock and Gross (*37*) have shown that it causes a temporary increase in the respiration rate of the fruit. If a post-bloom spray for thinning has a similar effect on the young fruits and vegetative tissues of the tree, it could conceivably reduce the food supply to the young fruits and in this way induce abscission of the "weaker" fruits. Whatever the cause, naphthaleneacetic acid sprays tend to eliminate the type of fruit that is likely to develop into low grade apples at harvest.

Concentration

The concentrations of naphthaleneacetic acid that have been found most appropriate for thinning apples range from 5 to 20 p. p. m. It is not possible to make general recommendations, since the concentration that may prove best will depend on the variety, the stage of fruit development when applied, and the environmental factors that affect fruit setting. Some of the results pertaining to concentration are summarized in table 6. In attempting to interpret these data the variety, orchard, year, and area should be considered in comparing the normal set of check trees with the amount of thinning resulting from a given concentration. In many areas of the East and Midwest apple sections the weather in 1945 and 1947 was unfavorable for fruit setting.

In general, under East conditions, varieties that consistently set heavily, such as Wealthy, Baldwin, and Golden Delicious, require a

TABLE 6.—*Effectiveness of naphthaleneacetic acid sprays for thinning certain varieties of apples*

Variety	Year	Spray concentration	Growth stage when applied	Fruits per 100 blossoming spurs		Reduction in fruit set	State and literature reference
				Check	Sprayed		
		P. p. m.		*Number*	*Number*	*Percent*	
Baldwin:							
Orchard 1	1947	10	Full bloom	33	20	39	New York (*39*).
		20	Calyx	33	19	42	
Orchard 2	1947	20	do	26	8	69	
Delicious:							
Orchard 1	1946	5	do	53	35	34	New York (*22*).
		10	do	53	24	55	
		10	9 days after calyx.	53	30	43	
Orchard 2	1947	7	Full bloom	64	19	70	New York (*39*).
		10	Calyx	64	17	73	
Orchard 3	1947	10	do	33	2	94	
Delicious:							
Orchard 1	1946	10	Full bloom	55	51	7	Washington(*5*).
		10	Calyx	55	44	20	
		15	do	55	38	31	
		20	do	55	27	51	
		30	do	55	11	80	
Do	1948	10	do	66	45	31	
		20	do	66	14	79	
		20	First cover [1]	66	43	34	
Orchard 2	1948	15	Calyx	64	29	54	Washington.
Orchard 3	1948	10	do	42	10	76	
		20	do	42	1	98	
Orchard 4	1948	15	do	66	6	91	
Duchess	1945	10	do	24	18	25	Michigan (*41*).
		15	do	19	15	21	
		20	do	19	13	36	
EarlyMcIntosh:							
Orchard 1	1948	20	Early calyx	32	3	90	Massachusetts (*40*).
Orchard 2	1948	20	Late calyx	50	35	30	
		50	21 days after calyx.	50	12	76	
Golden Delicious:							
Orchard 1	1948	15	Calyx	41	31	24	New York.
		20	do	41	23	44	
Orchard 2	1948	15	do	59	28	52	
		20	do	59	32	46	
Do	1949	20	do	63	30	52	
Golden Delicious:							
Orchard 1	1945	15	Full bloom	109	69	37	Washington(*5*)
Do	1946	15	Calyx	109	67	38	
		15	Full bloom	99	73	26	
Orchard 2	1946	15	do	100	91	9	Washington
		15	Calyx	100	75	25	
Do	1948	20	do	94	32	66	
		20	First cover [1]	94	36	62	

TABLE 6.—*Effectiveness of naphthaleneacetic acid sprays for thinning certain varieties of apples*—Continued

Variety	Year	Spray concentration	Growth stage when applied	Fruits per 100 blossoming spurs		Reduction in fruit set	State and literature reference
				Check	Sprayed		
Jonathan:		*P. p. m.*		*Number*	*Number*	*Percent*	
Orchard 1	1948	15	Calyx	67	38	43	Washington.
Do	1949	10	do	79	76	4	
		15	do	79	72	9	
		20	do	79	62	22	
Orchard 2	1948	15	do	62	42	32	
Orchard 3	1948	10	do	33	27	18	
		20	do	33	8	76	
		20	First cover [1]	33	18	45	
Orchard 4	1949	20	Calyx	69	36	48	
Orchard 5	1949	15	do	77	53	31	
		20	do	77	48	38	
Northern Spy	1947	5	Full bloom	46	27	41	New York.
		10	Calyx	46	23	50	
Rome Beauty:							
Orchard 1	1946	10	do	48	54	0	New York (*22*).
		15	12 days after calyx.	48	47	2	
Do	1947	20	Calyx	53	4	92	New York (*39*).
Do	1948	15	do	36	33	8	New York.
		20	do	36	39	0	
Do	1949	20	do	67	57	15	
Orchard 2	1949	20	do	84	70	16	
Wealthy	1945	10	Early calyx	26	16	38	Michigan (*41*).
		15	do	40	20	50	
		20	do	34	7	79	
Do	1946	10	Calyx	60	40	33	New York (*22*).
		15	do	60	51	15	
		15	12 days after calyx.	60	34	43	
		20	do	60	31	48	
Do	1947	15	Early calyx	68	59	13	New York (*39*).
		20	Calyx	68	27	60	
Winesap:							
Orchard 1	1946	10	Full bloom	96	87	10	Washington(*5*).
		10	Calyx	96	84	12	
Do	1948	10	do	72	18	75	Washington.
		20	do	72	1	99	
Orchard 2	1946	10	Full bloom	54	25	54	Washington(*5*).
Orchard 3	1948	15	Calyx	54	1	98	Washington.
Orchard 4	1948	15	do	64	1	98	

[1] About 2 weeks after calyx period.

somewhat stronger concentration than those that set lighter. However, this does not always hold. For example, Duchess, which is a heavy-setting variety, can usually be thinned satisfactorily with a weaker concentration than is required for Wealthy.

Some of the data in table 6 indicate that, under a given set of conditions, the same concentration thins somewhat heavier when applied

at bloom or calyx time than at a later stage of development. There were a few instances however, where either the reverse was true or there was seemingly no difference in the amount of thinning obtained as related to time of application. The amount of thinning probably depends on absorption of the chemical as well as concentration and susceptibility of the flowers and young fruits to abscission. There is a continuous increase in leaf surface for absorption as the season advances, and the size and condition of the foliage as well as the weather at the time of application may influence the results.

Varietal Response

Although the concentration of naphthaleneacetic acid required for adequate thinning varies with the variety, spray applications have, under many conditions, resulted in a significant reduction in set for practically all varieties, with the possible exception of Rome Beauty. The lack of effectiveness of naphthaleneacetic acid in thinning Rome Beauty under New York conditions in 3 years out of 4 is illustrated by the fruit-set records for this variety in table 6. In the 1947 test the weather was cool and extremely wet during the bloom period and for several weeks following petal fall. Under these conditions of limited sunshine, the foliage was quite succulent and a calyx spray of naphthaleneacetic acid at 20 p. p. m. seriously overthinned Rome Beauty despite the fact that the unsprayed trees set heavier than desirable. In 1946, 1948, and 1949, when bloom weather was favorable for fruit setting, sprays of 10, 15 and 20 p. p. m. applied at the calyx stage resulted in little or no thinning.

