HILGARDIA

A Journal of Agricultural Science Published by the California Agricultural Experiment Station

VOLUME 21 NOVEMBER, 1951 NUMBER 7

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From 1946 to 1950, field experiments were conducted to study the effects of 2,4-D and other plant growth regulators on navel oranges, with respect to fruit-drop (both young and mature fruits), yield, fruit size and quality, and susceptibility to water spot.

In 1947, a progress report was prepared for growers. This included some of the results obtained by use of dilute 2,4-D sprays to reduce drop of mature, or nearly mature fruits.

The present paper summarizes the 1947 findings and reports results obtained since that time. The earlier experiments were mainly concerned with effects of 2,4-D applied to trees bearing mature fruits, and the later experiments to those bearing young fruits. Generally, the 2,4-D was added to a mixture containing other spray chemicals. In nearly all cases, satisfactory control of fruit-drop was reported, and there were no reports of reduced yield, lower fruit quality, or tree injury when instructions were followed. When a severe drop of mature navel oranges is anticipated or in progress, spraying with 2,4-D is now becoming standard practice.

H I L G A R D I A

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EFFECTS OF 2,4-D AND RELATED SUBSTANCES ON FRUIT-DROP, YIELD, SIZE, AND QUALITY OF WASHINGTON NAVEL ORANGES[1,2]

W. S. STEWART,[3] L. J. KLOTZ,[4] and H. Z. HIELD[5]

INTRODUCTION

CALIFORNIA WASHINGTON NAVEL orange trees flower in the spring, and their fruit matures in the winter. In the San Joaquin Valley, the fruit may be harvested as early as November 15, and in southern California, as late as May 15. In the late spring or early summer, there is usually an excessive shedding of young fruits (June drop) which is more severe with Washington Navel oranges than with other citrus fruits. Toward the end of the harvest season, in southern California especially, the mature fruit tends to drop from the tree (preharvest drop). Sometimes it fails to drop but develops "fruit-stem dieback." Under this condition, it loses water, shrivels, and has little commercial value. Furthermore, the branch may die back for a few inches to several feet from the fruit, thus reducing the amount of potential fruit-bearing stems for the following year.

Another malady which affects mature navel oranges is "water spot." This is a condition wherein the rind absorbs large amounts of water in localized areas during periods of prolonged rain or dampness. If the affected areas do not dry rapidly, they are invaded by blue and green molds. Susceptibility of fruit to water spot increases with increasing maturity. Fruit from trees sprayed with oil-water emulsions for pest control is more susceptible to water spot than is that from nonsprayed trees (Ebeling, Klotz, and Parker, 1938).[6]

In 1946, it was found that 2,4-D foliage sprays applied to Washington Navel orange trees in June could induce modifications in the fruit growth (Stewart and Klotz, 1947). It was also observed that sprays of from 25 to 225 p.p.m. 2,4-D induced the development of rudimentary seeds, and that

[1] Received for publication August 29, 1950.

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[6] See "Literature Cited" for citations, referred to in the text by author and date.

TABLE 1

EFFECT OF DRENCHING WATER SPRAYS OF 2,4-D ON MATURE FRUIT-DROP* FROM WASHINGTON NAVEL ORANGE TREES

Location of experiment	Spray date	Fruit-drop to:	Number of trees per treatment	Fruit-drop per tree		Concentration of 2,4-D	Form of 2,4-D	Reduction in fruit-drop
				Non-sprayed (control)	Sprayed with 2,4-D			
						p.p.m.		*per cent*
1947 harvest:								
Rivera	10/15/46	1/30/47	8	138	111†	5	diethanolamine salt	19.9
	10/15/46	1/30/47	8	138	38†	25	diethanolamine salt	72.4
Highgrove	1/10/47	4/10/47	13	85	28	25	diethanolamine salt	67.1
Camulos	2/13/47	4/14/47	40	152	6	25	diethanolamine salt	96.1
1948 harvest:								
Camulos	10/22/47	4/15/48	12	80	27	8	triethanolamine salt	66.7
	2/13/48	4/15/48	12	42	14	5	triethanolamine salt	66.3
Azusa	12/11/47	4/2/48	7	120	51†	8	diethanolamine salt	57.3
	12/11/47	4/2/48	7	120	40†	10	diethanolamine salt	66.7
	12/11/47	4/2/48	7	120	44†	20	diethanolamine salt	63.3
Pomona	12/15/47	4/19/48	10	272	99	16	triethanolamine salt	63.8
Riverside	2/18/48	4/19/48	15	48	23	6	sodium salt	52.3
Corona	1/27/48	4/22/48	5	71	27	4	triethanolamine salt	62.7
	1/27/48	4/22/48	5	71	36	8	triethanolamine salt	49.3
	2/21/48	4/22/48	9	101	60	8	ammonium salt	40.4
	3/22/48	4/16/48	4	17	10‡	10	triethanolamine salt	37.6
	3/22/48	4/16/48	5	27	9	10	triethanolamine salt	66.4
Arlington Heights	1/15/48	4/20/48	13	43	27	8	ammonium salt	36.7
	2/2/48	5/4/48	8	25	5	8	.....	79.3
	2/13/48	4/6/48	6	16	12	6	.....	20.7
Moreno	2/2/48	5/4/48	8	143	73	8	triethanolamine salt	49.0
Highgrove	2/17/48	4/6/48	8	27	17	5	diethanolamine salt	35.6
	3/26/48	4/30/48	10	34	13†	10	triethanolamine salt	62.8
	3/26/48	4/30/48	10	34	9†	20	triethanolamine salt	74.4
San Dimas	4/2/48	5/6/48	9	418	251	6	triethanolamine salt	39.9

* Fruit-drop counted from date of spraying.
† Difference from nonsprayed significant at 1 per cent.
‡ Not significant. No indication of significance means no analysis of variance was made.

some of the fruits on trees sprayed with 75 or 225 p.p.m. 2,4-D grew excessively large in size and had a thick rind and protruding navel, while others grew somewhat cylindrical in shape. Some results obtained by using more dilute 2,4-D sprays to reduce drop of mature, or nearly mature, fruits were presented in 1947 as a progress report for growers (Stewart, Klotz, and Hield, 1947). Results obtained since that time, on the effects of 2,4-D applied to trees bearing mature fruits and to trees bearing young fruits, are presented in this paper, along with a summary of the 1947 results.

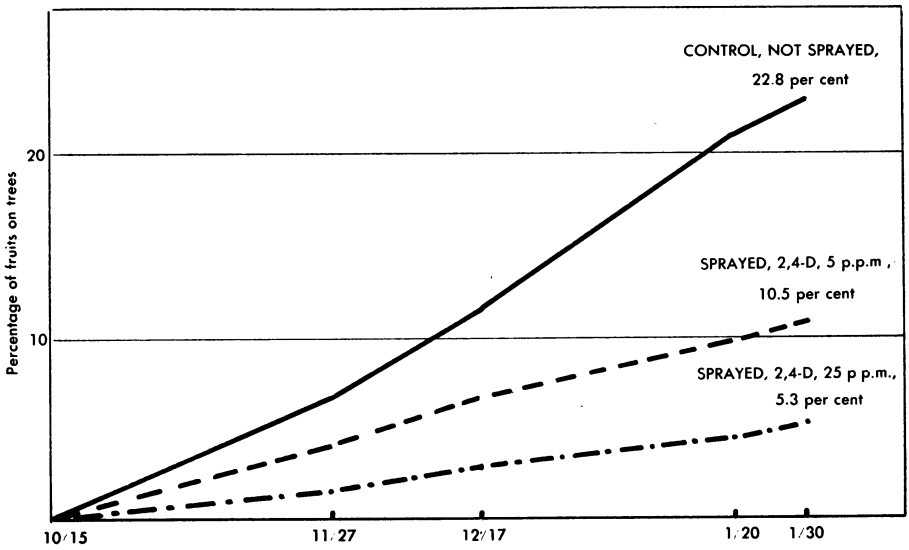

Fig. 1. Navel orange fruit-drop, as percentage of fruits on tree, from trees sprayed with 5 or 25 p.p.m. 2,4-D water solutions. Spray applied October 15, 1946. Fruit harvested January 30, 1947. Data average 8 trees per treatment. Plot in Rivera district.

METHODS

These studies were based on field experiments. Unless noted otherwise, standard spray equipment and 2,4-D as formulated for weed killing were used. Fruit-drop counts were made by clearing away dropped fruits immediately after spraying and making subsequent periodic counts of fruit-drop. Fruit yield was determined by obtaining the field box production per tree at the time of harvest. Partially filled boxes were estimated to the nearest tenth of a box or the fruit was counted. In many experiments, estimates were made of the number of fruits harvested per tree on the basis of the count of fruits per box. The amount of dropped fruit was added to this number, to give the total fruits on the tree at the beginning of the experiment. The dropped fruit was then expressed as a percentage of that total. If no drop had occurred before the spray was applied, this percentage would represent the crop loss by fruit-drop. Fruit size was measured in several ways: by number of fruits required to fill a box; or by the diameter of every tenth fruit in a box; or by obtaining the packing house size grading. The quality of fruit and juice was determined by standard laboratory pro-

cedures, supplemented in some cases by packing house quality gradings. Water spot susceptibility was determined either by a rain chamber technique (Ebeling and Klotz, 1936) or by grading the fruit in the packing house.

In most cases the experiments were designed to allow statistical analyses of the data for significance.

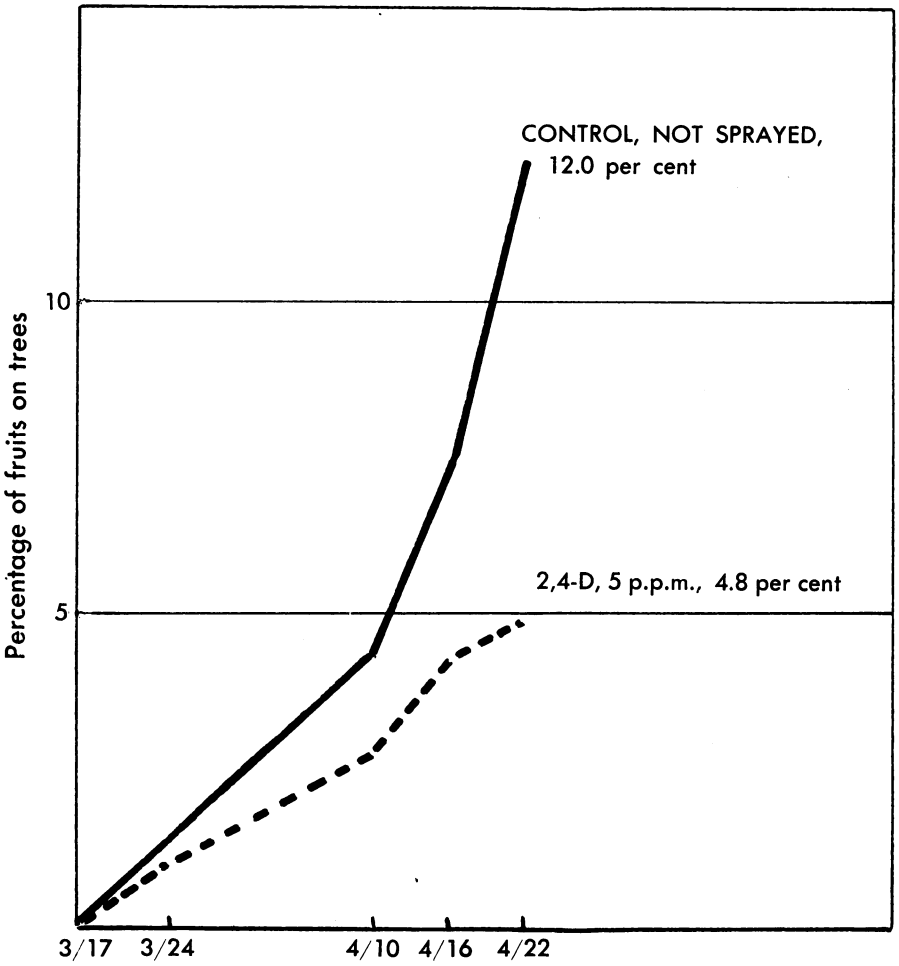

Fig. 2. Navel orange fruit-drop, as percentage of fruits on tree, from trees sprayed with 5 p.p.m. 2.4-D in water. Spray applied March 17, 1947. Fruit harvested April 22, 1947. Data average 10 trees per treatment. Plot in Highgrove district.

