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Initial Soil-Mix and Postplanting Liquid Fertilization Effects on Nutrient Concentrations in Valencia Orange Seedling Leaves

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EFFECTS OF MIX COMPOSITION, FERTILIZATION, AND pH ON CITRUS GROWN IN U.C.-TYPE POTTING MIXTURES UNDER GREENHOUSE CONDITIONS

Effects of mix composition, fertilization, and pH on citrus seedlings grown in several U.C.-type potting mixtures in containers were studied over a 5-year period. The mixtures, consisting of fine sand, sphagnum peat moss, and redwood shavings consistently produced greater growth than did a mix containing clay loam, fine sand, and peat moss. Copper deficiency, often encountered in plants grown in soils and soil mixtures containing peat, could be prevented by the addition of $CuSO_4$ to the mixtures. Availability of other micronutrients to the plants appeared to be influenced primarily by soil pH which could be changed by varying materials used in the added fertilizer solution. When the soil-leachate pH was higher than approximately 7.0, plants exhibited more micronutrient deficiency leaf patterns and made less growth.

The system which evolved as a result of these experiments has been tried with marked success in one large-scale greenhouse operation which

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Effects of Mix Composition, Fertilization, and pH on Citrus Grown in U.C.-Type Potting Mixtures under Greenhouse Conditions[1]

INTRODUCTION

THE U.C. SOIL mixture and system for producing container-grown plants was first reported by Baker *et al.* (1957),[2] and has now gained widespread commercial usage for growing ornamentals in containers. U.C.-type mixtures consist of a low-nutrient inorganic material and an organic fraction; fine sand and sphagnum peat moss are commonly used. These materials produce a well-drained and well-aerated rooting medium of high moisture-holding capacity. Fertilization is normally accomplished by adding nutrients when mixing and periodically in solution after planting. Pathogenic organisms are eliminated by steam sterilization or chemical treatment, and strict sanitary procedures must be exercised during and after planting.

As part of the Citrus Variety Improvement Program of the University of California at Riverside (Nauer *et al.*, 1967) citrus seedlings are grown in large quantities for virus detection by leaf-symptom expression in young leaves. Vigorous growth-flushes free of nutrient deficiency or excess symptoms are required, and when the program was begun (in 1958), it was believed that a U.C. mix might produce this type of growth. However, early results were not wholly satisfactory because of micronutrient deficiency symptoms including severe Cu deficiency. High-peat soils have been shown to induce Cu deficiency in a large number of crops (Allison, Bryan, and Hunter, 1927; Forsee, 1940 and 1952). After Cu deficiency was corrected by the use of a nutrient solution containing chelated Cu as ethylenediamine tetraacetic acid (EDTA), seedlings made satisfactory growth but chlorotic leaf patterns indicative of Fe, Mn, or Zn deficiency sometimes appeared and caused interference with virus symptom expression.

The liquid fertilization formula was also considered too cumbersome for a large greenhouse operation, as it involved many chemicals and much time and labor. Because of precipitation of some nutrients, a highly-concentrated stock solution could not be made. It was believed that a simpler formula might be used if pH of the soil mix could be controlled.

Uptake of micronutrients by citrus is strongly influenced by soil pH as well as by the presence or absence of the nutrients in the soil, and by other factors (Camp and Reuther, 1937; Camp and Fudge, 1939; Pratt *et al.*, 1959;

[1] Paper number 1789, University of California Citrus Research Center, Riverside. Submitted for publication February 9, 1967.

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

Spencer, 1960). Reitz *et al.* (1959) recommended that the pH of Florida soils used for growing citrus be maintained between 5.5 and 6.5 by liming to counteract effects of acidifying fertilizers.

An experiment was initiated in 1963 in order to compare citrus seedling growth in several U.C. soil mixes containing different quantities of lime and micronutrients fertilized with two liquid fertilizers having opposite effects on soil pH.

The present publication reports the results of this experiment and of several earlier experiments on the use of U.C. mixtures for citrus in the greenhouse.

MATERIALS AND METHODS

Citrus seedlings germinated and grown in flats were transplanted when 1 to 3 inches high into experimental soil mixtures in 1-gallon painted metal containers. Seedlings were selected for uniformity, and all off-types visibly not of nucellar origin were discarded. Various species of citrus were used as test plants. Mexican lime (*Citrus aurantifolia* [Christm.] Swingle) was extensively used, as it is the primary tristeza virus indicator in the Citrus Variety Improvement Program.

Soils were mixed in a cement-type mixer for at least 3 to 5 minutes to insure uniformity of mix. Insoluble nutrients were added dry and tumbled in the mixer with dry soil ingredients; soluble nutrients were dissolved in water for adding to the soil in the mixer. In all experiments U.C. mixtures were steamed for 1 hour to attain a temperature of 212°F. Soil mixtures containing clay were treated with chloropicrin. After planting, fertilizer solution was applied in tap water by siphoning through a hose.

