GROWTH RESPONSES AND NUTRIENT ABSORPTION BY CITRUS AS INFLUENCED BY GIBBERELLINS

by

CHAO-CHI TING

INTRODUCTION

Since the potentialities of auxin were first recognized some twenty or thirty years ago, no other plant hormones have drown so much attention as the gibberellins to the botanists and horticulturists. Gibberellins are produced by a fungus named *Gibberella fujikuroi* (Saw.) Wr. These compounds strikingly stimulate the growth of many plants, promote flowering in some cases, and cause various other interesting responses morphologically and physiologically. Different responses of gibberellins were shown in most kinds of plants studied, the most obvious response was stem elongation, and different genera gave different responses. Wittwer and Bukovac[3] have evaluated in detail the implications of this development for agriculture and horticulture, they came to a conclusion that a given species or variety responds to a wide range of various concentrations, and different species and varieties within a species react differently to the same treatment. There is voluminous information about the effects of gibberellins on various plants[2,4,18,20]. However, little information can be found on citrus trees.

With this view point in mind, the author started to set up experiments, reported herein, in June, 1958 with the hope that some information may be obtained about the growth responses and nutrient absorption by citrus as influenced by gibberellins.

The most typical action of gibberellins on higher plant is the enhancement of cell elongation[13]. Once cell elongation has been initiated, the treated plants develope longer internodes and the leaves are somewhat narrower in shape and lighter in color[1,3,10,14,16]. Although chlorosis on the gibberellins-treated plants is very obvious, the cause of this chlorosis is not known, eventhough, it was reported that the Bakanae diseased rice plants had fewer chloroplast[19] and the chlorophyll content was lower than the normal plants[19]. Chlorophyll formation is known to be influenced by nutritional and genetic factors as well as by light[9]. In the case of gibberellins-treated plants, the influence of genetic and light factors to the occurrence of chlorosis may not be considered, because gibberellins can only cause cell elongation and no evidence can be obtained that gibberellins cause mutation of plants. Therefore, the albino occurrence attributed to the influence of gibberellins is not necessary the case.

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One of the factors causing chlorosis of plants is obscuration, however, plants using in this experiment were all grown under normal sunlight conditions, there is lack of information confirming that gibberellins poses the effect of decreasing light absorption by plants. Therefore, the only possible factor causing chlorosis of the gibberellins treated plants seems to be nutritional in nature, and chlorosis due to nitrogen deficiency is the typical one. The question arises that whether gibberellins reduced the absorption of nitrogen and or other essential elements by plants, and consequently, this reduction in nutrient absorption will lead to a chlorosis of the plants.

Investigators[12,20] had pointed out that gibberellins retard root growth noticably in terms of length, weight and number of roots. Since the absorption of water and nutrients by plants depend upon a well distributed and healthy root system, should gibberellins limit the development of roots, then the absorption of nutrients will also be reduced accordingly. The effects of gibberellins on the development of root system and consequently the change of top to root ratio has also been investigated under various fertility conditions.

Based on the previous work done by various investigators as outlined above, the author has laid out experiments to cover the following points:

1. Morphological studies of general growth responses of citrus by gibberellins.
2. The influence of gibberellins on the development of roots.
3. Nutrient absorption by citrus as influenced by gibberellins treatments. Radioactive calcium is also used as a tracer to determine the absorption and distribution of nutrients within the plant.
4. Effects of fertilizer combinations on the occurrence of chlorosis as influenced by gibberellins.

MATERIALS AND METHODS

Citrus grandis has been used for indicator plants in this experiment. Gibberellic acid manufactured by Chas. Pfizer & Co., Inc., N.Y. was used in a form of water solution and applied in 3 different ways to the plants: a). Gibberellic acid was applied to the growing point as droplets by means of a micropipette. b). The solution was applied to the whole plant by using a mannual-operated sprayer, c). The gibberellic acid was added to the nutrient solution or sand.

Seeds from fresh fruits were sown in quartz sand in the greenhouse where the average day temperature was about 35°C. Water was given at 3-day intervals. The seeds germinated 30–40 days after sowing and the seedlings were given adequate quantities of nutrient solution at 3-day intervals, which was made up by the modified Hoagland's formula containing the following amount of plant nutrients: N: 225.6 ppm, P: 31 ppm, K: 195 ppm, Mg: 49 ppm, Ca: 100 ppm, S: 464 ppm, B: 0.5 ppm, Mn:

0.5 ppm, Zn: 0.5 ppm, Mo: 0.01 ppm. 1 ml. per liter of Iron solution which has a concentration of 6.3 g. $FeSO_4$ $7H_2O$ per liter was also added.

