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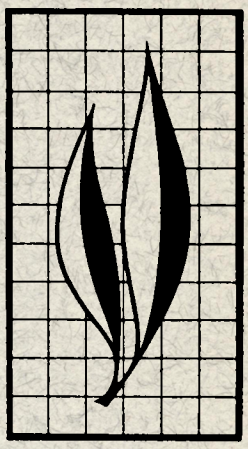
H. Z. Hield, C. W. Coggins, Jr., and M. J. Garber

UNIVERSITY OF CALIFORNIA DIVISION OF AGRICULTURAL SCIENCES



Earlier work has shown that gibberellin treatment of individual flowers or small fruits of many citrus varieties gave increased fruit set. The Washington Navel orange was selected for field scale experiments, entire trees being sprayed to determine the effect on fruit set. Phytotoxic responses of twig dieback and leaf drop resulted. Fruit set was not increased by overall gibberellin sprays. Often a significant reduction in yield resulted. Fruit size and quality responses are related to gibberellin concentration and date of application. The difference between response to applications on individual flowers or fruits and response to spraying the entire tree suggests the possible involvement of water relations and also indicates an influence of the gradient flow of gibberellin between the fruit and branch. Certain similar and contrasting responses of citrus to gibberellin sprays and some other plant growth regulators are noted.

THE AUTHORS:

H. Z. Hield is Specialist, C. W. Coggins, Jr., is Associate Plant Physiologist, and M. J. Garber is Associate Biometrician and Lecturer in the Citrus Research Center and Agricultural Experiment Station, Riverside.

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INTRODUCTION

GIBBERELLIN TREE SPRAYS have been tested in both California and Florida to determine their influence on fruit set in citrus. Experiments in California showed increased fruit set when gibberellic acid (GA) or potassium gibberellate (KGA) was applied to flower clusters or individual young fruit of lemon, lime, and Washington Navel orange trees (Hield, Coggins, and Garber, 1958). Soost and Burnett (1961) reported on the response of mandarins to tree sprays with KGA and GA, and Krezdorn and Cohen (1962) studied the effect of GA tree spray treatments on tangelo and the Dream Navel orange. The effect of KGA for fruit set was studied on Valencia oranges (Coggins, Hield, and Boswell, 1960) and on grapefruit (Coggins, Hield, and Burns, 1962). Although there have been occasional successes with increased fruit set from tree sprays (Coggins, Hield, and Garber, 1960; and Krezdorn and Cohen, 1962), the general pattern has been for the undesirable effects of the GA or KGA treatments to outweigh the beneficial. The increased fruit set from treatments limited to flower clusters only or small fruiting branches has been repeated and confirmed in Florida (Krezdorn and Cohen, 1962) and in Japan (F. P. Coyne, Plant Protection Limited, Fernhurst, Haslemere, England, 1963, private communication).

Since fruit set in navel oranges is generally less than the potential of this fruit, the Washington Navel orange was selected for an evaluation of the effects of KGA when applied to entire trees. A practical method of using gibberellin to increase fruit set remains a possibility, but these experiments do not offer a solution to this problem. The data presented herein furnish information on the effects of KGA treatments under certain conditions and the varying response to these treatments.

METHODS AND MATERIALS

1958 Experiments (Experiments 1, 2, 3, and 4). Three experiments were conducted on commercial plantings of Washington Navel orange trees in locations selected as representing the major navel orange-producing areas. Single-tree plots were used, with 8 replications in a randomized block design. Potassium gibberellate (KGA) was applied at concentration levels of 46, 92, and 184 ppm,

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TABLE 1

DEVELOPMENTAL STAGES OF BLOOM AND YOUNG FRUIT OF WASHINGTON NAVEL ORANGE TREES WHEN SINGLE SPRAY APPLICATIONS OF KGA WERE MADE ON DIFFERENT DATES