Citrus seedlings normally grow as a single leader with few laterals until top weight bends the stem over. For uniformity, all seedlings in these experiments were tied to stakes to encourage single-leader growth, and laterals were removed as they appeared. The plants were harvested when 3 to 4 feet tall. Tops were cut off and weighed, and the leaves visually evaluated for clearness of young growth flush and malnutrition symptoms. Leaves were analyzed for mineral elements in some instances.

Comparison of U.C. and loam mix. The first two experiments compared a U.C. mix with a loam mix in general greenhouse use at the Citrus Research Center at the time. The U.C. mix was composed of 50 per cent fine sand and 50 per cent Canadian sphagnum peat moss by volume. To each cubic yard of U.C. mix, materials as follows were added: 0.25 pounds KNO_3, 0.25 pounds K_2SO_4, 2.5 pounds single superphosphate, 7.5 pounds dolomitic lime, and 2.5 pounds calcium carbonate lime (Formula I [c], Baker *et al.,* 1957). The loam mix consisted of five parts Ramona clay loam, three parts fine sand, and two parts peat moss by volume; no fertilizer material was added at the time of mixing. Mexican lime and Standard sour orange (*C. aurantium* Linn.) seedlings were used as the test plants.

For experiment 1, liquid fertilizer L-7 (Baker *et al.*, 1957) consisting of 5 pounds each of NH_4NO_3, $NH_4H_2PO_4$, and KCl per 1,000 gallons of water was used. Seedlings received this fertilizer with every irrigation weekly while small, and more frequently as they grew and greenhouse temperature rose. This experiment was carried out at two locations, Riverside and Los Angeles, and at each location treatments were replicated 28 times, each replication consisting of one can containing one plant. An added treatment at Riverside only was the use of a complete nutrient solution for the seedlings growing in the loam mix, as this was standard greenhouse practice at the time. This solution contained 1.12 pounds K_3PO_4, 4.25 pounds

KNO_3, 10 pounds $Ca(NO_3)_2$, and 4.12 pounds $MgSO_4$ per 1,000 gallons; micronutrients included were 0.5 ppm Cu and 5 ppm Fe as EDTA chelates, 0.6 ppm Mn and 0.05 ppm Zn as sulfates, 0.5 ppm B as H_3BO_3, and 0.1 ppm Mo as $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$. This solution was applied weekly. The seedlings were transplanted into cans on February 17, and harvested July 2.

Experiment 2 was initiated when Cu deficiency was recognized as a serious problem. The same soil mixtures and test seedlings were used as in experiment 1, but all received the complete nutrient solution. There were 28 replications, each replication consisting of one can of four seedlings. Seedlings were planted in cans June 25 and harvested October 28.

Effect of redwood shavings. To lighten soil mix, redwood shavings from a planing mill were tested as a soil ingredient. Mexican lime seedlings were utilized as the test plants; they were fertilized with the complete nutrient solution. This was the only experiment of the series not conducted in the greenhouse, the plants being grown in a screenhouse. Soil mixtures consisted of various combinations of redwood shavings, peat moss, and fine sand; loam mix was also used. There were five replicates of each treatment, each replicate consisting of a single can containing two seedlings. This experiment was set up April 2, and harvested October 28.

Effect of sources of peat moss, initial nutrients added, and liquid fertilizers. During 1963, an experiment was conducted to test variations in initial fertilization and liquid fertilization, with emphasis on pH control. A soil mix consisting of equal parts by volume of peat moss, redwood shavings, and fine sand was used. All mixtures received 0.25 pounds KNO_3, 0.25 pounds K_2SO_4, and 2.5 pounds single superphosphate per cubic yard. Treatments included two sources of sphagnum peat moss, Canadian and American; three levels of lime and micronutrients added at the time of mixing; and two liquid fertilization formulae. Table 1 shows initial soil treatments. Copper, Zn, Mn, and Fe were added as sulfates, B as H_3BO_3, and Mo as $(NH_4)_6Mo_7O_{24}$; all were dissolved in water for adding to the mix.