A. General growth of gibberellin-treated plants as influenced by various concentrations dosages and fertilizer combinations.

When the seedlings reached to a height of about 7 cm in the seed bed, they were transplanted to 8 cm clay pots filled with sandy loam soil. The pots were set in the open field under partial shading. This part of the experiment was divided into the following sections:

1). One spray of gibberellic acid on the seedlings, concentrations used were 0, 50, 100, and 500 ppm.

2). One application of gibberellic acid as droplets to the growing point of the seedlings. Quantities of gibberellic acid used were 0, 25, 50, and 100 micrograms per plant.

3). Seedlings were sprayed with gibberellic acid at a concentration of 100 ppm. Treatments consisted of from one to eight applications at weekly intervals.

4). Seedlings received 50 microgram of gibberellic acid per plant as droplets for each application. Treatments consisted of from one to eight applications at weekly intervals.

5). One application of painting 100 ppm gibberellic acid on the surface of one of the old leaves.

6). Two applications of painting 100 ppm gibberellic acid on the surface of one of the old leaves at weekly intervals.

7). Three applications of painting 100 ppm gibberellic acid on the surface of one of the old leaves at weekly intervals.

8). Seedlings were sprayed with a one to seven hundred gibberellic acid and urea mixture from one to eight times at weekly intervals. The concentration for gibberellins was 100 ppm and for urea 2.64 g. per liter.

The treated plants were measured for their height at 4-day intervals, starting from the second week after treatments and continued until the 9th week when these plants were harvested. The length of root, diameter of stems and fresh and dry weights of the plants were also recorded. After the plants are dried in an oven at 70°C for 48 hours, they were grounded through a 40-mesh screen in a micromill. Samples were then weighted out for nitrogen determination.

A second trial for testing the fertilizer combination on the general growth of the gibberellic acid treated-plants has also been laid out. The fertilizer treatments were as following:

1. IN+IP+IK
2. 2N+2P+2K (IN: 5 g ammonium sulfate, IP: 2.5 g superphosphate
3. 3N+3P+3K IK: 2.5 g potassium chloride)

4. 2N+IP+IK
5. 3N+IP+IK
6. IN+2P+IK
7. IN+3P+IK
8. IN+IP+2K
9. IN+IP+3K
10. Control (1) (no fertilizer)
11. Control (2) (no gibberellins but with fertilizer)

The plants were grown in 10cm clay pots filled with soil. The fertilizers were dissolved in 300 ml. of water and then applied to each pot once every month. Same amount of water was also given to each pot at weekly intervals Each plant received 50 micrograms of gibberellic acid as droplets onto the growing point at weekly intervals. The plants were harvested after 90 days from planting, and the height, weight and diameter of stem were measured. Nitrogen, phosphorus and potassium content of plant tissues were analyzed chemically.

B. The growth of roots of citrus as influenced by gibberellins.

The following arrangement was made to study the influence of gibberellic acid to root growth of citrus seedlings.

a). Group I. Four seedlings were planted in each of the height porcelain pots containing 3000 ml. of distilled water. Adequate aeration was provided by compressed air throughout the experiment. Treatments consisted of 0.5, 1, 2, 5 ppm of gibberellic acid in the water and 12.5, 25, and 50 microgram per plant of gibberellic acid applied to the growing point as droplets at weekly intervals. The water was renewed every other week.

b). Group II. Same as group I except that the culture medium was changed from water to nutrient solution.

Root development of all plants was observed closely, and the occurrence of mold on the surface of the roots was recorded. Tissues from the roots were also examined microscopically.

C. Calcium absorption and translocation of gibberellic acid-treated plants, using radioactive calcium as a tracer.

When the seedlings reached to height of about 8–10 cm., they were then transplanted into bottles contained full-strength Hoagland's solution. Gibberellic acid treatments were given as follows:

1. Control
2. Nutrient solution containing 5 ppm G. A.
3. Nutrient solution containing 2 ppm G. A.
4. Nutrient solution containing 1 ppm G. A.

