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EFFECTS OF 2,4-D AND RELATED SUBSTANCES ON FRUIT-DROP, YIELD, SIZE, AND QUALITY OF GRAPEFRUIT

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From 1947 to 1950, 34 field experiments were conducted to study the effects of applications of 2,4-D and related substances on fruit-drop, yield, size, and quality of grapefruit in California. It was found that water sprays of 8 ppm 2,4-D reduced mature fruit-drop an average of 44 per cent, as compared with nonsprayed trees, and that this response to 2,4-D occurred under a wide range of climatic and environmental conditions. This spray was more effective in reducing fruit-drop when applied in May than when applied in July, and annual applications of 2,4-D for three years have shown no accumulative detrimental effects. The differences in fruit-drop resulting from the use of various forms of 2,4-D were not great.

Thus far, 2,4-D has not proved incompatible with any agricultural spray chemicals, and has been effective in reducing mature fruit-drop when applied in conjunction with other spray treatments. The 2,4-D sprays had no undesirable effects on the quality of fruit which was mature, or nearly mature, at the time of spraying.

Trees sprayed with 2,400 ppm 2,4-D as a kerosene "aeromist" at less than 10 gallons per acre showed a reduction in mature fruit-drop, as compared with nonsprayed trees, but this method cannot yet be recommended for commercial use. A water spray of 8 ppm 2,4,5-T was as effective as an 8 ppm 2,4-D spray in reducing mature fruit-drop. A spray of 25 ppm naphthaleneacetic acid was not effective, and a spray of 25 ppm naphthoxyacetic acid was only slightly effective.

Application of 8 ppm 2,4-D to trees with young, expanding leaves induced a curling and deformation of the leaves. Subsequent leaf growth was normal. Application of the spray between leaf growth flushes minimized the distortion. No influence on yield or fruit quality was noted as a result of the leaf curl.

There was an increase in fruit size of commercial value if the correct concentration of 2,4-D was sprayed on trees bearing fruit less than 16 weeks old. However, the fruit quality was lowered when trees bearing young fruit (less than 16 weeks) were sprayed with 2,4-D at too high a concentration in relation to the stage of fruit growth. A lowering in quality as a result of an 8 ppm 2,4-D spray was observed in only one experiment, where the application was made on trees in full bloom.

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W. S. STEWART[3] and E. R. PARKER[4]

INTRODUCTION

IN 1946, preliminary studies based on two field experiments indicated that it was possible to reduce preharvest fruit-drop and modify fruit growth of grapefruit by foliage sprays of from 5 to 225 ppm 2,4-D (2,4-dichlorophenoxyacetic acid) (Stewart and Parker, 1947).[5] Subsequently, 34 experiments were conducted throughout southern California to determine whether similar responses would be obtained in different districts, whether various formulations and times of application would differ in effectiveness, and what effects repeated, annual 2,4-D applications would have. Results on fruit-drop, size, yield, and fruit quality are reported in this paper.

EXPERIMENTAL DESIGNS

"Latin Square."—This design, with four trees per plot, was used in the longer-term experiments. These trials were conducted to determine the effects of 2,4-D and other growth regulators when applied to the same trees for one, two, or three years. In 1947, all of the four trees per plot received the same treatment. In 1948, two of the four trees were resprayed, but the other two were not. In 1949, one of the two trees resprayed in 1948 was resprayed again, but the other tree was not, nor were the two that had been sprayed only in 1947. Thus, for each treatment, one tree received three annual sprayings, one received two sprayings, and two trees received one spraying. The sprayed trees were separated in every direction from adjoining, treated trees by "buffer" or guard trees that intercepted any spray drift.

"Randomized Block."—From five to 12 trees per replicate per treatment were used for this design. The purpose of these experiments was to study the effect of 2,4-D sprays on fruit-drop and fruit size of grapefruit.

[1] Received for publication February 10, 1953.
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[5] See "Literature Cited" for citations, referred to in the text by author and date.

"Miscellaneous."—These plots were generally established in conjunction with a commercial spray application, and were used in simpler field trials. The experiments were mainly concerned with preharvest drop, and usually involved only a comparison between treated and nontreated trees. For this purpose, fruit-drop was determined from a minimum of eight treated and eight nontreated trees of comparable size and in as comparable locations as possible. (Often the nontreated trees were located along both sides of a treated row.)

Unless noted otherwise, all applications were made as drenching water sprays, with standard equipment. The source of 2,4-D was commercial formulations for weed killing. Fruit-drop was determined by removing all the fruits on the ground underneath the tree immediately after spraying, and by counting all subsequently dropped fruits. Yield was determined by counting the number of field boxes; partially filled boxes were estimated to the nearest tenth of a box. Fruit size was measured either by counting the number of fruits per field box, by measuring the diameter of every tenth fruit harvested, or by converting packing-house fruit sizes. Juice quality was determined by usual standard analytical procedures. Fruit quality was determined from observations of the amount of rind, rag, and juice; from packing-house grading statements; or from both sources. Representative samples for fruit and juice quality analyses usually consisted of 80 fruits. In all comparable samples, the fruits were of uniform size.

METHODS AND RESULTS

Three-year Experiments

Fillmore Experiment.—The first of the five Latin square experiments (which were continued for three years) was near Fillmore. The treatments were: (1) control, nonsprayed; (2) 8 ppm 2,4-D as the diethanolamine salt; (3) 4 ppm 2,4-D as the diethanolamine salt; (4) 25 ppm naphthaleneacetic acid; and (5) 25 ppm naphthoxyacetic acid. The latter two substances were dissolved in alcohol and then added, with agitation, to the water in the spray rig tank.

Fruit-drop per tree, from the time of the first spraying (May 1, 1947) until harvest (August 27, 1947), averaged 117.4 fruits from the nonsprayed trees, 60.1 fruits from those sprayed with 8 ppm 2,4-D, and 92.9 from those sprayed with 4 ppm (table 1). The probability that these reductions in fruit-drop, as a result of treatment, would occur by chance is less than 5 per cent. The other treatments failed to alter the fruit-drop.

The yield at harvest, as would be expected from these results, was greatest from the trees sprayed with 8 ppm 2,4-D, but the difference, compared with nonsprayed trees, fell somewhat short of significance at 5 per cent (table 1). None of the yield increases resulting from the other treatments was so great, although all treatments yielded more than did the control trees. There were no significant differences in fruit size among any of the treatments. Detailed studies also failed to show any appreciable effects on fruit quality.