RESULTS

Applications to Reduce Mature Fruit-Drop

From October, 1946, to April, 1947, 17 field experiments were established to study the effect of 2,4-D and related substances on mature fruit-drop. In most experiments the 2,4-D was applied as a drenching water spray. The results

from some of the experiments are shown in Table 1 and Figures 1 and 2. In all experiments, the application of 2,4-D reduced fruit-drop after spraying (fig. 4, p. 168). In some experiments, the reduction in drop could be detected within four days. The amount of reduction varied according to the grove and certain other factors, such as season, age of trees, previous orchard practice, and the like.

The reduction in fruit-drop ranged from 27 to 96 per cent when 2,4-D was applied as a water spray at concentrations of from 5 to 25 p.p.m. In general, a drenching spray of 8 p.p.m. 2,4-D reduced fruit-drop 30 to 60 per cent. It appeared that in groves having heavy drop—for example, toward the end of the season—the reduction was usually greater than 60 per cent. In one experiment, trees sprayed with 8 p.p.m. 2,4-D on March 24, 1947, showed a reduction in drop of 86 per cent, during the next 26 days, over that of nonsprayed trees (fig. 3).

In experiments in two different groves, 8-p.p.m. water sprays of 2,4-D as the diethanolamine salt were applied on November 22, 1946, just six hours before a heavy rainstorm. Additional 2,4-D applications, on previously nonsprayed trees, were made on November 25, after the storm. There were no appreciable differences in fruit-drop, within the same grove, between the trees sprayed before or after the rain. It thus appears that it is only necessary to have a rain-free interval of six hours, or possibly less, in order to have a 2,4-D application effective in reducing drop.

During the 1948 navel harvest season, 16 additional experiments were established to study the effect of 2,4-D application on mature fruit-drop of Washington Navel oranges.

Table 1 shows that applications of 2,4-D on February 2, 1948, resulted in a 50 to 80 per cent reduction in fruit-drop until May 4, 1948, when the fruits were harvested.

In addition to its application as a drenching water spray, 2,4-D was applied during the harvest seasons of 1947 and 1948 at a low volume per acre by various machines. The "spray duster" machine was most frequently used. This machine, so named because it can be used to apply either sprays or dusts, consists of a vertical row of 9 to 15 nozzles mounted on the back of a truck in conjunction with an airblast; spray from the nozzles is distributed through the tree by the force of the air. In addition, the nozzles and the airblast oscillate so that, in operation, there is a tendency to turn the leaves. The spray duster is driven through the grove at a slow speed, the rate depending on the gallonage of application desired. Concentrations of 2,4-D varying from 16 to 125 p.p.m. were applied with a spray duster at the rate of 100 to 1,000 gallons per acre. The results are shown in Table 2 and Figure 4. A commercially satisfactory control of fruit-drop was obtained from applications of 16 p.p.m. 2,4-D as the isopropyl ester at 500 to 750 gallons per acre.

On February 8, 1947, fruit quality analyses were made for two of the experiments. In one of them, 2,4-D had been applied on October 15, 1946; in the other, on November 25, 1946. There were no appreciable differences between the pH, the amount of ascorbic acid, the percentage of soluble solids, and the total acid in the juice of fruit from trees sprayed with 25 p.p.m. 2,4-D and of that from the nonsprayed trees.

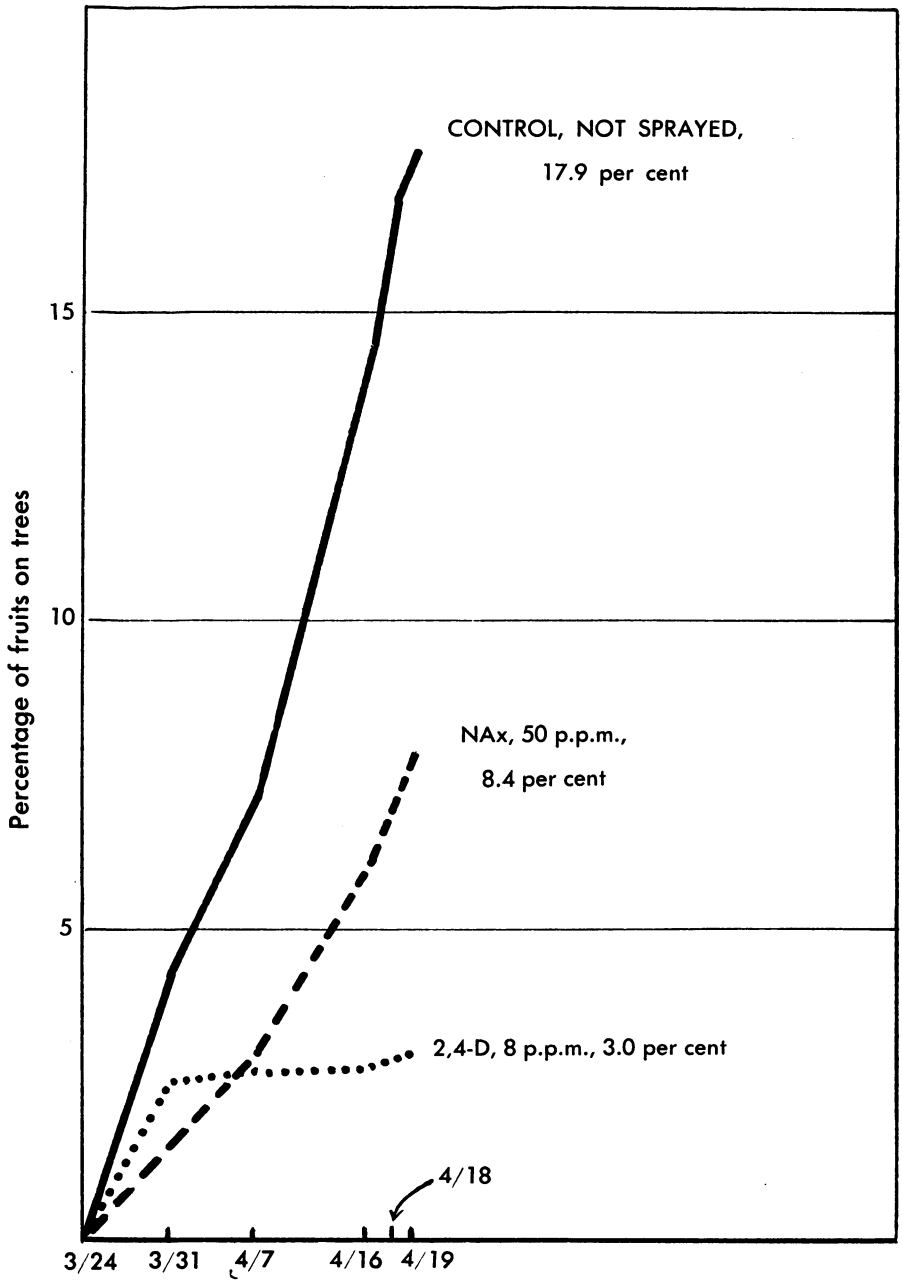

Fig. 3. Navel orange fruit-drop, as percentage of fruits on tree, from trees sprayed with water solutions containing 8 p.p.m. 2,4-D, 50 p.p.m. naphthoxyacetic acid (NA_x). Spray applied March 24, 1947. Fruit harvested April 19, 1947. Data average 5 trees per treatment. Plot in Corona district.

TABLE 2

EFFECT OF 2,4-D APPLICATION BY SPRAY DUSTER MACHINE ON MATURE FRUIT-DROP* FROM WASHINGTON NAVEL ORANGE TREES

Location of experiment	Spray date	Fruit-drop to:	Number of trees counted	Fruit-drop per tree		Concentration of 2,4-D	Gallons per acre	Form of 2,4-D	Reduction in fruit-drop
				Non-treated (control)	Treated with 2,4-D				
						p.p.m.			*per cent*
1947 harvest:									
Covina	12/12/46	2/28/47	14	81	47	50	150	diethanolamine salt	42.1
Azusa	12/12/46	2/5/47	15	159	131†	25	100	diethanolamine salt	17.6
	12/12/46	2/5/47	15	159	101†	125	100	diethanolamine salt	36.1
	12/12/46	3/25/47	8	599	385†	50	150	diethanolamine salt	35.7
1948 harvest:									
Camulos	10/22/47	4/14/48	12	80	39	8	500‡	triethanolamine salt	51.4
Pomona	12/15/47	4/19/48	10	272	100§	16	1,000	triethanolamine salt	63.1
	12/15/47	4/19/48	10	272	161	16	500	triethanolamine salt	40.8
	12/15/47	4/19/48	10	413	169	16	1,000	isopropyl ester	59.1
	12/15/47	4/19/48	10	413	182	16	500	isopropyl ester	56.0
	12/15/47	4/19/48	10	413	239	16	250	isopropyl ester	42.0
	1/17/48	4/8/48	8	164	89	16	750	isopropyl ester	45.8
	2/16/48	4/9/48	8	208	132	16	750	isopropyl ester	36.6
Riverside	1/12/48	5/13/48	8	272	100	16	750	isopropyl ester	63.3
	1/13/48	4/6/48	8	62	40	16	750	isopropyl ester	36.1
	3/5/48	5/4/48	6	45	26	16	750	isopropyl ester	43.1
Moreno	2/2/48	5/4/48	8	152	51	16	750	isopropyl ester	66.4

* Fruit-drop counted from date of spraying.
† Difference from nonsprayed significant at 1 per cent. No indication of significance means no analysis of variance was made.
‡ A hand spray application of about 6 gallons per tree; 12 gallons per tree reduced drop to 26.7 fruits per tree.
§ A hand spray application of the same solution reduced drop to 98.5 fruits per tree.

Later in the season, pickers harvesting fruit from 2,4-D-sprayed trees commented on its firmness and feeling of "early season" fruit.