Experiment	1st spray date	Stage of development	2nd spray date	Stage of development	3rd spray date	Stage of development	4th spray date	Stage of development
1.....	3-26-58	Small green flower buds	4-10-58	Small flower buds with some white	5-1-58	Past peak bloom with heavy petal fall	5-15-58	Bloom past with slight young fruit drop
2.....	3-24-58	Early bloom with many open flowers	4-8-58	Heavy bloom with moderate petal fall	4-21-58	Few flowers with petal fall near completion	5-5-58	Very few flowers and slight drop of small fruit
3.....	3-28-58	White buds and open flowers	4-9-58	Heavy bloom with light petal fall	4-22-58	Heavy bloom and heavy petal fall	.....	.....
4.....	.....	.....	.....	.....	.....	.....	5-6-58	Few flowers with light drop of tiny fruit
5.....	4-13-59	Heavy petal fall at end of bloom	4-28-59	Fruit diameter range 3/16 to 3/8 inch	5-8-59	June drop with diameter range 3/8 to 1/4 inch	.....	.....
6.....	4-12-60	Peak bloom with range of buds to petal fall	4-25-60	Bloom past but light fruit drop	5-23-60	June drop well in progress	.....	.....

calculated on an acid-equivalent basis. Single-spray applications were made on four approximately biweekly dates during the bloom and early fruit-setting periods. The trees in the control treatment were not sprayed. The sprays, hand-applied with an orchard gun, gave a light wetting of leaves and flowers. A non-ionic wetting agent (X-77) was used at 50 ml per 100 gallons of spray mixture.

Experiment 1, in the Ivanhoe district of Tulare County, involved trees approximately 40 years old and on a sour-orange rootstock. Experiment 2, located in the Corona district of Riverside County, used trees 25 years old and on trifoliate rootstock. Trees used in Experiment 3, located in the Arlington Heights district, also in Riverside County, were approximately 43 years old and on sweet-orange rootstock.

When it was time to apply the fourth spray treatment in Experiment 3, it was evident that earlier treatments had caused tree damage, and for this reason that spray application was not made. Instead, the treatments planned for the fourth spray date of Experiment 3 were applied to the trees of Experiment 4, which was established at Riverside. This orchard was approximately 32 years old, and the trees were on a sour-orange rootstock.

The spray dates, together with the stage of development of the flowers or young fruit at the time of spraying, are indicated in table 1.

Fruit quality measurements were obtained from samples of 30 fruits per plot, the fruit ranging from 2.72 to 2.84 inches in diameter. Soluble solids were read on an Abbe refractometer. The total citric acid was determined by potentiometric titration with NaOH. Percentage of juice was determined on a weight basis. Length, width, and rind-thickness measurements were made on the fruit samples. Fruit size, as diameter, was determined by measurement of 100 random fruits per plot prior to harvest. Leaf drop was measured either on the basis of weight or on a count of leaves from a comparable area beneath the tree. Yield was measured in terms of field boxes of fruit per tree.

1959 Experiment. Experiment 5 was established in 1959 at Riverside in an orchard approximately 40 years old with trees of a sweet-orange rootstock. Four-tree plots with 8 replications were completely randomized, with three dates of spray application and three KGA levels compared to a non-sprayed control. Acid-equivalent concentrations of KGA were applied at 12.5, 25, and 50 ppm as single sprays. The sprays were applied so as to wet both foliage and flowers or fruit, using an average of 4 gallons per tree. The dates of spraying and bloom or fruit development for Experiment 5 are also shown in table 1. A count of fallen, split fruit was made on September 29, 1959. Fruit drop was counted December 1, 1959, and again on April 14, 1960, following harvest. The color development of the fruit on the south quadrant of the tree was rated on December 1, 1959. Fruit diameter was measured on 30 fruits per tree on January 14, 1960. Fruit quality measurements were obtained as in 1958, but on samples of 20 fruits per plot.

1960 Experiment (Experiment 6). During the bloom and early fruit-set period of 1960, identical KGA treatments were applied to the trees sprayed in 1959, and designated Experiment 6. The spray dates for 1960, together with the conditions of growth, are likewise shown in table 1. Fruit diameter of 30 fruits per tree was measured on January 11, 1961, and yield in field boxes per tree was obtained on April 4, 1961.