Environmental Factors Affecting Results

As in the case of dinitro bloom sprays for thinning, when environmental factors tend to make a light set the use of a postbloom hormone spray usually results in overthinning. In this connection, it may be assumed that any treatment that can be depended upon to thin apples will overthin the crop if the normal set is less than or no more than that required for a commercial crop. This is illustrated in the thinning experiments conducted on Duchess and Wealthy in Michigan by Stebbins, Neal, and Gardner (*41* and table 6.) Assuming that 25 to 30 fruits per 100 blossoming points constitute a normal crop for these varieties in that area, the fruit-set records in table 6 indicate that an excessive set did not occur in 1945. Similarly, overthinning of Early McIntosh (orchard 1) in Massachusetts (*40* and table 6) was accompanied by a much lighter set on untreated trees than in orchard 2 where the same concentration resulted in a more satisfactory degree of thinning.

In seasons when cool, cloudy or wet weather occurs during a part of the bloom period, apples may set heavily even though the average number of seeds per fruit is lower than when the bloom weather is exceptionally favorable for bee activity. This is especially true in vigorous well-cared-for orchards. Under conditions of a low average seed content, a postbloom spray of naphthaleneacetic acid may thin heavier than when the average seed content is high following strong

cross-pollination. This is indicated by the data in table 6 for the variety Delicious (orchards 1 and 2), New York (*22*, *39*), for the years 1946 and 1947. These two orchards located on neighboring farms were similar with respect to soil, age of trees, culture, and provisions for cross-pollination. The season of 1946 was characterized by good weather for cross-pollination throughout the bloom period, while in 1947 a general rain lasting about 30 hours occurred at the peak of bloom. Although the check trees set somewhat heavier in 1947 than in 1946, a calyx application of the sodium salt of naphthaleneacetic acid at 10 p. p. m. resulted in greater thinning in 1947 than in 1946; the percentage of thinning amounted to 73 and 55, respectively.

The fruit-set data in table 6 for Delicious and Winesap under Washington conditions show that naphthaleneacetic acid applied at the same stage of development reduced set considerably more in 1948 than in 1946. The bloom season of 1948 in central Washington was characterized by relatively cool weather and occasional heavy showers, which probably interfered with the normal amount of cross-pollination of these two self-unfruitful varieties.

In Washington there is usually greater variability in results (particularly on Winesap and Delicious) when naphthaleneacetic acid is used as compared with the dinitro materials. Thus in seasons favorable for fruit set naphthaleneacetic acid generally is not so effective as the dinitro materials, while in seasons when adverse conditions exist for fruit set there seems to be a greater likelihood of overthinning with this material. In Washington, Golden Delicious and Jonathan under most conditions can be sprayed with naphthaleneacetic acid with little danger of overthinning or foliage injury, although generally the dinitro sprays are considered preferable for use on these varieties.

When conditions for cross-pollination are uniform, trees on imperfectly drained soil seldom set as heavily as trees growing on deep well-drained soil. This is especially pronounced in wet springs when anaerobic soil conditions prevent the early growth of new rootlets. Under such conditions a naphthaleneacetic acid spray may seriously overthin the crop, even though untreated trees set too heavily for good commercial size. In table 6 fruit-set records are given for two New York Baldwin orchards, in which thinning experiments were conducted in 1947 (*39*). Orchard 1 was located on well-drained land. Although the set of the check trees was not excessive, both treatments (10 p. p. m. at full bloom and 20 p. p. m. at calyx) proved worth while from the standpoint of producing fruit of good commercial size. In orchard 2, where the soil was waterlogged for a period of several weeks during the early part of the growing season, a calyx spray of 20 p. p. m. severely overthinned the crop. Under these conditions the naphthaleneacetic acid treatment at calyx was more drastic in its thinning effect than dinitro sprays applied during full bloom. Similar results were obtained with Delicious in orchard 3 (*39* and table 6), growing on imperfectly drained soil. In this instance a calyx spray of naphthaleneacetic acid at 10 p. p. m. practically defruited Delicious. These results are in contrast to those obtained the same season in orchard 2 (*39*) where the soil was well-drained and

in orchard 1 (*22* and table 6) where, in addition to good drainage, the 1946 bloom weather was exceptionally favorable for cross-pollination.

It has been pointed out that naphthaleneacetic acid reduces fruit set to a greater extent on weak wood lacking food reserves than on vigorous wood containing adequate amounts of stored food. Trees exhibiting nitrogen deficiency seldom set so heavily as those well supplied with this element. For this reason the treatment is likely to overthin when the nitrogen level is insufficient for good vigorous growth. Any condition that would reduce the efficiency of the foliage during the previous season, such as spray injury or insect damage, would likely interfere with the accumulation of reserve food and predispose the trees to a light set. All such factors should be considered before using a hormone spray for thinning.

The question of combining the naphthaleneacetic acid for thinning with one of the normal postbloom fungicide and insecticide sprays is frequently raised. Many of the fungicides and insecticides contain wetting agents, as do the naphthaleneacetic acid preparations, and when combinations are made excessive runoff may take place. It is also possible that some of the numerous materials now employed for pest control may interfere with the solubility of naphthaleneacetic acid or its absorption by the foliage, thus modifying the results. Sprays for the control of insects and diseases are usually applied to all trees in the orchard while a thinning spray may be used only on certain varieties, and the appropriate concentration for these may vary. It, therefore, seems advisable to apply the thinning spray as a separate operation.

OTHER CHEMICALS USED FOR THINNING APPLES

Most of the investigational work on chemical thinning as well as the commercial application of the practice has centered around the use of dinitro bloom sprays or postbloom applications of naphthaleneacetic acid. There are, however, several other types of materials that have been tested for reducing the set of apples which should receive mention. Following the preliminary work of Auchter and Roberts (*2*), Shepard (*36*) reported 6 years' results on the spraying of apples for the prevention of fruit set. The main purpose of this work was to defruit biennial-bearing varieties so as to change the year in which the trees bore their crop. Among a number of materials used, cresylic acid and a tar oil distillate were the most effective in preventing fruit set.

Magness, Batjer, and Harley (*31*) used sprays of tar oil distillate (TOD) and dinitro-ortho-cyclohexyphenol in oil (DNO) with two objects in view: (1) To defruit the trees as a possible means of lowering the codling moth population; and (2) to determine the possibility of reducing the set of biennial-bearing trees sufficiently during the heavy-bloom year to cause fruit-bud formation for the year following. The reduction in set due to treatment was found to vary mainly with the variety, the stage of development at which the spray was applied, and the type of spray or dosage. The data presented from experiments conducted in the States of Washington and West Vir-

ginia show that one application of either of these materials failed to prevent completely fruit set on York Imperial, Golden Delicious, Jonathan, and Yellow Newtown. Almost complete defruiting was obtained on Winesap, Delicious, Grimes Golden, and Gano; Stayman was intermediate.

Magness and Batjer (*30*) reported later that all the trees sprayed in these initial experiments on which the set of fruit was reduced to not more than 1 fruit per 10 blossom clusters on heavily blooming trees formed fruit buds and set good crops the year following treatment. During a second season's work substantially the same results were obtained on York Imperial, Stayman, and Gano. The data indicated that TOD at 0.8 percent concentration, thoroughly applied, was sufficient to prevent the set of a large proportion of the bloom of all varieties investigated, with the possible exception of Yellow Transparent. DNO, an insecticide preparation, at one-half dormant strength (1 percent) appeared to be slightly more effective than TOD at 0.8 percent in preventing set. The delayed cluster bud or early pink stage was found to be the most satisfactory stage for reducing fruit set. There were indications that later sprays of these materials might result in sufficient injury to prevent fruit-bud formation. These treatments killed all young foliage as well as blossom buds that were effectively hit. All of the blossoms and leaves were killed on many spurs and some of the weaker spurs failed to make any further growth, giving the immediate appearance of very serious injury. In most cases, however, the leaf bud in flower clusters was not injured, and as a result of a reduced fruit set and conservation of reserve foods greater foliage growth was produced by sprayed trees than by unsprayed trees in advance of the period of fruit-bud formation.