Liquid fertilizer #1 consisted of 5 pounds $Ca(NO_3)_2$, 2 pounds $MgSO_4$, and 1.25 pounds KNO_3 per 1,000 gallons of water. Liquid fertilizer #2 consisted of 5 pounds NH_4NO_3, 3 pounds KCl, and 1 pound NH_4HPO_3 per 1,000 gallons. This formula was used by Matkin, Peterson, and Cochrane (1962), for

TABLE 1
INITIAL SOIL MIXES USED IN THE 1963 EXPERIMENT

Soil*	Type of peat moss	Materials added	
		Lime per cu. yd.	Micronutrients
I	Canadian	7.5 lb. dolomite 2.5 lb. $CaCO_3$	25 ppm Cu
II	American	7.5 lb. dolomite 2.5 lb. $CaCO_3$	25 ppm Cu
III	Canadian	3.75 lb. dolomite 1.25 lb. $CaCO_3$	25 ppm Cu 10 ppm Zn 10 ppm Mn 25 ppm Fe 0.2 ppm B 0.2 ppm Mo
IV	American	3.75 lb. dolomite 1.25 lb. $CaCO_3$	25 ppm Cu 10 ppm Zn 10 ppm Mn 25 ppm Fe 0.2 ppm B 0.2 ppm Mo
V	Canadian	1.88 lb. dolomite 0.63 lb. $CaCO_3$	25 ppm Cu 10 ppm Zn 50 ppm Mn 50 ppm Fe 0.2 ppm B 0.2 ppm Mo
VI	American	1.88 lb. dolomite 0.63 lb. $CaCO_3$	25 ppm Cu 10 ppm Zn 50 ppm Mn 50 ppm Fe 0.2 ppm B 0.2 ppm Mo

* All soils were equal parts of peat moss, redwood shavings, and fine sand, to which was added 0.25 lb. KNO_3, 0.25 lb. K_2SO_4, and 2.5 lb. single superphosphate per cubic yard (see also tables 4 and 7).

growing several species of ornamentals in a U.C. mix. The amounts of nutrients supplied by liquid #1 per 1,000 gallons applied were: 1.03 pounds N, no P, 0.48 pounds K, 1.22 pounds Ca, and 0.41 pounds Mg; liquid #2 supplied 1.75 pounds N, 0.27 pounds P, 1.58 pounds K, no Ca, and no Mg.

Seedlings used were Mexican lime, King mandarin (*C. reticulata* Blanco), Valencia orange (*C. sinensis* Linn.), Standard sour orange, Kara mandarin (*C. reticulata*), Madam Vinous sweet orange (*C. sinensis*), Rubidoux trifoliate orange (*Poncirus trifoliata* Linn.), and Troyer citrange (*C. sinensis* × *P. trifoliata*). Of the first three listed, there were five replicates, each replicate consisting of one can containing four seedlings. There were three single-can replicates of each of the other varieties with sour orange, Kara mandarin, and sweet orange being planted four seedlings per can, and trifoliate orange and Troyer citrange one per can. Seedlings were transplanted into cans during June, July, and August, as the different varieties in the seed flats attained transplanting size. Initially, and after 5, 7, and 11 months, pH determinations were made on a soil leachate obtained by adding tap water to several cans and catching the solution which came out the drainage holes in the bottom. After 4 to 6.5 months growth, the seedlings were cut back to a 6-inch stem. The tops were weighed and leaves visually evaluated for chlorosis, specific micronutrient deficiency symptoms, and other abnormalities. For this evaluation a scale of 0 to 5 was used; a 0 rating denoted normal dark-green leaves, and 1 to 5 indicated varying degrees of abnormal chlorotic patterns with a rating of 5 for the most severe. After being cut back the seedlings were allowed to grow again for 4.5 to 7.5 months, at which time the tops were cut off 2 inches above the previous cut, and weighed and evaluated as before. No root weights were obtained because seedlings were subsequently used for virus indexing. Leaves of theValencia orange seedlings were collected for nutrient analysis. Results are reported by Labanauskas, Nauer, and Roistacher (1967).

RESULTS

Comparison of U.C. and loam mix. The first result with experiment 1 was the development after about 2 to 3 months of abnormally small leaves near the growing terminals, dieback of the growing terminals, multiple buds, and gum pockets on the stems of seedlings receiving the L-7 fertilizer; this occurred with both mixes and at both locations. These abnormalities were ascribed to severe Cu deficiency, so a micronutrient solution containing Cu chelate (EDTA) was applied weekly thereafter. At harvest, new growth showed little or no Cu deficiency symptoms but the plants were already stunted, many of the growing tips having died. Table 2 shows the average fresh weights of the seedling tops in grams. Due to the low temperature requirement of another experiment in the same greenhouse, the temperature at Riverside was consistently lower than at the Los Angeles greenhouse, resulting in less total growth at Riverside. The average fresh weight of seedlings grown in the loam mix and fertilized with the complete nutrient solution was 61 per cent and 57 per cent of the weight of the seedlings grown in U.C. mix for Mexican lime and sour orange, respectively, at Riverside, and 39 per cent and 33 per cent at Los Angeles.