TABLE 2

VEGETATIVE AND FRUITING RESPONSES OF WASHINGTON NAVEL ORANGE TREES IN EXPERIMENT 1 TO SINGLE KGA SPRAY APPLICATIONS

Factor	Date	Control	Spray dates												A value†	
			3-26-58			4-10-58			5-1-58			5-15-58				
			KGA concentrations (ppm)													
			46	92	184	46	92	184	46	92	184	46	92	184	.05	.01
Field boxes per tree.....	3-16-59	10.0	8.7	8.0*	7.7*	9.0	8.5	6.3**	10.1	9.5	8.1*	9.1	10.0	8.5	1.88	2.39
Rind thickness—mm.....	1-13-59	6.49	6.57	6.13	6.20	6.18	6.23	6.44	6.31	6.31	6.57	6.49	6.59	6.90*	0.40	0.51
Rind color—per cent of rind green.....	12-1-58	19.4	20.6	21.2	31.0	27.8	29.4	46.7**	20.7	25.5	41.9**	22.3	23.6	42.8**	12.2	15.5
Number of dead twigs per tree.....	6-11-58	15	117*	213**	206**	259**	306**	339**	125**	205**	264**	10	16	33	76.8	102.1
Twig dieback rating‡.....	9-3-58	1.00	1.37	2.00**	2.13**	2.63**	2.87**	2.75**	1.87*	2.63**	2.87**	1.13	1.25	1.25	0.72	0.89

† One-sided comparison between treatment and control.
‡ 1 = light amount; 2 = moderate amount; 3 = severe amount.
*, ** = statistical significance at the .05 and .01 level of probability.

RESULTS

1958 Experiments

(Experiments 1, 2, 3, and 4)

Tree Response. The purpose of the various dates of KGA application was to measure fruit-set response at early stages of flower and fruit development. In Experiment 1 the spring growth flush and bloom commenced later than in Experiments 2 and 3. However, once growth in Experiment 1 was started, it progressed more rapidly.

A heavy leaf drop resulting from the spray treatment occurred about two weeks after the first date of spraying in Experiments 1, 2, and 3. The initial leaf drop consisted of fully matured leaves that were chlorotic and destined for drop, and dark green leaves which normally would not be expected to fall. In Experiments 3 and 4, a similar leaf-drop response occurred after subsequent spray treatments, as illustrated by data in tables 4 and 5. Observations on Experiments 1 and 2 indicated a similar response. A stimulation of vegetative growth was also noted. Growth flushes when KGA treatments were given progressed more rapidly, and the new shoots were characterized by an increased number and length of thorns compared with growth on control trees. Cooper and Peynado (1958) also observed this latter response and considered it evidence of a more juvenile nature of the growth where gibberellin was applied.

Another type of leaf loss occurred in the first three experiments, but was most pronounced in Experiment 1. Four weeks after the first spray application, a severe amount of twig dieback occurred on the new spring growth, with dead leaves remaining attached to small terminal branches. Susceptibility to this was closely linked with the period of expanding young growth of the spring flush; no twig dieback occurred from the fourth spray date of May 15, 1958. The affected twigs were 6 to 10 inches long. This was a different occurrence from the loss of mature leaves which dropped from affected branches.

New growth on living twigs commenced about four weeks after the period of leaf drop and twig dieback. While this growth was out of cycle with the regular summer growth flush and made a direct comparison impossible, the general appearance of the growth was normal. The smallest twigs which had suffered defoliation often died and the new growth appeared on the slightly larger wood.

Yield. In Experiments 1, 2, and 3, fruit production was reduced by the KGA spray applications for the first three dates (tables 2, 3, and 4).

Where significant effects of treatment were indicated by subjecting the data to analysis of variance, orthogonal comparisons in regression were computed. A tabulation of the factors which were significant and the source of the variation determined by factorial analysis are given in table 8. For Experiments 2 and 3 these calculations show that the regression of yield on concentration was not of importance, while the regression of yield on spray dates was of major importance. In Experiment 1 both concentration and date of spray application were found to contribute significantly to the decreased yield. Thus, sprays applied during the period of bloom were most damaging to yield. Sprays applied to the young fruit before or during the period of "June drop," while causing less tree injury, gave no indication of increased yield.

