THE EFFECTS OF SOME GROWTH-REGULATING CHEMICALS ON THE GERMINATION OF CITRUS SEEDS

by

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STATEMENT OF THE PROBLEM

The propagation of citrus rootstock by commercial nurserymen in the various citrus areas of the United States has presented many technical problems in the field of germination of citrus seed. The low percentage of germination necessitated the planting of excess seed to obtain sufficient seedlings for budding to commercial varieties.

Asexual propagation of citrus for rootstock purposes is not economical since this method requires more labor, larger greenhouse facilities, and more exacting conditions than would be needed for sexual propagation.

This research has been directed toward means of increasing the germination of sour orange and Cleopatra mandarin seed, two desirable disease-resistant rootstocks. The main objective of this study was to increase germination of citrus seed used for rootstocks.

Two groups of growth regulators were selected. The first group has been reported in the literature as affecting growth processes other than seed germination, and the second group has been reported as affecting seed germination. The two groups were:

Group I: Alpha naphthalene acetic acid
2,4,5 trichlorophenoxyacetic acid
Indolebutyric acid
Maleic hydrazide

Group II: Thiourea
2,4-Dichlorophenoxyacetic acid

REVIEW OF LITERATURE

Many chemical compounds have been synthesized during the past twenty years, and more specifically during the period since 1941, which have an effect on plant growth. Most of these materials are hormones or hormone-like substances which have an effect on the development, flowering, and fruit set of plants. The reaction of growth regulators on germination of seed and on plant growth may be different at various levels of concentration. An example of this is 2,4-D which is used widely as a weed killer in commercial crops, being especially recommended for broad-leaf plants and in citrus orchards to reduce fruit drop or for other beneficial results.

Mahmoud (12) in his recent research found that 2,4-D could be used to reduce respiration in stored citrus fruit. Franklin (5) found that ammonium salt of 2,4-D at 20 p.p.m. would facilitate bolting and the production of seed in head lettuce.

Zimmerman and Hitchcock (15) of the Boyce Thompson Institute published their work in 1942 describing the use of 2,4-D as a plant-growth regulator; and in 1944 North and Mitchell (13) of the U.S. Department of Agriculture reported on the destruction of many weeds with 2,4-D.

Limited research work has been done with 2,4-D as an aid to seed germination. Haas and Brusca (10) in Riverside, California, found that the 2,4-D treatment of citrus seed would double the germination.

Hseuh and Lou (8) found that 2,4-D accelerated the germination of barley and rice seed at low concentrations, but would delay germination when a certain threshold of concentration was exceeded. Hamner, Moulton and Tukey (9) found in 1946 that solutions of 2,4-D had greater inhibiting effects than the dust form on cabbage, clover, and wheat seed. With 0.01 gm. per pot of soil, cabbage and clover seed failed to germinate, but 85 per cent of the wheat germinated.

Allard, DeRose and Swanson (1) found in 1946 that 2,4-D retarded the rate of germination of many plants used in their tests. The delay in initiation of growth increased proportionally with the increase of 2,4-D.

In 1949 maleic hydrazide was released for experimental work by the United States Rubber Company. Since then many workers have reported their results relative to the effect of maleic hydrazide on plant growth. Some of the suggested uses based on these investigations were to improve storage qualities of crops, as herbicide, and as a temporary growth inhibitor (6). Knott (11) in California demonstrated that the growth of pyracantha hedges could be controlled with maleic hydrazide.

Numerous growth regulators have been used commercially or experimentally in many phases of plant propagation, orchard management, and vegetable production. Batjer and

Moon (2) used naphthalene acetic acid spray to reduce the dropping of apples; Batjer, Thompson and Gerhardt (3) demonstrated that this growth regulator and 2,4-D could control pre-harvest drop of Bartlett pears; Gorman and Barton (7), using thiourea in solutions of 0.5 and 1.0 per cent, increased the germination of lettuce seed.

Many growth regulators have been used in rooting cuttings. Swartley and Chadwick (14) used indoleacetic and indolebutyric acid and found that these substances, when mixed with talc, would aid root production of evergreen and softwood deciduous cuttings. Cooper, William and Kenneth (4) used one mg. naphthalene acetic acid per gm. of talc for a rooting aid.

MATERIALS AND METHODS

The germination tests were conducted in the Horticulture Department's greenhouse, University of Arizona. This greenhouse provided excellent facilities for maintaining constant temperature by the use of hot water heat. The heating pipes located under the benches maintained a constant temperature of 70° F. during the winter months. Lead heating cables were placed under the rooting media to maintain soil temperature at 80° F.

Sour orange fruit was selected from healthy, good bearing trees from the citrus plot of the Horticulture Department. The fruit was large in size and high in quality. It was washed in tap water, cut into halves, and twisted by hand to avoid seed injury. The seed was washed in tap water several times and was selected for size, uniformity, and freedom from injury and disease.

The Cleopatra mandarin seed was obtained from the Grand Island Nurseries at Eustis, Florida. The seed was dried after extraction and was in good condition.

The solutions of 2,4-D; 2,4,5T; maleic hydrazide, thiourea, alpha naphthalene acetic acid, and indolebutyric acid were prepared in the laboratory of the Horticulture Department.

Experiment No. 1

The object of this experiment was to determine the effect of 2,4-D; 2,4,5T; and maleic hydrazide in various concentrations on germination of seed of freshly harvested sour oranges.

On June 12, 1953, three hundred (300) sour orange fruit of uniform size and color were collected from trees located on the University of Arizona campus. The seed was extracted from the fruit and washed thoroughly in water to remove pulp and juice. Twenty-four hundred seeds were selected for uniform size. After washing, the seed was placed in water and stored under refrigeration at 50° F. for 8 hours.

Solutions were made from 2,4-D (sodium salt 70 per cent) as follows. The 2,4-D was dissolved in 10 cc. carbo wax 1500, then in distilled water, and the following concentrations were prepared: 1 p.p.m., 10 p.p.m., 50 p.p.m., 100 p.p.m., 250 p.p.m., 500 p.p.m., and 1000 p.p.m.

The 2,4,5-T solutions were prepared in the same manner as the 2,4-D.

The maleic hydrazide concentrations were prepared from a liquid form, 30 per cent maleic hydrazide, and from that solution the following concentrations were prepared: 30 p.p.m., 90 p.p.m., 300 p.p.m., 600 p.p.m., 1500 p.p.m., 3000 p.p.m., and 6000 p.p.m. in distilled water.

On June 14, each group of 100 seeds was soaked for 30 minutes in the various solutions; 100 seeds were used as a control group. The seed was then planted in rows in the

Plate 1. View of Sour Orange Seedlings in Greenhouse Propagating Bench

Date of planting: 12/13/53
Date picture taken: 4/28/54

greenhouse and received adequate water. Figure 1 shows the exploratory arrangement of the planting in the greenhouse.

Experiment No. 2

The object of this experiment was to determine the rate of germination after 15 days, and the effect of the various growth regulators on germination. Sour orange seed used in this experiment was extracted from the fruit in the same manner as for Experiment No. 1.

Solutions were prepared of thiourea 4 per cent; thiourea 8 per cent; indolebutyric acid 1 p.p.m.; alpha naphthalene acetic acid 1 p.p.m., 10 p.p.m., 50 p.p.m., 100 p.p.m., and 250 p.p.m.