5. 25 microgram of G. A. were applied to the growing point as droplets at 4-day intervals
6. 12.5 microgram of G.A. were applied to the growing point as droplets at 4-day intervals

The nutrient solution were replaced weekly. After 40 days when they received 10 treatments of Gibberellic acid, 10 ml. of radioactive calcium solution in the form of $CaCl_2$ with an activity of 0.987 micro-curie per ml. were added to each bottle. Therefore, the total activity of each bottle was approximately 10 micro-curie. In the meantime, 1 ml. of the nutrient solution was taken from the bottle as ıeference solution. The plants remained in the bottles for a week in order to provide sufficient time for absorption. After the 7-day absorption period the plants were harvested, separated into sections of roots, stems and leaves. These sections or samples together with the reference solution were then dried in an oven at a temperature of 70°C for 48 hours. Finally, the dried samples were measured for their activity by means of a thin window Geiger Müller Counter.

D. Analytical methods

The analytical methods for nitrogen and phosphorus determination were mainly the ones described by Cotton[5]. For potassium, the wet digestion and flame photometer method[21] were used. For calcium, the radioactive isotope of Ca^{45} was used as a tracer.

EXPERIMENTAL RESULTS

A. General growth of citrus seedlings as influenced by various concentrations and dosages of gibberellic acid.

Plant height, fresh and dry weights and trunk diameter of citrus seedlings treated with one application of gibberellic acid at different concentrations and dosages are shown in Table I.

Data of Table I show that the greatest plant height increased was obtained from the higher concentrations and dosages of gibberellic acid. However, greater increase of fresh and dry weights of the seedlings were given by lower concentration and dosages.

When seedlings were sprayed with gibberellic acid at a concentration of 100 ppm and were treated with 50 microgram per plant of gibberellic acid from one to eight applications at weekly intervals. The height of seedlings was proportionally increased as the number of application was increased (Table 2). In the very beginning of this experiment, the terminal bud or growing point of some of the seedlings treated with higher dosages wilted and died. Consequently, the growth of lateral buds of these plants was markedly stimulated, and the spine-like thorns of the plants became lengthen and vigorous.

Table 1. Effects of one application of gibberellic acid at different concentrations and dosages on plant height, fresh and dry weights and diameter of citrus seedlings

G. A. Treatments	Relative height increase % (Comparison with control)	Relative fresh weight increase % (Comparison with Control)	Total dry weight (g)	Relative diameter Increase% (Comparison with Control.)
Control	100	100	1.9	100
50 ppm.	81	100	1.6	46.7
100 ppm.	214	93	1.9	113
500 ppm.	184	57	1.1	84.0
25 μg	142	112	1.9	80.0
50 μg	146	87	1.5	93.3
100 μg	150	55	1.1	66.6

Table 2. Effects of gibberellic acid treatments on plant height, fresh & dry weights and diameter of citrus seedling receiving from one to eight applications.

No. of application		Relative height increase %(Comparison with control)	Relative fresh weight increase % (Comparison with control)	Total dry weight (g.)	Relative diameter increase % (Comparison with control)
Spray (100ppm)	0	100	100	1.9	100
	1	100	98	1.8	100
	2	111	82	1.6	133
	3	136	63	1.4	66.6
	4	172	89	1.6	77.7
	5	206	63	1.3	144
	6	153	43	0.9	100
	7	203	58	1.2	66.6
	8	205	67	1.5	111
Droplets (50μg/pt/application)	0	100	100	1.9	100
	1	107	97	1.0	100
	2	243	61	1.7	91.6
	3	295	96	0.7	133
	4	235	26	1.2	75.0
	5	368	40	0.8	50.0
	6	401	43	1.0	50.0
	7	435	40	1.2	100
	8	537	66	1.4	66.6

Plants painted with 100 ppm gibberellic acid solution on one of the old leaves from 1–3 applications also demonstrated the typical effects of gibberellic acid. The results from this experiment confirm that when gibberellic acid is applied on the lower part of the leaf, it can transport acropetally up to the responsable region of the terminal bud where stimulation of growth is initiated.