Childs and Brown (*7*) used TOD sprays on Yellow Newtown in Oregon, employing a method termed "spot spraying." The applications were made when approximately 10 percent of the bloom was open. Since the Yellow Newtown is a distinct biennial bearer, the idea of spot spraying was to reduce fruit set sufficiently on a certain part of the bearing area so that in succeeding years each tree would produce some bloom each season. The data indicate that this was accomplished. Since annual hand thinning was still required for good commercial size and quality on that part of the tree bearing fruit, this approach would not seem to materially affect the total amount of hand thinning over a period of years. However, the changed tree performance would permit a much better distribution of the required man-hours for thinning from year to year and conceivably result in a better net return to the grower. Following the work of Childs and Brown the tar oil distillate spray for reducing fruit set probably reached its greatest commercial use on the Yellow Newtown variety in the Hood River Valley of Oregon. Because of its severe caustic properties it is not adapted for use as an annual thinning treatment.

Gardner (*13*) reported that sprays of an oil-wax emulsion at 1 and 5 percent concentrations applied on mature Duchess trees when in full bloom reduced the set of fruit. The results from the two concentrations were almost identical. The reduction in set was not drastic but sufficient to reduce substantially the amount of hand thinning required. As this oil-wax emulsion appeared nontoxic to all vege-

tative tissues, it was considered promising as a thinning agent. Conceivably, such a treatment, when properly timed, might reduce set by coating over the stigmatic surfaces and thus prevent either further pollination or pollen germination. In a later paper Stebbins, Neal, and Gardner (*41*) presented results on the use of three oil-wax formulations for thinning Wealthy, McIntosh, and Duchess apples. In this experiment the treatments had no significant effect on fruit set, and the authors concluded that these oil-wax emulsions used alone at a concentration of 1 gallon per 100 gallons of spray did not result in sufficient thinning to warrant their use for this purpose.

Kenworthy (*26*) observed a thinning effect on Delicious following the use of postbloom sprays of a mixture of polyethylene polysulfide (p. e. p. s.) and zinc dimethyl dithiocarbamate-cyclohexylamine complex (Zimate). This mixture was being tested for scab control. No reduction in fruit set occurred when these materials were used separately. The following year this spray mixture was used on Stayman 11 days after full bloom, for the purpose of thinning. The polyethylene polysulfide was used at the rate of 2 pounds per 100 gallons in all sprays and the Zimate at one-eighth and one-fourth pounds per 100 gallons. Prior to the June drop the checks showed 77.6 percent set, the one-eighth pound of the Zimate 47.3 percent set, and the one-fourth pound dosage 27.2 percent set. At harvesttime the trees receiving the one-fourth pound of Zimate bore 16.6 fruits per 100 blossoming spurs, while the difference in set between the one-eighth pound application and checks had disappeared, being 35.8 and 35.4 fruits per 100 blossoming spurs, respectively. In addition to showing promise as a postbloom thinner for apples, Kenworthy also reported that preliminary observations over a 2-year period indicated that this spray may reduce fruit set on peaches when applied near the shuckfall stage.

Flory and Moore (*12*) used the p. e. p. s.—Zimate spray mixture for the thinning of York Imperial. The concentration was 2 pounds of polyethylene polysulfide plus 1 pound of Zimate per 100 gallons. The treatments employed were (1) one spray 10 days after full bloom, (2) two sprays 10 and 20 days following full bloom, and (3) 3 sprays 10, 20, and 30 days following full bloom. The number of fruits set per 100 blossoming spurs were as follows: Checks, 31; 1 spray, 14; 2 sprays, 20; and 3 sprays, 12. In a test on Stayman similar results were observed, but less thinning occurred on this variety than from comparable treatments on York Imperial.

A spray containing 2 pounds of polyethylene polysulfide and one-fourth pound of Zimate per 100 gallons as used at the calyx stage on Rome Beauty apples and at the shuck stage on Elberta peaches by Southwick, Hoffman, and Edgerton (*39*). The treatment failed to reduce appreciably the set of either of these fruits. However, in the Rome Beauty experiment where conditions were not favorable for chemical thinning, both a dinitro bloom spray and a calyx spray of the sodium salt of naphthaleneacetic acid seriously overthinned the crop.

Experiments in central Washington performed by Batjer and Thompson (*5*), involving the use of the polyethylene polysulfide and Zimate spray, failed to result in fruit-set reduction on Winesap and

TABLE 7.—*Effect of Elgetol thinning sprays on fruit size and yield of several apple varieties grown in different fruit areas*

Variety	Year	Treatment	Fruits per 100 blossoming spurs	Fruits per bushel [1]	Yield per tree [1]	State and literature reference
			Number	*Number*	*Bushels*	
Wealthy	1941	Check	47	182	15	New York (*20*).
		Elgetol	27	124	15	
Golden Delicious	1944	Check	--------	200	16	New York (*25*).
		Elgetol	--------	150	17	
Do	1944	Check	54	220	24	West Virginia (*4*).
		Elgetol	34	170	20	
York Imperial	1944	Check	56	198	29	Do.
		Elgetol	32	144	28	
Delicious	1946	Check	60	134	46	Idaho (*42*).
		Elgetol	37	111	45	
Rome Beauty	1946	Check	100	113	49	Do.
		Elgetol	48	81	47	
Winesap	1945	Check	73	121	29	Washington (*5*).
		Elgetol	49	110	28	
Delicious	1947	Check	66	86	35	Do.
		Elgetol	50	79	36	

[1] In the Washington and Idaho experiments a standard apple box (containing 33 to 35 pounds of fruit) was used as the unit of measure.

Golden Delicious. In the same experiments Elgetol was used, resulting in appreciable thinning on both varieties.

The limited amount of work that has been done with the polyethylene polysulfide and zinc dimethyl dithiocarbamate-cyclohexylamine complex indicates that the results may be considerably more variable than those obtained with other thinning agents.

EFFECTS OBTAINED BY THINNING APPLES WITH CHEMICAL SPRAYS

FRUIT SIZE AND YIELD

In practically all cases where chemical thinning experiments have been conducted increased fruit size has proved an outstanding result. Where the sprays have resulted in appreciable set reduction, size difference between treated and check trees become apparent within a few weeks following bloom. Typical data relating to the effect of Elgetol sprays on fruit size in several areas are presented in table 7. When the chemically thinned trees are compared with check trees with no hand thinning (table 7—New York, West Virginia, and Idaho), differences are particularly outstanding. Much smaller differences in fruit size were obtained in the Washington experiments where the check trees were hand-thinned (35 to 50 days following full bloom) and the chemically thinned trees were supplemented with hand thinning if the crop appeared excessive. Such a practice doubtlessly accounts for the smaller differences that might be expected on the basis of fruit-set reduction. In other Washington experiments

where thinning operations were similarly performed, chemical thinning (supplemented with hand thinning if necessary) has invariably resulted in small but consistent increases in fruit size over conventional hand thinning. During the past 6 years with 65 separate experiments involving 2,600 trees the check (hand-thinned) trees averaged 15 more fruits per box than chemically thinned trees.

Results on fruit size have been variable in experiments where naphthaleneacetic acid has been compared with the dinitro chemicals. In New York (*39*) with several varieties of apples about the same benefit in increased fruit size was obtained when the two types of thinning agents were compared. In Washington naphthaleneacetic acid generally has not produced so much larger fruits as might be expected on the basis of the amount of thinning accomplished. This probably is due to the fact that fruit generally attains considerable size before dropping when naphthaleneacetic acid is used. Experimental results in Washington indicate that unless the use of naphthaleneacetic acid results in more thinning than is desirable there is little or no benefit in fruit size as compared with hand-thinned check trees.