On July 7, 1953, each group of 50 seeds was treated by soaking in the solutions as follows:

Group 1 in thiourea 4 per cent for one hour

Group 2 in thiourea 4 per cent for 8 hours at 50° F.

Group 3 in thiourea 8 per cent for one hour

Group 4 in thiourea 8 per cent for 8 hours at 50° F.

Group 5 in indolebutyric acid, 1 p.p.m., for one hour and for 8 hours

Group 6 in alpha naphthalene acetic acid 1 p.p.m., 10 p.p.m., 50 p.p.m., 100 p.p.m., 250 p.p.m. for one hour

Group 7 in 2,4-5 15 p.p.m.

Group 8 was the control or untreated seed.

All seed was planted July 7 in clay pots in sand.

Row no.	
	2,4-D
1	1 ppm
2	10
3	50
4	100
5	250
6	500
7	1000
8	Control
	2,4,5T
1	1 ppm
2	10
3	50
4	100
5	250
6	500
7	1000
8	Control
	Maleic Hydrazide
1	30 ppm
2	90
3	300
4	600
5	1500
6	3000
7	6000
8	Control

Figure 1. Arrangement of Fresh Sour Orange Seed and Treatments in Greenhouse

Experiment No. 3

Each group of 100 seeds of sour orange was treated with maleic hydrazide 6000 p.p.m., maleic hydrazide 12,000 p.p.m., thiourea 8 per cent; and 100 untreated seeds acted as a control. The seed was soaked for 8 hours, then planted in a randomized block on August 25 in a sand medium and was irrigated frequently. (See Fig. 2.)

Row 1	Maleic hydrazide 12,000 ppm	Maleic hydrazide 6000 ppm	Thiourea 8%	Control
Row 2	Maleic hydrazide 6000 ppm	Maleic hydrazide 12,000 ppm	Control	Thiourea 8%
Row 3	Thiourea 8%	Control	Maleic hydrazide 6000 ppm	Maleic hydrazide 12,000 ppm.
Row 4	Control	Maleic hydrazide 12,000 ppm	Thiourea 8%	Maleic hydrazide 6000 ppm

Figure 2. Latin Square Arrangement of Sour Orange Seed Plots in the Greenhouse

Experiment No. 4

Sixteen hundred seeds were collected from 120 sour orange fruits on December 4, 1953. After extraction and washing, the seed was dried in the sun for 6 hours and kept for 9 days in the laboratory at 75° F. On December 13 each group of 400 seeds was treated as follows:

Group A - not treated

Group B - soaked in maleic hydrazide 6000 p.p.m.

Group C - soaked in thiourea 4 per cent

Group D - soaked in 2,4-D 100 p.p.m.

The seed was soaked in the various solutions for 50 minutes, then planted in randomized blocks in a sand medium with temperature set at 80° F. (See Fig. 3.)

Experiment No. 5

In this experiment 800 sour orange seeds were treated in the same manner as those in Experiment No. 4, and planted on December 13. The plot was randomized, and temperature maintained at 80° F. (See Fig. 4.)

Experiment No. 6

This experiment was conducted with Cleopatra mandarin. The dried seed was divided into two groups. Growth-regulating solutions were made of 2,4-D 100 p.p.m., maleic hydrazide 6000 p.p.m., and thiourea 4 per cent. The two groups were treated as follows:

Group 1 - soaked in tap water for 48 hours, then placed in the 2,4-D; maleic hydrzaide, and thiourea solutions for one hour

Group 2 - placed directly into the same growth-regulating solutions as Group 1 for one hour.

The seed was planted immediately after being removed from the solutions. Dried and wet seeds were planted beside each other in a randomized block in the greenhouse, with temperature set at 80° F. (See Fig. 5.) The date of planting was December 13, 1953.

Row no.	Treatment
1	Control
2	Maleic hydrazide 6000 ppm.
3	Thiourea 4%
4	2,4-D 100 ppm
1	Thiourea 4%
2	2,4-D 100 ppm
3	Control
4	Maleic hydrazide 6000 ppm
1	Maleic hydrazide 6000 ppm
2	Control
3	Thiourea 4%
4	2,4-D 100 ppm
1	2,4-D 100 ppm
2	Thiourea 4%
3	Maleic hydrazide 6000 ppm
4	Control

Figure 3. Arrangement of Dried Sour Orange Seed in Rows with 16 Replications

Row 1	2,4-D 100 ppm	Control	Maleic hydrazide 6000 ppm	Thiourea 4%
Row 2	Maleic hydrazide 6000 ppm	Thiourea 4%	2,4-D 100 ppm	Control
Row 3	Control	2,4-D 100 ppm	Maleic hydrazide 6000 ppm	Thiourea 4%
Row 4	Thiourea 4%	Maleic hydrazide 6000 ppm	Control	2,4-D 100 ppm

Figure 4. Latin Square Arrangement of Fresh Sour Orange Seed Plots in Greenhouse

Row no.	Seed	Treatment
1	Dried	Thiourea 4%
2	Wet	Thiourea 4%
3	Dried	2,4-D 100 ppm
4	Wet	2,4-D 100 ppm
5	Dried	Maleic hydrazide 6000 ppm
6	Wet	Maleic hydrazide 6000 ppm
7	Dried	Control
8	Wet	Control

Figure 5. Arrangement and Treatment of Cleopatra Mandarin Seed in the Greenhouse

Plate 2. View of Cleopatra Mandarin Seedlings in Greenhouse Propagating Bench

Date of planting: 12/13/53
Date picture taken: 4/28/54

PRESENTATION OF RESULTS

Experiment No. 1

Experiment No. 1 was exploratory and was not designed for statistical analysis.

Germination of the treated and check plot was first evident July 2, 1953 as follows:

Control	4 seedlings
2,4,5T 10 ppm	1 "
Maleic hydrazide 30 ppm	1 "
2,4-D	None

The seed in the control plots increased in germination every day until July 23, 1953; a germination of 68 per cent was reached.

The seed treated with 2,4,5T germinated as follows:

1 p.p.m. - the seed started to germinate 4 days after the control (on July 6, 1953) and stopped on July 23 with 35 per cent germination

10 p.p.m. - 41 per cent of the seed germinated by July 23

50 p.p.m. - 4 per cent of the seed germinated

100 p.p.m. - one per cent of the seed germinated

With solutions containing 2,4,5T in concentrations of 250, 500 and 1000 p.p.m. there was no germination.

These results indicated that 2,4,5T is not beneficial in the germination of citrus seed. The germination percentage generally was low, and the seedlings from 2,4,5T-treated seed were small and weak. (See Fig. 6.)

Maleic hydrazide also inhibited the germination of seed, but it was not toxic when used in concentrations below 6000 p.p.m. The results of this experiment were as follows:

Germination of sour orange seed treated with maleic hydrazide in solutions of 30 and 6000 p.p.m. exceeded that of the control plots. Using 6000 p.p.m., 73 per cent germination was obtained. Growth of the seedlings was satisfactory.

Solutions containing maleic hydrazide in concentrations of 90, 300, 1500 and 3000 p.p.m. delayed germination for 11 days (see Table I). The inhibited seed germinated rapidly after 10 days, and germination was completed on July 23, 1953.

