HILGARDIA

A JOURNAL OF AGRICULTURAL SCIENCE PUBLISHED BY
THE CALIFORNIA AGRICULTURAL EXPERIMENT STATION

Volume 38, Number 15 · November, 1967

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

E. M. Nauer, C. N. Roistacher, C. K. Labanauskas

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

C. K. Labanauskas, E. M. Nauer, C. N. Roistacher

UNIVERSITY OF CALIFORNIA DIVISION OF AGRICULTURAL SCIENCES

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

(Continued inside back cover)

THE AUTHORS:

E. M. Nauer is Associate Specialist in the Horticultural Science Department in the University of California Citrus Research Center and Agricultural Experiment Station, Riverside.

C. K. Labanauskas is Lecturer and Associate Horticulturist in the University of California Citrus Research Center and Agricultural Experiment Station, Riverside.

C. N. Roistacher is Laboratory Technician IV, Plant Pathology, in the University of California Citrus Research Center and Agricultural Experiment Station, Riverside.

C. K. Labanauskas, E. M. Nauer, and C. N. Roistacher

Initial Soil-Mix and Postplanting Liquid Fertilization Effects on Nutrient Concentrations in Valencia Orange Seedling Leaves[1]

INTRODUCTION

CITRUS SEEDLINGS are being grown in large quantities for virus detection by leaf-symptom expression in young leaves, as part of the Citrus Variety Improvement Program at Riverside initiated in 1958 (Reuther, 1959).[2] Vigorous growth flushes, free of nutrient deficiency or excess symptoms, are required. A. U.C.-type soil mix recommended by Baker (1957) was compared with a standard clay-peat mix then in current use, and although early trials were encouraging, leaf flushes showed micronutrient deficiency symptoms (Nauer *et al.*, 1967). The first serious trouble encountered was severe Cu deficiency. After this was corrected by application of Cu chelate (EDTA) or $CuSO_4$, micronutrient deficiency symptoms resembling those of Zn, Mn, and Fe appeared.

Reitz *et al.* (1959) suggested that the pH of Florida soils used for growing citrus be maintained between 5.5 and 6.5 by liming to counteract the acidifying effects of fertilizers. It has also been shown that uptake of micronutrients by citrus plants depends upon soil pH and the presence (or absence) of nutrients in soil (Camp and Fudge, 1939; Camp and Reuther, 1937; Pratt *et al.*, 1959; Spencer, 1960). Nauer *et al.* (1967) found that availability of micronutrients to the citrus seedlings depended primarily upon soil pH, which was changed by varying the fertilizer materials used in the liquid feed. Therefore it was on the basis of these suggestions that an experiment was initiated to compare citrus seedling growth, degree of chlorosis, and nutrient concentrations in the leaves of Valencia orange seedlings grown in several U.C.-type soil-mixes with varying rates of soil amendments, fertilizers, and two postplanting liquid fertilizers having opposite effects on soil pH.

MATERIALS AND METHODS

In June, 1963, Valencia orange seedlings germinated and grown in flats were transplanted when 1 to 3 inches high into the various experimental soil mixtures in 1-gallon painted metal containers. Seedlings were selected for uniformity, and those visibly off-type and apparently 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

[1] Paper number 1786, University of California Citrus Research Center, Riverside. Submitted for publication November 1, 1966.

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

tristeza virus indicator in the Citrus Variety Improvement Program.

The initial U.C.-type potting-mix (Baker, 1957) contained equal parts by volume of peat moss, redwood shavings, and fine sand. All such mixes received 0.25 pounds of KNO_3, 0.25 pounds of K_2SO_4, and 2.50 pounds of single superphosphate per cubic yard. In this experiment two sources of peat moss, Canadian and American, were used. Three levels of lime and three levels of micronutrients were added at the time of mixing. Insoluble nutrients were added dry and tumbled in the mixer with the dry soil ingredients. Then the following micronutrients were dissolved in H_2O and added to the soil mix: Zn, Mn, Cu, and Fe, as sulfates; B as boric acid; and Mo as $(NH_4)_6Mo_7O_{24}$. This potting material was mixed in a cement-type mixer to insure uniformity (table 1). After mixing potting material it was steam-sterilized for 1 hour to a temperature of 212° F.