The trees in Experiments 1, 2, and 3 were not treated again in 1959. Yield records were obtained for Experiment 3 in the year following treatment, the harvest season of 1960. The field-box yields showed no carry-over effect from the 1958 KGA application.

Fruit Size. Measurements showed that in the first three experiments the KGA treatments had no effect on fruit

TABLE 3

FRUITING RESPONSES OF WASHINGTON NAVEL ORANGE TREES IN EXPERIMENT 2 TO SINGLE KGA SPRAY APPLICATIONS

Factor	Date	Control	Spray dates												A value†	
			3-24-58			4-8-58			4-21-58			5-5-58				
			KGA concentrations (ppm)													
			46	92	184	46	92	184	46	92	184	46	92	184	.05	.01
Field boxes per tree.....	4-12-59	4.60	2.63*	2.71*	1.75**	1.99**	1.53**	1.41**	2.69*	2.11**	2.33**	4.13	4.29	3.09	1.57	2.02
Rind thickness—mm.....	2-3-59	5.61	5.23	5.21	5.54	5.06*	5.11*	5.82	5.50	5.81	6.21**	5.97	5.90	6.22**	0.47	0.57
Fruit length/width.....	2-3-59	1.000	1.016	1.011	1.018	0.998	0.999	1.011	1.012	1.020	1.024*	1.008	1.020	1.028*	0.024	...
Juice per cent.....	2-3-59	50.5	53.0	53.1	52.0	52.9	51.0	51.4	51.8	49.3	47.5*	49.8	49.0	48.2	2.8	3.4

† One-sided comparison between treatment and control.
*, ** = statistical significance at the .05 and .01 level of probability.

TABLE 4

VEGETATIVE AND FRUITING RESPONSES OF WASHINGTON NAVEL ORANGE TREES IN EXPERIMENT 3 TO SINGLE KGA SPRAY APPLICATIONS

Factor	Date	Control	Spray dates									A value†	
			3-28-58			4-9-58			4-22-58				
			KGA concentrations (ppm)										
			46	92	184	46	92	184	46	92	184	.05	.01
Field boxes per tree.....	2-19-59	6.76	4.50*	4.06**	3.13**	2.92**	2.10**	1.68**	2.86**	2.66**	2.73**	1.79	2.25
Rind thickness—mm.....	2-17-59	5.62	5.63	5.68	5.96	5.47	5.57	5.91	5.68	6.01*	6.40**	0.386	0.486
Juice per cent.....	2-17-59	49.7	50.5	50.3	50.8	50.8	51.2	50.4	50.0	49.4	49.4	NS	.....
Leaf drop—grams per 2.25 sq. ft.....	6-9-58	70.0	151.4**	168.4**	150.7**	171.0**	144.6**	192.9**	155.3**	146.1**	184.5**	41.8	52.6
Trees not sprayed in 1959 (Sprayed in 1958 as indicated above)													
Field boxes per tree.....	3-15-60	4.00	3.23	3.15	3.69	3.30	4.16	3.81	2.61	3.79	4.07	NS	.....

† One-sided comparison between treatment and control.
*, ** = statistical significance at the .05 and .01 level of probability.
NS = non-significant at the 0.05 level.

diameter. Besides a lack of influence on diameter, there was a reduction in field-box yields, indicating that the number of fruits was lessened by the application of KGA sprays during the period of bloom. As the measurement of 100 fruits per tree gives a reliable fruit-size distribution, we are also confident that a reduction in the number of fruits per tree did not result in the expected increase in fruit size.

Fruit Quality. Significantly increased rind thickness was found in Experiments 1, 2, and 4 (substituted trial for fourth date of Experiment 3) at the 184 ppm concentrations on the fourth spray date (tables 2, 3, and 5). An increase of rind thickness was also demonstrated at the 184 ppm level for the third spray date in Experiments 2 and 3, and at the 92 ppm level in Experiment 3 (third date). In Experiment 4 an increase was also found for the 92 ppm level. The increased rind thickness was reflected by a decrease in percentage of juice. However, in general, reduction in percentage of juice was not as frequently found as increased rind thickness; it was seen at the 184 ppm level in Experiment 4 and for the third spray date in Experiment 2. The data for percentage of juice in Experiment 1 were lost.