In another series of experiments, 2,4-D was applied at volumes of less than 10 gallons per acre by using a Hi-Fog[7] machine. This machine produces a mist of small-droplet size by forcing the solution to be applied (in these studies, kerosene) through an atomizing-type nozzle. Both the back-pack Hi-Fog machine and a motor-driven model were used in these studies. No differences in

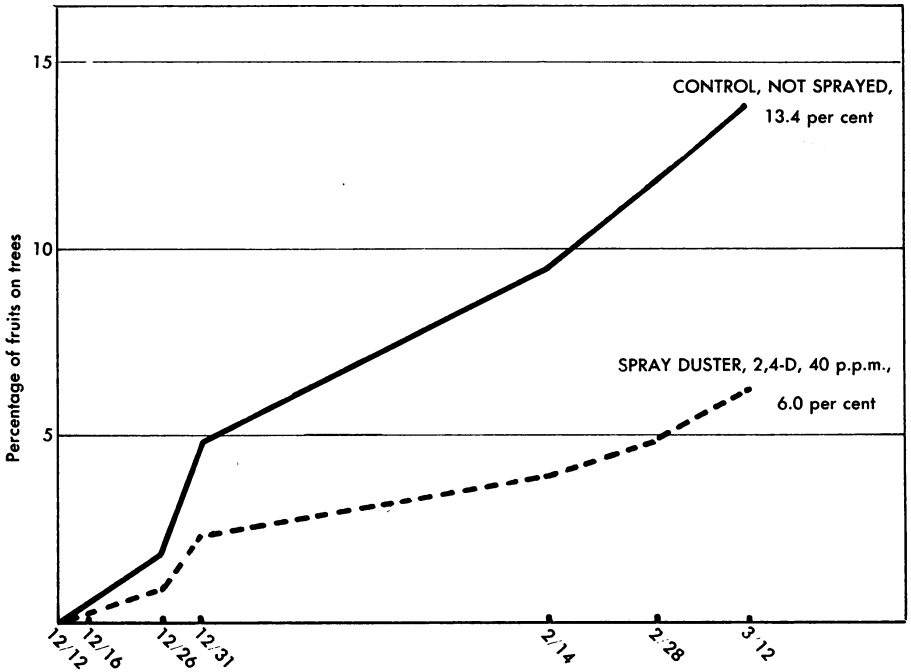

Fig. 4. Navel orange fruit-drop, as percentage of fruits on tree, from trees given a spray duster application of 40 p.p.m. 2,4-D in water. Spray applied December 12, 1946. Fruit harvested March 12, 1947. Data average 14 trees per treatment. Plot in Covina district.

results were noted between the two models. In all experiments, fruit-drop was reduced by 2,4-D as the technical grade isopropyl ester, in kerosene, at concentrations of from 1,200 to 7,200 p.p.m., applied at less than 10 gallons per acre. The results are shown in Table 3.

In one experiment, 2,4-D was applied, by helicopter, at 5 gallons per acre and at a concentration of 2,400 p.p.m. The technical grade isopropyl ester was dissolved in kerosene. In an adjoining plot in the same grove, another application was made by helicopter of 1,000 p.p.m. 2,4-D as the triethanolamine salt in water, applied at 11 gallons per acre. Average fruit-drop from the nonsprayed (control) trees was 92.5 fruits per tree; from those treated with 2,4-D in kerosene it was 47.5; and from trees treated with 2,4-D in water it was 65.3. It is noted that fruit-drop was reduced in both cases by the 2,4-D, but the re-

[7] Loaned for use in these studies by the manufacturers, Banta and Driscoll Co., Los Angeles.

duction was greater as a result of the kerosene application. Whether this was mainly due to the use of kerosene instead of water is not known since the concentration of 2,4-D in kerosene was 2,400 p.p.m., as compared with 1,000 p.p.m. in water.

In one experiment, application of 2,4-D as a dust (Frianite), at concentrations of 500 or 1,000 p.p.m., failed to reduce fruit-drop significantly. Further tests with dust applications of 2,4-D were not made.

TABLE 3

EFFECT OF LOW-VOLUME 2,4-D* AND 2,4-D DUST APPLICATIONS ON MATURE FRUIT-DROP† FROM WASHINGTON NAVEL ORANGE TREES

Location of experiment	Spray or dust date	Fruit-drop to:	Number of trees counted	Fruit-drop per tree		Concentration of 2,4-D	Reduction in fruit-drop
				Non-treated (control)	Treated with 2,4-D		
						p.p.m.	*per cent*
1947 harvest:							
Azusa	12/28/46	2/24/47	9	236	147	2,400	37.7
	12/28/46	2/24/47	9	236	116	4,800	50.9
	12/26/46	3/25/47	9	520	370**	1,200	28.7‡
	12/26/46	3/25/47	8	520	491**	2,400	5.6‡
	12/26/46	3/25/47	9	520	293**	7,200	43.7‡
Downey	1/7/47	1/21/47	12	128§	48§	2,400	62.5
Azusa (dust)‖	12/28/46	2/24/46	5	189	240**	500	
			5	189	162‡‡	1,000	14.3
1948 harvest:							
Corona	1/20/48	3/5/48	6	11	6††	1,200	48.1
	1/20/48	3/5/48	6	11	7††	1,800	39.8
	1/20/48	3/5/48	6	11	5**	2,400	50.9
Covina (helicopter application)	12/11/47	4/2/48	10	93	48¶	2,400	48.7

* Unless otherwise noted, low-volume application was made either by a Hi-Fog machine (Banta and Driscoll Co.) or by helicopter, and amounted to less than 10 gallons per acre. 2,4-D, as the technical grade isopropyl ester, was dissolved in kerosene.

† Fruit-drop counted from date of application.

‡ Fruit-drop reduction calculated from the percentage of fruit on the tree at the time of treatment was: 23.7 per cent, 14.6 per cent, and 41.9 per cent, respectively, for the 1,200, 2,400, and 7,200 p.p.m. treatments.

§ Dropped sound (i.e., marketable) fruit from nontreated and treated trees was 111 and 39, respectively. The difference between these figures and those above is unsound (cull) fruit.

‖ Diluted from a 5 per cent 2,4-D dust on Frianite by the addition of appropriate amounts of D. S. Frianite and applied with a hand duster.

¶ Helicopter application of 1,000 p.p.m. 2.4-D in water as the triethanolamine salt reduced drop to 65.3 fruits per tree.

** Difference from nonsprayed significant at 1 per cent.

†† Significant at 5 per cent.

‡‡ Not significant. No indication of significance means no analysis of variance was made.

Experiments with other growth regulators have not indicated one that is superior to 2,4-D for reduction of fruit-drop from navel orange trees. The materials investigated at various concentrations were: 2,4,5-trichlorophenoxyacetic acid; 2-chlorophenoxyacetic acid; and naphthoxyacetic acid. Results obtained with these substances are shown in Table 4 and Figure 3.

It had been repeatedly observed that application of 2,4-D to young, actively growing shoots and leaves of citrus induced a leaf curling and distortion of the blade, and also that if the concentration of 2,4-D, when applied as a drenching spray, was over 25 p.p.m., a nastic curvature of the young stem

usually occurred (Stewart and Ebeling, 1946; Stewart and Klotz, 1947). These same responses were noted whenever young shoots were present on navel orange trees sprayed with 2,4-D to reduce fruit-drop. However, from late fall to early spring there is usually little, if any, new shoot growth, and these responses are therefore not observed. Application of the salt form (inorganic or alkanolamine salt) of 2,4-D at 25 p.p.m., in January or later, usually resulted in some leaf blade curl of the spring growth flush. While ade-

TABLE 4

COMPARISON OF EFFECT OF VARIOUS PLANT GROWTH REGULATORS WITH 2,4-D* WHEN APPLIED AS A DRENCHING WATER SPRAY TO REDUCE MATURE FRUIT-DROP† FROM WASHINGTON NAVEL ORANGE TREES

Location of experiment	Spray date	Fruit-drop to:	Number of trees per treatment	Treatment		Fruit-drop per tree		Reduction in fruit-drop
				Growth regulator‡	Concentration	Non-treated (control)	Treated	
					p.p.m.			*per cent*
Azusa	11/22/46	1/2/47	7	2,4-D	20	34	20	42.7
	11/22/46	1/2/47	7	2,4,5-T	20	34	18	47.9
	11/25/46	1/2/47	7	2,4-D	20	34	23	32.5
	11/25/46	1/2/47	7	2,4,5-T	20	34	24	30.1
	11/22/46	2/5/47	7	2,4-D	20	158	85§	46.7
	11/22/46	2/5/47	7	2,4,5-T	20	158	94‖	40.7
	11/25/46	2/5/47	7	2,4-D	20	159	110‖	30.5
	11/25/46	2/5/47	7	2,4,5-T	20	159	100‖	37.0
Highgrove	3/17/47	4/21/47	10	2,4-D	5	104	32	69.2
	3/17/47	4/21/47	10	2-Cl	20	104	72	31.7
Corona	3/24/47	4/19/47	5	2,4-D	8	160	57§	64.6
	3/24/47	4/19/47	5	2-Cl	50	160	130¶	18.6
	3/24/47	4/19/47	5	NAx	50	160	96‖	40.0

* 2,4-D added as diethanolamine salt in all cases. Other chemicals dissolved in small amounts of alcohol before adding water.

† Fruit-drop counted from date of spraying.

‡ Abbreviations: 2,4,5-T is 2,4,5-trichlorophenoxyacetic acid; 2-Cl is 2-chlorophenoxyacetic acid; NAx is naphthoxyacetic acid.

§ Difference from nonsprayed significant at 1 per cent.

‖ Significant at 5 per cent.

¶ Not significant. No indication of significance means no analysis of variance was made.

quate data were not obtained, it was believed that this response was not so great as when ester forms of 2,4-D were similarly applied. In January and February, applications of 16 p.p.m. 2,4-D as the isopropyl ester, at 750 gallons per acre, resulted in little, if any, leaf curling of the spring growth flush, whereas application of the same concentration of 2,4-D as an alkanolamine or inorganic salt frequently resulted in appreciable leaf curl.

In an attempt to eliminate the tendency of 2,4-D to distort young leaves, several experiments were conducted using various forms and combinations of 2,4-D in conjunction with activated carbon (Norit A). The carbon adsorbed and held the 2,4-D, but whenever the adsorption was sufficient to reduce or eliminate leaf curling, there was less reduction in fruit-drop. No indication was obtained that the material could be used to eliminate leaf curling resulting from 2,4-D without also eliminating the effect of 2,4-D in reducing fruit-drop.

Application of 2,4-D to Young Fruit to Modify Growth

"June Drop" Studies.—It was noted in 1946 that application of 2,4-D at 25 p.p.m. failed to reduce June drop permanently, but that it delayed the drop and modified the subsequent growth of the fruit that failed to drop. Since it was possible that concentrations of 2,4-D at less than 25 p.p.m. might be effective in reducing, and not merely delaying June drop, further studies on this subject were made in 1947 and 1948.

The experiments on June drop of Washington Navel oranges were established at Edison, an orange-growing district near Bakersfield in the southern end of the San Joaquin Valley. This district is characterized by extremely warm spring weather abruptly following cold winter weather. The navel orange trees usually have a heavy bloom and may set a large crop, but at the onset of the warm weather such severe June drop occurs that the trees may bear only half or less of the crop that is borne elsewhere by trees of similar size.

In both 1947 and 1948, the experiments were established in a Latin square design of one tree per plot. The treatments were applied as drenching water sprays on April 8, 1947, about two weeks after full bloom. Counts of subsequent June drop were made by placing three lug boxes in comparable positions under each tree and making periodic counts of the fruits dropped into each box. During the period from April 28 to May 6, 1947, it was necessary to remove the boxes from under the trees to allow cultivation of the orchard. During those eight days, there was an extremely heavy June drop, and the ground was literally covered with small fruits.

The results of the experiment are shown below.

TREATMENT	FRUITS DROPPED* (through June 3, 1947)‡	FRUITS HARVESTED† (January 2, 1948)
		pounds
Nonsprayed (control)	195.4	150.2
Naphthoxyacetic acid, 50 p.p.m.....	241.8	125.0
Naphthalene acetic acid, 50 p.p.m.....	242.2	150.0
2,4-D, as diethanolamine salt, 2 p.p.m...	160.6	169.6
2,4-D, as diethanolamine salt, 8 p.p.m..	190.0	177.6

Although as compared with nonsprayed trees, the yield from trees sprayed with either 2 or 8 p.p.m. 2,4-D was greater, the increase lacked significance. In view of these results, another similar experiment was established at full bloom on April 15, 1948, on other trees in the same grove. The preparations were applied as drenching water sprays. The treatments were:

1. nonsprayed (control)
2. 2,4-D, 4 p.p.m. as the butyl ester
3. 2,4-D, 8 p.p.m. as the butyl ester
4. 2,4-D, 12 p.p.m. as the butyl ester
5. 2,4-D, 8 p.p.m. formulated in lanolin
6. 2,4,5-T, 8 p.p.m. as the butyl ester

* Least significant difference at 5 per cent was 154.7; at 1 per cent, 217.0. There were no statistically significant differences.