B. General growth of gibberellic acid-treated plants as influenced by various fertilizer combinations.

Seedlings sprayed with one to seven hundred gibberellic acid and urea mixtures from one to eight times at weekly intervals were observed. The results from the 1:700 treatments are shown in Table 3.

Table 3. Effects of 1:700 gibberellic acid-urea mixture sprays on plant height, fresh and dry weights and diameter of citrus seedlings

Number of application	Relative height increase %	Relative fresh wt. increase %	Dry weight (g.)	Relative diameter increase %
1	100	100	1.0	100
2	80.0	152	2.1	97.2
3	43.0	72.0	1.2	120
4	40.0	112	1.4	113
5	65.0	160	1.7	109
6	90.0	80.0	1.3	120
7	112	80.0	1.1	151
8	82.0	110	1.4	116

The increase of plant height was not apparent. However, the increase of fresh and dry weights was very significant as compared with the controls. The general condition of the plants was good. The size and thickness of the leaves were increased and the leaf color was as dark as those of healthy trees.

Another trial consisted of various concentration of nitrogen, phosphorus and potassium applied along with gibberellic acid had also been laid out. From the morphological points of view, the results that those treated plants had elongated stems, light green and narrower leaf-blades and spine-like hard thorns. There was no significant difference of height and diameter between the treated and non-treated plants.

From results shown in Table 4, it is also obvious that root growth of plants was markedly depressed by gibberellic acid treatments both in root and foliar applications. Moreover, according to the author's observation, this depression of root growth was more pronounced when the gibberellic acid was applied to the roots than when it was applied to the growing point. And also the depression was even more obvious when the chemicals was added to the nutrient solution in water culture than when it was applied to the soil or sand medium. In water or nutrient culture, the roots of the plant were easily affected by two genera of fungi which have been isolated as Pythium sp. and Fusarium sp. when the roots are affected by these fungi, their growth is retarded and finally be rotten and dead.

Table 4. The length of main roots and number of lateral roots as effected by gibberellins under the different treatments

Treatment	The length of roots (cm)				Mean	Number of lateral roots			Mean
Control	10,	10,	9,	12,		32,	26,	28	
	9,	10,	11,	10	10,2	22,	28,	30	27.6
25μg/plant droplet	10,	7,	9,	8,		13,	30,	24,	
	7,	6.5,	8,	9	8.06	22,	26.	20	22.5
25 p.p.m. in cultural solution	10,	10,	8,	9,		17,	26,	25,	
	9,	9,	7.5,	8	8.87	17,	18,	16	19.8
50 p.p.m. spray	10,	10,	9,	7,		26,	16,	18,	
	9,	9,	8,	8	8.75	15,	18,	17	18.3

C. Composition of leaves as influenced by gibberellic acid treatment and fertilizer combinations.

The total nitrogen content of the gibberellin-treated citrus trees is given in Table 5 and 6. Generally, the nitrogen content of the treated plants was decreased as compared with the control plants, and this decrease of nitrogen content was proportional to the quantity of gibberellic acid applied both as spray and droplet treatments.

Table 5. Effects of one sprays of gibberellic acid on nitrogen content of citrus (%) (The leaves were analyzed 9 weeks after treatments)

Treatment / Samples	Control	50 ppm.	100 ppm.	500 ppm.	25 μg.	50 μg.	100 μg.
I.*	2.10	2.26	1.52	2.00	2.26	2.06	1.52
II.	1.98	2.06	1.73	1.40	2.10	2.00	2.00
III.	2.21	2.28	1.76	1.21	2.76	2.10	1.95
Average	2.06	2.26	1.73	1.62	2.62	2.37	1.82

L. S. D. 5%: 0.0246%; 1%: 0.0469% (*Each figure represents the average of 3 plants)

Table 6. Effects of number of application of gibberellic acid (50 micrgoram/pt./application) on nitrogen content of citrus seedling. (%)

No. of application / Samples	Control	1	2	3	4	5	6	7	8
I.*	2.76	2.40	2.00	2.10	2.24	2.10	1.96	2.06	1.01
II.	2.48	2.32	2.26	2.07	2.43	1.72	2.10	1.96	1.51
III.	2.54	2.26	2.75	1.76	2.00	1.65	1.99	1.76	0.95
Average	2.59	2.32	2.32	2.06	2.22	1.32	2.01	1.92	1.12

L. S. D., 5%: 0.0195%; 1%: 0.0365% (*Each figure represents the average of 3 plants)

When the trees were sprayed with the gibberellic acid-urea mixture, the total nitrogen content of the tissue was markedly increased. In the case of 1:700 treatment (Table 7), there was a tendency that the increase in nitrogen content was direct proportional to the number of application.