All seed treated with maleic hydrazide germated at the rate of 46 to 73 per cent. (See Fig. 7.)

The effect of 2,4-D on germination of citrus seed varies with the concentration of the solutions used in soaking the seed. A solution of 2,4-D 1 p.p.m. inhibited germination for 10 days, when germination started slowly. It was completed on July 23, 1953.

The plot treated with the 10 p.p.m. solution began to germinate on July 3, and germination proceeded very slowly during the next 10 days.

Germination in the plots using 50 p.p.m. solution began July 9 and resulted in 27 per cent germination.

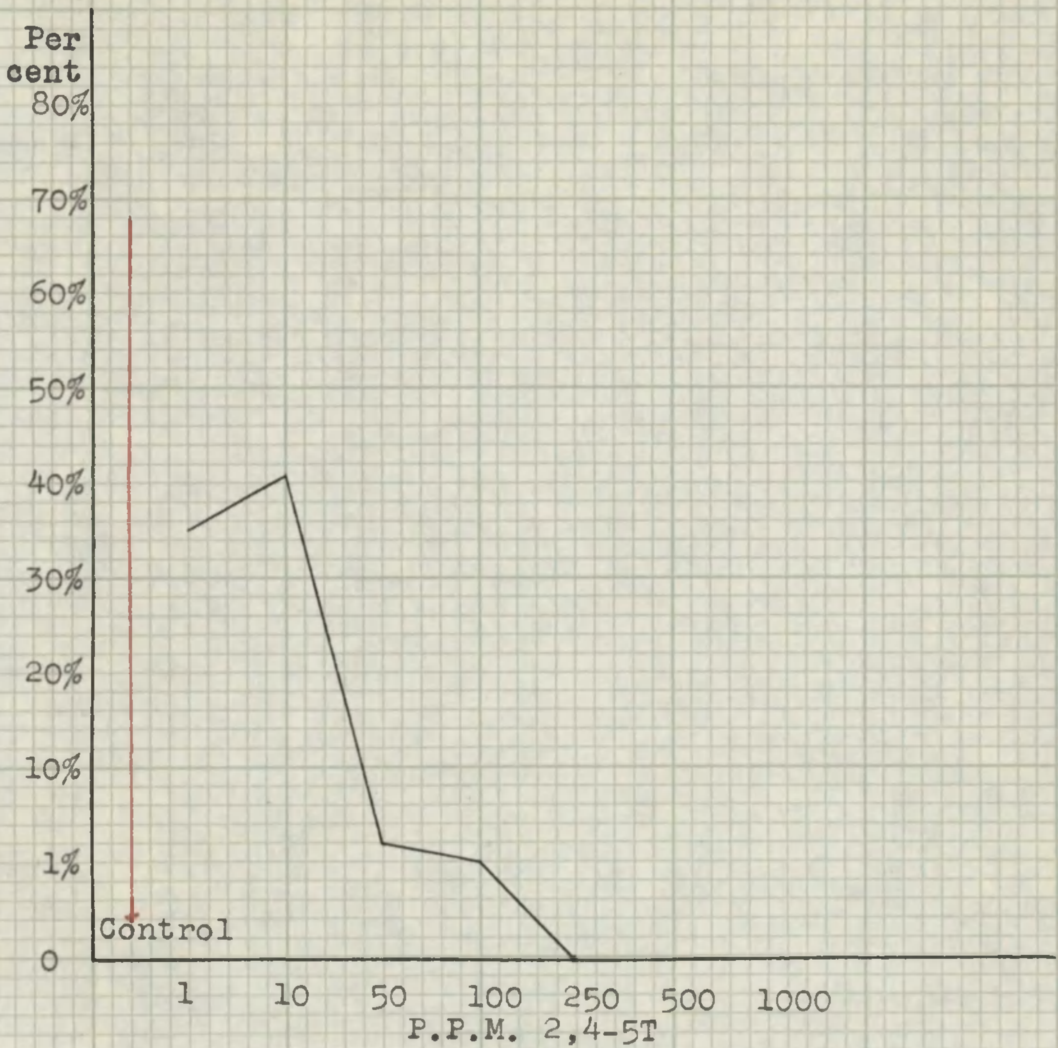


Fig. 6. The Effect of 2,4,5T on the Germination of Sour Orange Seed

Table I. Percent Germination of Sour Orange Seed (100 Seed Used in Each Row)

Date	2,4-D							2,4,5T							Maleic hydrazide							Control
	1	10	50	100	250	500	1000	1	10	50	100	250	500	1000	30	90	300	600	1500	3000	6000	
	p.p.m.							p.p.m.							p.p.m.							
7/ 2/53									1						1							4
7/ 3		1		3					1						1							5
7/ 4		1		6	2				1						1						3	6
7/ 5		3		8	4				1						1						3	20
7/ 6		3		14	7			1	4						2						3	21
7/ 7		5		19	8			2	5						3						3	28
7/ 8		5		21	11			4	5						7						3	29
7/ 9		5	1	26	13			6	7						7						5	30
7/10		6	3	36	14			8	9						13						10	30
7/11		7	3	42	17			9	12	1	1				15				4	4	17	33
7/12	1	10	6	49	17			14	23	1	1				16	2	3	3	8	5	22	35
7/13	6	16	9	54	19			19	26	2	1				25	9	7	6	9	8	30	36
7/14	7	17	11	58	20			20	26	2	1				33	15	14	9	20	13	40	41
7/15	20	21	15	62	21			35	39	3	1				40	23	16	15	26	14	48	47
7/16	21	24	19	65	21			35	40	3	1				47	28	24	20	30	21	51	51
7/17	21	25	23	70	26	1		35	41	4	1				51	38	25	23	35	24	56	52
7/18	24	28	26	70	27	1		35	41	4	1				60	44	52	33	39	31	59	61
7/19	26	29	27	72	27	1		35	41	4	1				65	47	53	41	39	35	62	62
7/20	27	30	27	76	29	1		35	41	4	1				72	52	60	48	46	41	69	66
7/21	27	32	27	76	30	1		35	41	4	1				72	54	61	49	48	52	69	66
7/22	27	32	27	76	31	1		35	41	4	1				73	57	62	55	48	43	69	68
7/23	27	33	27	76	31	1		35	41	4	1				72	66	67	60	53	46	73	68