Five replications were set up, each consisting of one can containing four seedlings. Initially, and at the end of the experiment, pH determinations were made on a soil leachate, obtained by adding tap water to several cans and catching the solution which came out of the drainage holes in the bottom. After planting the seedlings, liquid fertilization was applied in tap water by venturi siphoning through a hose. Two liquid fertilizers were used: liquid #1 consisted of 5 pounds of $Ca(NO_3)_2$, 2 pounds of $MgSO_4$, and 1.25 pounds of KNO_3 per 1,000 gallons of water; liquid #2 consisted of 5 pounds of NH_4NO_3, 3 pounds of KCl, and 1 pound of $NH_4H_2PO_4$ per 1,000 gallons of water. Amounts of nutrients supplied by liquid #1 per 1,000 gallons applied were: 1.03 pounds of N, no P, 0.48 pounds of K, 1.22 pounds of Ca, and 0.41 pounds of Mg; liquid #2 supplied 1.75 pounds of N, 0.27 pounds of P, 1.58 pounds of K, no Ca, and no Mg.

After 5 months' growth, seedlings were cut back to a 6-inch stem. Tops were weighed and leaves visually evaluated for presence or absence of chlorosis, nutrient deficiency symptoms, and other abnormalities. For this evaluation a scale of 0 to 5 was used; a 0 rating denoted normal dark leaves and 1 to 5 indicated varying degrees of abnormal chlorotic patterns, with a rating of 5 for the most severe. These data were presented in a previous paper (Nauer *et al.*, 1967). After seedlings were cut back they were allowed to grow again for 6 months, at which time the tops were cut off 2 inches above the previous cut and weighed and evaluated. The whole new flush of leaves between 4 and 5 months of age was taken for chemical

TABLE 1
DESCRIPTION OF INITIAL MIXES USED IN THE EXPERIMENT

Soil*	Type of peat moss	Amount of lime per cubic yard added	Concentrations of micronutrients added
I	Canadian	7.50 lb. dolomite 2.50 lb. $CaCO_3$	25 ppm Cu
II	American	7.50 lb. dolomite 2.50 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 0.20 ppm B 0.20 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 0.20 ppm B 0.20 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 6 and 7).

analysis of nutrient content. Each leaf was handwashed in an aqueous solution of 0.1 per cent v/v detergent (JOY) by passing the fingers and thumb over the total surface of the leaf, then rinsing it in deionized water. Samples were dried in a forced-draft oven at 60°C for 48 hours, ground in a chromium-plated Christy and Norris laboratory mill, and stored in glassine-lined bags (Labanauskas, 1966).

Twenty-five mg of ground material were used for N determination by the micro-Kjeldahl method. Chlorine was determined on a 0.5 gm sample by an HNO_3-aqueous extraction and direct electrometric titration with $AgNO_3$ (Brown and Jackson, 1955).

Phosphorus, K, Ca, Na, Zn, Cu, Mn, B, and Fe were obtained from the same 5-gm sample of ground material weighed into VYCOR crucibles and ashed at 550°C for 12 hours. The ash was cooled and dampened with a few drops of deionized water; two 5 ml portions of 3N HCl were then added, and the whole slightly heated but not boiled. After heating, the sample was filtered through a Whatman 42 filter paper into a 50-ml volumetric flask and made to volume. From the 50-ml volumetric flask, an aliquot equivalent to a 0.5 gm of dried material was transferred into a 100-ml volumetric flask for P, K, Ca, Mg, and Na determinations. To this aliquot 5 ml of 0.5 M $SrCl_2 \cdot 6H_2O$ was added to eliminate anionic interferences in the flame and then made to volume. Phosphorus was determined by the colorimetric method (Kitson and Mellon, 1944). Potassium, Ca, Mg, and Na were determined with the Beckman Model DU flame photometer with photomultiplier tube attachment by essentially the same method described by Clifford and Winkler (1954) for Na determination.