It is evident from the data presented in table 7 that fruit yields were about the same when trees sprayed with Elgetol were compared with either unthinned or hand-thinned check trees. As will be shown later, chemical thinning sprays tend to increase yields over a period of 2 years or more through their effect in altering the biennial bearing habit of apple trees. It is of course obvious that if thinning sprays are applied under conditions resulting in fruit-set reduction below the limit of a capacity crop fruit yields will be adversely affected.

Biennial Bearing

Heavy and light crop years with apples usually result from an excess of fruit setting on the tree during the "on year." When the quantity of fruit on the tree in relation to the amount of foliage is excessive, fruit-bud formation is either reduced or may entirely fail

Table 8.—*The effect of Elgetol thinning sprays on yield and bearing habit of apple trees over a period of several years in certain areas*

Variety	Treatment	Trees per treatment	First year	Second year	Third year	Fourth year	Average total yield per tree	State and literature reference
		Number	*Boxes*	*Boxes*	*Boxes*	*Boxes*	*Boxes*	
Golden Delicious.	Check [1]	10	35	25	47	6	113	Washington.
	Elgetol	10	37	36	36	30	139	
Rome Beauty.	Check [1]	10	41	9	------	------	50	Idaho (*42*).
	Elgetol	10	52	23	------	------	75	
Wealthy	Check [2]	10	20	0	19	0	39	New York (*21*).[3]
	Elgetol	10	17	12	15	21	65	

[1] Hand-thinned (35 to 50 days following bloom) if needed.
[2] Not hand-thinned.
[3] In the New York experiment a bushel was used as the unit of measure.

to take place. Thus, in the season following the "on year" there is a reduced bloom resulting in a short crop. Under these conditions excessive fruit-bud formation takes place. Once such a fruiting habit is established alternate years of heavy bloom and heavy crop are followed by relatively light bloom and light crop. Under many conditions practically all varieties show a tendency toward alternate bearing, although this characteristic is much more pronounced with certain varieties than others. Even with varieties considered regular in their bearing habits, very early thinning is often necessary if the tendency toward alternation is to be kept at a minimum. With biennial varieties, under most conditions it is not feasible to hand-thin early enough to avoid pronounced alternation.

Perhaps one of the most outstanding features of chemical thinning sprays is their effect on alternate bearing. These sprays, particularly the dinitro chemicals, reduce fruit set in the blossom stage, thus eliminating many fruits at the earliest possible time. Thinning in the bloom stage avoids wastage of carbohydrates, thereby enabling the tree to form a greater number of fruit buds for next year's crop. The data in table 8 illustrate this point. Increase in yield as a result of chemical thinning varied from 23 to 66 percent. The check trees of the Wealthy variety without benefit of hand thinning were completely biennial, as may be noted from the absence of crop the second and fourth year of the experiment. With both Golden Delicious and Wealthy the chemically thinned trees produced sufficient bloom each year to necessitate chemical thinning.

Yield records of commercial orchards using chemical thinning sprays over a period of 2 or more years often show an increase of 15 to 20 percent over hand-thinned or nonthinned fruits. In orchards or blocks of trees that were decidedly biennial, chemical thinning frequently resulted in a more substantial increase.

Reduction in Thinning Cost

In some fruit areas chemical thinning has been used with the objective of eliminating the need for hand thinning entirely. How successfully this can be accomplished will depend upon a variety of factors that have been discussed previously. In many instances use of chemical thinning sprays do not result in sufficient reduction in fruit set. In central Washington heavy thinning is required for satisfactory annual crops of good size and quality. In this section chemical thinning generally results in accomplishing one-half to three-fourths the thinning necessary. It is common for fruit growers in certain years to do all their thinning with sprays.

In some instances the amount of fruit on sprayed trees following the June drop may appear as great as on similar trees not sprayed. In such cases the unsprayed trees seem to have a much greater initial fruit set but may "shed down" to a point following the June drop where both sprayed and unsprayed trees have about the same ultimate set. In several experiments (*5*) fruit set following the June drop was approximately the same on both sprayed and unsprayed trees; nevertheless the amount of bloom the following years was appreciably greater on the trees that had received the dinitro spray. Reduction

TABLE 9.—*Effectiveness of thinning sprays on several peach varieties, 1942-49*

Variety	Age of trees	Year	Treatment	Concentration per 100 gallons	Blossoms open when sprayed	Blossoms setting fruit	Yield per tree	Fruits per bushel	State and literature reference
	Years			*Quantity*	*Percent*	*Percent*	*Bushels*	*Number*	
Golden Jubilee.	10	1942	Check [1]	0		19	10.0	189	Maryland (*3*).
			do [2]	0		16	6.0	166	
			Elgetol	.8 pt	95	7	3.8	123	
			do	1.6 pt	95	6	4.4	124	
			do	3.2 pt	95	2	.9	107	
Elberta	10	1942	Check [1]	0		28	11.3	173	Do.
			do [2]	0		28	6.1	125	
			Elgetol	1.6 pt	70	7	2.7	98	
			do	3.2 pt	70	2	1.3	77	
			do	.8 pt	95	21	5.8	130	
			do	1.6 pt	95	13	6.5	100	
			do	3.2 pt	95	4	2.7	93	
Do	7	1944	Check [1]	0		12	4.9		Missouri (*32*).
			Elgetol	.5 pt	100	11	4.3		
			do	1.0 pt	100	11	4.3		
			do	2.0 pt	100	6	3.8		
			do	4.0 pt	100	3	4.0		
Halehaven.	8	1944	Check [1]	0		20			New York (*23*).
			Elgetol	.5 pt	95	19			
			do	1.0 pt	95	9			
			do	1.5 pt	95	4			
Rochester.	18	1944	Check [1]	0		23			Do.
			Elgetol	1.5 pt	95	5			
Elberta	8	1944	Check [1]	0		22			Do.
			Elgetol	.5 pt	95	11			
			do	1.0 pt	95	6			
			do	1.5 pt	95	4			
Do	4	1944	Check [1]	0		21			Do.
			Elgetol	.5 pt	95	11			
			do	1.0 pt	95	5			
			do	1.5 pt	95	4			
Do		1946	Check [1]	0		46	3.1	166	New York (*38*).
			Elgetol	1.0 pt	95	20	2.8	140	
			do	1.5 pt	95	13	1.6	120	
			DN No. 1.	.5 lb	95	16	2.3	124	
			DN No. 2.	.5 lb	95	18	2.6	128	
			DN No. 111.	1.0 lb	95	17	3.1	124	
Do		1947	Check [1]	0		35	3.4	300	New York (*39*).
			Elgetol	1.0 pt	95	13	3.0	205	
			DN No. 1.	.5 lb	95	17	3.2	199	
			DN No. 289.	.5 pt	95	10	2.2	181	
Do	8	1948	Check [2]	0		69	11.0	150	Washington.
			Elgetol	1.0 pt	80	39	11.5	110	
			do	2.0 pt	80	26	9.5	97	
			DN No. 1.	.5 lb	80	44	11.0	127	
			do	1.0 lb	80	29	10.0	113	

TABLE 9.—*Effectiveness of thinning sprays on several peach varieties, 1942-49*—Continued

Variety	Age of trees	Year	Treatment	Concentration per 100 gallons	Blossoms open when sprayed	Blossoms setting fruit	Yield per tree	Fruits per bushel	State and literature reference
	Years			*Quantity*	*Percent*	*Percent*	*Bushels*	*Number*	
Halehaven.	6	1948	Check [2]	0		63			Washington.
			Elgetol	1.5 pt	85	28			
			do	1.5 pt	100	47			
Do		1949	Check [1]	0		64			New York.
			DN No. 1.	.7 lb	95	24			
			DN No. 289.	.7 pt	95	16			
Raritan Rose.		1949	Check [1]	0		36			Do.
			DN No. 1.	.7 lb	95	15			
			DN No. 289.	.7 pt	95	11			
Elberta	9	1949	Check [2]	0		54			Washington.
			Elgetol	1.0 pt	75	48			
			do	2.0 pt	75	45			
			do	1.0 pt	100	58			
			do	2.0 pt	100	55			
			do	2.0 pt	(3)	50			
Halehaven.	7	1949	Check [2]	0		33			Do.
			Elgetol	1.0 pt	85	35			
			do	2.0 pt	85	33			

[1] Not thinned.
[2] Hand-thinned after fruit-set counts were obtained.
[3] Treatment applied at petal-fall stage, 3 days following full bloom.

in the initial set by bloom spraying seems to have enabled the trees to differentiate more fruit buds for the following year.