TABLE 1

EFFECT OF WATER SPRAYS OF VARIOUS PLANT GROWTH REGULATORS ON FRUIT-DROP, PRODUCTION, SIZE, AND QUALITY OF GRAPEFRUIT
(Three-year Fillmore experiment. 5 × 5 Latin square, 4 trees (A, B, C, D) per plot)

Factor	Treatment					Least significant difference	
	Non-sprayed control	2,4-D* 8 ppm	2,4-D† 4 ppm	NAc‡ 25 ppm	NAx§ 25 ppm	At 5 per cent	At 1 per cent
Trees A, B, C, and D sprayed May 1, 1947; harvested August 27, 1947							
Fruit-drop per tree	117.4	60.1	92.9	125.6	102.1	47.7	65.6
Yield, as field boxes per tree	7.78	10.32	9.00	8.66	9.20	n. s.	....
Size, as fruits per field box	73.6	73.2	73.5	71.8	77.5	n. s.	....
Trees A, B resprayed May 4, 1948; harvested July 21, 1948							
Fruit-drop per tree	36.3	11.9	20.7	37.4	27.9	14.5	20.3
Yield, as field boxes per tree	7.74	7.46	8.08	7.58	7.70	n. s.	....
Size, as fruits per field box	65.4	62.0	65.2	66.1	61.6	n. s.	....
Trees C, D not resprayed 1948; harvested July 21, 1948							
Fruit-drop per tree	36.2	23.8	42.2	51.0	37.8	14.3	20.1
Yield, as field boxes per tree	7.74	7.42	6.76	7.94	6.50	n. s.	....
Size, as fruits per field box	65.4	61.8	65.4	65.2	67.2	n. s.	....
Fruit quality, trees A, B, C, D; harvested July 21, 1948							
Rind (per cent)	47.6	47.2	48.3	41.0	47.2	....	....
Rag (per cent)	5.9	8.4	7.3	8.5	8.6	....	....
Juice (per cent)	45.9	44.0	43.7	51.1	43.2	....	....
Soluble solids (per cent)	10.17	10.23	9.97	10.17	10.23	....	....
Total acid (per cent)	2.04	3.24	1.92	1.89	1.89	....	....
Ratio soluble solids to total acid	4.98	3.16	5.20	5.38	5.41	....	....
pH	2.84	2.82	2.82	2.86	2.84	....	....
Tree A resprayed May 10, 1949; harvested July 19, 1949							
Fruit-drop per tree	13.0	6.6	12.2	12.4	11.6	n. s.	....
Yield, as field boxes per tree	9.50	10.90	9.54	10.80	11.30	n. s.	....
Size, as fruits per field box	83.0	84.4	77.2	73.8	85.3	n. s.	....
Tree B not resprayed May 10, 1949, but sprayed in 1947 and 1948							
Fruit-drop per tree	13.0	11.4	8.6	16.6	17.2	n. s.	....
Yield, as field boxes per tree	9.50	10.70	10.80	10.90	10.70	n. s.	....
Size, as fruits per field box	83.0	89.2	79.4	75.6	81.6	n. s.	....
Trees C, D not resprayed in 1948 or 1949; sprayed in 1947 only; harvested July 19, 1949							
Fruit-drop per tree	12.7	15.2	15.4	16.1	18.4	....	....
Yield, as field boxes per tree	9.50	10.40	10.60	11.50	9.10	....	....
Size, as fruits per field box	83.4	80.7	81.7	74.9	86.2	....	....

* 2,4-D as diethanolamine in 1947, triethanolamine 1948, and as 4 ppm butyl ester in lanolin emulsion 1949.
† 2,4-D as diethanolamine in 1947, triethanolamine in 1948 and 1949.
‡ NAc is napthaleneacetic acid; in 1948 and 1949 the trees were resprayed with 4 ppm 2,4-D as isopropyl ester.
§ NAx is naphthoxyacetic acid; in 1948 and 1949 the trees were resprayed with 4 ppm 2,4-D as the butyl ester.

In view of the failure of naphthaleneacetic acid and naphthoxyacetic acid to reduce preharvest drop, these two treatments were replaced, in 1948, by 4 ppm 2,4-D as the isopropyl ester and by 4 ppm 2,4-D as the butyl ester. The triethanolamine salt of 2,4-D was used in place of the diethanolamine salt.

The second spray was applied on May 4, 1948, to trees A and B of each plot, leaving trees C and D unsprayed at that time. No significant differences in drop, among any of the treatments, were observed the following year on May 5, 1948, before respraying. Fruit-drop counts from May 5, 1948, to July 21, 1948, showed that the average fruit-drop per tree was 36.3 from the nonsprayed trees and 11.9 from those sprayed with 8 ppm 2,4-D. The decrease in fruit-drop was significant at the 1 per cent probability level. The drop from trees sprayed with 4 ppm 2,4-D averaged 20.7 fruits per tree, and in this case the decrease in drop was significant at 5 per cent. Other treatments failed to affect the fruit-drop appreciably (table 1). The fruit-drop from all the trees was not so great in 1948 as in 1947, perhaps because of the earlier harvest date. This may also account for the fact that there were no significant differences in yield among the treatments when the trees were harvested on July 21, 1948. There were likewise no significant differences in fruit size or quality.

In 1948, there was some indication of a reduction in drop of mature fruit from the trees (C and D) that had been sprayed with 8 ppm 2,4-D in May, 1947, but which were not sprayed prior to harvest in 1948. This reduction almost attained statistical significance at 5 per cent. Since a similar trend was noted in other experiments, this response may actually be real even though, in this case, it was not significant at odds of 19 to 1.

Quality analyses of the fruit harvested in 1948 are also shown in Table 1. These fruit were young and actively growing at the time of spraying in 1947. It was found that all of the treatments had induced an increase in the percentage of rag[6] in the fruit. Since quality analyses in 1947 indicated no effect of the sprays applied on nearly mature fruit, it is likely that this response was due to the 1947 spray and not to the 1948 treatments. Except for fruit from trees sprayed in 1947 with 25 ppm naphthaleneacetic acid, the amount of juice was about 2 per cent less in the sprayed fruit than in fruit from nonsprayed trees, but there were no appreciable differences in the percentage of rind. Fruit from trees sprayed with naphthaleneacetic acid in 1947 had about 14 per cent less rind, but more juice and rag, than did fruit from nonsprayed trees. (This observation needs further substantiation before being finally accepted.)

With regard to juice quality, it was found (table 1) that there were only slight differences among the treatments in the percentage of soluble solids and, except for fruit from trees sprayed with 8 ppm 2,4-D in 1947, in the percentage of total acids. The acid percentage in fruit from trees receiving the 8 ppm 2,4-D spray was appreciably increased. This may have reflected a delay in fruit maturation as a result of the treatment. There was little effect on pH of the juice.

[6] Tissue not passing through the vibrating screen of an electric juice extractor.