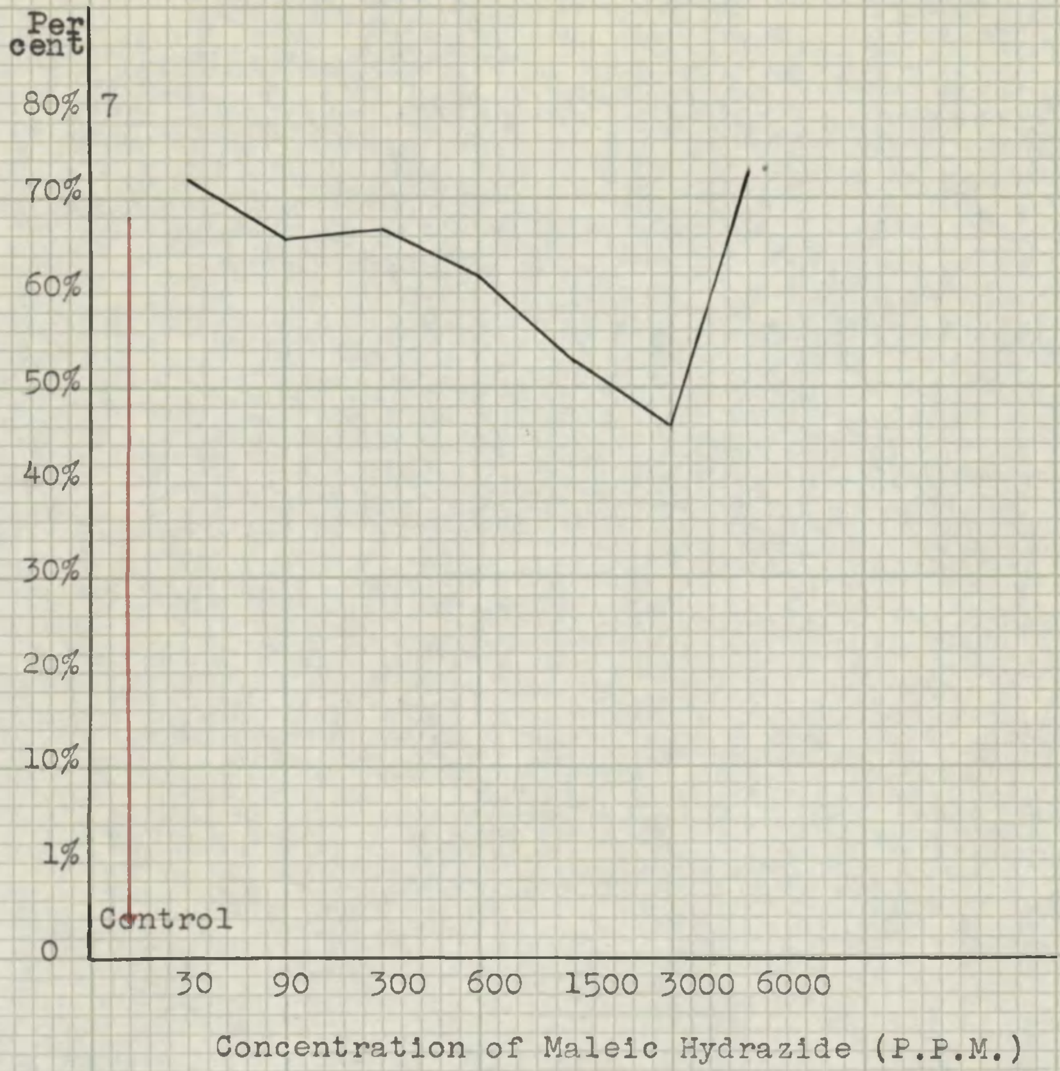


Fig. 7. The Effect of Maleic Hydrazide on the Germination of Sour Orange Seed

The seed soaked in 100 p.p.m. began germinating on July 3 with 3 seedlings; germination increased every day, exceeding the control plots with an additional 8 seedlings.

Optimum germination was obtained with the concentration of 100 p.p.m. 2,4-D. (See Table I and Fig. 8.)

Germination of 31 per cent resulted from the solution of 250 p.p.m.

The 500 p.p.m. solution effected the germination of one seedling on July 17, and the 1000 p.p.m. solution gave no germination. (See Fig. 9.)

As shown graphically in Figure 8, the optimum germination results obtained in Experiment 1 were:

1.	2,4-D 100 ppm	76%
2.	Maleic hydrazide 6000 ppm	73
3.	2,4,5T 10 ppm	41
4.	Control	68

Experiment No. 2

On July 22, 1953, the sour orange seed was taken from the clay pots and washed with tap water. The seed that had germinated in each group was counted, and it was decided the seed needed more than 15 days to germinate. Results from this experiment were:

Thiourea 4 per cent gave 30 per cent germination when the seed had been soaked for one hour.

A temperature of 50° F. reduced the rate of germination as compared with room temperature, about 76° F.