† Least significant difference at 5 per cent was 52.8 pounds.

‡ Fruit-drop from June 3 through July 22, 1947, amounted to less than 4 fruits per tree, indicating that June drop had terminated by June 3, 1947.

TABLE 5

EFFECT OF APPLICATIONS OF 2,4-D ON YIELD, SIZE, AND QUALITY OF WASHINGTON NAVEL ORANGES GROWING NEAR EDISON*

Factor	Non-sprayed (control)	Treatment with 2,4-D butyl ester					Treatment with 2,4,5-T 8 p.p.m.	Least significant difference	
		4 p.p.m.	8 p.p.m.†	12 p.p.m.		8 p.p.m.		At 5 per cent	At 1 per cent
				All fruits	Large fruits‡				
Field boxes per tree	2.48	2.57	2.08	2.28	.....	2.27	1.98	0.77	1.05
Weight of fruit per tree (kg)	62.9	64.1	50.9	57.1	.....	55.9	48.4	19.1	26.0
Number of fruits per tree	476	464	354	370	.....	354	364	47.6	64.9
Size:									
As weight per fruit (gm)	135.0	139.5	143.7	159.5	.....	160.7	137.4	12.47	17.01
As number of fruits per box	183.0	177.0	173.2	159.5	.....	157.2	165.0	17.0	23.2
As average diameter of fruits (mm)	64.3	65.5	66.1	68.0	.....	67.7	65.6	1.31	1.79
Fruit quality:									
Rind and rag (per cent)	44.9	46.7	47.6	46.9	50.7	48.6	47.5	.....	.....
Juice (per cent)	55.2	52.3	53.2	51.4	47.4	50.3	52.1	.....	.....
Ratio length to width	0.986	0.989	0.981	0.998	1.013	1.001	0.992	.....	.....
Juice quality:									
Soluble solids (per cent)	13.02	12.97	12.43	12.51	12.37	12.37	12.58	.....	.....
Total acid, as citric (per cent)	1.345	1.438	1.450	1.491	1.418	1.390	1.386	.....	.....
pH	3.50	3.47	3.44	3.42	3.48	3.46	3.50	.....	.....
Ratio soluble solids to total acid	9.68	9.02	8.57	8.39	8.72	8.90	9.08	.....	.....

* Trees sprayed April 15, 1948, at full bloom. Fruit harvested December 21, 1948. Figures average 6 trees each. Analyses made on composite samples of 90 fruits per treatment. All fruits of equal size.

† Formulated in lanolin.

‡ No comparably large fruits on nonsprayed trees.

Counts of young fruits dropped were not obtained; however, effects of the various treatments on June drop were measured by determining the fruit yield, size, and quality at harvest on December 21, 1948. The results are given in Table 5.

It was found that instead of increasing the number of fruits per tree as a result of reducing June drop, the spray treatments actually decreased the number. The decrease was significant at 1 per cent for all treatments except the 4 p.p.m. 2,4-D. Even though the number of fruits per tree was significantly reduced, field box yield was not significantly lowered as a result of the treatments. This is probably accounted for by the increased size of the fruit from the sprayed trees. Measurements of fruit size, either by the number of fruits required to fill a box, by weight per fruit, or by fruit diameter, showed an increased fruit size as a result of the treatments. It is interesting to note (table 5) that the lanolin emulsion formulation of the 2,4-D butyl ester was the most effective of any of the treatments in increasing fruit size, as shown by weight per fruit (the most accurate measure), and also to note that the 2,4,5-T spray was not significantly different from the 2,4-D spray in increasing fruit size.

Fruit quality determinations on samples of 90 fruits of uniform size, from each of the treatments, showed that the percentage of rind and rag was increased in all treatments and that the percentage of juice decreased as compared with nonsprayed trees. The percentage of soluble solids was lower and the acid higher in juice of fruit from treated trees than in that from nontreated. These various factors may all be an indication of delayed fruit maturity. It was observed at harvest that fruit from the treated trees was greener in color than was that from the nontreated trees. Measurements showed that the treatments had tended to make the fruit grow slightly more in length than in width.

On the basis of the negative results obtained in these two experiments on the control of June drop, no additional experiments were performed.

Water Spot Studies.—In view of the increased percentage of rind observed in 1946 in fruit from trees sprayed with 25 to 225 p.p.m. 2,4-D, it was considered desirable to determine if applications of 2,4-D could modify the rind so that it was more resistant to water spot. Three experiments were conducted to obtain further information on this point.

The first experiment was established July 7, 1947, on Washington Navel oranges at Azusa. It consisted of a randomized block design of one tree per treatment per block, and five replicate blocks. The treatments consisted of water sprays of: 8, 24, 36, 48, and 72 p.p.m. 2,4-D. Later, on August 22, 1947, all of the trees received the usual 2 per cent medium emulsible oil spray for citrus pest control.

Observations and fruit quality analyses on November 25, 1947, in comparison with nonsprayed trees, showed that, with few exceptions, in proportion to the amount of 2,4-D: maturity of the fruit (as shown by persistence of green rind color) had been delayed; percentage of rag had been increased; percentage of juice decreased; and the percentage of rind increased (tables 6 and 7, fig. 4). A delay in rind coloration (hence in maturity) was still apparent on December 17, 1947, when rain-chamber tests of water spot susceptibility were made. It was found that water spot was reduced in proportion

to the amount of 2,4-D applied. After 16 hours in the rain chamber, 59 per cent of the nonsprayed fruit had water-spotted, whereas only 9 per cent of the fruit sprayed with 72 p.p.m. of 2,4-D had water spot. It is believed that this reduction in water spot was mainly the result of delayed fruit maturity, although some of the other modifications in fruit growth, especially the thickened rind, may have contributed to the decrease. The experimental fruit was harvested on January 21, 1948. Fruit-size measurements and production records were not obtained.

Fruit quality analyses at harvest showed that there were no consistent differences, in the percentage of soluble solids or total acids, between sprayed

TABLE 6

DELAYED MATURITY* AND SUSCEPTIBILITY TO WATER SPOT OF WASHINGTON NAVEL ORANGES FROM TREES SPRAYED WITH 2,4-D†

Treatment	Mature fruit-drop to 1/21/48‡	Fruits with green rind on:		Water spot in rain chamber, 12/15/47	
		11/25/47	12/15/47	16 hrs.	64 hrs.
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
No spray (control)	151.8	26.5	1.3	59.0	77.0
Sprayed 2,4-D:					
8 p.p.m.	85.2	32.8	2.5	51.0	69.0
24 p.p.m.	45.8	57.2	8.5	35.0	59.0
36 p.p.m.	32.0	63.0	7.5	31.0	63.0
48 p.p.m.	30.6	80.9	8.5	29.0	69.0
72 p.p.m.	41.0	87.3	17.0	9.0	43.0

* As shown by green-colored rind.
† Trees sprayed July 7, 1947. (Azusa water spot experiment, 1947.)
‡ Least significant difference at 5 per cent, 52.7; at 1 per cent, 71.9.

and nonsprayed fruit (table 7). It was also found that, in comparison with fruit from nonsprayed trees, the percentage of rind and rag was increased and that of juice decreased. These relationships might have changed if the harvest had been later in the season when the effect of the treatment in delaying maturity might not have been so pronounced. It should also be mentioned that the size of the fruit sample from the nonsprayed trees was half, or less, than that from the 2,4-D-sprayed trees. A portion of the differences noted may have been due to an inadequate sample.

On the basis of these promising results on reduction of water spot, two additional experiments were established in 1948 to study the problem further. The object of these experiments was to obtain packing house grading of fruit quality as well as to examine every fruit for water spot. Both experiments were of randomized block design of four trees per plot per block, five replicate blocks, and four treatments per experiment, or a total of 20 trees per treatment. The treatments, applied as drenching water sprays, were:

1. nontreated (control)
2. trees sprayed with 8 p.p.m. 2,4-D as the isopropyl ester
3. trees sprayed with 24 p.p.m. 2,4-D as the isopropyl ester
4. trees sprayed with 48 p.p.m. 2,4-D as the isopropyl ester

A drenching spray of 48 p.p.m. 2,4-D was considered the maximum possible for commercial use in view of the tendency of sprays of high 2,4-D concentration to lower fruit quality. In both experiments, the trees were sprayed in early October with the usual oil-water emulsion for citrus pest control. In a row adjacent to the Latin square the trees were not oil-sprayed but were treated for pest control by cyanide fumigation. These trees received no 2,4-D spray.

TABLE 7

QUALITY OF WASHINGTON NAVEL ORANGES FROM TREES SPRAYED WITH 2,4-D*

Factor	Non-sprayed (control)	Treatment with 2,4-D				
		8 p.p.m.	24 p.p.m.	36 p.p.m.	48 p.p.m.	72 p.p.m.
Fruit analyzed November 25, 1947						
Fruit quality:						
Rind (per cent)	42.3	45.1	50.7	....	55.2	45.3
Rag (per cent)	1.9	1.6	1.8	....	2.7	11.4
Juice (per cent)	55.8	53.3	47.5	....	46.6	43.3
Ratio length to width	0.971	0.998	1.014	....	1.011	1.033
Soluble solids (per cent)	11.03	11.11	11.23	....	10.37	10.03
Total acid (per cent)	1.58	1.70	1.73	....	1.70	1.70
Ratio soluble solids to total acid	7.26	6.82	6.77	....	6.36	6.12
Fruit analyzed January 21, 1948						
Fruit quality:						
Rind (per cent)	29.6	39.7	47.1	48.7	50.7	49.3
Rag (per cent)	1.9	2.1	2.6	2.5	2.2	2.5
Juice (per cent)	68.5	58.1	50.3	48.9	47.1	48.2
Soluble solids (per cent)	12.58	13.12	12.64	12.51	12.64	12.51
Total acid (per cent)	1.26	1.35	1.32	1.29	1.38	1.29
Ratio soluble solids to total acid	9.98	9.72	9.58	9.70	9.16	9.70

* Trees sprayed July 7, 1947. (Azusa water spot experiment, 1947.)

One of the experiments was located west of Claremont (Experiment 1), and the other south of Claremont (Experiment 2). Fruit grown in this district usually develops considerable water spot. The treatments were applied in Experiment 1 on June 15 and in Experiment 2 on June 22, 1948. On these dates the fruits averaged 8.6 mm in diameter in Experiment 1, and 12.2 mm in diameter in Experiment 2.

Observations of the fruit growth were made in both experiments on October 11, 1948. At that time it appeared that, with increasing concentrations of 2,4-D (as applied in June), there was a tendency for the fruits to remain greener in color, to become larger in size and somewhat elongated, and to develop a larger navel, rudimentary seeds (not commercially objectionable, but noted even in the navel), larger oil glands in the rind, and thicker stems. Most of these responses to 2,4-D sprays applied in June had been previously noted (Stewart and Klotz, 1947).

On November 2, 1948, in Experiment 1, 40 fruits from the nonsprayed trees and 40 from the trees sprayed with 48 p.p.m. 2,4-D were selected at random,

tagged, and measured. They were measured again on December 9, 1948, and on March 16, 1949. From November 2 to March 16, the nonsprayed fruits increased, on the average, 3.64 mm in diameter, while the fruits on trees sprayed with 48 p.p.m. 2,4-D increased 4.80 mm. The difference in growth between the nonsprayed fruits and the fruits sprayed with 48 p.p.m. 2,4-D was significant at 1 per cent.