On May 10, 1949, one of the two trees in each plot that had been sprayed in 1948 (tree A), was sprayed for the third consecutive season. The treatments were the same except that the 8 ppm 2,4-D spray was changed to 4 ppm 2,4-D as the butyl ester, formulated at 13 per cent free acid equivalent in a lanolin emulsion.[7] Thus, all of the trees sprayed at that time received 4 ppm 2,4-D, but in various forms and formulations.

Fruit-drop counts to harvest time (July 19, 1949) showed that the nonsprayed trees had dropped an average of 13.0 fruits per tree, whereas those sprayed in May, 1949, with 4 ppm 2,4-D as the butyl ester in a lanolin emulsion formulation, dropped 6.6 fruits (table 1). This small difference was not statistically significant. Likewise, none of the other 4 ppm 2,4-D sprays, including the butyl ester form, induced a significant fruit-drop reduction.

Comparisons of data obtained on trees sprayed in May for the third successive season (tree A in each plot) with similar data from trees sprayed either in 1947 only, or in both 1947 and 1948, failed to show any real difference in fruit-drop. In the case of yields, production in 1949 tended to be greater from trees receiving the 2,4-D sprays in both 1947 and 1948 (tree B; or, in 1947, 1948, and 1949, tree A) than from the nonsprayed trees. The increases were not, however, significant at the 5 per cent level. It is apparent that there were no indications of a reduced yield as a consequence of the use of 2,4-D sprays for three years.

As in the 1948 harvest, no trends or significant differences in fruit size were noted among any of the treatments.

No studies were made of the quality of the fruit harvested in 1949 from trees in the Fillmore experiment. Casual observations showed no apparent effects of the various treatments.

Arlington Heights Experiment.—The additional four Latin square experiments were established near Arlington Heights. The trees were about 15 years old at the start of the experiments.

The first of these experiments was designed to study the effects of 8 ppm 2,4-D applied as the diethanolamine salt (1947) or the triethanolamine salt (1948 and 1949), in May, June, or July. As in the Fillmore experiment, each of the four trees in each treated plot was sprayed in 1947; two of these trees (A, B) were resprayed in 1948; while one tree (A) was sprayed for the third time in 1949. By this procedure, both the accumulated effects and the aftereffects of the sprays could be determined.

The results of this experiment are given in Table 2. In the first year of the treatments (1947), the May application resulted in an average reduction of drop amounting to 39.2 fruits per tree (from 86.7 to 47.5), while the June and July sprays reduced the drop to 31.4 and 28.0 fruits per tree, respectively, in the period from July 21 to time of harvest on September 9, 1947. These reductions were statistically significant at 5 per cent. The increased value of the May treatment indicated by these results appears to be due to the longer period of time through which the spray was effective on the trees.

In 1948, the drop of mature fruit was light in the period from May 11 to time of harvest on August 23, and the spray applied that year (to trees A and B) failed to cause significant reduction in drop, although all treatments

[7] Furnished by the Sherwin-Williams Company.

TABLE 2

EFFECT OF 2,4-D ON FRUIT-DROP, YIELD, SIZE, AND QUALITY OF GRAPEFRUIT

(Three-year Arlington Heights experiment. 4 × 4 Latin square, 4 trees (A, B, C, D) per plot)

Factor	Treatment				Least significant difference	
	Nonsprayed control	8 ppm 2,4-D applied in*			At 5 per cent	At 1 per cent
		May	June	July		
Trees A, B, C, D sprayed 1947; harvested Sept. 9, 1947						
Fruit-drop per tree (after July 21)...	86.7	47.5	55.3	58.7	27.8	45.0
Yield, as field boxes per tree.....	4.53	4.54	4.91	4.83	n. s.	....
Size, as fruits per field box.....	72.6	73.6	72.1	71.5	n. s.	....
Trees A, B resprayed 1948; harvested August 23, 1948						
Fruit-drop per tree (after May 11)..	16.0	11.4	14.1	13.8	n. s.	
Yield, as field boxes per tree.....	3.26	3.37	3.11	2.75	n. s.	
Trees C, D not resprayed 1948; harvested August 23, 1948						
Fruit-drop per tree (after May 11)..	20.4	15.1	19.0	13.1	n. s.	....
Yield, as field boxes per tree.....	4.41	2.81	2.87	2.22	1.46	2.21
Tree A resprayed 1949; harvested August 15, 1949						
Fruit-drop per tree (after July 8)...	20.3	9.5	11.7	13.0	7.9	12.4
Yield, as field boxes per tree.....	3.65	6.25	4.75	6.37	1.28	1.93
Tree B not resprayed in 1949 but sprayed in 1947 and 1948; harvested August 15, 1949						
Fruit-drop per tree (after July 8)...	29.7	19.0	28.3	22.3	n. s.	
Yield, as field boxes per tree.....	4.15	3.95	5.13	4.07	n. s.	
Trees C, D not resprayed in 1948 or 1949, but sprayed in 1947; harvested August 15, 1949						
Fruit-drop per tree (after July 8)...	23.4	19.9	18.0	21.3	n. s.	
Yield, as field boxes per tree.....	4.87	4.31	3.90	4.75	n. s.	

* Applied as the diethanolamine salt in 1947; as the triethanolamine salt in 1948 and 1949.

tended to cause some reduction. The trees that were not resprayed in 1948 (C and D) also tended to drop fewer mature fruits than did control trees which had never been sprayed, but this reduction was likewise not significant.

In 1949, fruit-drop counts were made between July 8 and time of harvest on August 15. During that period the drop was relatively light. However, the trees sprayed in that year (trees A), as well as in 1947 and 1948, dropped a significantly smaller number of fruits than did their controls. They also dropped less fruit than did the trees (B) sprayed in 1947 and 1948 only, or

those (C and D) sprayed only in 1947. The trees sprayed only in the earlier years dropped almost, but not quite, as many fruits as did their controls.

No data on fruit size were obtained in 1948 or in 1949, but size measurement on fruit harvested in 1947 showed no significant differences as a result of the treatments.

Except in 1947, sprays applied about the first of May, June, or July caused nearly equal effects in fruit-drop. In 1947, the May sprays caused greater reduction in fruit-drop than did the June or July sprays. In that year, the harvest period was later than in 1948 or 1949, and the number of dropped fruits was consequently larger. The effects of time of spraying might have been greater had the preharvest drop been more severe in the last two years.

The yields from all treatments in this experiment are low for grapefruit. Since the trees in this orchard may alternate in yields, the data are perhaps not critical in regard to the cumulative effects of the treatments on yield. Statistically, the data show that, compared with nonsprayed trees: (1) Trees sprayed with 2,4-D annually for three consecutive years (trees A) yielded more fruit during the third year; (2) trees sprayed for two years (trees B), but not three, failed to show any significant yield differences during the third year; and, oddly, (3) trees sprayed only once (1947, trees C and D) yielded less fruit in 1948 but showed no significant difference in 1949. These observations require additional data to establish their reproducibility. This is especially true of the last one in view of results obtained to the contrary in the Fillmore and other experiments.