A slight decrease in rind thickness was found in Experiment 2 (table 3) for the 46 and 92 ppm levels at the second spray date. These were the only instances where rind thickness was decreased in this series of experiments.

The length-to-width ratio showed a significant lengthening of the fruit in Experiment 2 at the 184 ppm level for both the third and fourth spray dates. This change of fruit shape was related to both concentration and date of application (table 8).

An influence of the KGA treatments on rind color at maturity was found only in Experiment 1. In this experiment the per cent of green area on the rind was increased at the 184 ppm concentration level by the second, third, and fourth spray dates when evaluated on December 1, 1958. The retention of the green rind pigments was associated most strongly with concentration effects but was also influenced by spray date. A second rating of fruit color in this experiment on January 19, 1959, showed that the color differences had disappeared.

TABLE 5

FRUITING RESPONSES OF NAVEL ORANGE TREES IN EXPERIMENT 4 TO A KGA SPRAY APPLICATION ON MAY 6, 1958

Factor	Date	Control	KGA (ppm)			A value†	
			46	92	184	.05	.01
Field boxes per tree	4-6-59	3.44	2.97	2.59	1.37**	1.09	1.49
Rind thickness—mm	3-18-59	5.3	5.2	5.7*	5.9**	0.28	0.38
Juice per cent	3-18-59	51.1	51.9	49.8	49.0*	1.7	2.3
Leaf drop—number per 2.25 sq. ft.	5-29-58	13.6	84.5	132.1**	142.3**	47.0	62.5
Rind color—per cent of rind green	1-22-59	0.8	1.2	1.7	4.5*	2.8	3.8
	Not sprayed: 1959						
Field boxes per tree	4-4-60	2.73	2.67	2.67	2.06	NS	....

† One-sided comparison between treatment and control.
*,** = statistical significance at the .05 and .01 level of probability.
NS = non-significant at the 0.05 level.

1959 Experiment

(Experiment 5)

The 1959 KGA sprays applied in Experiment 5 increased the number of fruits which split at the stylar (navel) end (table 6). A count on September 29, 1959, showed a highly significant increase in the number of split fruits on trees which had received 25 and 50 ppm KGA on the first spray date and on those trees which received 50 ppm at the second spray date. Statistical analysis of the data showed that this effect was associated with both concentration and date of application and that this increase of split fruits was of a linear nature (table 8). The fruit drop counted on December 1, 1959, was caused by *Alternaria* rot, wind damage and by splitting of fruit. This fruit drop was not analyzed as to the specific cause of drop in each case. However, it is likely that some further influence on splitting was a major factor for the increased drop shown in table 6 for the 50 ppm treatment of the first spray date.

Twig dieback did not occur with the KGA concentration levels applied in Experiment 5. A light drop of mature leaves which was seen was associated with the KGA treatments. No fruit quality effects were found as a result of spraying. Field-box yields and fruit-size distribution showed no significant differences from the control (table 6).

1960 Experiment

(Experiment 6)

A heavy leaf drop occurred approximately two weeks following the first date of KGA application. Observations indicated that all concentration levels caused increased leaf drop, the severity increasing with increasing concentration levels. No twig dieback occurred. The KGA treatments at the second and third spray dates caused no leaf drop. By the time of the third spray date it was evident that a light crop could be expected, since a heavy "June drop" had occurred. A fruit-size measurement made on January 11, 1961, showed no fruit-size differences resulting from any of the treatments (table 7). Field-box yields obtained on April 4, 1961, confirmed the anticipated light crop. The yield was reduced by all KGA levels of the first spray date and was unaffected by treatments at the other spray dates. Fruit quality was not influenced by the KGA treatments, and fruit drop, counted at the time of harvest, was also unaltered.