In experiment 2, use of a complete nutrient solution containing chelated Cu on all plants eliminated Cu deficiency symptoms in this short-term experiment. In this experiment, Mexican lime and sour orange growth in the loam mix was 73 per cent and 56 per cent, re-

TABLE 2

AVERAGE FRESH TOP WEIGHT OF MEXICAN LIME AND SOUR ORANGE SEEDLINGS GROWN IN U.C. MIX AND LOAM MIX

Soil	Fertilizer solution	Experiment 1*				Experiment 2‡	
		Los Angeles		Riverside		Riverside	
		Mexican lime	Sour orange	Mexican lime	Sour orange	Mexican lime	Sour orange
		gm†					
U.C.	L-7	33.5	15.9	9.0x	6.0x	....	....
U.C.	Complete nutrient solution	....	....	....	....	34.7	28.4
Loam	L-7	13.2	5.3	4.4y	2.5y	....	....
Loam	Complete nutrient solution	....	....	5.5y	3.4y	25.3	15.9
Significance		**	**	**	**	**	**

* Each value is a mean of 28 individual determinations.
† Ranked at the 1% level by Duncan's (1955) multiple-range test. Mean values are statistically different if they do not have a common subscript letter.
‡ Each value is a mean of 112 individual determinations.
** Indicates significance at the 1% level or higher.

spectively, of the growth in U.C. mix.

Effect of redwood shavings. Soil mixtures containing both redwood shavings and peat moss produced greater plant growth than mixtures containing only shavings or only peat moss in combination with fine sand. The loam mix produced the least growth of all. No nutrient deficiency symptoms were seen on any of the plants. This experiment indicates that redwood shavings can be successfully substituted for part but not all of the peat moss in U.C. mixtures used for growing citrus.

Effect of types of peat moss, initial nutrients added, and liquid fertilizers. Liquid fertilizer #2 containing NH_4NO_3 consistently produced larger seedlings with fewer abnormal leaf patterns than did liquid #1 containing $Ca(NO_3)_2$. Effects of the various soil mixtures were less marked and less consistent than those of liquid fertilizers. The two liquid fertilizers had pronounced opposite effects on the pH of the soil leachate. From an initial range of 5.6 to 6.5, the pH of leachates of all soils receiving liquid #2 rose during the first several months and then fell; after 11 months, it ranged from 3.8 to 6.1 for the various soil mixes. The initial rise was assumed to be due to the slowly soluble lime incorporated in the soil mix. Table 4 shows the leachate pH values. When nitrate was the primary source of N, the pH of the leachate after 11 months was not noticeably influenced by source of peat moss or by concentration of

TABLE 3

AVERAGE FRESH TOP WEIGHT OF MEXICAN LIME SEEDLINGS GROWN IN U.C. MIXES WITH AND WITHOUT REDWOOD SHAVINGS

Soil mixtures	Weight* *gm*
50% sand, 25% shavings, 25% peat	37.7x
33.3% sand, 33.3% shavings, 33.3% peat	32.9x
50% sand, 50% peat	29.4xy
50% sand, 50% shavings	22.0yz
Loam mix	16.6z

* Each value is a mean of 10 individual determinations. Mean values are statistically different at the 1% level if they do not have a common subscript letter.

TABLE 4
pH OF SOIL LEACHATE

Fertilizer	Soil	pH values			
		Initial	5 months	7 months	11 months
#1	I	5.7	7.6	7.8	7.7
#1	II	6.5	8.0	7.7	7.8
#1	III	5.6	7.6	7.8	7.7
#1	IV	6.2	7.8	7.9	7.8
#1	V	5.6	7.8	7.8	7.8
#1	VI	6.5	7.8	7.8	7.8
#2	I	5.7	6.5	6.6	5.7
#2	II	6.5	6.7	7.1	6.1
#2	III	5.6	6.1	6.7	4.1
#2	IV	6.2	7.3	6.4	5.4
#2	V	5.6	6.2	5.2	3.8
#2	VI	6.5	6.9	6.4	4.0
Calculated average of #1:	...	5.9	7.8	7.8	7.8
Calculated average of #2:	...	5.9	6.4	5.9	4.4
Significance	...	NS	**	**	**

** Significance at 1% level.

added liming materials. Soils I and II, which initially received the largest amount of lime, had the highest leachate pH values after 11 months fertilization with ammonical N (liquid #2); soils III and IV, which received the intermediate quantity of lime, had somewhat lower pH values after 11 months; and soils V and VI, which received the least lime, had the lowest final pH values. This indicates that the amount of lime added initially had a marked and prolonged effect on the pH of the soil solution.