The remaining three Latin square experiments at Arlington Heights were conducted in an effort to determine the effects of 8 ppm 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) and of 8 and 16 ppm 2,4-D in comparison with nontreated, control trees. One Latin square experiment was treated about May 1, another about June 1, and the third about July 1 of each year. As in the other experiment at Arlington Heights, four trees were sprayed in each treated plot in 1947, two (A and B) were resprayed in 1948, and one (A) was resprayed again in 1949. In 1947, the 2,4,5-T was applied as the free acid, and in 1948 and 1949, as the butyl ester. The 2,4-D was applied as the diethanolamine salt in 1947, and in 1948 and 1949, as the triethanolamine salt.

In 1947, the first year of the experiment, the fruit-drop was reduced on trees A, B, C, and D by 52.8 per cent as a result of the May application of the various materials, while June applications reduced drop 44.4 per cent, and July applications, 35.2 per cent. In 1948, the trees sprayed in May for the second season (A and B) dropped 44.9 per cent less fruit than did the check trees; the June-sprayed trees dropped 35.0 per cent less than their controls; and those sprayed in July showed no reduction in fruit-drop, probably because of the slight amount (5.3 fruits per tree) dropped from the nonsprayed trees. In 1949, the trees (A) sprayed for the third consecutive year in May and June dropped 42.3 per cent and 46.7 per cent less fruit, respectively, than did their controls, while the July-sprayed trees dropped only 19.3 per cent less than their controls. From these data it is evident that sprays in May were most effective on trees sprayed the first or second season,

while in the third season, sprays in May and June were equally effective in reducing the drop of mature fruit.

There appeared to be no cumulative effects on preharvest drop from spraying for one, two, or three consecutive years. The average reduction in drop in the first year of spraying (with all materials at all treatment dates) was 44.1 per cent, while after two and three years of treatments, the average reductions were 39.9 and 36.1 per cent, respectively.

Interesting effects on preharvest drop were noted when 2,4,5-T and 2,4-D sprays were discontinued. In the 1948 crop, fruit-drop from all C and D trees (sprayed in 1947 but not in 1948) averaged 19.5 per cent less than the drop from the nonsprayed trees. In the 1949 crop, the preharvest drop from trees (B) sprayed in 1947 and 1948, but not in 1949, was reduced an average of 15.7 per cent in all plots, while the drop from trees sprayed in 1947 (but not 1948 or 1949) was reduced by 12.3 per cent. These reductions represent roughly one-third the amount of drop observed from trees that were sprayed in the year of harvest. Thus there was apparently some residual effect of the spray treatments for two years after spraying. This residual response was not affected by the nature of the different materials used in these trials nor by the month in which they were applied.

The effects of time of spraying on yields are somewhat conflicting, partly because of the alternate bearing of the trees and partly because of the high variability which required large differences for statistical significance. In 39 cases, yield was apparently increased as a result of the treatment. Three of these cases were statistically significant. In 18 cases there was an apparent decrease in yield, although only one of these was statistically significant.

Unfortunately, it was not possible to obtain adequate data, in this series of experiments, to demonstrate the effects of these preharvest sprays on fruit size. Fruit counts made on the 1947 crop failed to indicate a significant effect in this respect, and on the basis of other work none was expected. On the average, there were 76.0 fruits per field box in the crop harvested from the sprayed trees and 77.4 fruits per field box in the crop from untreated trees. No data were obtained in 1948.

In 1949, a separate picking was made to harvest the large-sized fruits (100 or fewer per box, minimum diameter 3.5 inches) from all trees sprayed in May or July of 1948. By this procedure, large-sized fruits were picked from all of the treated trees and from those which had never received treatment. It was found that, on the average, the treated trees produced 13.6 per cent more field boxes of large-sized fruits than did the nonsprayed trees. This suggests that young grapefruit respond to application of 2,4-D and that their size increase is similar to that observed in Washington Navel and Valencia oranges (Stewart, Klotz, and Hield, 1951; Stewart, Hield, and Brannaman, 1952).

To determine the average effects of the various spray formulations on yield and fruit-drop, the data resulting from applications in May, June, and July were combined in Table 3. Yield from treated trees appeared to be increased in 10 cases by an average of about 17 per cent, and to have decreased an average of 3 per cent in seven cases.

TABLE 3

AVERAGE EFFECTS OF 2,4,5-T AND 2,4-D ON FRUIT-DROP, YIELD, AND SIZE OF GRAPEFRUIT

(Three-year Arlington Heights experiment. Trees sprayed about first of May, June, or July)

Factor	Nonsprayed control	Average increase (+) or decrease (−) from control, per cent		
		8 ppm 2,4,5-T*	8 ppm 2,4-D†	16 ppm 2,4-D†
Trees A, B, C, D sprayed 1947; harvested 1947				
Fruit-drop per tree	110.7	−42.6	−43.3	−54.3
Yield, field boxes per tree	6.44	+ 2.2	− 3.7	− 2.2
Size, as fruits per field box	77.4	− 3.6	− 2.7	+ 0.8
Trees A and B resprayed 1948; harvested 1948				
Fruit-drop per tree	12.6	−26.2	−27.0	−46.8
Yield, field boxes per tree	2.59	+14.3	+22.8	+19.3
Trees C and D not resprayed 1948; harvested 1948				
Fruit-drop per tree	14.1	−19.1	− 9.7	−28.4
Yield, field boxes per tree	3.1	− 3.2	− 4.9	+ 9.8
Tree A resprayed 1948 and 1949; harvested 1949				
Fruit-drop per tree	28.4	−31.2	−44.6	−56.8
Yield, field boxes per tree	5.9	0.0	− 1.0	+13.3
Tree B not resprayed 1949, but sprayed 1947 and 1948; harvested 1949				
Fruit-drop per tree	29.1	− 8.9	−12.3	−24.7
Yield, field boxes per tree	4.9	+31.6	+21.1	+18.7
Trees C and D not resprayed 1948 or 1949, but sprayed in 1947: harvested 1949				
Fruit-drop per tree	29.2	−23.2	−13.3	−12.3
Yield, field boxes per tree	5.1	+16.9	− 4.3	− 2.3

* Applied as the free acid in 1947; as the butyl ester in 1948 and 1949.
† Applied as the diethanolamine salt in 1947; as the triethanolamine salt in 1948 and 1949.