DISCUSSION

Applications of KGA to entire trees of navel oranges in three different growing seasons failed to increase fruit set. In fact, a concentration as low as 12.5 ppm applied during the bloom period sometimes resulted in a decreased yield. It was not determined whether the decreased yield was due directly to the loss of young fruit because of dieback of the fruiting wood of the spring growth flush, to the induced abscission of young fruit, or to an inability of the tree to support the fruit as a result of leaf drop.

The navel orange tree is more susceptible to KGA-induced leaf drop than Valencia orange, lemon, grapefruit (Coggins, Hield, and Garber, 1960; Coggins, Hield, and Boswell, 1960; Coggins, Hield, and Burns, 1962), tangelo (Krezdorn and Cohen, 1962), or mandarin (Soost and Burnett, 1961). The drop of mature leaves was greatest when KGA sprays were applied during the period of bloom.

The increase of twig dieback (more prevalent in Experiment 1), characterized by the leaves drying but failing to drop from the twig, has also been associated with severe water stress in the early spring (Klotz *et al.*, 1962). It is plausible that the stimulation of vegetative growth by KGA results in a greater water demand and thus causes

TABLE 6

FRUITING RESPONSES OF WASHINGTON NAVEL ORANGE TREES IN EXPERIMENT 5 TO SINGLE-SPRAY APPLICATION OF KGA

Factor	Date	Control	1959 spray dates									A value†	
			4-13-59			4-28-59			5-8-59				
			KGA concentrations (ppm)										
			12.5	25	50	12.5	25	50	12.5	25	50	.05	.01
Field boxes per tree.....	4-14-60	3.25	3.25	3.03	3.01	3.22	3.62	3.34	3.09	3.63	3.63	NS	.....
Fruit diameter—mm.....	1-14-60	69.0	68.2	68.3	66.7	67.1	67.5	67.3	67.8	67.9	67.8	NS	.....
Fruit length/width.....	2-15-60	1.047	1.047	1.047	1.037	1.048	1.038	1.031*	1.045	1.051	1.040	0.015	.....
Juice per cent.....	2-15-60	58.8	58.4	58.3	58.5	57.7	57.9	57.4	57.9	57.3	56.8	NS	.....
Split fruit drop per tree.....	9-29-59	75.8	98.5	119.2**	148.4**	83.6	98.4	109.5*	76.2	68.9	79.2	29.9	37.7
Fruit drop per tree.....	12-1-59	30.1	36.9	35.4	40.4*	29.2	34.2	34.8	30.7	24.5	28.2	8.6	10.8
Fruit drop per tree.....	4-14-60	60.1	62.1	75.8	74.2	76.7	69.8	57.2	69.6	66.4	60.6	NS	.....

† One-sided comparison between treatment and control.
NS = non-significant at the .05 level.
*, ** = statistical significance at the .05 and .01 level of probability.

TABLE 7

FRUITING RESPONSES OF WASHINGTON NAVEL ORANGE IN EXPERIMENT 6 TO SINGLE-SPRAY APPLICATIONS OF KGA

Factor	Date	Control	1960 spray dates									A value†	
			4-12-60			4-25-60			5-23-60				
			KGA concentrations (ppm)										
			12.5	25	50	12.5	25	50	12.5	25	50	.05	.01
Field boxes per tree.....	4-4-61	1.51	1.03*	0.86**	0.78**	1.43	1.75	1.53	1.64	1.79	1.84	0.37	0.47
Fruit diameter—mm.....	1-11-61	59.5	59.6	57.3	58.9	58.4	58.0	60.3	59.3	60.3	60.6	NS	.....

† One-sided comparison between treatment and control.
*, ** = statistical significance at the .05 and .01 level of probability.
NS = non-significant at the .05 level.