Soils I, III, and V, containing Canadian peat moss, had lower leachate pH values than their corresponding soils, II, IV, VI, containing American peat moss, both initially and after 11 months fertilization with liquid #2. As only single sources of Canadian and American peat moss were used it does not necessarily follow that other sources of Canadian peat moss will produce more acid potting mixtures than other brands of American peat moss, but these results emphasize that significant differences in initial and residual acidity among peats do occur.

Weight and leaf-symptom effects. Table 5 compares effects of liquids 1 and 2 on fresh top weight and leaf symptoms for all varieties; these figures are the average for all six soil mixes used. At harvest, seedlings of six of the eight varieties made significantly greater growth when fertilized with liquid #2 than they did when fertilized with liquid #1; the other two varieties showed no significant differences. At harvest five of the eight varieties showed significantly less abnormal chlorosis under liquid #2 fertilization; two varieties showed no significant difference, and one variety (Mexican lime) showed significantly more abnormal leaf symptoms. The reason for this reversal with Mexican lime was not apparent, but poor growth of citrus in low pH soils has been previously reported. Smith (1957) attributed the unfavorable effect of low pH on sweet orange seedlings in solution culture to high hydrogen ion concentration. Guest and Chapman (1944) reported that poor growth of citrus under acid conditions resulted from excessive solubility of Zn and Cu.

When Canadian and American peat moss were compared, most of the differences were nonsignificant (table 6). At harvest there were no significant effects

TABLE 5

EFFECT OF LIQUID FERTILIZERS ON WEIGHT OF TOPS AND ON LEAF SYMPTOM RATING

Item	Fertilizer	Variety of tree							
		Lime‡	King‡	Valencia‡	Sour§	Kara§	Sweet§	Trifoliate¶	Troyer¶
Weight at cutback (gm).	#1	26.8	20.5	13.4	28.4	13.5	21.9	4.4	21.0
	#2	23.4	27.5	15.8	30.2	20.6	20.7	5.1	18.4
Significance*............		**	**	**	NS	**	NS	NS	NS
Weight at harvest (gm)..	#1	18.8	22.8	17.1	22.7	15.0	24.2	6.4	43.5
	#2	23.1	27.4	25.6	38.4	29.3	28.8	7.6	41.3
Significance*............		*	*	**	**	**	**	NS	NS
Degree of chlorosis at cutback†..............	#1	0.09	1.75	1.03	0.78	2.59	0.03	....	....
	#2	0.07	0.26	0.08	0.27	0.32	0.19	....	....
Significance*............		NS	**	**	**	**	*		
Degree of chlorosis at harvest†............	#1	0.24	3.00	1.28	1.01	3.88	0.39	0.97	0.00
	#2	0.78	1.09	0.13	0.03	1.43	0.04	0.72	0.06
Significance*............		**	**	**	**	**	**	NS	NS

* NS = Nonsignificant; * = significant at 5% level; ** = significant at 1% level.
† O = Dark green leaves, no chlorosis; 1 = very mild chlorosis pattern on a few leaves only; 2 = mild chlorosis or other abnormal leaf symptoms; 3 = moderate chlorosis or other abnormal leaf symptoms; 4 = severe chlorosis or other abnormal leaf symptoms; 5 = very severe chlorosis or other abnormal leaf symptoms.
‡ Each value is a mean of 120 individual determinations.
§ Each value is a mean of 72 individual determinations.
¶ Each value is a mean of 18 individual determinations.

TABLE 6

EFFECT OF PEAT MOSS SOURCES ON AVERAGE FRESH WEIGHT OF TOPS AND ON LEAF SYMPTOM RATING

Item	Type of peat moss†	Variety of tree							
		Lime§	King§	Valencia§	Sour¶	Kara¶	Sweet¶	Trifoliate‖	Troyer‖
Weight at cutback (gm)................	Canadian	26.7	23.1	13.7	32.3	17.4	22.6	4.4	18.9
	American	23.5	25.0	15.4	26.4	16.7	20.1	5.1	20.5
Significance*..........		*	NS	NS	**	NS	NS	NS	NS
Weight at harvest (gm)................	Canadian	20.5	23.2	20.5	30.7	21.5	32.8	6.5	43.1
	American	21.4	27.0	22.5	30.4	22.8	30.1	7.5	41.7
Significance*..........		NS	NS	NS	NS	NS	NS	NS	NS
Degree of chlorosis at cutback†.........	Canadian	0.12	1.19	0.55	0.42	1.43	0.14	....	....
	American	0.04	0.81	0.56	0.62	1.48	0.07	....	....
Significance*..........		NS	NS	NS	*	NS	NS		
Degree of chlorosis at harvest†..........	Canadian	0.58	2.27	0.68	0.42	2.57	0.18	0.81	0.00
	American	0.45	1.83	0.73	0.63	2.74	0.25	0.89	0.06
Significance*..........		NS	*	NS	*	NS	NS	NS	NS