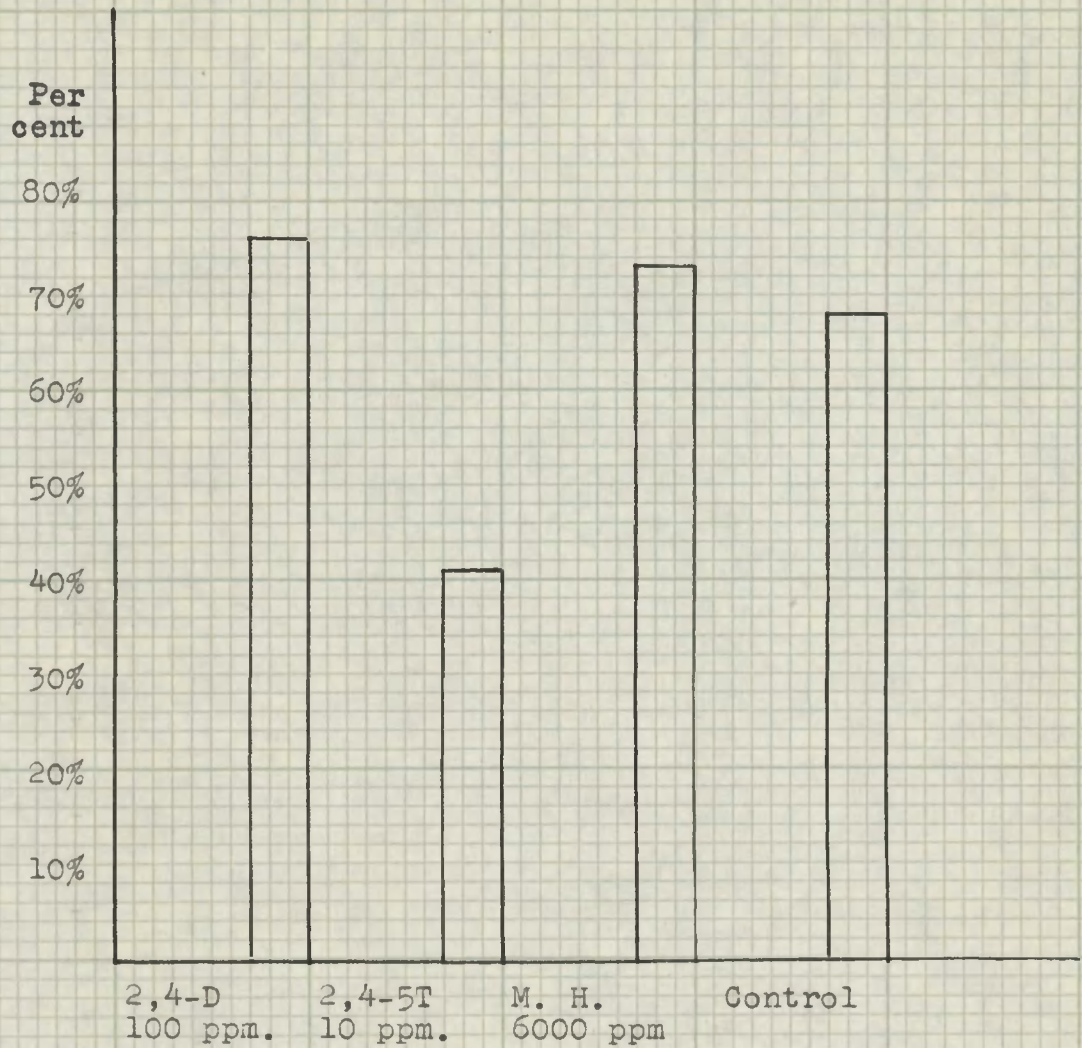


Fig. 8. Optimum Germination of Sour Orange Seed Using Various Growth Regulators

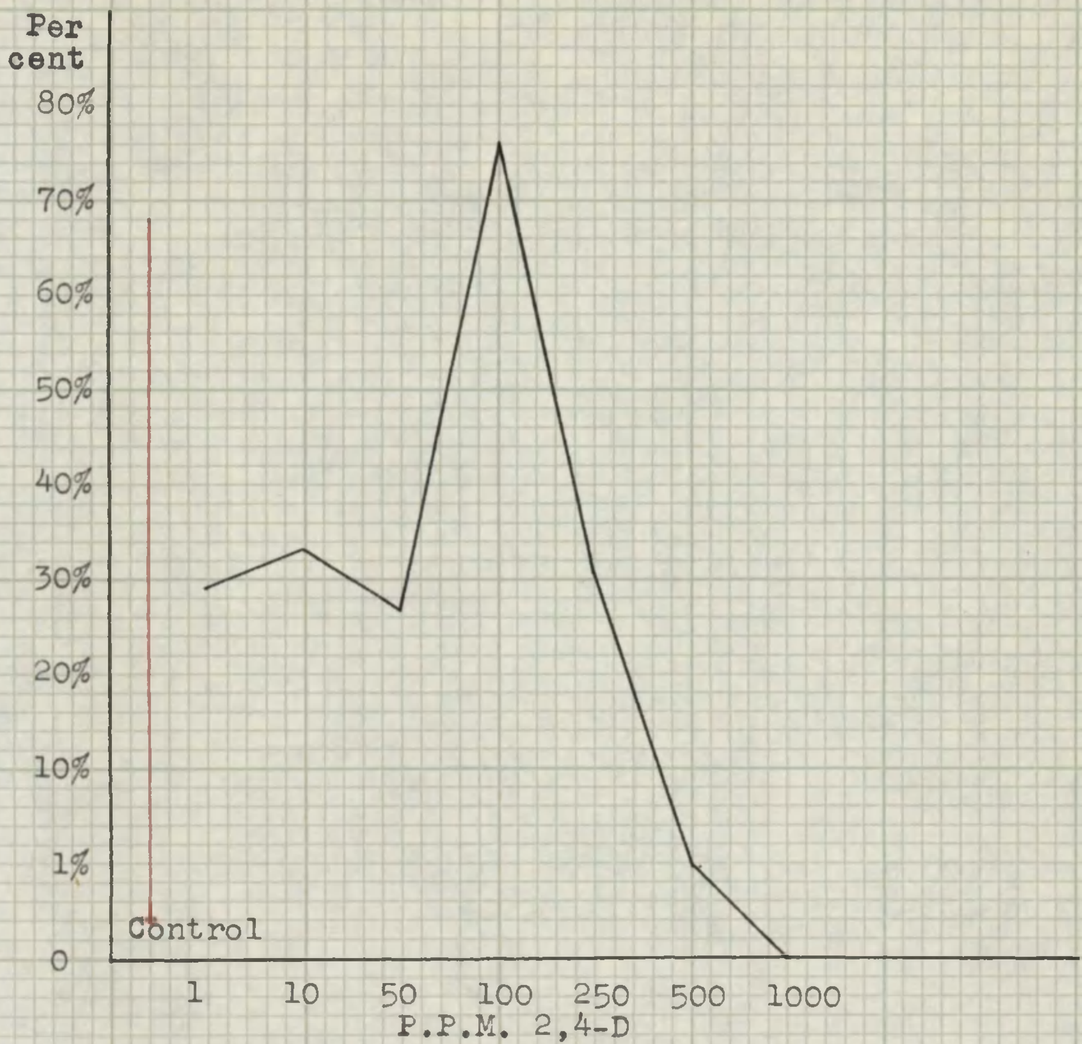


Fig. 9. The Effect of 2,4-D on the Germination of Sour Orange Seed

Indolebutyric acid 1 p.p.m. gave 18 per cent germination when the seed had been soaked one hour, and 6 per cent when the seed was soaked for 8 hours.

With 2,4-D 15 p.p.m. there was germination of 2 per cent.

In the control seed 3 per cent germination occurred, and in that soaked in alpha naphthalene acetic acid no germination took place. (See Table II.)

Table II. Percent Germination of Fresh Sour Orange Seed

Treatment	% of seeds germinated on July 22
Thiourea 4% for 1 hour	30
Thiourea 4% for 8 hrs. at 50° F.	24
Thiourea 8% for 1 hour	20
Thiourea 8% for 8 hrs. at 50° F.	14
Indolebutyric acid 1 ppm for 1 hour	18
Indolebutyric acid 1 ppm for 8 hrs.	6
Alpha naphthalene acetic acid 1 ppm, 10 ppm, 50 ppm for 1 hour	0
2,4-D 15 ppm for 1 hour	2
Control	3

Experiment No. 3

The fresh sour orange seed plots in the greenhouse started to germinate on September 13, 1953. The rate of germination increased, then stopped on October 18 (Table III). The statistical analysis showed no significant difference, as is evident from Table IV.

Experiment No. 4

The total germination of the dried sour orange seed was very poor. It reached 50 per cent, including the control (Fig. 10 and Table V). The statistical results gave significance in the F 0.01, as shown in Table VI. There was no significant difference at F 0.05.

Experiment No. 5

The germination of the fresh sour orange seed ranged from 69 to 80 per cent (Table VII). From the statistical standpoint, the results showed no significant difference (Table VIII).

Experiment No. 6

The seed of the Cleopatra mandarin was slow in germinating, but the germination of both dried and wet seed was highly significant. The germination of seed soaked with the growth regulators showed a greater increase than that in the control plots. In the control there was no difference between the dried and wet seed (Table IX and Fig. 11).

Treatments are significant at the 5 per cent level, and not significant at the 1 per cent level. The results in Table X show that there is a significant difference in the data from Experiment 6.