Aliquots were taken from the remainder of the filtrate in the 50-ml volumetric flask for Zn, Cu, Mn, B, and Fe determinations. Zinc and Cu were determined by using the color reactions with 2-carboxy-2′-hydroxy-5′-sulfoformazylbenzene (Jackson and Brown, 1956), Mn by oxidation to permanganate essentially by the method described by Sandell (1950), except for omission of HNO_3 in the procedure, Fe by the color reaction with o-phenanthroline (Sandell, 1950), and B by color reaction with carmine (Hatcher and Wilcox, 1950). Color densities for Zn, Cu, Mn, B, and Fe, were determined with the Beckman Model B spectrophotometer. Data obtained from visual and chemical observations were analyzed statistically (Duncan, 1955).

RESULTS AND DISCUSSION

Peat moss effects. Table 2 shows that the pH of initial soil-leachate from containers incorporating Canadian peat moss was lower than pH of similar soil-leachate obtained from containers incorporating American peat moss. However, by the end of the experiment the pH of the two leachates did not differ to any great degree. Even so, pH of Canadian peat moss leachate was still somewhat lower than the pH of similar potting-leachate obtained from pots containing American peat moss. In addition to the lower pH of leachate from the Canadian peat moss containers, concentrations of N, K, Zn, B, and Fe in the leaves of seedlings were higher, while Ca and Mg were lower. The two differential sources of peat moss used in the initial potting-mixes did not significantly influence fresh weight of tops, degree of chlorosis, or concentrations of P, Na, Cl, Cu, and Mn in the leaves. Concentrations of nutrients found in the 4- to 5-month-old leaves were in optimum range (Reuther *et al.*, 1962). Increases and decreases in nutrient concentrations in leaves of these seedlings can be attributed to differences in soil pH or to differential amounts of nutri-

TABLE 2

PEAT MOSS EFFECTS ON pH OF SOIL-LEACHATE, FRESH WEIGHT OF PLANTS, DEGREE OF CHLOROSIS, AND NUTRIENT CONCENTRATIONS IN LEAVES OF VALENCIA ORANGE SEEDLINGS

Item	Type of peat moss*		Significance of difference†	C.V.‡
	Canadian	American		
Initial pH of soil-leachate	5.60	6.40	....	..
pH of soil-leachate at harvest	6.10	6.50	....	..
Fresh plant wt. at harvest (gm)	20.50	22.20	NS	14
Degree of chlorosis	0.70	0.70	NS	13
N per cent (dry wt.)	3.20	3.12	0.05	4
P per cent (dry wt.)	0.159	0.166	NS	6
K per cent (dry wt.)	2.64	2.52	0.01	12
Ca per cent (dry wt.)	2.07	2.23	0.01	6
Mg per cent (dry wt.)	0.208	0.217	0.05	7
Na per cent (dry wt.)	0.006	0.005	NS	33
Cl per cent (dry wt.)	0.065	0.067	NS	27
Zn parts per million (dry wt.)	24.0	20.0	0.01	13
Cu parts per million (dry wt.)	10.0	9.0	NS	21
Mn parts per million (dry wt.)	33.0	35.0	NS	27
B parts per million (dry wt.)	50.0	48.0	0.05	8
Fe parts per million (dry wt.)	66.0	56.0	0.05	28

* Each value is a mean of 30 individual determinations, except for soil-leachate pH values which were determined from the composite of 30 individual leachate samples.

† NS = differences between means are not significant; 0.5 = differences between means are significant at the 5 per cent level; 0.1 = differences between means are significant at the 1 per cent level or higher.

‡ C.V. = coefficient of variability expressed in per cent.