TABLE 8

SUMMARY OF STATISTICAL SIGNIFICANCE FOUND FOR FACTORS IN EXPERIMENTS 1, 2, 3, 5, AND 6 BY ANALYSIS OF VARIANCE AND FACTORIAL REGRESSION COMPARISONS

Factor†	Experiment 1				Experiment 2				Experiment 3			Experiment 5			Experiment 6
	1958 sprays				1958 sprays				1958 sprays			1959 sprays			1960 sprays
	Field boxes per tree (3–16–59)	Rind thickness (1–13–59)	Twig dieback rating (9–3–58)	Rind color: per cent of rind green (12–1–58)	Field boxes per tree (4–13–59)	Rind thickness (3–10–59)	Fruit length/ width ratio (2–3–59)	Juice (3–10–59)	Field boxes per tree (2–19–59)	Rind thickness (2–17–59)	Leaf drop: grams per 2.25 sq. ft. (6–9–58)	Split fruit drop per tree (9–28–59)	Fruit drop per tree (12–3–59)	Fruit length/ width ratio (2–15–60)	Field boxes per tree (4–4–61)
		mm				*mm*		*per cent*		*mm*					
Treatment	xx	xxx	xxx	x	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xx	x	xxx
CK vs. other	x		xxx	xx	xxx		x		xxx		xxx	x			
Concentration	xxx	x	xx	xxx		xxx	x	xx		xxx		xx			
Cl	xxx		xxx	xxx	x	xxx	x	xxx	x	xxx		xxx		xx	
Cq		x		xxx		x							xxx		
Dates	x	xxx	xxx	xx	xxx	xxx	xx	xxx	xx	xxx		xxx	xxx		xxx
Dl	xx	xxx	xxx		xxx	xxx		xxx	xx	x		xxx	xxx		xxx
Dq		xx	xxx	xxx	xxx				xx	xx					
Dc				xx		xx		xx							
C × D		x					x								
Cl × Dl		xxx													
Cl × Dq						x									
Cl × Dc			xxx												
d.f. error	84	84	84	84	81	81	81	79	63	63	63	63	63	63	63

† C = concentration; D = date; and l, q and c indicate the linear, quadratic and cubic components of regression. Only significant interactions are shown.
x, xx, xxx = statistical significance at the .05, .01 and 0.1 level of probability, respectively. Lack of significance is indicated by no entry.

increased dieback in times of water stress. In Experiments 2 and 3, another type of twig dieback also occurred which was characterized by twigs dying after leaf abscission. In no case were subsequent growth flushes delayed or abnormal on trees suffering dieback or leaf drop caused by KGA.

Bradley and Crane (1957) reported tests in which cambial activity in fruiting spurs of apricot was stimulated by gibberellin. This suggests the possibility of altered conductive tissues in the developing shoot. In experiments employing cotton stem-petiole sections, abscission was retarded or enhanced, depending on GA concentration and the site of GA application (Carns *et al.*, 1961). Localized applications of KGA or GA to flowers or small fruit on citrus trees have caused increased fruit set, apparently as the result of reducing abscission. It is suggested that gradients as well as concentration may be important; and, at least where citrus leaf abscission is involved, water supply is possibly an influence.

When the number of citrus fruits is reduced at an early stage (because of adverse weather, hand-thinning, or chemical fruit-thinning sprays), the expected response is an increased fruit size (Parker, 1934; Hield, Burns, and Coggins, 1962). This was not the case when KGA was applied to the navel orange. A reduction of fruit size and a reduction in number and size of seeds has been reported by Soost and Burnett (1961), testing KGA sprays on Clementine mandarin. Krezdorn and Cohen (1962) found that the application of GA sprays to Orlando tangelo at prebloom and post-bloom periods increased fruit set compared with the control and with sprays made during the bloom period only. A leaf drop was associated with the treatments given during bloom but not with the pre- or post-bloom applications. Sprays of KGA from 37.5 to 300 ppm applied during bloom increased the fruit set of Valencia oranges in a single experiment in California (Coggins, Hield, and Garber, 1960). A slight but significantly increased leaf drop was associated with these KGA treatments. Fruit size was decreased and the fruit was lengthened.