EFFECTIVENESS OF CHEMICAL THINNING SPRAYS ON PEACHES

Mature peach trees of good vigor generally present a thinning problem in orchards where fruit buds have not been damaged by winter temperatures and in areas where injury from spring frost is of little concern. Most of the commercially important peach varieties are self-fruitful, and with favorable bloom weather many varieties set excessively heavy crops that necessitate thinning in order to attain satisfactory size and quality.

DINITRO THINNING SPRAYS

The results with dinitro bloom sprays for thinning peaches have, in some cases, been rather variable. With vigorous mature trees, the failures have been due more often to insufficient thinning or no thinning rather than to overthinning. Overthinning has occasionally resulted on young trees or on mature trees that have failed to set heavily because of certain environmental conditions.

Typical results obtained in tests using dinitro sprays for thinning peaches in various fruit sections are summarized in table 9. In considering these data, it should be remembered that fruit-set records are often confusing and fail to present a complete picture, because the number of fruit buds borne per unit of shoot growth vary greatly with different varieties as well as with the amount and type of growth made by the tree the previous season. Yield records, where they are given, may also be somewhat misleading because of variations in tree size and vigor. Also, the total yield per tree in many instances is not an indication of the monetary value of the crop. In many areas and seasons the price differential between large and small sizes may be as much as 50 to 100 percent.

It may be seen from the data presented in table 9 that the same range of concentration suggested for apples is effective in reducing the set of peaches. While in most cases spray applications of 1 pint of Elgetol per 100 gallons reduced fruit set, concentrations of 1½ and 2 pints were generally more effective. As with apples, the data are too variable to permit definite recommendations as to concentration for any particular variety or environmental conditions.

The flower buds of peaches develop earlier and more rapidly than do the leaf buds. At full bloom there is very little exposed leaf surface on peach trees, which may tend to minimize any indirect or "shock" effect of a dinitro spray in reducing fruit set. Furthermore, the stems of peach flowers are short and thick and for this reason may be more protected from the caustic action of the spray than the long, slender, highly exposed stems of plum, pear, and apple flowers.

Bloom sprays for thinning peaches have usually given the most satisfactory results when a rather constant and uninterrupted opening of blossoms occurs over a 3- to 5-day period. For greatest effectiveness generally the sprays should be applied when about 75 to 95 percent of the flowers are open. If the spray application is delayed until all flowers are open the amount of thinning may be disappointing.

More exact timing seems to be necessary with peaches than is the case with apples. There are, however, a few reports of thinning resulting from sprays applied after full bloom. Havis (*17*), in a well-planned experiment with the Elberta variety, obtained more thinning with a concentration of 1½ pints of Elgetol per 100 gallons 4 days after full bloom than with the same concentration at the full bloom stage. In contrast, Murneek and Hibbard (*33*) reported insufficient thinning when Elgetol sprays at concentrations of 1 pint, 1 quart, and 2 quarts per 100 gallons were applied to vigorous Elberta trees 3 to 4 days after full bloom. The strongest concentration resulted in some thinning, but the trees still carried an overload of fruit.

Under any given set of weather conditions different varieties may vary considerably in the time required for them to reach the proper stage of bloom development for the application of dinitro sprays. Where several varieties are grown in the same orchard it will seldom be possible to spray them all on the same day with equally satisfactory results. Even in large blocks of a single variety, variations in soil and exposure may cause enough difference in bloom development

so that all trees cannot be sprayed with the same results on one particular day.

The more southern peach areas often experience winters with insufficient chilling to break completely the rest period of the trees. This results in a relatively long period of bloom development. Under such conditions dinitro bloom sprays would obviously be less adapted for thinning than in areas where delayed dormancy is no problem.

According to the data presented in table 9 the various forms of dinitro material when used at the same concentration of the active ingredient have resulted in about the same amount of thinning. An exception to this is DN 289 (23 percent triethanolamine salt of dinitro-ortho-sec-butylphenol). In a New York test (table 9) this material proved about as effective as other dinitro chemicals when used at about one-half the concentration of toxicant.

Under some conditions dinitro sprays may overthin young peach trees. The fruit-set records for the 4- and 8-year-old Elberta trees (*23* and table 9) chemically thinned in 1944 in New York illustrates this point. The wood growth of the 4-year-old trees was very vigorous and had fewer fruit buds per foot of growth than the 8-year-old trees. As a result, the normal set of 21 percent on the young trees constituted a satisfactory crop and all treatments overthinned. With the much heavier bloom on the older trees a reduction in set from 22 to 6 percent was required for adequate size.

As is true with apples, success with chemical thinning sprays on peaches is based on the assumption that fruit set will be in excess of that required for a commercial crop of satisfactory size and quality. Aside from possible frost hazards, peach trees in normal vigor generally set heavily, provided favorable weather occurs during the blossoming period. While the danger of overthinning most peach varieties with dinitro sprays is not great, nevertheless, for greatest safety dinitro sprays should be used on a trial basis until properly evaluated for a particular set of environmental conditions.

Peaches form their fruit buds laterally on the current season's shoots and are not so subject to biennial blossoming as is the case with the apple, which forms its fruit buds terminally on both spurs and shoots. However, the yield of peach trees may vary considerably from year to year, depending on the amount and type of shoot growth produced the previous season. In addition to the improvement in size and quality of the current crop, one of the most striking benefits from bloom thinning of peaches is the increased shoot growth and bud formation for the next crop (*23*). This is especially noticeable in nonirrigated regions when a heavy fruit set is accompanied by a dry growing season such as was experienced in an Elberta experiment in New York during the 1944 growing season.

In this experiment the dinitro-thinned trees yielded essentially the same quantity of fruit as the hand-thinned check trees. At harvest-time the fruits from hand-thinned trees averaged 1¾ to 2 inches in diameter while those from the chemically thinned trees attained a size of 2¼ to 2⅜ inches. The average length of terminal growths was 10.6 inches for hand-thinned trees and 15.6 inches for chemically thinned trees. Counts of fruit buds on 50 terminals from each treatment showed that the hand-thinned trees had formed an average of

4.5 buds per foot of growth, while those chemically thinned at bloom time had formed 12.1 buds per foot of growth. Although the average tree yield of the dinitro-thinned trees was less in 1945 than in 1944, the trees that were hand-thinned in 1944 yielded only one-third as much fruit in 1945 as those trees that were chemically thinned in 1944 and again in 1945.