TABLE 3

EFFECTS OF VARIOUS AMOUNTS OF LIME ON pH OF SOIL-LEACHATE, FRESH WEIGHT OF PLANTS, DEGREE OF CHLOROSIS, AND NUTRIENT CONCENTRATIONS IN VALENCIA ORANGE SEEDLING LEAVES

Item	Pounds of lime per cubic yard added to soil-mix*			Significance of difference†	C.V.‡
	2.5	5.0	10.0		
pH of soil-leachate initially	6.0	5.9	6.1	....	..
pH of soil-leachate at harvest	5.8	6.2	6.8	....	..
Fresh plant wt. at harvest (gm)	20.6	22.7	20.6	NS	14
Degree of chlorosis	0.6	0.7	0.8	NS	13
N per cent (dry wt.)	3.22y	3.18y	3.07x	0.05	4
P per cent (dry wt.)	0.158	0.160	0.169	NS	6
K per cent (dry wt.)	2.61y	2.66y	2.46x	0.01	12
Ca per cent (dry wt.)	2.02x	2.11x	2.33y	0.01	6
Mg per cent (dry wt.)	0.200x	0.204x	0.233y	0.01	7
Na per cent (dry wt.)	0.006	0.006	0.005	NS	33
Cl per cent (dry wt.)	0.061	0.069	0.068	NS	27
Zn parts per million (dry wt.)	24.0y	24.0y	19.0x	0.01	13
Cu parts per million (dry wt.)	10.0	10.0	8.0	NS	21
Mn parts per million (dry wt.)	39.0y	31.0x	33.0x	0.01	27
B parts per million (dry wt.)	51.0y	49.0xy	47.0x	0.01	8
Fe parts per million (dry wt.)	69.0y	63.0xy	49.0x	0.01	28

* Each value is a mean of 20 individual determinations, except for pH values of soil-leachate which were determined from composite of 20 soil-leachate samples. Letters x and y after mean values indicate statistical populations. Mean values are statistically significant only if they do not have a letter in common after values.

† NS indicates that differences between means are not significant; 0.05 indicates that differences between means are significant at the 5 per cent level; 0.01 indicates that differences between means are significant at the 1 per cent level or higher.

‡ C.V. = coefficient of variability expressed in per cent.

ents in the two sources of peat moss. Because only one brand of Canadian and of American peat moss was used, it is not known whether other sources of Canadian peat moss would produce more acid soils than do other brands of American peat moss. Also (because nutrient concentrations in the peat mosses were not predetermined in this experiment) it is uncertain if differences in nutrient concentrations in leaves are due to soil pH or to different amounts of nutrients in the mosses. Most of these nutrients are more abundant in the leaves of plants grown in soils of lower pH than they are in plants grown in soils having a higher pH (Labanauskas *et al.*, 1962; Pratt *et al.*, 1959; Reitz *et al.*, 1959).

Effects of lime. Table 3 shows that increased amounts of lime in the initial potting-mix considerably increased pH values of soil-leachate by the end of the experiment, as well as the concentrations of Ca and Mg in the leaves of the seedlings, but reduced the concentrations of N, K, Zn, Mn, B, and Fe. However, pH values of initial soil-leachate, fresh weight of plant tops, degree of chlorosis, and the concentrations of P, Na, Cl, and Cu in the leaves of Valencia orange seedlings were not significantly affected by the different amounts of lime used in the initial potting-mix. The pH of the initial soil-leachate was not changed by the increased amount of lime used in the initial potting-mix, probably because of the relative insolubility of lime; the degree of chlorosis was slightly, although not significantly, increased in the leaves of the seedlings, while the concentrations of nutrients in the leaves remained in an adequate range (Reuther *et al.*, 1962). Variations in micronutrient concentrations in the leaves are probably induced by soil pH, and those of N and K by Ca and Mg antagonism. The data obtained pertaining to the effects of lime on nutrient concentrations in leaves of citrus seedlings are in accord with results reported earlier by Labanauskas *et al.* (1962), Pratt *et al.* (1959), Reitz *et al.* (1959) and Smith (1964).