Single-year Experiments on Fruit-drop and Fruit Sizes

Additional experiments to study the effect of 2,4-D sprays on fruit-drop and fruit size of grapefruit were established in Ventura County. Two experiments, of the randomized block type, were near Saticoy and Camarillo, respectively, while one experiment, of a paired comparison design, was near Fillmore, a location more inland than the first two.

Saticoy Experiment.—The trees in this randomized block experiment were sprayed while in full bloom on May 3, 1947, with 8 or 16 ppm 2,4-D as the

ammonium salt. Fruit-drop until July 24, 1947, was reduced from an average of 36.0 fruits per tree to averages of 18.3 and 18.2, respectively, significant at 1 per cent (see table 4). Production records in 1947 were not obtained.

In 1948, no further sprays were applied nor were fruit-drop records maintained. However, on August 4, 1948, the year after treatment, yield and size of the fruit set in May, 1947, were measured and, in addition, the packing-house statement on fruit size and quality was obtained. Fruit samples were also taken for laboratory quality analyses.

TABLE 4

EFFECT OF 2,4-D ON FRUIT-DROP, YIELD, SIZE, AND QUALITY OF GRAPEFRUIT

(Saticoy experiment. Thirty trees per treatment)

Factor	Non-sprayed control	2,4-D spray*		Least significant difference	
		8 ppm	16 ppm	At 5 per cent	At 1 per cent
1947:					
Fruit-drop per tree	36.0	18.3	18.2	8.6	12.2
1948:					
Yield, as field boxes per tree	10.8	11.5	9.9	2.5	3.5
Size, as fruits per field box	59.4	52.4	49.9	3.5	5.0
Size, as diameter of fruit (cm)	9.73	10.06	10.23	0.27	0.38
Fruit quality:					
Rind (per cent)	51.96	53.40	53.05	n. s.	.....
Rag (per cent)	7.28	7.46	8.66	1.11	1.58
Juice (per cent)	39.12	37.77	37.18	n. s.	.....
Soluble solids (per cent)	9.63	9.54	9.63	n. s.	.....
Total acid, as citric (per cent)	1.836	1.859	1.811	n. s.	.....
Ratio soluble solids to total acids	5.2	5.1	5.3	n. s.	.....
pH	2.94	2.93	2.95	n. s.	.....
Packing-house grading:†					
Fruit size 64 or larger, first and second grade, as per cent of packed boxes	22	33	48	.....	.....
First-grade fruit, as per cent of packed boxes	51.0	44.4	35.5	.....	.....

* Applied as the ammonium salt, at full bloom, May 3, 1947.
† Fruit harvested August 4, 1948.

It was found that spraying during bloom resulted in an increase in fruit size but no significant difference in yield. Quality, as percentage of packed boxes that were first and second grade, was reduced in proportion as the concentration of 2,4-D was increased. According to the packing-house grading, quality dropped from 51.0 per cent first-grade fruit from nonsprayed trees to 35.5 per cent from trees sprayed with 16 ppm 2,4-D. Quality grading in the packing house was based mainly on external appearance of the fruit, taking into account rind roughness, scarring, and other blemishes.

The laboratory analyses showed no significant differences in percentages of rind, juice, acid, or soluble solids; there was, however, an increase (significant at 5 per cent) in percentage of rag in fruit from trees sprayed with 16 ppm 2,4-D in comparison with fruit from nonsprayed trees.

Camarillo Experiment.—The second randomized block experiment in Ventura County was near Camarillo. The treatments were: (1) control, non-

sprayed; (2) 8 ppm 2,4-D as the diethanolamine salt applied during the first week of May; (3) 8 ppm 2,4-D as the diethanolamine salt applied during the first week of June; (4) 8 ppm 2,4-D as the diethanolamine salt applied during the first week of July; and (5) 8 ppm 2,4-D as the ammonium salt applied during the first week of May. The trees were in flower during April, and on May 1 it was noted that there was a heavy set of pea-sized fruits (about 5 mm in diameter).

Fruit-drop in 1947 averaged 23.1 fruits per tree from the nonsprayed trees during the period June 16 to July 31, and 15.9 and 21.8, respectively,

TABLE 5

EFFECT OF 2,4-D ON FRUIT-DROP, YIELD, SIZE, AND QUALITY OF GRAPEFRUIT
(Camarillo experiment)

Factor	Non-sprayed control	8 ppm 2,4-D as ammonium salt	8 ppm 2,4-D as diethanolamine salt		
		May	May	June	July
1947:					
Fruit-drop* per tree from:					
6/16/47 to 7/31/47	23.1	12.1	15.9	21.8	.....
7/15/47 to 7/31/47	7.2	5.3	5.3	6.2	7.1
1948:					
Yield, as field boxes per tree	2.63	2.88	2.85	3.07	3.33
Packing-house grading:†					
Fruit size, 64 per box and larger (per cent)	38.5	58.2	47.3	39.5	41.4
First-grade fruit, as per cent of packed boxes	71.9	61.2	69.1	71.4	73.6

* Fruit-drop figures average 30 trees each.
† Based on fruit from 15 trees harvested August 16, 1948.

from those sprayed during the first week of May or June with 8 ppm 2,4-D as the diethanolamine salt. Compared with the nonsprayed trees, those sprayed in July showed no difference in preharvest fruit-drop. Fruit-drop from trees sprayed in May with 8 ppm 2,4-D as the ammonium salt was not significantly different from that of trees sprayed with 2,4-D as the diethanolamine salt.

Fruit-drop counts were not made in 1948. However, the yields of fruit from trees in three of the five replications of this experiment were obtained on August 16, 1948, and size and grade measurements were secured in the packing house. It was found that the application in May, 1947, of 2,4-D either as the diethanolamine salt or as the ammonium salt had induced an appreciable increase in fruit size with no yield reduction (table 5). The ammonium salt was more effective than the diethanolamine salt, but it also reduced the percentage of packed boxes of first-grade fruit from 71.9 per cent, in the nonsprayed, to 61.2 per cent. Trees sprayed with 2,4-D as the diethanolamine salt had 69.1 per cent first-grade fruit. Applications of 8 ppm 2,4-D as the diethanolamine salt in June or July, 1947, failed to increase fruit size or to influence the quality of fruit harvested in 1948.

From this, as well as from the previous experiments, it appears that the younger fruit is more susceptible to growth modifications than is the older, and that there is a stage in fruit development beyond which modification by 2,4-D is difficult, if not impossible.

The apparent increases in yields due to the treatments were not statistically significant. Relatively large differences for significance were required owing to the fact that yield data were available from only three of the five replicates.