Additional observations on trees in Experiment 1 were made on November 10, 1948, by measuring at random the diameter of at least 60 fruits per treatment per plot. It was found that on that date the nonsprayed fruits averaged 57.70 mm in diameter, while the fruits on trees sprayed with 48 p.p.m. 2,4-D averaged 61.39 mm. This difference was significant at 1 per cent.

It was noted on December 29, 1948, that there was a greater percentage of green-colored fruit on trees sprayed with 2,4-D than on the nonsprayed trees (table 8). The differences were in proportion to the concentration of 2,4-D and, for the 24 p.p.m. and 48 p.p.m. 2,4-D treatments, were significant at 5 per cent and 1 per cent, respectively.

At harvest on March 17, 1949, the nonsprayed trees yielded the fewest field boxes of fruit, while those sprayed with 48 p.p.m. 2,4-D yielded the greatest number (table 8). The difference was significant at 1 per cent. Fruit size, as the number of fruits per box, also showed an increase when compared with nonsprayed trees, as a result of the 2,4-D sprays, although the differences lacked statistical significance.

After harvest, the fruit was taken to the packing house for sizing and grading according to treatment. Water-spotted fruit was segregated by hand.

Among the trees receiving the fall oil spray, those sprayed with 48 p.p.m. 2,4-D in June had 14.2 per cent water-spot[8] fruit as compared with 28.9 per cent and 37.9 per cent, respectively, from non-2,4-D-sprayed trees and from trees sprayed with 8 p.p.m. 2,4-D (table 9). The least percentage of water-spot fruit, 12.8 per cent, was obtained from the non-oil-sprayed trees. This agrees with previous findings on the effects of oil sprays for citrus pest control on water spot (Ebeling, Klotz, and Parker, 1938). The data also indicated that water spot was responsible for 85 per cent to 90 per cent of the defects in the "loose fruit" grade.

Table 9 shows that the increase observed in field box production as a result of the 2,4-D sprays is also reflected in the yield of packed boxes. For example, there was an increase of 2.0 boxes of first-grade fruit per tree from trees sprayed with 48 p.p.m. 2,4-D as compared with the trees not sprayed with 2,4-D. Fruit size, as expected from the field observations, was increased as a result of the 2,4-D sprays. The increase in size did not result from a decrease in the number of fruits, as observed in the June drop studies, since the packing house records show that, per tree, there were approximately 1,267 fruits from the trees not sprayed with 2,4-D, whereas there were 1,476, 1,074, and 1,429 fruits from those sprayed with 8, 24, or 48 p.p.m. 2,4-D, respectively.

Results obtained from the second 1948 experiment on the effect of 2,4-D sprays applied in June on water spot of Washington Navel oranges were similar to those described above, and are shown in Tables 10 and 11.

[8] Because of a very cold winter, the rind was damaged with snow and ice injury. Since it was not possible to segregate this injury from water spot, it was included as water spot.

TABLE 8

YIELD, SIZE, AND QUALITY OF FRUIT* FROM WASHINGTON NAVEL ORANGE TREES SPRAYED WITH 2,4-D (JUNE 15, 1948) AND WITH OIL (OCTOBER 6, 1948)†

Factor	Nonsprayed (control)		Sprayed with 2,4-D						Fumigated (no oil, no 2,4-D)‡	Least significant difference (1949)	
			8 p.p.m.		24 p.p.m.		48 p.p.m.			At 5 per cent	At 1 per cent
Fruit harvested in	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*		
Field boxes per tree	4.89	7.4	6.31	8.4	6.09	7.0	6.59	6.7	5.72	1.39	1.95
Size, as fruits per box	212	151	211	145	195	143	201	136	.....	20.3	....
Green-colored fruits, December 29, 1948 (per cent)	24.2	.....	26.5	....	31.4	.....	44.0	.....	.....	6.1	8.6
Fruit quality:											
Rind (per cent)	48.4	36.1	46.7	48.3	47.7	48.3	47.4	48.7	47.2	....	....
Rag (per cent)	3.7	9.1	4.5	10.3	5.3	10.2	5.2	11.5	4.4	....	....
Juice (per cent)	46.8	54.8	47.5	41.4	45.4	41.5	45.0	39.8	47.0	....	....
Juice quality:											
Soluble solids (per cent)	11.91	11.96	12.01	11.96	12.01	11.77	11.71	11.63	13.12	....	....
Total acid (per cent)	0.75	1.13	0.73	1.11	0.78	1.14	0.72	1.12	0.85	....	....
pH	3.46	3.50	3.39	3.52	3.40	3.51	3.44	3.50	3.34	....	....
Ratio soluble solids to total acid	15.9	10.6	16.5	10.8	15.4	10.3	16.3	10.4	15.4	....	....
Ascorbic acid, mg/100 cc	.....	63.01	.....	62.48	.....	64.77	.....	62.13	.....	....	....
Ratio fruit-stem diameter to fruit diameter:											
11/11/49		0.0595		0.0606		0.0645		0.0680	.....	0.0095	.....
1/18/50		0.0465		0.0483		0.0498		0.0516	.....	0.0023	0.0037

* Young fruit diameter: 8.6 mm in 1948; 13.3 mm in 1949.

† Fruit harvested March 17, 1949. Figures average 18 to 20 trees each. Trees resprayed June 27, 1949, and harvested March 18, 1950. (1950 harvest averages 10 to 14 trees.) (Water spot Experiment 1, west of Claremont.)

‡ Not included in analysis of variance.

Among fruits harvested from trees not sprayed with 2,4-D, there was a lower percentage with water spot in the second experiment (14.5) than in the first (28.9). This difference may be a result of the late harvest date of the first experiment, March 17, as compared with February 18 in the second. In both experiments, among the trees sprayed with oil, the lowest percentage of fruit

TABLE 9

WATER SPOT, QUALITY, AND SIZE OF FRUIT AS DETERMINED IN THE PACKING HOUSE ON FRUIT FROM WASHINGTON NAVEL ORANGE TREES SPRAYED WITH 2,4-D (JUNE 15, 1948) AND WITH OIL (OCTOBER 6, 1948)*

Factor	Nonsprayed (control)		Sprayed with 2,4-D						Fumigated (no oil, no 2,4-D)
			8 p.p.m.		24 p.p.m.		48 p.p.m.		
Fruit harvested in	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*
Water spot† as per cent of:									
All fruit harvested	28.9	....	37.9	....	19.1	....	14.2	....	12.8
Loose fruit	53.2	....	51.4	....	48.5	....	40.5	....	38.3
Yield packed boxes per tree	2.32	4.5	2.86	5.1	2.59	4.1	4.36	4.1	2.75
1st grade (per cent)	90.0	82.2	90.9	90.2	88.9	87.8	93.9	78.0	94.4
Size‡ as fruits per tree:									
100	0.4	11.8	0.5	21.5	0.4	21.8	0.8	41.2	0.3
126	3.5	50.7	6.2	69.6	4.1	63.6	6.7	76.5	3.5
150	15.0	104.1	20.1	135.1	21.4	124.2	26.7	121.7	17.2
176	30.4	150.0	46.3	181.1	31.9	156.9	44.3	138.5	28.2
200	47.9	161.0	70.2	162.2	65.6	127.4	84.7	106.5	59.2
220	96.5	145.6	115.5	144.1	107.2	102.1	142.5	88.0	88.1
252	143.5	120.1	130.2	124.2	127.4	76.1	177.6	63.0	166.3
288	146.5	89.3	188.1	89.9	173.2	46.3	229.3	44.5	176.7
344	92.5	40.4	120.6	41.3	100.9	21.9	183.9	24.9	160.7
392	16.0	10.1	21.9	9.0	18.0	3.6	31.5	4.5	28.2
Yield, total loose fruit,§ pounds per tree:	66.1	67.8	70.7	51.5	63.6	58.3	59.7	69.6	42.0
Juice fruit (per cent)	76.0	25.8	71.8	44.7	70.9	51.4	64.1	57.5	54.6
Cull fruit (per cent)	4.5	34.9	2.8	32.0	2.9	22.1	4.6	23.3	6.1
Very small fruit (per cent)	14.1	12.2	17.8	4.9	18.9	3.1	20.6	21.7	30.3
Rot fruit (per cent)	5.3	27.0	7.6	18.4	7.2	23.3	10.7	16.5	8.9

* Fruit harvested March 17, 1949. Figures average 18 to 20 trees each. Trees resprayed June 27, 1949, and harvested March 18, 1950. (1950 harvest averages 10 to 14 trees.) (Water spot Experiment 1, west of Claremont.)
† Includes rind injury due to ice and snow.
‡ Packing house size units: 100 is 3.50 inches in diameter; 392 is 2.00 inches in diameter.
§ Loose fruit is nonpacked fruit.

with water spot (11.9) was that harvested from trees sprayed with 48 p.p.m. 2,4-D. There was 9.7 per cent water-spotted fruit from trees that were not oil-sprayed but were fumigated. As in the first experiment, production of field boxes of fruit was significantly increased as a result of the 2,4-D spray, as were packed boxes of fruit, and fruit size (table 11). The latter was noted as early as November 10, 1948, when diameter measurements were made of a number of nonsprayed fruits and of fruits on trees sprayed with 48 p.p.m. 2,4-D. The average diameters were 56.39 mm and 57.75 mm, respectively. The difference was significant at 5 per cent by the t test. Also, as before, the in-

TABLE 10

YIELD, SIZE, AND QUALITY OF FRUIT FROM WASHINGTON NAVEL ORANGE TREES SPRAYED WITH 2,4-D (JUNE 22, 1948)* AND WITH OIL (OCTOBER 13, 1948)†

Factor	Nonsprayed (control)		Sprayed with 2,4-D						Fumigated (no oil, no 2,4-D)‡	Least significant difference			
			8 p.p.m.		24 p.p.m.		48 p.p.m.			At 5 per cent		At 1 per cent	
Fruit harvested in	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*	*1949*	*1950*	*1949*	*1950*
Field boxes per tree	5.73	7.04	6.52	7.32	6.24	7.80	7.20	7.66	5.72	0.96	1.39	1.35	1.96
Size, as fruits per box	.....	124	.....	110.0	.....	117	.....	100	.....	.....	12.4	.....	17.41
Green-colored fruits, December 29, 1948 (per cent)	22.1	.....	26.4	.....	31.4	.....	40.8	.....	.....	6.55	.....	9.03	.....
Fruit quality:													
Rind (per cent)	49.0	50.7§	53.3	56.8	55.1	61.2	56.0	56.1	46.7	.....	.....	.....	.....
Rag (per cent)	3.4	4.3	2.4	3.5	2.4	2.8	2.3	3.4	4.0	.....	.....	.....	.....
Juice (per cent)	46.8	45.0	43.4	39.7	41.8	36.0	37.7	40.5	46.1	.....	.....	.....	.....
Juice quality:													
Soluble solids (per cent)	11.23	12.06	11.17	12.23	11.23	12.43	11.23	12.06	13.38	.....	.....	.....	.....
Total acid (per cent)	0.75	0.97	0.74	1.21	0.81	0.99	0.74	0.93	0.88	.....	.....	.....	.....
pH	3.40	3.73	3.40	3.70	3.34	3.69	3.36	3.70	3.32	.....	.....	.....	.....
Ratio soluble solids to total acid	15.0	12.4	15.1	10.11	13.9	12.56	15.2	12.97	15.2	.....	.....	.....	.....
Ratio fruit-stem diameter to fruit diameter:													
11/11/49	0.0546		0.0599		0.0592		0.0606		....	0.0053		.....	
1/18/50	0.0452		0.0472		0.0481		0.0493		....	0.0024		0.0033	

* Young fruit diameter: 12.2 mm in 1948; 16.5 mm in 1949.