Edgerton (*10*) has shown that the fruit buds on dormant peach trees chemically thinned the previous spring show more resistance to winterkilling than buds on trees not thinned or hand-trimmed during

TABLE 10.—*A comparison of dinitro sprays at blooming time and of growth-regulating thinning sprays 1 month later for reducing the set of peaches, 1950*

Variety	Treatment	Concentration per 100 gallons	Date applied	Blossoms setting fruit		Average weight per fruit July 10
				June 8	July 10	
		Quantity		*Percent*	*Percent*	*Grams*
Golden Jubilee	Check	0		69	23	27
	DN No. 289	.5 pt	May 6		19	30
	NAA [1]	15 p. p. m.	June 8	69	14	31
	do	20 p. p. m.	do	70	9	34
	do	30 p. p. m.	do	75	2	
Halehaven	Check	0		69	45	27
	DN No. 1	.5 lb	May 6		32	34
	NAA [1]	30 p. p. m.	June 8	74	20	35
Raritan Rose	Check	0		55	30	25
	DN No. 289	.5 pt	May 7		20	29
	NAA [1]	20 p. p. m.	June 8	57	10	33
	do	30 p. p. m.	do	50	7	38

[1] Naphthaleneacetic acid.

the summer. This increase in hardiness is no doubt due to the greater food reserves resulting from thinning at bloom time.

NAPHTHALENEACETIC ACID THINNING SPRAYS

Attempts to thin peaches with naphthaleneacetic acid sprays at the bloom or early postbloom period have given negative results. Southwick, Edgerton, and Hoffman (*38*) reported that concentrations of 10 to 40 p. p. m. of the sodium salt of naphthaleneacetic acid or the methyl ester of naphthaleneacetic acid applied at full bloom, petal fall, and 8 days after petal fall were of no value in reducing the set of the Valiant and Elberta varieties. Similar results were obtained by Murneek and Hibbard (*33*) for Elberta and several other varieties. Later Murneek [3] suggested that naphthaleneacetic acid sprays applied about 30 days after bloom offered promise for reducing the set of peaches.

Naphthaleneacetic acid treatments 1 month after bloom were included in several peach thinning tests in New York during the 1950

[3] Murneek, A. E., in correspondence to M. B. Hoffman, Cornell University, Ithaca, N. Y., May 18, 1949.

season. The results are given in table 10. The thinning obtained in these trials as compared to the lack of effect from bloom and early postbloom treatments mentioned above may be due to the greater leaf surface present when the later treatments were applied and hence greater absorption of the hormone. On June 8 when the naphthaleneacetic acid treatments were applied, the trees were in heavy foliage but the terminal buds had not formed and shoot growth was still active. At this time there was no indication of the beginning of the June drop.

The greater fruit set recorded for the check trees (table 10) from June 8 to July 10 represents the normal June drop for these varieties under the conditions of these tests. In all cases the hormone sprays resulted in a greater increase in drop, the magnitude of which was related to the concentration of the spray. On July 10, when the June drop was over and the final set counts were made, there was a noticeable difference in size of fruits on trees receiving the various treatments. This size difference is illustrated by the average weight of 100 fruits taken at random from each of the 8 trees in each treatment.

The data in table 10 also show that the amount of thinning resulting from any given concentration of naphthaleneacetic acid varied considerably with the variety. The most satisfactory results were obtained with 15 p. p. m. on Golden Jubilee, 20 p. p. m. on Raritan Rose, and 30 p. p. m. on Halehaven. It is conceivable that for any given variety the results may vary from one year to another, depending upon environmental conditions that influence tree growth and fruit set.

TABLE 11.—*Effectiveness of Elgetol thinning sprays on Bartlett pears at Wenatchee, Wash., 1947-48*

Orchard and treatment	Concentration per 100 gallons	Date sprayed	Bloom stage	Fruits per 100 blossoming spurs	Reduction in fruit set
Kane orchard:	*Pints*			*Number*	*Percent*
Check (1947)				100	
Elgetol	1	April 12, 1947	Full bloom	66	34
Do	2	do	do	65	35
Do	1	April 14, 1947	Early petal fall	68	32
Do	2	do	do	59	41
Muffley orchard:					
Check (1948)				7	
Elgetol	1	May 9, 1948	Full bloom	4	43
Do	2	do	do	2	71
Nichols orchard:					
Check (1948)				22	
Elgetol	1	May 4, 1948	Full bloom	17	23
Do	2	do	do	13	41
Peterson orchard:					
Check (1948)				42	
Elgetol	1	May 10, 1948	Full bloom	32	24
Do	2	do	do	29	31

These hormone sprays resulted in a "flagged" appearance of the foliage, which existed for about 3 to 4 weeks after the application. The trees, however, assumed a normal appearance well in advance of harvest, and the fruits matured with excellent size and quality. Exploratory tests with concentrations stronger than 30 p. p. m. resulted in considerable foliage yellowing and occasional killing of terminal shoot tips.

The thinning of peaches with naphthaleneacetic acid sprays has not been investigated sufficiently to justify any suggestions for commercial use. They were limited experiences recorded here merely indicate that the possibilities should be explored on an experimental scale.

EFFECTIVENESS OF CHEMICAL THINNING SPRAYS ON PEARS, APRICOTS, AND PLUMS

Pears

Under favorable conditions of weather and cross-pollination Bartlett pears in the Northwestern fruit districts tend to set too heavily for satisfactory size and quality. Limited experiments (table 11) with this variety indicate that it responds to dinitro thinning sprays in about the same manner as apples. It may be seen from the data presented in table 11 that most of the spray treatments appreciably reduced fruit set. Within the limits tested, the higher concentrations of Elgetol (1 quart per 100 gallons) reduced fruit set slightly but more consistently than th eweaker dosages. In the Kane orchard, sprays applied 2 days later than full bloom (early petal fall) resulted in about the same amount of thinning as the full-bloom sprays.

The 1948 results obtained in the Peterson, Nichols, and Muffley orchards are of interest in that they emphasize the importance of cross-pollination when considering chemical thinning, particularly in a year when fruit set is restricted by unfavorable weather. In the Peterson orchard the Bartlett was interplanted with the Anjou, which is considered a good pollinizer for Bartlett. In the Nichols and Muffley orchard, Anjou pollinizers were located a distance of 160 feet and 2,000 feet, respectively, from the experimental trees. In these three orchards it may be noted that fruit set on unsprayed trees closely paralleled the proximity of pollinizers.

As stated previously, successful use of thinning sprays is predicated on the assumption that fruit set will be in excess of the amount necessary for an adequate crop. When fruit set is limited by lack of cross-pollination and/or unfavorable weather, thinning sprays will frequently result in greater set reduction than desired. As far as is known the same factors relating to the use of dinitro sprays on apples are applicable in the case of pears. At the present time these sprays are in limited commercial use on Bartlett pears in central Washington under conditions where a heavy fruit set may be expected.

TABLE 12.—*Effectiveness of thinning sprays on apricots in central Washington, 1947-49*

Orchard and variety	Treatment	Concentration per 100 gallons	Date sprayed	Bloom stage	Fruits per 100 blossoming spurs	Reduction in fruit set
		Pints			*Number*	*Percent*
Atwood orchard: Wenatchee Moorpark	Check (1948)				44	
	Elgetol	1	April 16, 1948	Full bloom	36	27
	do	2	do	do	28	36
	do	1	April 18, 1948	Early petal fall	43	2
	do	2	do	do	44	0
Do	Check (1949)				15	
	Elgetol	1	April 13, 1949	Full bloom	14	7
	do	2	do	do	13	3
Clark orchard: Tilton	Check (1947)				27	
	Elgetol	1	March 19, 1947	Early petal fall	27	0
	do	2	do	do	22	18
Do	Check (1949)				26	
	Elgetol	1	April 7, 1949	Full bloom	22	15
	do	2	do	do	14	46
	do	1	April 9, 1949	Early petal fall	26	0
	do	2	do	do	24	8
Welch orchard: Wenatchee Moorpark	Check (1947)				15	
	Elgetol	2	March 29, 1947	Full bloom	1	93
	do	2	March 31, 1947	Early petal fall	5	67

Apricots and Plums

On apricots, results with chemical thinning experiments in central Washington have been highly variable. The data in table 12 illustrate this. Reduction in fruit set has varied from almost no thinning to serious overthinning (Welch orchard, 1947). In general, 10 to 15 percent of the blossoms setting fruit is all that is required for a satisfactory apricot crop. Under many conditions the Wenatchee Moorpark variety (the most important commercial variety in Washington) will set fruit in excess of this amount, a condition that necessitates thinning in order to obtain satisfactory size. However, in a number of instances this variety fails to set excessively for no apparent reason. In such cases, thinning sprays are likely to result in overthinning. Tilton and Royal varieties are generally more consistent in their fruit setting tendencies. Preliminary experiments both in Washington and California indicate considerable promise in thinning these varieties with dinitro sprays.