Table 7. Total nitrogen content of citrus seedlings treated with 1 to 8 sprays of gibberellin-urea mixture at the rate of 1:700. (%)

Samples \ Number of application	Control	1	2	3	4	5	6	7	8
I.*	2.10	2.26	2.25	2.45	2.35	2.30	2.43	2.48	2.75
II.	2.48	2.48	1.51	2.67	2.24	2.25	2.40	2.53	2.54
III.	2.21	2.80	2.06	2.24	2.30	2.43	2.78	2.78	2.09
Average	2.26	2.51	1.92	2.12	2.29	2.32	2.53	2.71	2.46

L. S. D. 5%: 0.0190%; 1%: 0.0396% (* Each figure represents the average of 3-plants)

The nitrogen, phosphorus and potassium contents of the plants treated with various fertilizer combinations and gibberellic acid were illustrated in Table 8. It is noted that the total nitrogen content of gibberellin-treated plants was all lower than those of the gibberellin controls, but the total nitrogen content in the treatments of complete fertilizer were higher than the non-nitrogen group. It is obvious that the nitrogen content of all fertilizer-treated group was increased more than the non-fertilizer control group.

Table 8. Contents of major elements (N. P. K.) of the gibberellin-fertilizer treated plants

Nutrients content % \ G. A. fertilizers treatments	8 applications of 50 μg of G. A. with various combinations of fertilizers (%)										G. A. Control
	N: P: K:	2N: 2P: 2K	3N: 3P: 3K	2N: P: K	3N: P: K	1N: 2P: K	1N: 3P: K	N: P: 2K	N: P: 3K	Con-trols	1N:P:K
Nitrogen	3.05	4.3	4.3	3.5	4.25	4	3.8	3.8	3.35	2.8	4.8
Phosphorus	0.23	0.26	0.28	0.24	0.22	0.25	0.25	0.21	0.24	0.20	0.27
Potassium	1.90	1.70	1.92	1.52	1.40	1.74	1.60	1.58	2.24	1.50	1.74

L. S. D. for K: 5%: 0.0260%; 1%: 0.0453%
L. S. D. for N: 5%: 0.0178%; 1%: 0.0312%
L. S. D. for P no significant difference.

The greater amounts of phosphorus applied has no effect on the phosphorus content of the plants. Even when the plant received 2 or 3 times the normal amounts, the phosphorus content was not increased.

From the results recorded in Table 8, it is evident that the heavy application on potassium, triple the amount of application in this case, increased the potassium content of the plant tissue significantly. Although the content of potassium in the plant was increased by the heavy applications, but morphologically, there was no difference between the heavy and light applications of potassium.

D. Calcium absorption and translocation of gibberellin-treated plants using radioactive calcium as a tracer.

As shown in Table 9, the absorption of applied calcium was higher in the control plants than in the gibberellin-treated plants both for root and foliar applications. Also, the calcium content of the plants treated with gibberellic acid on the growing point was higher than those treated as root application. It is seen from Table 9 that calcium absorption was reduced by gibberellic acid treatments and this reduction was reversely proportional to the amount or concentration of gibberellic acid applied.

Table 9. Radioactive calcium absorption and translocation of gibberellin-treated plants.