† Fruit harvested February 18, 1949. Figures average 18 to 20 trees each. Trees resprayed June 27, 1949, and harvested May 5, 1950. (Water spot Experiment 2, south of Claremont.)

‡ Not included in analysis of variance.

§ Rind determined by difference in 1950.

creases in fruit size did not result from a decrease in the number of fruits per tree. It was found that, per tree, there were approximately 1,448 fruits from the non-2,4-D-sprayed trees and 1,629, 1,589, and 1,777 from those sprayed with 8, 24, or 48 p.p.m 2,4-D, respectively.

Observations of fruit-drop at the time of harvest (February 18, 1949) of the second experiment indicated no significant differences, or trends, among the treatments.

TABLE 11

WATER SPOT, QUALITY, AND SIZE OF FRUIT AS DETERMINED IN THE PACKING HOUSE ON FRUIT FROM WASHINGTON NAVEL ORANGE TREES SPRAYED WITH 2,4-D (JUNE 22, 1948) AND WITH OIL (OCTOBER 13, 1948)*

Factor	Nonsprayed (control)		Sprayed with 2,4-D						Fumigated (no oil, no 2,4-D)
			8 p.p.m.		24 p.p.m.		48 p.p.m.		
Fruit harvested in	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*	*1950*	*1949*
Water spot† as per cent of:									
All fruit harvested	14.5	....	14.4	....	14.4	....	11.9	....	9.7
Loose fruit	37.1	....	38.5	....	37.5	....	33.0	....	24.8
Yield, packed boxes per tree	3.1	4.3	3.7	4.4	3.4	4.5	4.1	4.1	3.2
First-grade fruits (per cent)	91.3	81.1	87.1	76.1	87.6	77.4	82.7	74.9	91.0
Size,‡ as fruits per tree:									
100	0.3	43.9	0.3	75.1	1.4	65.6	0.3	76.8	0.3
126	1.2	85.6	2.5	107.8	2.7	97.5	1.6	119.7	0.9
150	5.9	132.6	9.3	137.2	7.2	140.6	5.3	129.7	4.1
176	22.4	158.4	27.1	140.8	23.1	162.1	22.4	114.4	15.4
200	34.5	117.9	43.0	93.0	39.1	114.7	41.1	71.0	27.4
220	101.0	90.3	126.7	64.9	104.8	79.9	142.2	44.0	81.5
252	140.2	57.1	181.6	35.3	148.5	49.1	215.0	21.4	127.5
288	300.2	36.4	350.3	24.5	337.7	33.4	405.9	11.5	341.5
344	171.4	12.7	180.8	5.1	188.8	10.8	204.5	1.7	197.7
392	103.3	....	95.3	....	116.0	....	100.6	....	119.6
Yield, total loose fruit, pounds per tree:§	115.0	1.12	120.4	0.95	125.1	1.47	137.2	1.46	111.2
Juice fruit (per cent)	7.3	30.5	9.5	50.5	9.1	27.1	19.3	50.9	12.1
Cull fruit (per cent)	15.8	34.3	15.0	41.6	15.8	28.2	17.7	30.7	16.2
Very small fruit (per cent)	33.4	2.3	30.3	2.6	33.7	1.8	26.4	1.4	42.8
Rot fruit (per cent)	43.5	32.9	45.1	5.3	41.4	28.6	36.6	17.1	28.9

* Fruit harvested February 18, 1949. Trees resprayed June 27, 1949, and harvested May 5, 1950. Figures average 18 to 20 trees each. (Water spot Experiment 2, south of Claremont.)
† Includes rind injury due to ice and snow.
‡ Packing house size units: 100 is 3.50 inches in diameter; 392 is 2.00 inches in diameter.
§ Loose fruit is nonpacked fruit. For 1950 it is given as field boxes per tree instead of pounds.

In view of the reduction in water spot observed in both of these experiments as a result of the 2,4-D sprays, they were continued in 1949 by respraying the same trees with solutions containing the same amount and form of 2,4-D used in 1948. The trees in both experiments were sprayed on June 27, 1949.

Observations during the fall of 1949 indicated that the fruit responses to the sprays were similar to those noted the previous year. To obtain quantitative data on the effect of the sprays on the diameter of the fruit stem in relation to fruit size, two diameter measurements of both fruit stems and fruits were

made on November 11, 1949, and again on January 18, 1950, for both experiments.

On November 11, 2 fruits per plot were measured (a total of 8 fruits), and on January 18, 20 fruits per plot were measured (a total of 80 fruits). In both experiments, the largest fruits in each treatment were selected for measurement. From the data recorded, it appears that not only were the fruit stems and fruits increased in diameter, but also the amount of stem in proportion to the fruit was greater on the trees sprayed with 2,4-D than on the nonsprayed trees. See Table 8 (Experiment 1) and Table 10 (Experiment 2) for the measurements and the least significant differences. The material is also presented graphically in Figure 5. It is interesting to note that, in both experiments, the amount of stem in proportion to fruit decreased from November to January, as the fruit increased in size. Is the stem diameter a factor limiting fruit growth?

In 1950 the harvest for Experiment 2 was delayed until May 5 and as a result there was an appreciable drop of mature fruit. The dropped fruit was counted and classified according to the apparent cause of drop. This showed that the drop of sound (i.e., marketable) fruit was less from the trees which had been sprayed the previous June with 24 or 48 p.p.m. 2,4-D than from the nonsprayed trees (table 12). No similar trends were noted for fruit-drop due to frost damage to rind, navel end split, freezing, Alternaria, or mechanical or unknown causes.

Application Prior to Bloom.—Modification of fruit growth may occur in response to 2,4-D sprays applied to trees prior to flowering as well as to young fruit after bloom, provided a sufficiently high concentration is used. Three experiments during the late winter of 1947 demonstrated this response.

The first experiment was in a navel orange orchard near Highgrove. Application of 2,4-D was made at a low volume, as a mist of small-droplet size, by use of a Hi-Fog machine (previously described). The trees were treated on February 10, 1947, with either 2,400 or 7,200 p.p.m. 2,4-D, as the technical isopropyl ester, in light-medium spray oil.

From the time of application until April 21, 1947, fruit-drop from the nontreated trees amounted to 115 fruits per tree while from those treated with 2,400 or 7,200 p.p.m. 2,4-D it was 27 and 45 fruits, respectively. Flowering occurred in early April, and as the fruit developed it became evident that the 2,4-D-treated fruit was larger than the nontreated. On January 13, 1948, measurements were made of the fruit-stem thickness. The stems on 45 fruits of a size between 6.67 cm and 6.98 cm were selected for measurement. It was found that stems on the nonsprayed fruits averaged 3.545 mm in diameter and those on fruits treated with 7,200 p.p.m. 2,4-D averaged 3.862 mm in diameter. The difference is significant at 1 per cent. Observations of the percentage of fruit with green-colored rind were also made on the same day. About 1,400 fruits were observed in each treatment. It was found that 2.65 per cent of the nontreated fruits was green whereas 7.81 per cent and 5.53 per cent, respectively, of the fruits on trees treated with 2,400 or 7,200 p.p.m. 2,4-D were green.

The second experiment to demonstrate the effect of fruit-growth modification by 2,4-D spray applied prior to bloom was in a navel orange grove near

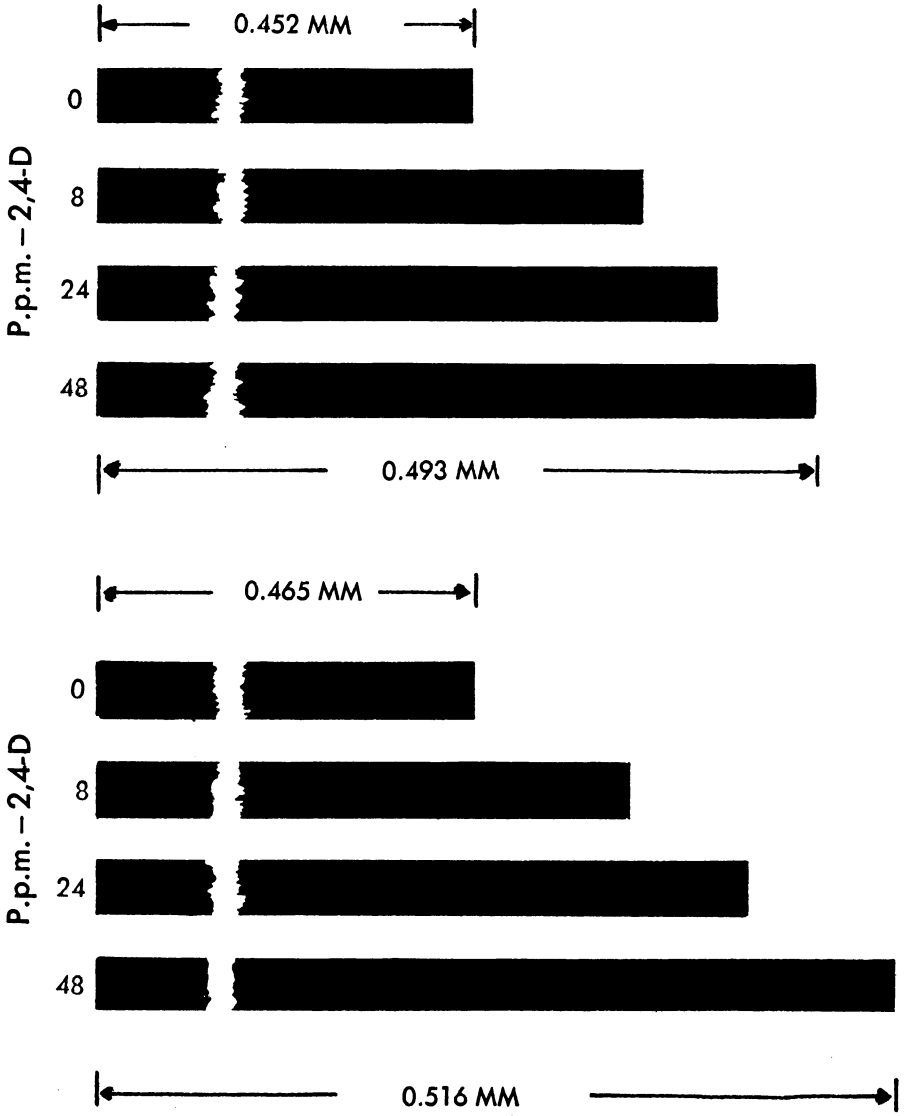

Fig. 5. Stem diameter (mm) (abscission) per centimeter of fruit diameter on Washington Navel orange trees sprayed June 27, 1949, with 8, 24, and 48 p.p.m. 2,4-D. Measurements, made on January 18, 1950, are averages of 80 fruits each. Top: Experiment 2, south of Claremont; bottom, Experiment 1, west of Claremont.