Micronutrient effects. Three levels of micronutrients (table 1) were used in the initial potting-mix, but thereafter the different micronutrient levels are referred to as low, intermediate, and high (table 4). Increasing the amount of micronutrients in the initial potting-mix decreased chlorosis and concentrations of Ca and Mg in the leaves, but increased the concentrations of N, K, Zn, Mn, B, and Fe. Copper concentration in leaves was not significantly affected because all the differential treatments received uniform amounts of $CuSO_4$ in the initial potting-mix. Increase in micronutrient concentrations in leaves is directly correlated to the amounts of micronutrients used in the initial soil-mix, or indirectly to lower pH values. The increase in N and K, and decrease in Ca and Mg concentrations in the leaves, may be attributed to the acidifying effects of the anion supplied with these micronutrients used in the initial soil-mix, as Zn, Mn, and Fe were used in sulfate forms.

Effects of liquid fertilization after planting. The differences between the effects of the two liquid fertilizers were generally greater than differences due to sources of peat moss, rate of lime, or amount of micronutrients applied to the initial potting-mix. Soils watered with liquid fertilizer #2 increased acidity of the soil-leachate by harvest time, increased plant top weight, and greatly reduced micronutrient deficiency symptoms as compared with plants watered with liquid fertilizer #1 (table 5). Liquid fertilizer #2 consistently produced larger seedlings with practically no abnormal nutritional patterns. The pH of soil-leachates from soil containers watered with fertilizer #1 rose from an intial 5.9 to 7.8 in 5 months and remained at 7.8. The pH of soil-leachates from containers watered with fertilizer #2 rose during the first several months

TABLE 4

MICRONUTRIENT EFFECTS ON pH OF SOIL-LEACHATE, FRESH WEIGHT OF PLANTS, DEGREE OF CHLOROSIS, AND NUTRIENT CONCENTRATIONS IN LEAVES OF VALENCIA ORANGE SEEDLINGS

Item	Levels of micronutrients added per cubic yard to soil-mix*			Significance of difference†	C.V.‡
	Low	Intermediate	High		
pH of soil-leachate initially	6.1	5.9	6.0	....	..
pH of soil-leachate at harvest	6.8	6.2	5.8	....	..
Fresh plant wt. at harvest (gm)	20.6	22.7	20.6	NS	14
Degree of chlorosis	0.8	0.7	0.6	NS	13
N per cent (dry wt.)	3.07x	3.18y	3.22y	0.05	4
P per cent (dry wt.)	0.169	0.160	0.158	NS	6
K per cent (dry wt.)	2.46x	2.66y	2.61y	0.01	12
Ca per cent (dry wt.)	2.33y	2.11x	2.02x	0.01	6
Mg per cent (dry wt.)	0.233y	0.204x	0.200x	0.01	7
Na per cent (dry wt.)	0.005	0.006	0.006	NS	33
Cl per cent (dry wt.)	0.068	0.069	0.061	NS	27
Zn parts per million (dry wt.)	19.0x	24.0y	24.0y	0.01	13
Cu parts per million (dry wt.)	8.0	10.0	10.0	NS	21
Mn parts per million (dry wt.)	33.0x	31.0x	39.0y	0.01	27
B parts per million (dry wt.)	47.0x	49.0xy	51.0y	0.01	8
Fe parts per million (dry wt.)	49.0x	63.0xy	69.0y	0.01	28

* Each value is a mean of 20 individual determinations, except for the pH values of soil-leachate which were determined from the composite of 20 individual soil-leachate samples. Letters x and y after mean values indicate statistical populations. Mean values are statistically significant only if they do not have a letter in common after values.
† NS = differences between means are not significant; 0.05 = differences between means are significant at the 5 per cent level; 0.01 = differences between means are significant at the 1 per cent level or higher.
‡ C.V. = coefficient of variability expressd in per cent.