The evidence thus suggests that the lack of a size response when the number of fruit is reduced by KGA sprays may be due to a decreased ratio of leaves to fruit rather than a direct inhibition of fruit growth by the gibberellin. This is in contrast to applications of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,-5-T), which increased fruit size and prevented leaf abscission but resulted in a thickening effect on the fruit stem similar to that caused by gibberellin (Coggins, Hield, and Boswell, 1960; Krezdorn and Cohen, 1962). Erickson *et al.* (1952) and Gardner, Reece, and Horanic (1961) found that spraying with maleic hydrazide (MH) reduced fruit size. The effect of MH on fruit size was not associated with leaf drop.

Rind thickness of KGA-sprayed fruits was increased in certain instances in Experiments 1, 2, and 3. The increased rind thickness was sometimes accompanied by a decreased percentage of juice. Coggins, Hield, and Garber (1960) found a similar relationship between rind thickness and percentage of juice when KGA sprays were applied to the Valencia orange. KGA treatments on mandarins increased the percentage of juice, but this was due to a lower amount of dry juice vesicles (probably a delayed maturity effect) rather than a rind influence (Soost and Burnett, 1961). Both 2,4-D and MH cause increased rind thickness of citrus fruits when they are applied in early stages of fruit development.

During the course of the presently described experiments, 1959 was the only year when there was a general occurrence of split fruit. This was also the only year when application of KGA increased the splitting of developing navel fruit. Krezdorn and Cohen (1962) also found an increased occurrence of split

fruit on the Orlando tangelo as a result of gibberellin treatments.

In Experiment 1, gibberellin showed an influence in delaying the loss of green rind color (Coggins and Hield, 1958) in early December, but by mid-January an orange rind color had developed. Coggins *et al.* (1963) also showed that KGA treatment of citrus fruits—at later stages of development, but before the loss of green rind pigments—exerts the greatest influence on the retention of green rind color. The results indicated that KGA at the lower levels of the 1959 and 1960 spray concentration will not influence fruit color if the fruit is not harvested at an early stage of maturity.

The effects of KGA spray treatments of entire trees are pronounced and are horticulturally undesirable. Equally striking effects occur in KGA treatments of flower clusters or young fruit; the fruit set is approximately doubled (Hield, Coggins, and Garber, 1958). Further experiments are needed to determine whether the application of KGA to the flower clusters only on entire citrus trees increases fruit set. The report of experiments in Japan communicated by Coyne indicates that this is possible. Should such treatment succeed, practical methods of application, such that the concentration gradients are from the fruit to the rest of the tree, might be devised through insect dispersal of the gibberellin, or by other means.

SUMMARY

Experiments in three representative navel orange-growing districts of California tested the effects of KGA tree sprays on fruit set. In 1958, concentrations of 46, 92, and 184 ppm KGA were applied to Washington Navel orange trees as single sprays at four dates during flowering and early fruit set. A decreased yield of fruit resulted from almost all the treatments. This lower field-box yield, compared with that of the controls, along with no difference in fruit size resulting from treatments, indicated that KGA depressed fruit set. The occurrence of twig dieback and leaf drop due to the KGA treatments was correlated with the reduction in fruit set. Twig dieback and, to a lesser degree, leaf drop were most severe from the spray applications nearest the spring growth flush.

In all the experiments, whenever certain of the higher concentration levels of KGA were applied at the later spray dates, an increase in rind thickness of the fruit followed. KGA exerted a retarding effect on the development of orange rind color as the fruit approached maturity; but when the fruit was fully mature from a marketing viewpoint, this disappeared.

In 1959 and 1960, KGA sprays were applied at 12.5, 25, and 50 ppm levels in experiments at Riverside. Single-spray applications were made on three different dates during the period of bloom and early fruit set. The yield was not influenced by the 1959 spraying but was reduced by all KGA levels as a result of the first spraying in 1960. An increased number of split fruit was associated with the KGA treatments of 1959.

In previous experiments, in both California and Florida, fruit-set increases were obtained by KGA treatment of the flower cluster only or of isolated small branches of citrus trees. However, in the experiments reported herein, the spraying of entire trees with KGA, wetting most of the leaves, twigs, and flowers, failed to increase fruit set on the Washington Navel orange. It would seem that the potential exists for commercially increasing fruit set of citrus with KGA if its application can somehow be confined to the flower parts only.

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