TABLE 6

EFFECT OF 2,4-D ON FRUIT-DROP, YIELD, SIZE, AND QUALITY OF GRAPEFRUIT
(One-year Fillmore experiment)

Factor	Nonsprayed control	2,4-D spray*		
		8 ppm	16 ppm	24 ppm
1947:				
Fruit-drop per tree to 7/12/47	37.1	13.8	12.0	19.6
1948:				
Number of trees	125	72	59	28
Yield, as field boxes per tree	6.93	6.58	8.32	10.40
Packing-house grading:†				
Fruit size, 80 per box and larger (per cent)	47.9	48.5	65.3	79.7
Fruit quality, as per cent of packed boxes:				
1st grade	51.4	51.4	52.1	48.6
2d grade	31.4	31.0	29.9	33.6
3d grade	0.5	0.0	0.0	1.4
Juice grade	1.2	1.8	2.1	0.7
Cull grade	11.0	10.5	9.0	11.6
Decay	4.4	5.3	6.9	4.1

* Applied as the ammonium salt early in May, 1947.
† Fruit harvested August, 1948.

Fillmore Experiment.—The trees in this Fillmore experiment were sprayed soon after bloom (May 6, 1947) with 2,4-D at 8, 16, or 24 ppm as the ammonium salt. The treatments were applied by rows in a five-acre grove. From one edge of the grove to the other the sprays were applied in the following order: (1) four rows, 8 ppm; (2) three rows, nonsprayed; (3) four rows, 16 ppm; (4) four rows, nonsprayed; and (5) two rows, 24 ppm. The number of trees per treatment varied from 125 for the nonsprayed to 28 for the 24 ppm treatment.

Mature drop in 1947, determined from 12 trees per treatment (except the nonsprayed, where 24 trees were observed), was reduced from an average of 37.1 fruits per tree to 13.8, 12.0, and 19.6, respectively, from the trees sprayed with 8, 16, and 24 ppm 2,4-D.

The following year, on August 19, 1948, the fruits were graded and sized in the packing house. The results indicated that fruit size was increased in proportion to the concentration of 2,4-D applied. The nonsprayed trees produced approximately 48 per cent of the packed boxes as large-sized fruits (minimum size, 80 per packed box), whereas the trees sprayed with 24 ppm 2,4-D produced 80 per cent in this category. The data are shown in Table 6.

There was no decrease in fruit quality with either the 8 or 16 ppm 2,4-D spray. Fruit from trees sprayed with 24 ppm 2,4-D averaged 48.6 per cent first grade as compared with 51.4 per cent from nonsprayed trees.

In other experiments with grapefruit, no increase in fruit size has been observed in response to 24 ppm 2,4-D applications in September or later.

Yield, as field boxes per tree, was increased from 6.9 boxes from the nonsprayed trees to 8.3 and 10.4 boxes, respectively, from trees sprayed with 16 or 24 ppm 2,4-D. Trees sprayed with 8 ppm 2,4-D yielded 6.6 boxes. This difference (0.3 field box), compared with nonsprayed trees, is not considered significant.

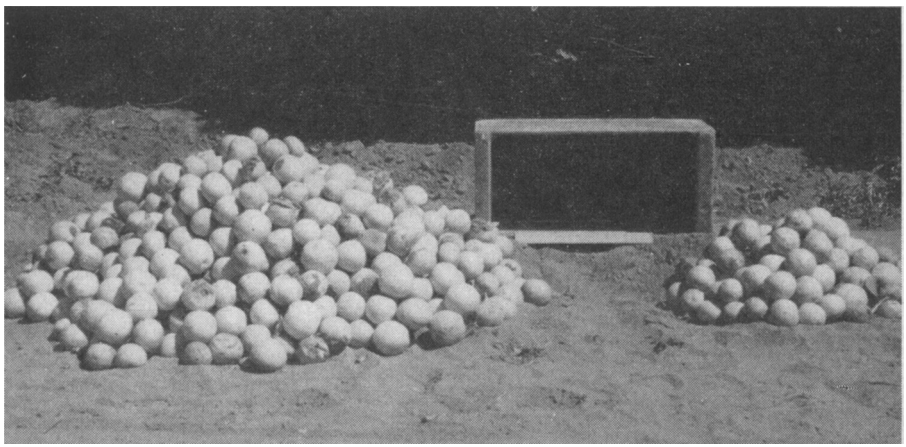

Fig. 1. Mature fruit-drop from grapefruit trees near Highgrove during the interval from June 4, 1947, to July 17, 1947. Left: 517 fruits from 10 nonsprayed trees; right: 87 fruits from 10 trees sprayed with 8 ppm 2,4-D on June 4, 1947. (Photograph by O. K. Anderson.)

The fruit from each treatment was sold separately by the packing house. Expressing the returns on a per tree basis, it was found that the nonsprayed trees grossed $6.40, while those sprayed with 8, 16, or 24 ppm 2,4-D yielded $5.34, $8.32, and $10.21, respectively. This increase was owing not only to the greater yield, but also to the higher value, at that market, of large-sized fruit.

One-year Experiments on Preharvest Fruit-drop

A large number of simple experiments, involving 61 comparisons of preharvest fruit-drop from nonsprayed trees and from those sprayed with 2,4-D, were established in a wide variety of tree, soil, and climatic conditions. The plots were located in the major grapefruit growing districts of California. The 2,4-D was sometimes applied alone as a water spray; at other times it was applied in combination with various insecticide or minor element applications. Applications were made when the fruit was mature or nearly mature.

Some of the results are summarized in Tables 7 and 8. In every experiment, applications of 2,4-D, alone or in combination with other spray chemicals, resulted in a reduction of mature fruit-drop. The average decrease was 30 fruits per tree or 44 per cent of the drop occurring from nonsprayed trees. The greatest reduction was 81 per cent, while the least was 13 per cent.

TABLE 7

EFFECT OF 2,4-D ON PREHARVEST FRUIT-DROP OF GRAPEFRUIT IN VARIOUS DISTRICTS IN CALIFORNIA*

Location	Experiment no.	Concentration of 2,4-D	Date of application	Date of last fruit-drop count	Fruit-drop per tree		Reduction in fruit-drop
					Non-sprayed	Sprayed with 2,4-D†	
		ppm	*1947*	*1947*			*per cent*
San Dimas	1	8	6/6	8/12	67	14	79
	2	8	7/1	8/18	23	17	26
Fontana	3	8	8/7	8/30	42	34	19
Redlands	4	8	6/11	9/17	48	19	60
	5	8	6/12	9/17	64	12	81
	6	8	6/13	9/8	12	5	58
	7	8	7/25	9/8	16	14	13
Highgrove	8	8	5/13	9/8	34	13	62
	9	8	6/6	7/23	6	4	33
	10	8	6/4	7/16	52	9	83
	11	8	6/4	8/6	10	6	40
	12	8	6/4	8/6	22	12	45
West Riverside	13	8	5/27	6/17	7	4	43
Arlington Heights	14	8	6/10	8/20	15	7	53
	14	16	6/10	8/20	15	5	67
Corona	15	8	7/17	9/18	23	11	52
Brea	16	8	5/28	7/11	57	28	51
Fillmore	17	8	5/1–15	7/12	37	14	62
	17	16	5/1–15	7/12	37	12	68
	17	24	5/1–15	7/12	37	20	46
	18	8	5/1–15	7/12	35	26	26
	18	16	5/1–15	7/12	35	11	69
	18	24	5/1–15	7/12	35	7	80
Camarillo	19	8	5/1	7/24	180	91	49
	19	16	5/1	7/24	180	91	49
	20	4	5/1	7/31	216	171	21
	20	8	5/1	7/31	216	164	24
	21	8	5/1	7/31	57	38	33
	21	8	5/1	7/31	57	35	39
	21	8	6/1	7/31	49	30	39
	21	8	7/1	7/31	19	14	26
Coachella	22	8	5/7	7/3	148	114	23