		Treatment means*
A A1	Thiourea, 4% "	12.43
B B1	2,4-D 100 ppm "	7.5
C C1	Maleic hydrazide 6000 ppm "	7.93
D D1	Control "	5.6
	L.S.D. at 5% level	5.6

*Number of seed germinated from total of 25 planted in each plot

Table III. Percent Germination of Fresh Sour Orange Seed

Date	Control	Maleic hydrazide 12,000 ppm	Maleic hydrazide 6000 ppm	8% Thiourea
9/13/53	10.0%	0 %	1.0%	1.0%
9/20/53	66.0	18.0	45.5	32.5
9/27/53	78.0	35.5	67.5	55.5
10/4/53	81.5	47.5	72.5	67.0
10/11/53	82.5	52.0	75.0	75.5
10/18/53	82.5	64.0	82.5	80.0

Table IV. Statistical Analysis of Data from Experiment No. 3

Source of variation	Degree of freedom	Sum of square	Mean square	F
Treatment	3	112.25	37.42	0.71
Replications	3	81.25	27.08	0.51
T x R error	9	474.25	52.69	
Total	15	667.75		

F 0.01 df 3,9 (6.99) not significant
F 0.05 df 3,9 (3.86) not significant

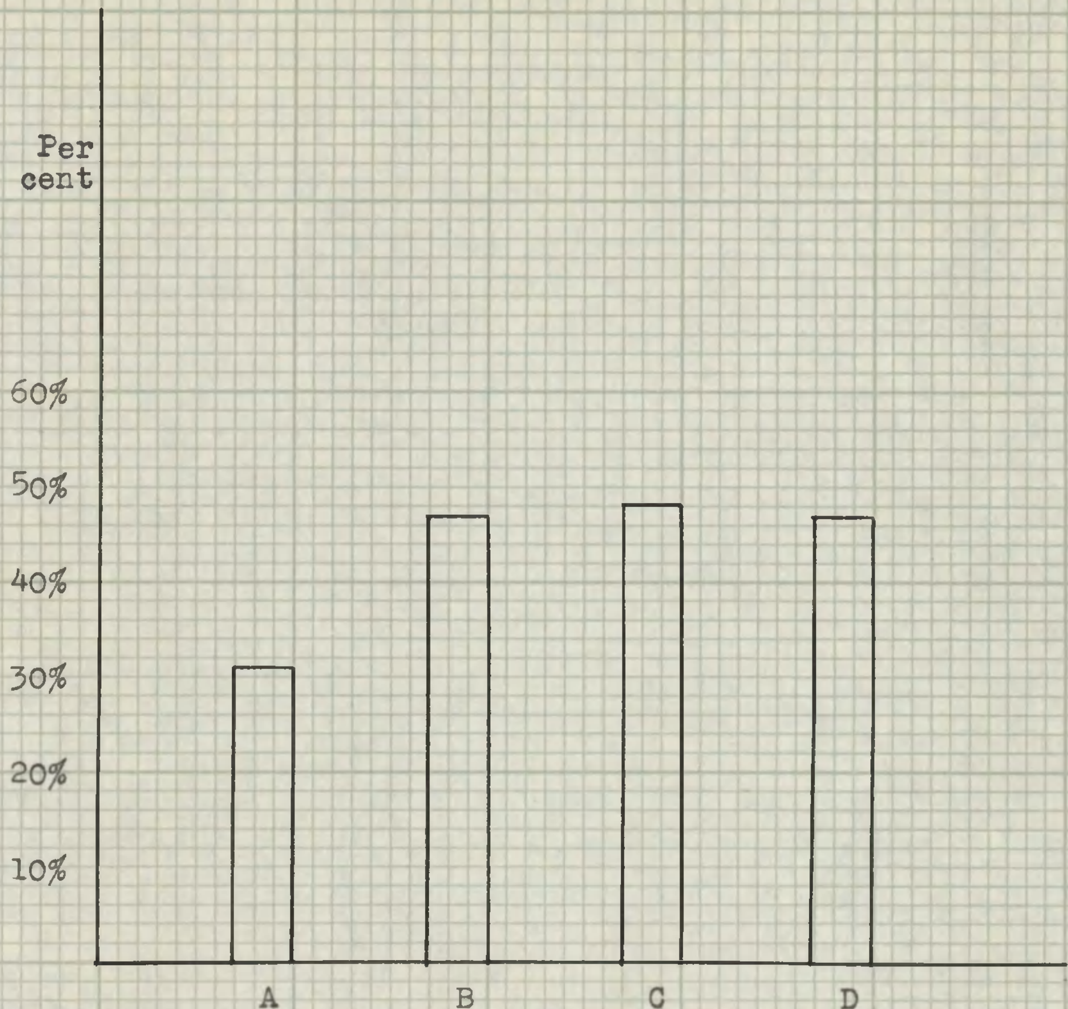


Fig. 11. Optimum Germination of Dry Sour Orange Seed Using Various Growth Regulators

A. Control

B. Maleic hydrazide, 6000 ppm

C. Thiourea 4%

D. 2,4-D, 100 ppm

Table V. Percent Germination of Dry Sour Orange Seed

Date	Control	Maleic hydrazide 6000 ppm	Thiourea 4%	2,4-D 100 ppm
1/27/54	25.5%	28.0%	24.5%	30.0%
2/ 6/53	26.5	37.5	36.0	39.0
2/14/53	30.5	46.5	48.5	47.0

Table VI. Statistical Analysis of Data from Experiment No. 4

Source of variation	Degree of freedom	Sum of square	Mean square	F
Treatment	3	53.62	17.87	3.07
Replications	15	61.97	4.13	
Error	45	261.64		
Total	64	377.23		

F 0.01 df 3,44 (4.26) significant
F 0.05 df 3,44 (2.82) not significant

Table VII. Percent Germination of Fresh, Treated Sour Orange Seed

Date	Control	Maleic hydrazide 6000 ppm	2,4-D 100 ppm	Thiourea 4%
3/10/54	50.0%	40.0%	51.0%	40.0%
3/20/54	57.0	53.0	62.0	59.0
3/30/54	80.0	69.0	74.0	73.0

Table VIII. Statistical Analysis of Data from Experiment No. 5

Source of variation	Degree of freedom	Sum of square	Mean square	F
Treatment	3	31.1	10.37	1.89
Replications	7	57.22	8.17	
Error	21	115.40	5.5	
Total	31	203.72		