Treatment		C. p. m.		Ca^{++} absorbed (μg/plant)		
		Root	Shoot	Root	Shoot	Total
Control	1	46.8	12.8	127.2	34.8	162.0
	2	9.8	6.8	26.6	18.4	45.0
	3	16.8	8.8	45.6	23.3	68.9
	4	11.8	4.8	32.0	13.0	45.0
	5	31.8	11.8	87.5	32.0	119.5
Mean		23.4	9.0	63.6	24.4	88.0
5 ppm G. A.	1	11.8	3.8	32.0	10.3	43.3
	2	6.8	4.8	18.4	13.0	31.4
	3	19.8	9.8	53.8	26.6	80.4
	4	6.8	2.8	18.4	7.6	26.0
	5	4.8	1.8	13.0	4.8	17.8
Mean		10.1	4.6	27.1	12.2	39.3
2 ppm G.A.	1	16.8	7.8	45.6	21.1	66.7
	2	13.8	4.8	37.5	13.0	50.5
	3	11.8	5.8	32.0	15.7	67.7
	4	9.8	4.8	26.6	13.0	39.6
	5	6.8	3.8	18.4	10.3	18.7
Mean		11.8	3.4	32.0	14.6	46.6
1 ppm G. A.	1	15.8	7.8	42.8	21.1	63.9
	2	17.8	8.8	48.3	23.3	71.6
	3	9.8	6.8	26.6	18.4	45.0
	4	12.8	5.8	34.8	15.7	50.5
	5	12.8	4.8	34.8	13.0	47.8
Mean		13.8	6.8	37.5	18.4	55.9

25 μg G. A.	1	13.8	5.8	37.5	15.7	53.2
	2	14.8	5.8	40.2	15.7	55.9
	3	16.8	5.8	45.6	15.7	51.3
	4	9.8	3.8	26.6	10.3	36.9
	5	8.8	3.8	23.3	10.3	43.6
Mean		12.8	5.0	34.8	13.5	58.3
12.5 μg G. A.	1	20.8	9.8	56.5	26.6	83.1
	2	18.8	10.8	51.0	29.3	80.3
	3	10.8	5.8	29.3	15.7	45.0
	4	18.8	7.8	51.0	21.1	72.1
	5	21.8	8.8	59.1	23.3	82.4
Mean		18.2	8.6	49.4	23.3	72.7

DISCUSSION

All the young plants treated with gibberellins grew abnormally tall and slender. Hyperelongation induced by the application of gibberellins in lanolin mixture has been confirmed with soybean, sunflower and tomato plants by Kato[13], who has reported that the physiological effect and mode of action of gibberellins are quite different from those of auxin (IAA). With Citrus grandis Obesk., pronounced stem elongation was obtained primarily with very high concentration of gibberellic acid after one week of application. The stem elongation is proportional to the number and dose of the gibberellic acid applied. In general, the duration of the effect of gibberellic acid to each kind of plant is different, the hard wood plants seemed to show lesser response than the soft wood plants and herbaceous. In the present work, 50 micrograms per plant per application of gibberellic acid and 500 ppm. were considered as high dosage and concentration, the increase in plant height by these quantities was always 3 to 5 times as those of the controls.

Gibberellic acid apparently does not show the polar movement within the plant which has been found to be the characteristics of auxin. From many reports that treatments by single droplet application, by spraying or as a solution to roots, are all effective on the entire plant[15]. The results, obtained from painting a single leaf at the base of the stem with gibberellic acid showed that movement of this chemicals in citrus tree is not polar in nature.

When gibberellins promote elongation, they do not always cause a parallel increase in dry weight. Ito & Kimura[11] found "bakanae" plants had increased in fresh weight, but the dry weight was less. Wittwer & Bukovac[4] had reported that a 50% increase in fresh and dry weight of celery was obtained from gibberellin-treated plants. However, working with several tomato varieties, they did not obtained dry weight increase with a dose as high as 20 micrograms per plant. In the present experiments gibberellic acid stimulated consistent stem elongation and leaf enlargement, but the fresh and dry weight increased were not significant.

Effects of gibberellins may never be beneficial to root growth under any known circumstances. A relatively high concentration of gibberellin may slightly inhibit root growth(2). The I. C. I. workers have obtained consistent root weight decreases in treated peas and wheats. They pointed out that nearly in all cases local root inhibitions was found. Moore, Rufus H.(17) has pointed out that gibberellin reduced the total yield and quality of Derris roots less than 6 mm. in diameter. When applied together with the nutrient solution, gibberellin increase the diameter, quality and yield of roots over 6 mm. in diameter to the level above the controls.

In the present work, the author found that root growth of citrus was suppressed both when gibberellic acid was applied to the plant directly and to the culture solution. The length, weight and number of lateral roots were all decreased as compared with the controls. Roots of the treated plants became rotten and two genera of fungi were found on the surface of the root. The occurrence of these fungi is thought to have 2 reasons. Firstly, the epidermis and cortex of the roots were easily destroyed by gibberellic acid at certain concentrations and then the causal organism which was originally attached to the root surface will grow with great ease. Secondary, the growth of the fungi might also be stimulated by gibberellic acid, although some investigators had pointed out that fungi and bacteria were not influenced by purified gibberellins(20). The author is planning to study more in detail the relation between the growth of fungi and the concentration of gibberellic acid in a later date.