TABLE 5

EFFECTS OF LIQUID FERTILIZATION APPLIED AFTER PLANTING ON pH OF SOIL-LEACHATE, FRESH WEIGHT OF PLANTS, DEGREE OF CHLOROSIS, AND NUTRIENT CONCENTRATIONS IN VALENCIA ORANGE SEEDLING LEAVES

Item	Liquid used after planting*		Significance of difference†	C.V.‡
	Liquid #1	Liquid #2		
pH of soil-leachate initially	5.9	5.9	....	..
pH of soil-leachate at harvest	7.8	4.4	....	..
Fresh plant wt. at harvest (gm)	17.1	25.6	0.01	14
Degree of chlorosis	1.3	0.1	0.01	13
N per cent (dry wt.)	2.80	3.52	0.01	4
P per cent (dry wt.)	0.115	0.210	0.01	6
K per cent (dry wt.)	2.34	2.82	0.01	12
Ca per cent (dry wt.)	2.89	1.42	0.01	6
Mg per cent (dry wt.)	0.235	0.190	0.01	7
Na per cent (dry wt.)	0.006	0.005	NS	33
Cl per cent (dry wt.)	0.023	0.108	0.01	27
Zn parts per million (dry wt.)	17.0	28.0	0.01	13
Cu parts per million (dry wt.)	7.0	12.0	0.01	21
Mn parts per million (dry wt.)	16.0	52.0	0.01	27
B parts per million (dry wt.)	42.0	57.0	0.01	8
Fe parts per million (dry wt.)	34.0	88.0	0.01	28

* Each value is a mean of 30 individual determinations, except for the pH values of soil-leachate which were determined from the composite of 20 individual soil-leachate samples.
† NS = differences between means are not significant; 0.01 = differences between means are significant at 1 per cent level or higher.
‡ C.V. = coefficient of variability expressed in per cent.

and then fell to 4.4 at harvest time; this could have been due to the slowly soluble lime incorporated in the initial soil-mix, or to the effects of NH_4 before nitrification took place. More detailed effects of liquid fertilizers on pH of soil-leachates have been presented by Nauer *et al.* (1967).

Leaves of seedlings watered with fertilizer #2 contained significantly higher concentrations of N, P, K, Cl, Zn, Cu, Mn, B, and Fe than did leaves of plants watered with fertilizer #1. Neither of these liquid fertilizers contained micronutrients except as impurities in the macronutrient chemicals used, or in the water. Sodium concentration was not influenced by either liquid fertilizer.

Higher concentrations of N, P, K, and Cl in the leaves of seedlings watered with fertilizer #2 can be attributed to the fact that larger amounts of these nutrients were applied than with fertilizer #1. Although no micronutrients were added to either liquid fertilizer, the concentrations of Zn, Cu, Mn, B, and Fe in leaves of plants watered with fertilizer #2 were significantly higher than in leaves of plants watered with fertilizer #1. Lower pH of soil watered with fertilizer #2 increased the availability of these nutrients to the seedlings. Only the concentrations of Zn, Mn, and Fe in leaves of plants watered with fertilizer #1 were in deficiency ranges (Reuther *et al.*, 1962). Therefore, deficiency symptoms observed on the leaves of this latter group were attributed to low levels of Zn, Mn, and Fe concentrations. The two liquid fertilizers used in this experiment induced definite changes in soil-leachate pH. As mentioned earlier, soils watered with fertilizer #2 became acid, and, therefore, Zn, Mn, Cu, B, and Fe became more available to the plants than they were in soils watered with fertilizer #1 (table 5).

Interactions. The post-planting application of liquid fertilizer #2 to the soils significantly increased the concentration of P, and reduced Ca and Mg in the seedling leaves, as compared with these concentrations found in the leaves of treatments in which liquid #1 was used (table 6). However, the degree of increase in P, and decreases in Ca and Mg varied considerably with the amount of lime and kind of peat moss used in the initial pre-planting potting-mix (table 1).

The data presented in tables 3 and 7 show that the increase in Zn, Mn, and Fe concentrations in leaves of trees watered with liquid #2 varied considerably with the amount of lime incorporated in the initial potting-mix, as compared with concentrations of these nutrients found in the leaves of trees treated with liquid #1.