Camulos in the Piru district. In this experiment, the trees were given a drenching water spray of 25 p.p.m. 2,4-D as the diethanolamine salt, on February 11, 1947. On April 13, 1947 (harvest), there was a spectacular reduction (96 per cent) in fruit-drop. The average drop from nonsprayed trees from the time of spraying to harvest was 152 fruits per tree as compared with an average of only 6 fruits from those sprayed with 2,4-D. This is

TABLE 12

DROPPED FRUITS CLASSIFIED AS TO APPARENT CAUSE OF DROP*

Sprayed with 2,4-D	Unit	Dropped fruits per tree							
		Total	Sound†	Frost damage to rind	Navel end split	Frozen	Alternaria	Mechanical	Unknown
p.p.m.									
0 (control)	Number of fruits	92.6	16.6	17.0	9.0	13.4	4.6	5.2	26.8
	Per cent of total	*100.0*	*17.9*	*18.4*	*9.7*	*14.5*	*5.0*	*5.6*	*28.9*
8	Number of fruits	76.4	13.2	18.6	5.6	7.8	2.2	6.8	22.2
	Per cent of total	....	*17.3*	*24.4*	*7.3*	*10.2*	*2.9*	*8.9*	*29.1*
24	Number of fruits	71.2	7.6	19.4	7.2	6.6	4.6	3.2	22.4
	Per cent of total	....	*10.7*	*27.3*	*10.1*	*9.3*	*6.5*	*4.8*	*31.5*
48	Number of fruits	42.6	2.4	5.8	3.8	5.4	3.4	2.2	19.6
	Per cent of total	....	*5.6*	*13.6*	*8.9*	*12.7*	*8.0*	*5.2*	*46.0*

* Trees sprayed June 22, 1948, and June 27, 1949. Drop counts made on May 5, 1950. Figures average 5 trees each. (Water spot Experiment 2, south of Claremont.)
† Least significant difference in number of sound fruits, at 5 per cent, is 13.35.

illustrated in Figure 6 where the fruit-drop occurring the last month before harvest is shown. As the succeeding crop began to develop, however, it became increasingly evident that its growth was modified as a result of the 2,4-D spray. The fruits on the 2,4-D-sprayed trees were larger, and had thicker stems and rougher rind than did fruits on the nonsprayed trees. At harvest, April 15, 1948, complete yield records were obtained, in the field, as were laboratory

Fig. 6. Above: 5,121 fruits dropped from 40 nonsprayed navel orange trees during the interval March 13, 1947, to April 13, 1947. Below: 115 fruits dropped during the same interval from 40 trees of comparable size but sprayed with 25 p.p.m. 2,4-D in water. Spray applied February 11, 1947. Fruit harvested April 13, 1947. Plot in Piru district. (Photograph by O. K. Anderson.)

analyses of fruit quality and the packing house quality grade. These data are summarized in Table 13. It was found that the fruit was larger on the trees sprayed with 2,4-D prior to bloom, the previous year, than on the nonsprayed trees. This was shown not only by visual observation but also by counts of the number of fruits per field box. Yield, as the number of fruits per tree, was decreased 24.0 per cent as a result of the 2,4-D spray; however, on the basis of field boxes per tree, it was reduced only 5.1 per cent. This difference resulted from the larger size of the fruits on the trees sprayed with 2,4-D.

The packing house grade showed that, of the packed fruit, there was 89.2 per cent first-grade fruit from the nonsprayed trees and 72.2 per cent first-grade fruit from the trees sprayed with 2,4-D. The 2,4-D-sprayed fruit was graded lower in quality largely because of the rough, pebbly texture of the rind and the excessive growth of the navels. The laboratory analyses indicated

that the juice of non-2,4-D-sprayed fruits had a lower percentage of soluble solids and acid than did that of 2,4-D-sprayed fruits of comparable size. Since there were no fruits on the nonsprayed trees comparable in size to the large fruits on the 2,4-D-sprayed trees, no quality comparison could be made between the two treatments for the large-sized fruits.

Drop of the mature fruit in 1948 was reduced from 64 fruits per tree, from the nonsprayed trees, to 20 fruits per tree from the sprayed ones. Expressed as percentages of the fruits on the tree, this amounted to 9.95 and 4.07 per cent, respectively.

TABLE 13

EFFECT OF A 25-P.P.M. 2,4-D SPRAY, APPLIED PRIOR TO BLOOM, ON SIZE, YIELD, AND QUALITY OF WASHINGTON NAVEL ORANGES*

Factor	Nonsprayed (control)	Sprayed with 2,4-D (25 p.p.m.)	
		All fruits	Large fruits†
Size as fruits per box	140.0	119.0	.....
Field boxes per tree	4.15	3.94	.....
Number of fruits per tree	645	490	.....
Fruit quality:			
Fruit weight (gm)	170.0	176.0	284.0
Rind (per cent)	42.9	44.0	48.4
Rag (per cent)	3.9	4.4	5.9
Juice (per cent	53.2	51.6	45.7
Juice quality:‡			
Soluble solids (per cent)	15.07	15.58	14.44
Total acid (per cent)	1.014	1.040	0.952
pH	3.47	3.45	3.51
Ratio soluble solids to total acid	14.9	15.0	15.2

* Fruit harvested April 15, 1948. Figures average 40 trees each. (Camulos experiment, 2,4-D application prior to bloom.)

† Large-sized fruits not comparable in size to control fruits. Nonsprayed trees had insufficient fruits of this size for comparison.

‡ Juice analyses on representative samples of 100 fruits of comparable size.

The third experiment in which a 2,4-D spray prior to bloom influenced growth of the young fruit was in a grove of Thompson Navel oranges near Azusa. (Thompson Navel oranges are considered to be a strain of Washington Navel orange.) The experiment was of randomized block design of one tree per block per treatment and four replicates. The treatments were:

1. nonsprayed (control)
2. sprayed with 1⅔ per cent light-medium emulsive oil
3. same as 2, plus 10 p.p.m. 2,4-D added as the technical grade of isopropyl ester

The trees were sprayed, while bearing mature fruit, on February 28, 1947.

Fruit-drop counts to May 8, 1947, showed that the nonsprayed trees dropped 645.8 fruits per tree; those sprayed with oil alone dropped 510.0 fruits; while those sprayed with oil plus 10 p.p.m. 2,4-D dropped only 128.0 fruits.

On September 20, 1947, it was noted that the trees sprayed with 2,4-D had fewer fruits per tree, but that the fruits had thicker stems and were firmer and greener than those on the trees not sprayed with 2,4-D. There were no apparent differences between the fruits on the non-oil-sprayed trees and on those sprayed with oil alone.

TABLE 14

EFFECT OF A SPRAY CONTAINING 10 P.P.M. 2,4-D* ON SIZE, YIELD, AND QUALITY OF THOMPSON NAVEL ORANGES†

Factor	Non-sprayed (control)	Treatment			Least significant difference	
		No 2,4-D	2,4-D at 10 p.p.m.			
			All fruits	Large fruits‡	At 5 per cent	At 1 per cent
Field boxes per tree	3.42	3.15	2.83	.....	1.75	2.64
Weight of fruit per tree (kg)	109.0	101.7	88.1	.....	41.9	63.4
Number of fruits per tree	902	784	451	.....	441.4	668.7
Size:						
As weight per fruit (gm)	120	134	196	.....	26.7	40.4
As fruits per box	261	269	155	.....	81.9	124.1
As weight per fruit (gm)	133	137	135	247	.....	.....
As average diameter of fruits (cm)	6.43	6.45	6.45	7.90	.....	.....
Fruit quality:						
Rind (per cent)	49.9	54.1	54.4	60.7	.....	.....
Rag (per cent)	1.4	1.3	2.0	2.3	.....	.....
Juice (per cent)	48.7	44.6	43.6	37.0	.....	.....
Juice quality:§						
Soluble solids (per cent)	14.58	14.58	14.78	13.78	.....	.....
Total acid (per cent)	1.26	1.24	1.26	1.22	.....	.....
pH	3.42	3.39	3.40	3.38	.....	.....
Ratio soluble solids to total acid	11.6	11.8	11.7	11.3	.....	.....

* Applied as the isopropyl ester, in a 1⅔ per cent light medium, emulsive oil spray, on February 28, 1947, prior to bloom.

† Fruit harvested April 8, 1948. (Azusa experiment, 2,4-D application prior to bloom.)

‡ Large-sized fruits not comparable in size to "no-2,4-D" fruits. Non-2,4-D-sprayed trees had insufficient fruits of this size for comparison.

§ Juice analyses on representative samples of about 100 fruits of comparable size.

The fruit was harvested April 8, 1948. Table 14 shows that the fruits from the 2,4-D-sprayed trees were larger in size than those from the non-2,4-D-sprayed trees. Again, as in the previous experiment, yield, as number of fruits per tree, was reduced approximately 42 per cent as compared with a reduction of 10 per cent in terms of field boxes. The difference resulted from the increase in fruit size. No packing house statement of quality was available for this experiment; however, it appeared that the decrease in quality, as a result of the 2,4-D, was about the same as in the previous experiment. Laboratory analyses of fruit quality also gave results similar to those found in the previous experiment.

DISCUSSION

Mature Fruit-drop.—Results from the experiments described above indicate that 2,4-D is effective in reducing mature fruit-drop of Washington Navel oranges grown in California under a wide range of environmental conditions. The 2,4-D was consistently effective in reducing fruit-drop when applied from as early as October 15 to as late as April 15. In one instance (water spot Experiment 2), 2,4-D applied in June significantly reduced mature fruit-drop until the following May although in several other experiments no similar reduction was observed. Even the October 15 applications reduced fruit-drop as late as May 15, when the experiments were terminated. Oil sprays containing 2,4-D, and applied for pest control in August, were effective in reducing fruit-drop of navel oranges as late as the following May (Stewart, Riehl, and Erickson, unpublished).

An application of 2,4-D to reduce preharvest drop of Winesap and Stayman Winesap apples is effective over a longer period of time and to a greater degree than is naphthalene acetic acid (Batjer and Thompson, 1947). The reason for this difference between the effect of 2,4-D and naphthalene acetic acid on apples, and also for the long period of effectiveness of 2,4-D on citrus, is not known. It may be, in view of the numerous examples of the effects of 2,4-D on vascular growth, that in abscission 2,4-D likewise primarily modifies the physiology of the vascular elements in the abscission region (particularly the phloem) and only secondarily influences the other cells in that region.

Application of 2,4-D to reduce mature fruit-drop of navel oranges was successful at low volumes of solution per acre as well as by drenching sprays. As the volume of solution applied per acre was decreased, the concentration of 2,4-D was increased. Thus, 500 gallons of a 16-p.p.m. spray applied with a spray duster machine was found to be nearly as effective in reducing fruit-drop as was application by hand of 1,000 gallons of an 8-p.p.m. 2,4-D solution While still lower gallonages of solutions of higher concentrations applied with a spray duster were effective, they are not recommended for commercial use until more observations have been made.

In five experiments, 2,4-D applications were made successfully at volumes of less than 10 gallons per acre and at concentrations as high as 7,200 p.p.m. Generally, these were applied as a kerosene mist of small-droplet size by use of a Hi-Fog machine. In one experiment, the application was by helicopter, with an atomizing type of nozzle on the spray boom. Mature fruit-drop from lemon trees was reduced by application of 3 gallons per acre of a kerosene solution containing 2,400 p.p.m. 2,4-D (Stewart and Hield, 1950). These volumes are similar to those used for airplane application of naphthalene acetic acid on apples, where 5 gallons per acre of a 2,400 p.p.m. solution are generally used. Batjer and Thompson (1948) found that if droplets of this solution contacted one of the first three leaves subtending an apple, abscission was delayed; however, contact with the fourth leaf, or other leaves still farther from the fruit, failed to delay abscission. These data indicate that the effect of naphthalene acetic acid in reducing abscission may be transmitted short distances in apple trees. Comparable information concerning transmission of the abscission-delaying effect of 2,4-D in citrus has not yet been obtained.