Some investigators have pointed out that gibberellin does not affect the composition of plants in the same way. In rice seedlings, Yabuta et al(23) found no difference between treated and non-treated plants in ash, reducing sugar, total nitrogen or total weight, but the treated plant contained less chlorophyll and total sugar. In cotton plants, Ergle Daved R.(8) concluded that the total ash and total nitrogen content (g/pt.) of stem and petioles, but not the leaves were increased by the growth promoting levels of gibberellins, but suppressed in both tissue fractions by the inhibitory level (1000 microgram/pt.). Wittwer and Bukowac(22) analyzed the gibberellins treated Kentucky bluegrass (Poa pratensis L.) did not find any significant alternation of the percentage in dry matter or mineral composition of the grass. The data shown in Table 5 and 6 indicated that in the ordinary fertilizer treatment the total nitrogen content of the gibberellin-treated plants was decreased markedly, and this decrease was proportional to the amount of gibberellins applied. The same results of gibberellins decreasing nitrogen content of the leaf was also found in lettuce of 5 varieties(7). The nitrogen absorption by bean plants grown in half-strength Hoagland solution containing 100 ppm. gibberellic acid was also reduced significantly(7).

According to the results from literature and from this investigation, we may consider that the decreased nitrogen content of the gibberellin-treated plant might due to the extraordinary fast elongation of the stem caused by the chemicals that leads the plant to some difficulties in maintaining its normal nutritional status. Furthermore, gibberellic acid retards root growth to a considerable extent, thus reduces the absorption area of the plant to some degree, and consequently the absorption of nutrients is decreased. When the nitrogen absorption is suppressed for a certain length of time, the plant will soon show symptom of deficiency of this element that chlorotic appearence is among one of them. Since nitrogen is one of the main constituents for chlorophyll formation, if nitrogen is deficient in the plant the formation of chlorophyll is disturbed, and naturally chlorotic appearence of the plant will be resulted.

When citrus seedlings were sprayed with gibberellic acid and urea mixture in the rate of 1 part of gibberellic acid to 700 part of urea, the nitrogen content in the plants was markedly increased, and it is even more so when the number of application was increased. Chen[6] has studied on the absorption of nitrogen by citrus from application of urea and demonstrated that citrus leaves can absorbed and assimilated nitrogen from the sprayed urea. And this absorption of nitrogen from urea spray can be readily measured in the plant within one hour after the application and continued its effect for at least 7 days at a steadily decreasing rate.

Nitrogen was also used in the form of $(NH_4)_2SO_4$, combined with KH_2PO_4 and KCl, in water solution, although the nitrogen content of the gibberellin-treated plants was increased by higher dosages of amonium sulfate, but this increase was small in comparing with the control plants. As to the phosphorus contained in the gibberellin-treated plant there was no significant difference between the treated and the controls, even when relatively high amount of KH_2PO_4 was supplied. The potassium content of the treated plant was the highest when KCl was applied 3 times the amount of the ordinary quantity. In gereral, the nitrogen as well as potassium content was lower in plants of the fertilizer control group which was treated with a greater dosage of gibberellic acid. It is readily seen that gibberellic acid has the effect of depressing the absorption of nutrients by plants.

It is shown in Table 9 that the gibberellic acid also decrease calcium absorption, and this decreased absorption of calcium was more pronounced as the concentration of gibberellic acid was increased. In this experiment, the root system of the citrus seedling, grown in nutrient solution containing gibberellic acid was in a very poor condition 4 weeks after the gibberellic acid applications, especially when the concentration of gibberellic acid in the cultural solution was high. Since nutrient absorption depends upon the condition of the root system, if root growth is retarded by gibberellic acid, the absorption of calcium will accordingly be retarded.

SUMMARY

1. The growth of citrus seedlings was stimulated by gibberellic acid by a single application of 100 ppm. spray solution, 50 microgram on the growing point or

0.5 ppm. in the culture solution. This stimulation was even more pronounced as the concentration or dosage was increased. The length of the effective period for various concentrations and dosages are also different.