F 0.01 df 3,21 (8.45) not significant
F 0.05 df 3,21 (4.35) not significant

Table IX. Percent Germination of Cleopatra Mandarin Seed

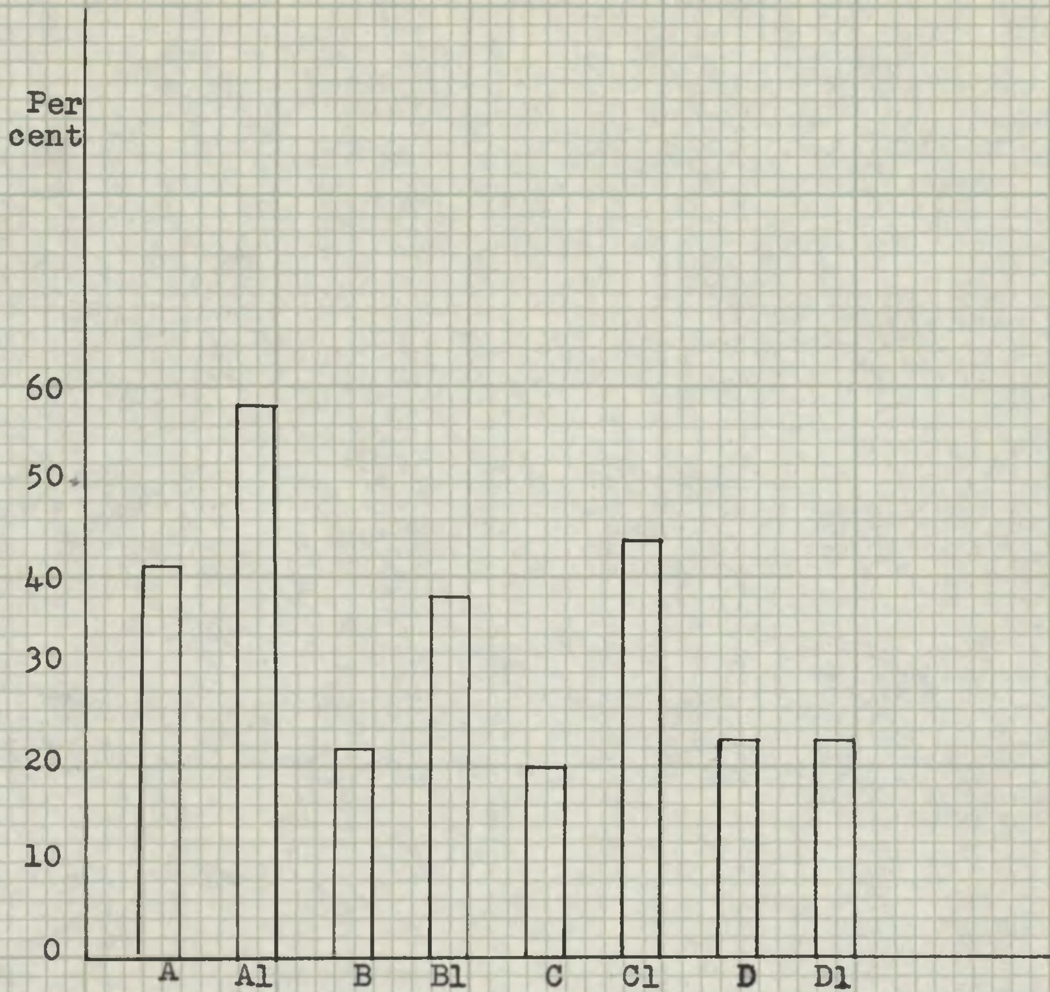
Date	Control		Thiourea 4%		2,4-D 100 ppm		Maleic hydrazide 6000 ppm	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
3/10/54	18.0	20.0	26.0	37.0	20.0	36.0	14.0	33.0
3/20/54	20.0	21.0	30.0	45.0	20.0	36.0	15.0	35.0
3/30/54	22.5	23.0	41.0	58.5	21.5	38.5	19.5	44.0

Table X. Statistical Analysis of the Number of Germinating Seed per Plot from Experiment No. 6 and Table IX, Date 3/30/54

	df	SS	Mean square	F
Material	3	394.93	131.64	4.6
Replications	7	45.11	6.44	
Error	21	609.38	28.59	
Wet and dry	1	4505.75	4505.75	776.8
Error	31	180.16	5.8	
Total	64	1303.23		

F 0.05 (df at 3 and 21) 3.07
F 0.01 (df at 3 and 21) 4.87

Therefore there is a significant difference in the treatment means, as shown on page 26.



A Wet seed treated with thiourea 4%
A1 Dried " "
B Wet seed treated with 2,4-D 100 ppm
B1 Dried " "
C Wet seed treated with maleic hydrazide 6000 ppm
C1 Dried " "
D Wet seed, not treated (control)
D1 Dried "

Fig. 11. Comparison of Optimum Germination of Dried and Wet Cleopatra Mandarin Seed Using Various Growth Regulators