On prunes, Lilleland (*27*), working in California, has reported promising results with dinitro sprays in thinning various varieties. In a number of tests he found that a spray of 2 pints of Elgetol per 100 gallons was generally the more satisfactory concentration. Triethanolamine salt of dinitro-ortho-sec-butylphenol (DN No. 289) used at 1 pint per 100 gallons (about one-half the toxicant concentration of 2 pints of Elgetol) gave similar results. An outstanding feature of his experiments was a marked benefit in increased fruit size, but this was obtained at the expense of total yield. Lilleland's work indicates that dinitro sprays have definite promise as a means of thinning prunes. However, he cautions against the possible hazards of overthinning and suggests that prune growers in California, before using thinning sprays on an extensive scale, proceed on a trial basis.

Preliminary work with certain varieties of plums (Santa Rosa, Beauty, Kelsey, and Wickson) indicate that dinitro sprays have considerable promise for fruit thinning when applied during the blossoming period. More information is needed relative to concentration, timing, and varietal response before specific recommendations are possible. As far as is known, the effective concentration of dinitro chemicals and other factors affecting results are essentially the same as for other stone fruits.

Timing the spray application with reference to blossom development seems to be a more important factor in determining the amount of thinning on stone fruits than is the case with apples and pears. It has been previously pointed out that dinitro sprays applied to peaches are usually less effective when applications are made rather late in the bloom period as compared with sprays applied when about 90 percent of the flowers are open but prior to any appreciable petal fall. It may be noted from the data presented in table 12 that early petal fall sprays on apricots were also generally less effective than when the sprays were applied 2 days earlier (full-bloom stage). Lilleland (*27*), working with prunes, has emphasized also the importance of timing in relation to results obtained. He obtained the greatest amount of thinning by spraying when about 90 percent of the blossoms were

open. Less thinning was obtained if spray applications were made earlier or later than this stage. Similar results have been obtained with Beauty and Santa Rosa plums.

As compared with apples and pears, stone fruits have much less foliage development at the blossoming period and for this reason less indirect action of dinitro would be expected. It is quite possible, therefore, that with stone fruits most of the thinning is a result of the dinitro material functioning directly as a pollinicide. Thus, the timing of the thinning spray with reference to pollination and fertilization seems to be more critical than with apples in determining the amount of thinning obtained.

EFFECT OF THINNING SPRAYS ON POLLINATING INSECTS

Cross-pollination is essential in the production of many apple varieties and certain other deciduous fruits. Without adequate cross-pollination good yields of those fruits would be impossible. The honey bee is credited, by some authorities, with about 90 percent of the pollen transfer in orchards. Although this may vary somewhat from one area to another, it does emphasize the importance of the honey bee in fruit growing. Furthermore, it is the only valuable cross-pollinizing agent that can be managed by the orchardist. For these reasons it is necessary to avoid the use of any sprays or dusts that would prove harmful to honey bees while they are being used in the orchard during the bloom period. States where fruit growing is of commercial importance have laws to this effect for the protection of these valuable insects.

When dinitro bloom sprays were first suggested as a possibility for chemical thinning the question of the toxicity of these chemicals to honey bees was immediately raised. An investigation conducted on this question by Goble and Patton (*15*) showed conclusively that dinitro compounds were toxic to honey bees. Working under controlled conditions the median lethal dose or concentration at which 50 percent mortality occurred was established by feeding bees dosages of 0.004 ml. of a dinitro-sugar mixture of known concentration. It was calculated that a bee need only consume 0.0028 ml. to get a lethal dose of dinitro spray containing 1 ounce of the active ingredient per 100 gallons of water.

This does not mean that dinitro bloom sprays for thinning cause widespread destruction of bees. In fact, work and observations under orchard conditions indicate quite the contrary. Dyce (*9*) observed that when dinitro sprays were applied to trees, bees immediately stopped visiting the blossoms but gradually returned as the spray dried. Then the bees visited sprayed flowers of some varieties in greater numbers than unsprayed blossoms. It was suggested that this phenomenon may have been due to the presence of more nectar in the nectaries of blossoms burned by dinitro sprays than the nectaries of normal flowers, thus resulting in sprayed bloom becoming more attractive to bees.

Nectar from the honey stomach of bees visiting dinitro-sprayed blossoms was collected by Goble [4] and upon analysis found to be completely free of dinitro material. This would seem to indicate that the nectaries were protected from the spray, and there was little chance of damage to brood or young adult bees in the hive from nectar collected from sprayed orchards.

When building up food reserves in the hive, bees gather and store pollen on which such poisons as arsenates have settled. Arsenate contamination of stored food is known to be very destructive to the brood. In the orchard observations made by Dyce (*9*), no bees were found collecting pollen from dinitro-sprayed bloom. These sprays kill all pollen immediately upon contact, and green or unripe anthers shrivel and dry up before shedding pollen. Such pollen is apparently unattractive to bees or difficult for them to collect. Goble [4] induced caged bees to collect pollen from a small bouquet of dinitro-sprayed apple flowers placed in the enclosure after the spray dried. The pollen pellets were removed from the bees and analyzed. Only an insignificant trace of dinitro was found, about 0.002 p.p.m.

To make further observations on the colony under orchard conditions, Goble and Patton (*15*) placed two hives of bees in a block of trees that were to be thinned with a dinitro spray. The complete brood was mapped on cellophane prior to the spraying and again 4 days after the application. Careful comparison of these outlines showed that no damage was done in this instance.

Dyce (*9*) collected bees from blossoms that had recently received dinitro sprays, and their mortality was compared with bees collected from unsprayed dandelions and other floral sources. The collected bees were placed in wire cloth cages and fed sugar sirup. No significant difference in the death rate was recorded among the bees exposed and those not exposed to the dinitro-sprayed bloom.

Writing on the subject of "Bees and Pollination Problems," Webster, Teleford, and Menke (*43*) state, "While blossom-thinning sprays are used to an ever-increasing extent in the Pacific Northwest, there have been no reports of widespread losses to bees brought into orchards during fruit bloom."

Following several years of careful orchard observations by apiculturists in the State of New York during which no significant loss of bees could be attributed to dinitro thinning sprays, beekeepers and fruit growers mutually agreed to a modification of the existing New York State law to permit the use of dinitro sprays during the blossoming period. This new regulation, administered by the State Commissioner of Agriculture and Markets, became effective in April 1948.

While no loss of bees has so far been observed in colonies located in orchards where these thinning sprays have been used, laboratory tests indicate that it would be unsafe to assume that losses never occur. Conceivably, very dry weather during the bloom should result in the most favorable conditions for possible damage. Under such circumstances bees collect water during the early morning from

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[4] GOBLE, G. J. THE MODE OF TOXIC ACTION OF DINITRO COMPOUNDS ON THE HONEYBEE (APHIS MELLIFICA LINN.). 1945 [Thesis on file in the Everett Franklin Phillips Beekeeping Library, Cornell University, Ithaca, N. Y.]

dew on the orchard cover and throughout the day from puddles near filling tanks or in the ruts made by spray machinery. Arsenic contamination of such water sources from preblossom sprays has often proved very destructive to bees. The possibility of damage from dinitro residues in any available water should not be overlooked. During dry bloom seasons the considerate grower would fill in all depressions where water contaminated with any poisonous spray material might collect and then furnish the bees with a nearby supply of suitable water for their use.