* Figures average from 5 to 59 trees per treatment.
† Applications made with conventional spray rig and thorough coverage.

Tables 7 and 8 indicate that, with the usual spray equipment, a concentration of 8 ppm 2,4-D applied as a drenching spray (about 1,000 gallons per acre) generally resulted in satisfactory control of preharvest drop. Higher concentrations usually reduced drop somewhat more, but the reduction was not in direct proportion to the concentration. In one experiment, 2,4-D applied at 10 ppm and 150 gallons per acre by use of a "spray duster" machine reduced fruit-drop as compared with drop from nonsprayed trees. In four other experiments, a kerosene "aeromist"[8] containing 2,400 ppm

[8] Produced by means of a Banta and Driscoll Company Hi-Fog Gun.

2,4-D as the technical isopropyl ester and applied at less than 10 gallons per acre was effective in reducing fruit-drop (table 8). Similar applications of kerosene containing concentrations of 600 to 1,200 ppm 2,4-D as the methyl ester reduced fruit-drop only 20 per cent or less in comparison with non-

TABLE 8

EFFECT OF VARIOUS FORMS OF 2,4-D ON PREHARVEST FRUIT-DROP OF GRAPEFRUIT WHEN APPLIED BY DIFFERENT METHODS*

Location	Experiment no.	Form of 2,4-D and method of application	Concentration of 2,4-D	Date of application	Date of last fruit-drop count	Fruit-drop per tree		Reduction in fruit-drop
						Non-treated	Treated	
			ppm	*1947*	*1947*			*per cent*
Coachella	23	diethanolamine salt, spray duster†	10	4/10	5/20	98	65	34
		diethanolamine salt, spray duster‡	10	4/10	5/20	114	58	49
Exeter	24	isopropyl ester, aeromist§	7,000	2/17	7/29	110	67	39
Coachella	25	isopropyl ester, aeromist	2,400	3/18	7/24	366	228	38
Fontana	26	methyl ester, aeromist	1,200	3/28	9/16	59	58	2
Brea	27	isopropyl ester, aeromist	2,400	5/28	7/11	69	35	49
		diethanolamine salt aeromist¶	2,400	5/28	7/11	69	53	23
		methyl ester, aeromist	600	5/28	7/11	69	55	20
Brea	28	diethanolamine spray	24	5/20	7/11	65	19	71
		ammonium salt spray	24	5/20	7/11	65	25	62
		butyl ester spray	48	5/20	7/11	65	23	65
		free acid spray	48	5/20	7/11	65	28	57
Brea	29	butyl ester spray	8	5/28	7/11	57	27	53
		butyl ester + lanolin spray	8	5/28	7/11	57	29	49
		isopropyl ester spray	8	5/28	7/11	57	19	67
		methyl ester spray	8	5/28	7/11	57	26	54
		ammonium salt spray	8	5/28	7/11	57	37	35
		diethanolamine spray	8	5/28	7/11	57	28	51
		free acid spray	27	5/28	7/11	57	15	74
Brea	29	2,4,5-T spray	8	5/28	7/11	57	23	60

* Applied with spray-duster machines, aeromist machines, or conventional spray rigs.
† 2,4-D added to 8 lbs. 50 per cent wettable DDT per 100 gallons, applied at 150 gallons per acre.
‡ 2,4-D added to a solution of 7 lbs. of Black Leaf 155 and 4 lbs. of sugar per 100 gallons, applied at 150 gallons per acre.
§ Less than 10 gallons per acre, applied as a kerosene aeromist.
¶ Applied as a water aeromist.

treated trees. Application of 2,4-D at 2,400 ppm as the diethanolamine salt in a water aeromist reduced fruit-drop 23 per cent compared with a reduction of 49 per cent in the same experiment (number 27) from a similar application of 2,400 ppm 2,4-D as the isopropyl ester in a kerosene aeromist.

LEAF INJURY BY 2,4-D

In all of the experiments it was noted that when 2,4-D or 2,4,5-T, even at concentrations as low as 4 ppm, was sprayed over young, actively expanding leaves, a growth distortion and curling of the leaf blade and petiole and of the stem occurred, in varying degrees, within 48 hours. Subsequent leaf

growth was usually normal when concentrations of 25 ppm or less were used. No apparent effect of these sprays on mature leaves was noted. Application of the sprays between growth flushes considerably reduced, or eliminated, curling of young leaves. No influence on yield or fruit quality was observed as a result of the leaf curling. It may be, however, that if a number of applications were made during a year, so that the leaves from every one of the several growth flushes were distorted, or if young trees, which have a higher proportion of young to old leaves, were sprayed, an effect on tree growth and yield would be found.

DISCUSSION

Extensive experiments throughout southern California substantiated earlier findings that a 2,4-D water spray was effective in reducing mature fruit-drop of grapefruit. The data also showed that 2,4,5-T is about equally as effective as 2,4-D in reducing fruit-drop. Probably certain of the other related chlorinated phenoxy acids would have a similar effect. Naphthaleneacetic acid had no apparent effect in reducing preharvest fruit-drop of grapefruit. This also was observed in Australia, in 1941, by McAlpin and Merrett (1949). Beta-naphthoxyacetic acid had only a slight, nonsignificant effect on reduction of fruit-drop in the experiments in southern California.

Results from the application of 2,4-D sprays on grapefruit in Arizona suggest that the spray induced an increase in production (by reducing fruit-drop) and in the percentage of firm, shippable fruit harvested late in the season (Anonymous, 1949). This is supported by the observation that grapefruit from trees sprayed with 2,4-D to reduce preharvest drop have a longer storage life than those from nonsprayed trees (Stewart, 1948).