* NS = Nonsignificant; * = significant at 5% level; ** = significant at 1% level.
† O = Dark green leaves, no chlorosis; 1 = very mild chlorosis pattern on a few leaves only; 2 = mild chlorosis or other abnormal leaf symptoms; 3 = moderate chlorosis or other abnormal leaf symptoms; 4 = severe chlorosis or other abnormal leaf symptoms; 5 = very severe chlorosis or other abnormal leaf symptoms.
‡ Figures for Canadian peat are the average for soils I, III, and V. Figures for American peat are the average for soils II, IV, and VI.
§ Each value is a mean of 120 individual determinations.
¶ Each value is a mean of 72 individual determinations.
‖ Each value is a mean of 18 individual determinations.

TABLE 7

EFFECT OF LIME AND MICRONUTRIENTS ON AVERAGE FRESH WEIGHT OF TOPS AND ON LEAF SYMPTOM RATING

Item	Soil	Variety of tree							
		Lime‡	King‡	Valencia‡	Sour§	Kara§	Sweet§	Trifoliate¶	Troyer¶
Weight at cutback (gm).	I, II	24.9	24.2	12.6	27.9	19.3y	20.4	5.7	18.9
	III, IV	24.4	27.3	16.2	31.6	18.4y	22.9	4.3	20.4
	V, VI	25.9	20.6	14.8	28.5	13.5x	20.7	4.3	19.8
Significance*............		NS	NS	NS	NS	*	NS	NS	NS
Weight at harvest (gm)..	I, II	22.6	27.7	20.6	33.2	25.7y	31.6	7.0	44.9
	III, IV	20.4	26.0	22.7	30.6	23.2xy	33.7	7.1	42.6
	V, VI	19.9	21.6	20.6	27.8	17.6x	29.1	7.0	39.7
Significance*............		NS	NS	NS	NS	*	NS	NS	NS
Degree of chlorosis at cutback†...........	I, II	0.11	1.08xy	0.51	0.40	1.93y	0.10	....	....
	III, IV	0.06	1.37y	0.52	0.67	1.42xy	0.15	....	....
	V, VI	0.06	0.56x	0.64	0.49	1.01x	0.07	....	....
Significance*............		NS	*	NS	NS	*	NS		
Degree of chlorosis at harvest†............	I, II	0.51	1.88	0.78	0.58	2.58	0.26	0.67	0.00
	III, IV	0.40	2.23	0.69	0.42	2.90	0.30	1.13	0.00
	V, VI	0.62	2.03	0.65	0.56	2.48	0.08	0.75	0.08
Significance*............		NS	NS	NS	NS	NS	NS	NS	NS

* NS = Nonsignificant; * = significant at 5% level; ** = significant at 1% level.
† O = Dark green leaves, no chlorosis; 1 = very mild chlorosis pattern on a few leaves only; 2 = mild chlorosis or other abnormal leaf symptoms; 3 = moderate chlorosis or other abnormal leaf symptoms; 4 = severe chlorosis or other abnormal leaf symptoms; 5 = very severe chlorosis or other abnormal leaf symptoms.
‡ Each value is a mean of 80 individual determinations.
§ Each value is a mean of 48 individual determinations.
¶ Each value is a mean of 12 individual determinations.

of the peat moss sources on fresh top weight on any variety. Six of the eight varieties also showed no difference in leaf symptoms; King mandarins exhibited more leaf chlorosis when grown in Canadian peat moss mixtures, while sour orange was more chlorotic in American peat moss mixtures.

Table 7 compares effects of lime and micronutrients initially added to the mixtures. Soils I and II were combined as a high lime, plus Cu only as micronutrient treatment; soils III and IV were combined as a medium lime plus medium micronutrient treatment; and soils V and VI were combined as a low lime plus medium micronutrient and higher Mn and Fe treatment. Differences were significant with only Kara and King mandarin. When first cut back, Kara mandarin seedlings grown in high lime plus low micronutrient soils I and II exhibited more top growth and more chlorosis than did Kara grown in low lime plus high micronutrient soils V and VI.

At harvest, both Kara and King Mandarin seedlings exhibited more chlorosis in soils I and II than they did in soils V and VI, but there were no significant differences in top weight for any variety.