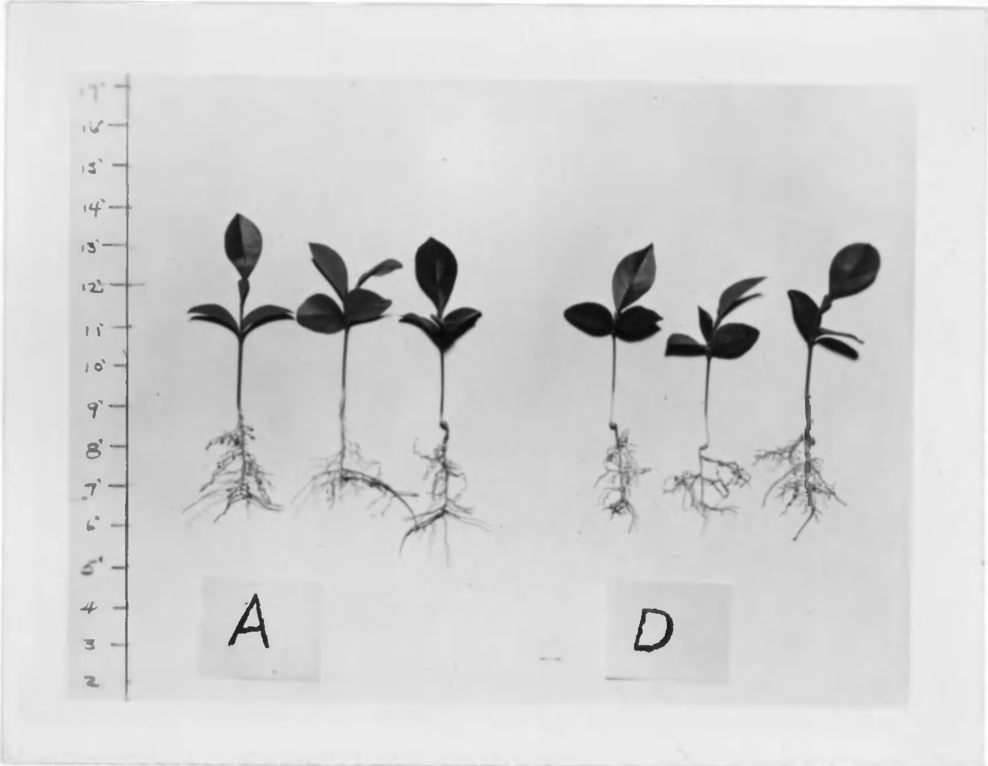


Plate 3. Sour Orange Seedlings
A. Treated with 4% Thiourea
D. Check Plants

Date of planting: 12/13/53
Date picture taken: 4/28/54

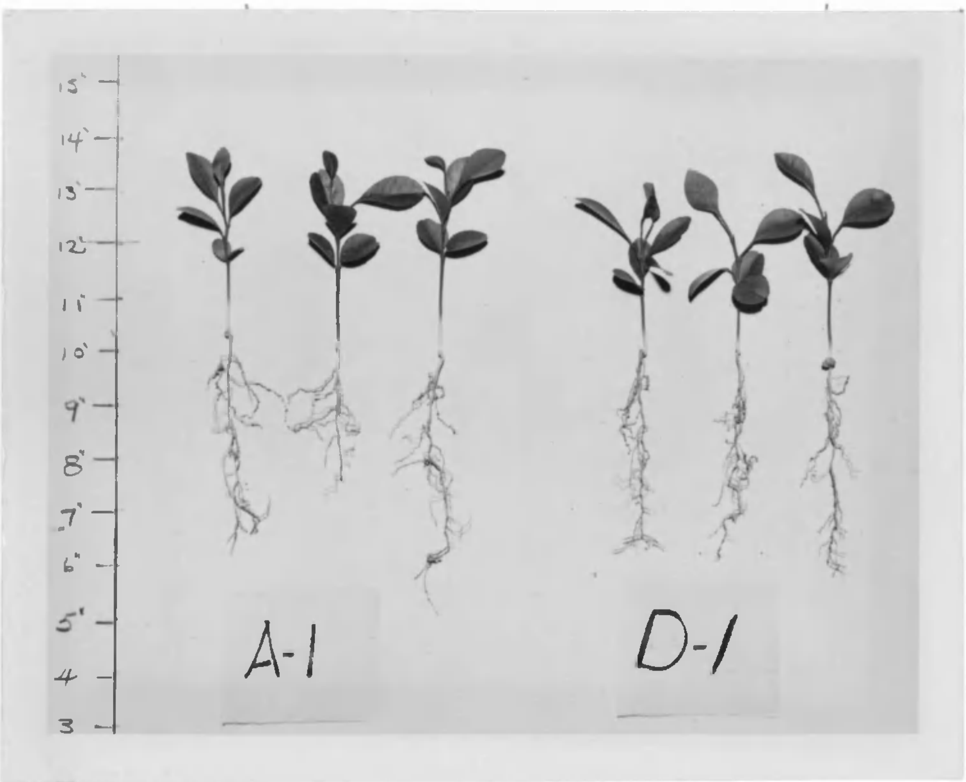


Plate 4. Cleopatra Mandarin Seedlings
A. Treated with 4% Thiourea
D. Check Plants

Date of planting: 12/13/53
Date picture taken: 4/28/54

DISCUSSION OF RESULTS

Six experiments were conducted to evaluate the effectiveness of growth-regulating solutions on the germination of citrus seed. These substances have been used extensively in asexual propagation of ornamental plants, but their effect on the germination of seed had not been reported when this experiment was undertaken.

The following growth-regulating chemicals were applied as seed treatments in the germination experiments: 2,4-D; 2,4,5T; maleic hydrazide; thiourea; alpha naphthalene acetic acid; indolebutyric acid. Sour orange and Cleopatra mandarin seed was used in the tests, as these two varieties are used for rootstocks in the commercial nursery trade. The germination percentage of these seeds is relatively low when planted under conditions used by the average nurseryman.

The selection of the growth-regulating substances for these experiments was based on the fact that certain chemicals had beneficial effects on the rooting of cuttings. It was therefore necessary to evaluate the effectiveness of these chemicals on an exploratory basis to eliminate those that had any adverse effect on the germination of citrus seed.

The first phase of the experimentation was exploratory and was designed to eliminate any chemical that lowered the germination percentage below that of the control plots. The seed was extracted from the sour orange fruit and placed directly into the solutions for a 30-minute period, then planted immediately in a sand medium. The results of this first experiment were:

Maleic hydrazide, 6000 p.p.m., 73 per cent germination; this treatment resulted in the highest germination.

Maleic hydrazide, 3000 p.p.m., 46 per cent germination; this treatment resulted in the lowest germination.

The effect of 2,4-D on the germination of citrus seed varied with the concentration used in the soaking solutions. The results obtained from using this chemical were outstanding since the concentrations had a beneficial or adverse effect on the germination of the citrus seed. Results obtained from using 2,4-D were as follows:

2,4-D, 100 p.p.m., 76 per cent germination; this treatment resulted in the highest germination.

2,4-D, 500 p.p.m., one per cent germination; this treatment resulted in the lowest germination.

The effect of 2,4,5T on the germination of citrus seed gave results similar to 2,4-D. The higher concentrations resulted in lower germination. Results obtained from the use of this chemical were:

2,4,5T, 10 p.p.m., 76 per cent germination; this treatment resulted in the highest germination.

2,4,5T, 100 p.p.m., 1 per cent germination; this treatment resulted in the lowest germination.

The second phase of the experimentation was also designed to be of an exploratory nature. Indolebutyric acid, alpha naphthalene acetic acid are commonly used in propagation of plants by asexual means, and their effect on the germination of citrus seed was studied in the hope of increasing germination. The results obtained from this test were as follows:

Indolebutyric acid, 1 p.p.m., 18 per cent germination.

Alpha naphthalene acetic acid, 1 p.p.m., 10 p.p.m., and 50 p.p.m., no germination.

These two growth regulators did not increase the germination of the citrus seed as compared with the control plots. The use of these chemicals is not recommended, as the results obtained do not warrant their use.

The third phase of experimentation was designed to evaluate the effectiveness of the three chemicals that gave the best results in Experiments Nos. 1 and 2. The test plots were enlarged to better study the effect of the chemicals on a larger scale. Cleopatra mandarin and sour orange seed was used in this test. The mandarin seed failed to give a high percentage of germination when planted without treatment. Maleic hydrazide, thiourea, and 2,4-D solutions were used in this test with the following results:

Dried Cleopatra mandarin seed soaked in a solution of 4 per cent thiourea gave a germination percentage of 58.5. This was the highest for the treated seed.

Dried Cleopatra mandarin seed soaked in the 100 p.p.m. 2,4-D solution gave a germination percentage of 38.5.

Dried Cleopatra mandarin seed soaked in the maleic hydrazide solution gave a germination percentage of 44.0.

SUMMARY AND CONCLUSIONS

The germination of citrus seed for rootstock purposes has been of concern to nurserymen, who often encounter difficulty in obtaining sufficient seedlings for budding to commercial varieties.

Growth-regulating substances have been used for many years to stimulate the rooting of cuttings, but these substances have not been used extensively in the sexual propagation of plants. A series of growth-regulating substances was used to determine their effectiveness in increasing the germination of sour orange and Cleopatra mandarin seed.

The results of these experiments, conducted under exacting conditions, are listed in the order of their effectiveness on germination.

1. Thiourea

    a. Thiourea was most effective in increasing the germination of dry citrus seed.

    b. Thiourea also gave more uniform growth response than any of the other growth substances.

    c. Higher germination percentage was obtained when used on dried citrus seed.

2. Maleic hydrazide

    a. Maleic hydrazide, 6000 p.p.m., increased the germination of dried Cleopatra mandarin seed, but it was found that it decreased germination of seed which had been soaked in water prior to treatment with maleic hydrazide.

b. Maleic hydrazide inhibited the germination of citrus seed for a period of 2 to 10 days as compared with the control plots. This inhibition did not have an adverse effect on the seed that germinated.

3. 2,4-D

a. 2,4-D, 100 p.p.m., increased the germination of dry Cleopatra mandarin seed, but it did not have any effect on seed soaked in water and later transferred to the 2,4-D solution. The most effective treatment, therefore, would be to place the dry seed directly into the solution.

4. 2,4,5T

a. 2,4,5T concentrations of 50 and 100 p.p.m. decreased the germination of citrus seed. The low concentrations of 1 and 10 p.p.m. gave relatively low germination of seed. This growth-regulating substance is not recommended for the treatment of citrus seed, as its effect on germination does not warrant its use.

5. Indolebutyric and alpha naphthalene acetic acid

a. These two growth-regulating substances have given excellent results in the rooting of cuttings, but they are not recommended for treating citrus seed since the results obtained in the germination tests did not increase the germination percentage.

Thiourea is the most promising growth-regulating substance for increasing the germination of citrus seed. Dried citrus seed should be placed directly into this solution before planting to obtain the most beneficial results.

The nurseryman should exercise caution in weighing the material, as excessive amounts could affect the germination when applied to the seed in the soaking process.

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