2. The terminal bud of the elongated plant was easily burn and dried under the hot sun, and consequently the growth of lateral buds was promoted that gave a branchy appearance to the plants.
3. There was no significant difference of the dry and fresh weights and the diameter of the trunk between the gibberellin-treated and non-treated plants.
4. Gibberellic acid (100 ppm.) painted on a single leaf at the base of the seedling gave the same response to the plant as those applied on the growing point or to the roots.
5. The leaves of the treated trees were lighter in color and narrower in shape, and had longer petioles than those of the controls.
6. Citrus leaves can absorb and assimilate nitrogen from the urea gibberellins mixture at a ratio of 1:700. Although the stimulation effect of gibberellin was not obvious, but the effect of the urea nitrogen in offsetting the symptoms of chlorosis caused by gibberellic acid was quite evident.
7. The nitrogen content of citrus was decreased by gibberellic acid treatments but this situation can be minimized by applying the proper amounts of amonium sulfate (30 g. or 60 g. per 1800 ml. of water).
8. The phosphorus content did not show any significant difference between the control plants and the treated-plants even when KH_2PO_4 was added in a relatively high amount. The content of potassium was increased by supplying KCl at the rate of 45 g. per 1800 ml. of water to the gibberellic acid treated plant.
9. Radioactivity measurements showed that gibberellin-treated plants had lower activity than the controls. In other words, the absorption of radioactive calcium by plants was reduced by gibberellic acid treatments
10. Gibberellic acid when added to the culture solution caused the occurrence of 2 genera of fungi identified as Pythium and Fusarium which are usully found in the soil. When this situation occurred, the root growth was retarded and became rotten and dead.
11. The decrease in fresh weight and length of roots and lateral roots gave a poorer root system which renders the absorption of nitrogen and other plant nutrients. Consequently, the content of nitrogen and other minerals was lower and the leaves became pale green in color, presumably, the formation of chlorophyll has been retarded.

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Gibberellic acid 對於柑橘生長及養分吸收之影響

丁 肇 琦

中 文 摘 要

一、柑橘幼苗經 Gibberellic acid 100 ppm., 50 μg/pt. 一次之處理，或栽培於 Gibberellic acid 0.5 ppm 之培養液中，植株均有被刺激生長之現象，而此效力隨所用 G. A. 濃度之增加而增加。其時效之長短，視濃度及用量多少而不一。

二、徒長之幼苗芽端易受日光灼傷而枯凋。但幼芽枯凋後，反促進側芽之叢生與徒長。

三、經 Gibberellic acid 處理後之柑橘植株，其植株雖然徒長甚長，但其乾溼重量，並無顯著之增加。

四、將 100 ppm. 之 Gibberellic acid 塗布於植株基部之一老葉片上，其對植株之刺激生長作用，與 Gibberellic acid 用於頂芽及根部有同樣之效果。

五、以 Gibberellic acid 處理後之植株，其徒長之葉片顏色變淡黃綠色，葉片變窄長，葉柄延長。

六、柑橘葉部可以吸收並利用 Urea 及 Gibberellic acid 以 1:700 之混合液，雖然 Gibberellic acid 對於植株之生長刺激不明顯，但 Urea 對於補救因 Gibberellic acid 所發生之黃斑病 (Chlorosis) 確有功效。

七、經 Gibberellic acid 處理後之柑橘葉部，含氮量減少，但可以適量之硫酸錏作肥料補救之，磷素之含量，處理與未處理者無顯著之差異，但鉀素之含量，由於 KCl 作肥料而使 G. A. 處理之植株中，含鉀量增加。

八、由放射性同位鈣素之應用，顯示 Gibberellic acid 處理之植株，要比未經處理者對 Ca^{45} 之吸收量減低。

九、當 Gibberellic acid 加入培養液中，常易誘發兩種 Fungus 因而使植株根部發育受阻，且使其腐爛，此兩種 Fungus 經培養鑑定爲 Pythium 及 Fusarium, 均爲土壤中，常見之眞菌，由於經 Gibberellic acid 處理之植株根部發育受阻，以致影響其對氮素及其他營養元素之吸收，因而使葉部之含氮量及其他元素之含量減少，而使葉色變淺黃綠色。