The observations in Arizona are of further interest in connection with fruit-stem die-back of grapefruit. When this condition occurs, not only does the stem die back, but the fruit also loses its firmness. Use of 2,4-D sprays on grapefruit in southern California resulted in a reduction of fruit-stem die-back (Klotz and Stewart, 1948), and in Arizona, in an increase in firmness of fruit. The latter observation may be another manifestation of the same effect of 2,4-D that causes a reduction in fruit-stem die-back. Whether the treatment results in a delayed maturation of the fruit-stem abscission tissue or an increase in the ability of the fruit itself to absorb and hold water, has not been determined. There is an indication that packing-house treatment of lemons with 2,4-D or 2,4,5-T prior to storage resulted in a significant reduction in water loss during storage as compared with nontreated fruits (Stewart, Palmer, and Hield, 1952).

It has been reported that 2,4-D sprays are effective in reducing mature fruit-drop of grapefruit in Australia (McAlpin and Merrett, 1949).

In addition to the evidence presented in this paper and based on experimental plots, for the past three years extensive acreages of grapefruit (estimated to be over 5,000 acres) in southern California have been commercially sprayed to reduce fruit-drop. Favorable reports have been made by the growers using this treatment.

From data presented in this report, it appears that low-volume 2,4-D applications can be successfully applied to grapefruit to reduce fruit-drop.

Volumes of less than 10 gallons per acre were successfully applied as a kerosene aeromist at concentrations between 2,400 and 7,000 ppm 2,4-D. A water aeromist application was only about one-half as effective as a kerosene aeromist. Concentrations lower than 2,400 ppm did not reduce fruit-drop sufficiently to be commercially satisfactory. These data are limited, however, and accordingly this method is not recommended for commercial use at present.

Data obtained here were insufficient to determine the comparative effectiveness of inorganic salts, amine salts, and esters of 2,4-D for reducing grapefruit fruit-drop.

In addition to the effect of 2,4-D in reducing fruit-drop, it was found that, under certain conditions, it induced an increase in fruit size. This resulted from the fact that, in southern California, grapefruit trees simultaneously bear the current crop of mature fruit as well as the crop of young fruit which matures the following year. Thus, a 2,4-D spray applied to reduce mature fruit-drop may also influence the growth of the young fruit. In some cases, the 2,4-D sprays applied during May or June were found to increase the size of the fruit harvested the following year. An increase in fruit size in response to 2,4-D was reported earlier for grapefruit and has also been observed for oranges and lemons (Stewart and Parker, 1947; Stewart and Klotz, 1947; Stewart and Hield, 1950*a*, 1950*b*).

Results obtained in the experiments described here indicate that 2,4-D sprays may be used commercially to increase fruit size of grapefruit. Care must be taken, however, to avoid lowering fruit quality by applications of sprays having excessive concentrations of 2,4-D. To generalize, it appears that flowering may be the stage in fruit growth most responsive to application of 2,4-D for fruit-size increase. As the fruit becomes older it becomes less and less responsive until, about 16 weeks after flowering, even high concentrations of 2,4-D fail to produce an increase in fruit size.

Fruit quality, as shown by external features, such as roughness of rind, delay of coloring (maturity), and the like, seems to follow a somewhat similar response pattern. Since it is sometimes desirable to increase the size of the fruit, it becomes important to determine the maximum increase possible without lowering of quality. This may be attained by application of a 2,4-D spray of the proper concentration in relation to fruit age from flowering. A lowering of fruit quality results from spraying with a concentration of 2,4-D which is too high in relation to the stage of fruit growth. On a given date, the stage of fruit growth is not necessarily the same in all districts, but varies according to the flowering date. For example: The trees in the Saticoy district experiment and the Fillmore district experiment were sprayed on May 3, 1947, and May 6, 1947, respectively, with the same concentration of 2,4-D (16 ppm). There was a difference of only three days in the time of application. At harvest, in 1948, it was found in both experiments that the fruit from trees sprayed with 2,4-D was larger than that from nonsprayed trees. In the Fillmore experiment, however, there was no lowering of quality, but in the Saticoy experiment, the quality of the 2,4-D-sprayed fruit was appreciably lower than that of the nonsprayed fruit. It is believed that this may have resulted from the fact that, although the two districts are within

20 miles of each other, the Saticoy fruit was at an earlier stage of development than the Fillmore fruit at the time of spraying. Because the Saticoy district is nearer the coast and generally has a somewhat lower spring temperature, the trees often bloom several weeks later than do those in the Fillmore district. Suggestions for application of 2,4-D sprays to increase citrus fruit size have been published (Stewart and Hield, 1950*a*).

SUMMARY AND CONCLUSIONS

As a result of 34 field experiments conducted from 1947 to 1950 to study the effects of applications of 2,4-D and related substances on fruit-drop, yield, size, and quality of grapefruit in California, it was found that:

1. A water spray of 8 ppm 2,4-D reduced mature fruit-drop an average of 44 per cent. This response to 2,4-D occurred under a wide range of climatic and environmental conditions.

2. The 2,4-D spray used at 8 ppm was more effective in reducing fruit-drop when applied in May than when applied in July.

3. Annual applications of 2,4-D for three years have shown no accumulative detrimental effects.

4. Applications of 2,400 ppm 2,4-D as a kerosene aeromist at less than 10 gallons per acre were effective in reducing mature fruit-drop although this method cannot yet be recommended for commercial use.

5. A water spray of 8 ppm 2,4,5-T was as effective as an 8 ppm 2,4-D spray in reducing mature fruit-drop.

6. A spray of 25 ppm naphthaleneacetic acid was not effective in reducing fruit-drop. A spray of 25 ppm naphthoxyacetic acid was only slightly effective in reducing fruit-drop.

7. The 2,4-D sprays had no undesirable effects on the quality of the fruit which was mature, or nearly mature, at the time of spraying.

8. There was an increase in fruit size if a sufficiently concentrated 2,4-D spray was applied on trees bearing fruit less than 16 weeks old.

9. The fruit quality was lowered when trees bearing young fruit (less than 16 weeks old) were sprayed with 2,4-D at too high a concentration in relation to the stage of fruit growth. A lowering in quality as a result of an 8 ppm 2,4-D spray was observed only in one experiment, where the application was made on trees in full bloom.

10. 2,4-D was found to be effective in reducing mature fruit-drop when applied in conjunction with other spray treatments. Thus far no agricultural spray chemical has been found with which 2,4-D was not effective in reducing fruit-drop.

11. Application of 8 ppm 2,4-D to trees with young, expanding leaves induced a curling and deformation of the leaves. Subsequent leaf growth was normal. Application of the spray between leaf growth flushes minimized the distortion. No influence on yield or fruit quality was noted as a result of the leaf curl.

12. The differences in fruit-drop resulting from the use of various forms of 2,4-D were not great.

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