DISCUSSION AND CONCLUSION

Initial experiments indicated that citrus seedlings grown in U.C. soil mixes as outlined by Baker *et al.* (1957) can be expected to develop severe micronutrient deficiencies. Further experiments demonstrated the feasibility of growing citrus seedlings in a modified U.C. soil mix. In addition, the U.C. system has been used at the University of California Citrus Research Center since 1959 for growing citrus seedlings for virus detection by leaf symptoms. It has been successful in producing healthy growth flushes of young leaves without nutrient deficiency symptoms which might mask mild virus symptoms. In comparisons of U.C. mix with a potting mix containing approximately 50 per cent clay loam, the U.C. mix consistently produced larger and healthier plants than did the potting mix containing clay loam. Because seedlings growing in the loam mix received a complete nutrient solution (and, in one experiment, received the same nutrient solution as in the U.C. mix) and no gross nutritional disturbance was apparent, it seems probable that the large growth differences were due primarily to differences in physical properties of the soil. The U.C. mix is much better-drained and aerated than the loam mix; moisture holding capacity is higher, and soil moisture level is maintained better between irrigations.

Each of the two liquid fertilizers supplied different amounts of N, P, K, Ca, and Mg, but this did not appear to materially affect plant growth or leaf-symptom expression. Nitrogen and K were in good supply in both liquid fertilizer solutions. Phosphorus, Ca, and Mg were added initially as superphosphate, $CaCO_3$, and dolomite, respectively. These materials are slowly soluble and the quantities used appeared sufficient for the 11 months of this experiment. Labanauskas, Nauer, and Roistacher (1967) found no serious deficiency or excess levels of these elements in leaves of the Valencia orange seedlings, and no leaf symptoms indicating a deficiency or excess of P, Ca, or Mg were seen on the other species of seedlings.

Copper deficiency of citrus associated with the use of U.C. mix appears to be induced by the relatively large quantity of peat moss in the mix. That this deficiency can be readily corrected by adding $CuSO_4$, either before or after planting, indicates that Cu deficiency should not be a limiting factor in using U.C. mixtures for citrus. There appeared to be little effect of soil pH on Cu uptake within a pH range of 3.8 to 7.8, because no typical Cu-deficiency symptoms appeared where 25 ppm Cu (as $CuSO_4$) was added to the initial mix. Where no Cu was added, severe Cu-deficiency symptoms appeared soon after planting; these symptoms could be alleviated by adding $CuSO_4$ dissolved in water. Thus there is little doubt that the symptoms were caused by Cu deficiency, even though leaf analyses for Cu were not available.

Micronutrients other than Cu (namely, Zn, Mn, Fe, B, and Mo) appeared mostly to be in adequate supply in bulk-soil ingredients, or as impurities in the fertilizers for the 11 months duration of this experiment when pH was controlled and kept below about 7.0. This can be seen in table 7 by comparing soils I and II, which received no added micronutrients other than Cu, with soils III and IV, and V and VI which receive added micronutrients. However, it is felt by the authors that the addition of small quantities of these micronutrients to a U.C. mix for growing citrus would be advisable, in view of probable variations in amounts of micronutrients present and their availability in different sources of bulk-soil ingredients and major nutrient fertilizers. When soil pH rose to above 7.0 (as was the case with liquid 1) micronutrient deficiency leaf patterns appeared in all cases, and the addition of micronutrient salts to the soil mix had little or no effect.

A test of the practicality of this revised system was presented to the authors when a large greenhouse operation producing Mexican lime seedlings experienced difficulty growing vigorous seedlings in a local soil mix. (Figure 1 shows seedlings grown in the modified