SUMMARY AND CONCLUSIONS

Application of chemical thinning sprays to fruit trees in order to reduce excessive fruit set has received considerable study in recent years. These sprays are applied during or shortly following the bloom period for the purpose of partially or completely overcoming the necessity of hand thinning. While results of numerous investigators have varied widely and possible hazards are attendant with their use, nevertheless, chemical thinning has become a commercial practice in several of the major fruit-producing areas. The results of various investigations seem at present to warrant the following conclusions.

Of a wide variety of materials tested for the purpose of reducing fruit set, the dinitro chemicals and naphthaleneacetic acid (a growth-regulating substance) have proved generally the most satisfactory. No outstanding differences in effectiveness have resulted in experiments involving the use of various forms of dinitro chemicals. At the present time (1950) sodium dinitro cresylate and dinitro-ortho-cyclohexylphenol are used more extensively than the other forms of dinitro chemicals.

For best results with apples generally, dinitro sprays should be applied as near the full-bloom stage as possible. Under many conditions, however, spray applications as late as 1 to 3 days following full bloom have proved as effective, or only slightly less effective, than at the full-bloom stage. For greatest effectiveness with peaches and other stone fruits, dinitro sprays should be applied a day or two ahead of full bloom or when about 75 to 95 percent of the blossoms are open. Sprays applied at the full-bloom stage or later often result in considerably less thinning than if applied earlier. Exact timing is, therefore, more important with stone fruits than with apples.

Dinitro thinning sprays seem to reduce fruit set on apples by direct action as a pollinicide, and also may prevent many of the fertilized flowers from developing indirectly through temporary alteration of growth processes. The latter type of thinning is more pronounced when the sprays are applied to trees in low vigor and/or under conditions of cool, humid weather. With stone fruits there seems to be much less thinning of the indirect type, which in all probability accounts for the necessity of more exact timing and the frequent failures of obtaining any appreciable thinning if the sprays are delayed until most of the blossoms have been pollinated and fertilized.

The effective concentration of dinitro sprays is related to weather conditions, tree vigor, variety, and other factors. The concentration of Elgetol, most generally used, ranges from 1 pint to 1 quart per 100 gallons. In areas where DN No. 1 is used, effective concentration varies from ½ to 1 pound per 100 gallons. Quantities greater than the above may result in appreciable foliage injury in some fruit sections, particularly when applied during cool, humid weather.

Success with dinitro thinning sprays is predicated on the assumption that fruit set will be heavy. It therefore follows that these sprays can be used with greater safety on varieties that consistently set fruit considerably in excess of the amount required for a commercial crop. The partially self-fruitful varieties of apples are considered best adapted for chemical thinning because of their heavy fruit-setting characteristic. This group includes Yellow Transparent, Duchess, Early McIntosh, Wealthy, Jonathan, Golden Delicious, Baldwin, York Imperial, Rome Beauty, and Yellow Newtown. In the Northwest fruit sections self-unfruitful varieties (Winesap, Delicious, Stayman, and McIntosh) are safely and effectively thinned with dinitro sprays when weather conditions are favorable for fruit set and in orchards where there is adequate provisions for cross-pollination. In Midwest and East fruit sections self-unfruitful varieties are not generally considered adapted for chemical thinning with dinitro sprays.

Weather conditions existing during the bloom period are perhaps the most important factor in the success of dinitro thinning sprays. If the weather from the time of the first opening of blossoms until full bloom (a period of about 3 to 7 days) is characterized by cool, humid conditions, dinitro sprays are likely to thin much heavier than if the spray application is preceded by warm, dry weather. When adverse weather and restricted cross-pollination conditions prevail, dinitro thinning sprays are likely to result in a greater set reduction than desired. In such instances, a combination of both a light set and a greater than average killing power of the spray may result in serious overthinning. Failure to obtain sufficient thinning with dinitro sprays is often associated with weather and other conditions that are conducive to heavy fruit set.

Overthinning is less likely to occur when dinitro sprays are applied to trees in a normal to above normal state of vigor. Trees are more susceptible to the action of thinning sprays when suffering from the effects of imperfectly drained soil, various types of root trouble, winter injury, low nitrogen level, or any condition that may affect normal functioning of growth and fruit-setting processes.

In many instances the application of dinitro sprays does not result in sufficient reduction of fruit set. In sections where heavy thinning is required for satisfactory size and quality dinitro sprays should be more properly regarded as a supplement rather than a substitute for hand thinning.

Naphthaleneacetic acid or its sodium salt is an effective thinning agent for most varieties of apples, particularly under conditions prevailing in Midwest and East fruit sections. This material is applied as a postbloom spray, and its chief advantages over the dinitro spray are greater latitude in timing and in the opportunity

to determine the initial amount of fruit set before applying a thinning spray. The latter advantage is an important factor in areas that are subjected to spring frosts during the bloom period.

Naphthaleneacetic acid sprays may be applied any time from the petal-fall stage until 2 to 3 weeks after the calyx period. Applications made at the petal-fall and calyx stage are more desirable from the standpoint of obtaining benefits of early thinning, but the danger from foliage injury is largely avoided by delaying the application until 2 to 3 weeks after calyx.

The concentrations of naphthaleneacetic acid that have been found most appropriate for thinning apples range from 5 p. p. m. to 20 p. p. m. Results indicate (though there are numerous exceptions) that the later the spray is applied, within the limits stated above, the stronger should be the concentration. Irrespective of timing, the most desirable concentration will depend upon such factors as variety, tree vigor, and environmental conditions.

Varieties of apples considered best adapted for naphthaleneacetic acid thinning sprays with the least possibility of foliage injury include Jonathan, Wealthy, Golden Delicious, Grimes Golden, and Baldwin. These sprays have proved generally more erratic on such varieties as Delicious, Winesap, Early McIntosh, and Yellow Transparent.

The choice between naphthaleneacetic acid and the dinitro materials as a thinning agent for apples depends upon a number of factors, such as fruit section, variety, and numerous environmental conditions. In the Northwest the dinitro materials have proved more consistent and satisfactory than naphthaleneacetic acid, while in certain Midwest and East fruit areas (for certain varieties) the reverse has been true.

The use of naphthaleneacetic acid thinning sprays on stone fruits is still in the experimental stage. Spray applications during the blossoming period and shortly following have given negative results. Preliminary results with peaches indicate that if the sprays are delayed until approximately 1 month following bloom effective thinning may be obtained.

Outstanding benefits derived from chemical thinning of apples when successfully executed include a substantial saving in hand-thinning labor, greater fruit size, and a pronounced tendency toward correction of alternate bearing. In many instances production has increased 15 to 20 percent with the continued use of dinitro sprays. The dinitro materials are generally more effective than naphthaleneacetic acid in correcting biennial bearing and increasing fruit size, principally because of the immediate effect of this material on fruit-set reduction. Thinning effects from naphthaleneacetic acid sprays may not take place until 3 to 6 weeks following bloom, depending upon the time of spray application.

It should be emphasized that chemical thinning sprays in their present form are not foolproof and for this reason cannot be generally recommended. Because of various reasons outlined in this circular some orchards and varieties are not adapted to the use of thinning sprays. However, there are many conditions under which these sprays can be safely and successfully used, provided the fruit

grower has a thorough knowledge of the many factors involved. It is suggested that the fruit grower without previous experience proceed on a trial basis until he determines how his trees respond. Within the same orchard results may vary widely from year to year, principally because of differences in weather conditions as they affect fruit-setting processes.

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