In addition to delaying mature fruit-drop of navel oranges, application of 2,4-D has been observed to reduce fruit-stem dieback (Klotz and Stewart, 1948). Dieback is usually most severe in non-2,4-D-sprayed groves toward the end of the harvest season, when the fruit may not drop, but desiccates and shrinks on the tree. The branch may die back several inches to several feet from the fruit, thus reducing the amount of fruit-bearing wood for succeeding crops. In the third experiment described above under the section "Application prior to bloom," fruit-stem dieback, when observed on May 20, 1947, was reduced from 87 per cent of the fruits on non-2,4-D-sprayed trees to 8 per cent on those sprayed with 2,4-D. Observations confirming this response were made on Valencia orange trees and grapefruit.

Application of 2,4-D as a dust at concentrations of 500 or 1,000 p.p.m. was not so successful in reducing fruit-drop as was application of 2,D-4 in solution. Dust applications of growth regulators for preharvest apple drop control have given variable results and are not recommended for commercial use (Vyvyan, 1946).

One commercial storage test of navel oranges from trees sprayed with 25 p.p.m. 2,4-D, and on which fruit-drop was reduced by the spray, indicated that the treatment reduced aging and "black-buttons" as compared with fruits from nonsprayed trees (Baker and Nedvidek, 1947). Although further data are necessary, this observation at least indicates no undesirable effects of 2,4-D on storage of navel orange fruits. Studies on the effect of sprays of 2,4-D on lemon trees, and of packing house applications of 2,4-D on lemons after harvest have indicated that such treatments increase the storage life of the fruits (Stewart, 1948).

"June Drop."—The June drop (shedding of young fruit in the late spring or early summer) of Washington Navel oranges is particularly severe—more so than with other citrus fruits. It is most severe in the hot, dry, inland valleys of California where high spring temperatures may abruptly follow a cold winter. Studies have indicated that these severe climatic conditions are the primary cause of the drop (Hodgson, 1917; Coit and Hodgson, 1917, 1919).

Experiments to study the effect of sprays of 2,4-D and other growth regulators on June drop of navel oranges were conducted from 1946 to 1949. In some instances a delay, but no permanent reduction, in June drop was observed (Stewart and Klotz, 1947). In other experiments, where the sprays were applied at full bloom (for example, the Edison experiment of 1948), the number of fruits harvested was actually decreased as a result of the 2,4-D applications. From these data it appears that, in addition to preventing abscission of the young fruits, other factors are necessary to allow the fruits to continue growth to maturity. Application of the growth regulators used in these experiments failed to accomplish this result. Although these experiments did not increase yield, they did show that 2,4-D could induce an increase in fruit size, delay fruit maturity, and modify fruit quality. Some of the changes in quality were in the direction of those commonly found in large-sized fruits on non-2,4-D-treated trees—for example, a coarse, pebbly, and thick rind.

Water Spot.—In certain citrus-growing districts of southern California, there is a considerable loss of Washington Navel oranges as a result of water

spot. This condition occurs in the winter harvest season during prolonged periods of damp or wet weather. It manifests itself as a somewhat translucent, water-soaked area in the rind, varying in size from a few to 50 millimeters or more in diameter. Severely water-spotted fruit is not marketable. Susceptibility to water spot increases with fruit maturity and is greater in fruits on trees sprayed with oil in the late summer, for pest control, than in fruits from non-oil-sprayed trees (Klotz, *et al.*, 1949).

Tests of water spot susceptibility of fruit from trees sprayed in June, 1946, with 75 p.p.m. 2,4-D indicated that such fruits were more resistant than those from nonsprayed trees. Accordingly, further experiments have been conducted every year since that time. It was found that application of 48 p.p.m. 2,4-D in June reduced subsequent water spot, so that it was only slightly greater than that from non-oil-sprayed (fumigated) trees. This was considered to result mainly from the delayed maturity of the fruit although the percentage of rind was also increased as a result of the 2,4-D. A spray containing 24 p.p.m. 2,4-D was less effective in reducing water spot than was a 48-p.p.m. spray. Application of a solution containing more than 48 p.p.m. 2,4-D is not considered practical from a commercial viewpoint because, while water spot resistance might be increased, so also would the possibility of lowered fruit quality. The gain in marketable fruit by further control of water spot would probably not compensate for the reduction in value due to poor quality.

Fruit Size.—In the experiments on water spot, as in the June drop studies, it was found that 2,4-D sprays applied to the young fruits tended to produce mature fruits of a large size. It was observed also that applications of 2,4-D, at sufficiently high concentrations, six to eight weeks prior to flowering induced large fruit size.

In the first experiment, 2,400 or 7,200 p.p.m. 2,4-D as the isopropyl ester was applied about eight weeks before flowering. It was combined with light-medium spray oil and dispersed among the trees as a fine mist or fog at less than 5 gallons per acre.

Investigations have shown that spray-oil residues may persist in intercellular spaces of citrus leaves for as long as two years (Rohrbaugh, 1941). It seems likely, therefore, that there was sufficient residual 2,4-D present to influence the growth of young fruits even if there was not a direct effect on flower primordia at the time of application.

The relatively nonvolatile diethanolamine salt of 2,4-D was applied at 25 p.p.m. in the second experiment, about six weeks before flowering. From application of similar alkanolamine salts of 2,4-D on lemons, there is evidence that this form of 2,4-D persists on the fruits and trees longer than do the ester forms (Stewart and Palmer, unpublished; Stewart and Hield, 1950). Furthermore, it was noted in the June drop experiments reported here, that as little as 4 p.p.m. of 2,4-D at full bloom significantly increased fruit size. The third experiment was based on application of a drenching oil spray containing 10 p.p.m. of the isopropyl ester of 2,4-D. The spray was applied about seven weeks before flowering. Again, as in the first experiment, in view of the long persistence of spray-oil residues, it is quite likely that 2,4-D residues were present at flowering and during fruit growth, along with the oil residues.

Fruit on trees sprayed with 2,4-D was larger in size at harvest primarily because it had an accelerated growth rate. Contributing factors may be: (1) the fruit has an increased amount of stem in proportion to the amount of fruit; (2) there is a direct effect on the growth of the tissues as shown, for example, by the development of rudimentary seeds in navel oranges and of navels in Valencia oranges and grapefruit (Stewart and Klotz, 1947; Stewart and Parker, 1947); and (3) there is, in some cases, a reduced number of fruits per tree. Extensive observations on the effect of 2,4-D applications on Valencia oranges to increase fruit size have led to similar conclusions (Stewart, Hield, and Brannaman, unpublished).

It is difficult to determine the influence of each of the above factors alone on fruit growth. It seems that fruit thinning (reduction of number of fruits per tree) is probably not a major factor since in several of the experiments reported here, increases in size were obtained with no reduction in number of fruits per tree. Furthermore, even when the number of fruits was reduced approximately 50 per cent by hand thinning (Parker, 1934), there were no size increases as large as some of those from 2,4-D sprays.

Application of 2,4-D at concentrations as low as 4 p.p.m. induced a curling and distortion of any young leaves present, but subsequent new growth was usually not distorted (Stewart and Klotz, 1947). Applications of less than 25 p.p.m. 2,4-D between leaf growth flushes generally induced little, if any, distortion of the subsequent young leaf growth. In some instances, however, when concentrations approaching 25 p.p.m. 2,4-D were applied as an inorganic or alkanolamine salt there was a leaf curling. This rarely was observed from applications of less than 25 p.p.m. 2,4-D as an ester.

An attempt to eliminate the leaf-curling effect of 2,4-D was made by including activated carbon (Norit A) in the spray solution. However, when sufficient Norit A was added to eliminate leaf curling, the effect of 2,4-D in reducing fruit-drop was also eliminated.

On navel orange trees over five years of age, the leaf curling resulting from 2,4-D applications has not been found to reduce yield or fruit quality. This may be owing to the fact that the trees produce several growth flushes a year, so that even if the leaf distortion slightly reduced the efficiency of the leaves of one growth flush, it would be compensated for by succeeding growth cycles. Since the new foliage in each growth flush on a tree less than five years of age represents a much greater percentage of the total leaf surface than it does on older trees, application of 2,4-D to young trees might be detrimental.

In two experiments, annual applications of 8 p.p.m. 2,4-D in an oil spray for pest control have been made for four years on Valencia orange trees (Stewart, Riehl, and Erickson, unpublished). There have been no indications of injurious or detrimental effects of the 2,4-D on these trees.

Application of 2,4-D has been observed to induce modification of young leaf growth of apples, pears, and peaches (Marsh and Taylor, 1947; Batjer, Thompson, and Gerhardt, 1948; Teske and Overholser, 1947).

Since 1947, when instructions for the use of 2,4-D on citrus fruits were first made available (Stewart, 1947), it has been applied commercially by numerous operators, using various methods, on a large acreage of navel orange trees. Generally, the 2,4-D was added to a mixture containing other spray chemicals,

such as zinc, manganese, and the like. Thus far, there is no spray chemical with which 2,4-D has been found to be incompatible. In nearly all cases satisfactory control of fruit-drop was reported. No reports of reduced yield, lower fruit quality, or tree injury have been received when instructions were followed.

In a few instances the complaint was made that the 2,4-D spray reduced the drop of cull (unmarketable) fruits as well as of sound fruits, and that the increased cost of removing the culls after harvest nullified the savings in sound fruits. This view is not generally held, however, and when a severe drop of mature navel orange fruit is anticipated, or in progress, spraying with 2,4-D is becoming standard practice.

SUMMARY AND CONCLUSIONS

From 1946 to 1950, 43 field experiments were conducted with navel orange trees to determine the effects of applications of 2,4-D and other plant growth regulators on mature fruit-drop, June drop of young fruits, water-spot susceptibility of fruits, yield, fruit size, and fruit quality. It was found that:

1. Application of an 8-p.p.m. 2,4-D solution as a drenching spray (i.e., 1,000 gallons per acre or more) reduced mature fruit-drop 56 per cent, on the average, as compared with nonsprayed trees.

2. Application of a 16-p.p.m. 2,4-D solution at 500 gallons per acre, by means of a spray duster or some similar machine, resulted in a satisfactory commercial control of mature fruit-drop.

3. Application of 2,4-D for fruit-drop control was made successfully as early as October 15 and as late as April 15. These applications were effective in reducing drop at least until the following May when the fruit was harvested.

4. Very low-volume applications (less than 10 gallons per acre) of high concentrations (2,400 p.p.m.) of 2,4-D were effective in reducing fruit-drop when applied, as a fog or fine mist, by helicopter or by a high-pressure spray gun with an extremely small disk orifice.

5. Application of 2,4-D as a dust was not so effective as was a spray for reducing fruit-drop.

6. No increase in yield was observed as a result of a decrease in June drop from application of 2,4-D in various forms or concentrations, or from other growth regulators tested.

7. June application of a spray containing 24 p.p.m. 2,4-D appreciably reduced water-spot susceptibility of the fruit.

8. Applications of 2,4-D to young fruits, or prior to bloom, at sufficiently high concentrations, generally induced an increase in fruit size at harvest. The increase was usually proportional to the concentration of 2,4-D. The size increase was primarily due to an accelerated growth rate. Factors apparently contributing to this were: (1) an increased diameter of fruit stem (pedicel) in proportion to the fruit diameter; (2) an increased growth of various fruit tissues in direct response to the 2,4-D; and (3) in some cases, especially when applications were made at high concentrations near flowering, a reduction of the number of fruits per tree.

ACKNOWLEDGMENTS

Appreciation is expressed to the numerous growers, pest control operators, and packing house men who coöperated in this work, as well as to the various chemical companies who contributed growth regulators. Mr. A. N. Kasimatis and Mr. J. D. Axtell, Farm Advisors of Kern County, greatly facilitated the Edison experiments.

The excellent assistance by technicians L. Brannaman and T. De Wolfe greatly facilitated the study. Refractometric measurements of the soluble solids in juice samples were kindly made by Dr. E. T. Bartholomew.

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