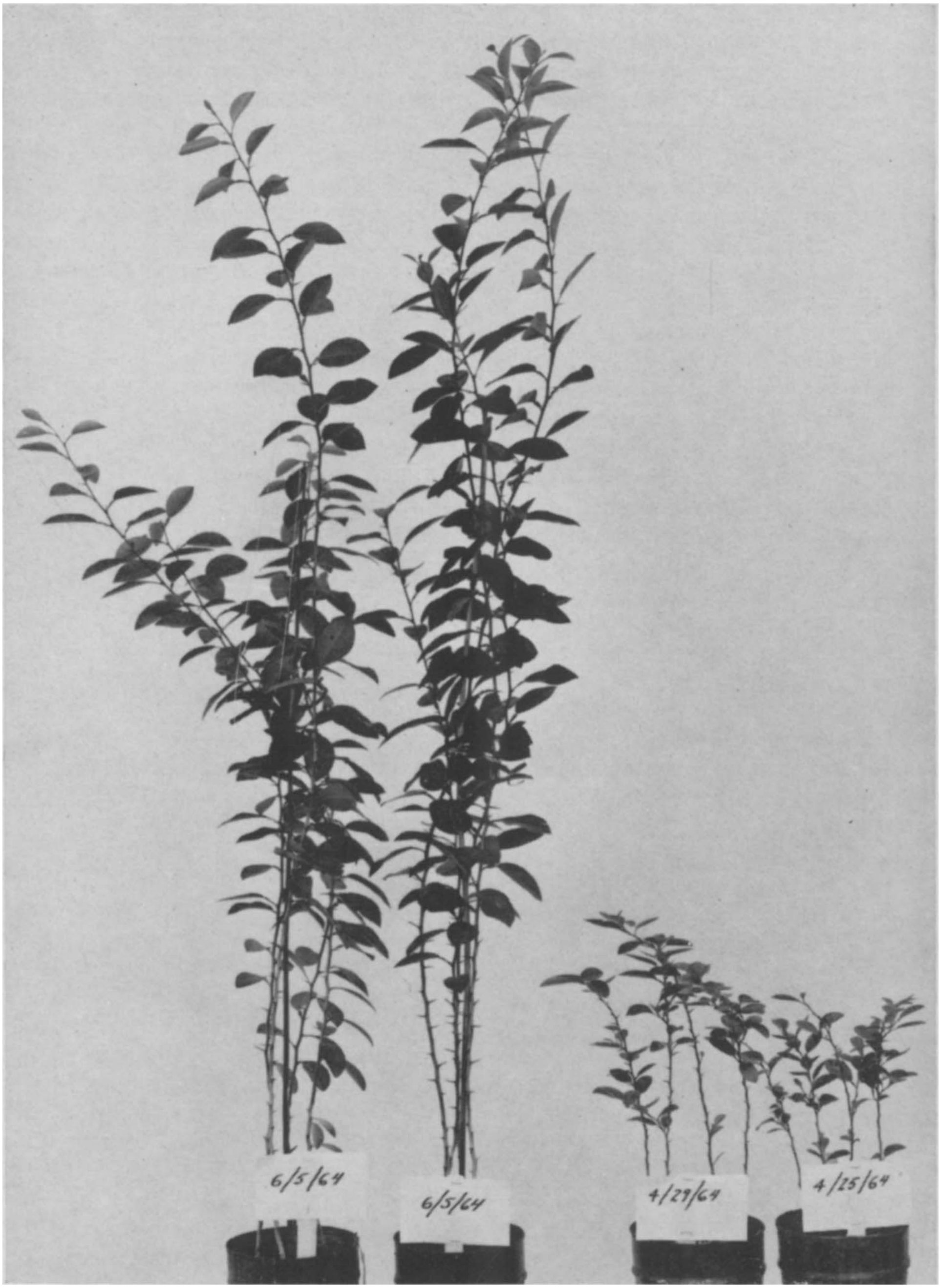

Fig. 1. Mexican lime seedlings grown in modified U.C. mix (left two) and in a local greenhouse mix (right two).

U.C. mix and in the local mix obtained from this greenhouse.) The operators of this greenhouse have since converted to the modified U.C. system with excellent results in plant growth, vigor, and lack of nutrient-deficiency symptoms.

On the basis of these experiments, soils I, II, III, and IV (table 1) and liquid fertilizer #2 can be recommended for growing citrus in containers on a trial basis. Soils V and VI are not recommended because of the low pH values of the soil leachate after 11 months (table 4). Continuous use of liquid fertilizer #2 can be expected to lower the pH of any U.C. soil mix with time. Therefore, if plants are to be kept in the same containers for an extended period, calcium nitrate or some other non-acidifying nitrogen source will need to be substituted for all or part of the ammonium nitrate in liquid fertilizer #2 before pH of the soil mix falls too low for good growth.

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previously had experienced difficulty in producing vigorous citrus seedlings free of nutrient-deficiency symptoms.

INITIAL SOIL-MIX AND POSTPLANTING LIQUID FERTILIZATION EFFECTS ON NUTRIENT CONCENTRATIONS IN VALENCIA ORANGE SEEDLING LEAVES

Effects of mix composition, fertilization, and pH on citrus seedlings grown in several U.C.-type potting mixtures in containers were studied. A liquid fertilizer containing NH_4NO_3, KCl, and $NH_4H_2PO_4$ significantly increased plant top weight, eliminated micronutrient deficiency symptoms, and increased N, P, K, Cl, Zn, Cu, Mn, B, and Fe concentrations in leaves to optimum levels as compared with seedlings watered with liquid fertilizer containing $Ca(NO_3)_2$, $MgSO_4$, and KNO_3. Availability of micronutrients to plants appeared to be influenced primarily by soil pH. When pH of soil-leachate was higher than 7.0, the plants exhibited more micronutrient deficiency symptoms and made considerable less growth than when pH was lower than 7.0. These findings have been successfully applied in several large scale greenhouse operations which had previously had much difficulty in producing vigorous citrus seedlings free of nutrient-deficiency symptoms.

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