SUMMARY

The effects of various initial potting-mixes and post-planting liquid fertilization on the pH of soil-leachate, on fresh weight produced, degree of chlorosis, and on 12 nutrient concentrations in Valencia orange seedling leaves were studied. Incorporation of Canadian peat moss in the soil-mix containers resulted in lower pH values of soil-leachate, higher N, K, Zn, B, and Fe, and lower Ca and Mg concentrations in the leaves than were obtained from incorporating American peat moss in the potting-mix. Increased amounts of lime in the initial potting-mix increased pH values of potting-leachate, as well as Ca and Mg in the leaves of orange seedling, while N, K, Zn, Mn, B, and Fe were decreased. Increasing the amounts of micronutrients, applied in SO_4 form in the initial potting-mix reduced pH values of the leachate, degree of chlorosis, and the concentrations of Ca and Mg in the leaves, while concentrations of N, K, Zn, Mn, B, and Fe in leaves were increased. Increase in micronutrient

TABLE 6

EFFECTS OF INTERACTIONS BETWEEN INITIAL SOIL TREATMENTS AND POST-PLANTING LIQUID TREATMENTS #1 AND #2 ON CONCENTRATIONS OF P, Ca, AND Mg IN LEAVES*

Soil, and type of peat moss	P		Ca		Mg	
	#1	#2	#1	#2	#1	#2
	per cent on dry weigh basis					
I Canadian...	0.113xyz	0.224y	2.93	1.65yz	0.244	0.208y
II American...	0.124yz	0.215xy	2.92	1.84z	0.244	0.237z
III Canadian...	0.100x	0.205xy	2.79	1.18x	0.219	0.178x
IV American...	0.128z	0.208xy	2.94	1.51y	0.239	0.180x
V Canadian...	0.105xy	0.204xy	2.82	1.07x	0.234	0.163x
VI American...	0.120xyz	0.202x	2.94	1.23x	0.231	0.173x
Significance of difference†....	0.01	0.01	NS	0.01	NS	0.01

* Each value is a mean of five individual determinations. Letters x, y, and z after mean values indicate statistical populations. Mean values are statistically significant only if they do not have a letter in common after values.

† NS = differences between means are not significant; 0.01 = differences between means are significant at the 1 per cent level or higher.

TABLE 7

EFFECTS OF INTERACTIONS BETWEEN INITIAL SOIL TREATMENTS AND POST-PLANTING LIQUID TREATMENTS #1 AND #2 ON CONCENTRATIONS OF Zn, Mn, AND Fe IN LEAVES*

Soil and type of peat moss	Zn		Mn		Fe	
	#1	#2	#1	#2	#1	#2
	parts per million on dry weight basis					
I Canadian..................	19y	24xy	16	47x	33	70x
II American..................	12x	20x	20	48x	30	64x
III Canadian..................	19y	31z	12	49xy	31	107yz
IV American..................	17xy	27yz	15	45x	39	77xy
V Canadian..................	17xy	33z	16	59yz	35	119z
VI American..................	16xy	29yz	19	61z	34	91xyz
Significance of difference†.......	0.01	0.01	NS	0.01	NS	0.01

* Each value is a mean of five individual determinations. Letters x, y, and z after mean values indicate statistical populations. Mean values are statistically significant only if they do not have a letter in common after values.

† NS = differences between means are not significant; 0.01 = differences between means are significant at the 1 per cent level or higher.

concentrations in seedling leaves was directly proportional to the amounts of these nutrients applied in the original soil-mix and to the acidity of the potting-leachate. A liquid fertilizer containing NH_4NO_3, KCl, and $NH_4H_2PO_4$ significantly increased acidity of potting-leachate and plant top weight, greatly reduced micronutrient deficiency chlorosis, and increased N, P, K, Cl, Zn, Cu, Mn, B, and Fe concentrations in the leaves as compared with these values found in seedlings watered with a liquid fertilizer containing $Ca(NO_3)_2$, $MgSO_4$, and KNO_3.

Potting-mixes are useful for growing citrus seedlings because the chemical composition in the leaves of the seedlings can be maintained within a normal range for the elements concerned. This may be accomplished by appropriate additions of chemicals to the original soil-mix or by watering with solutions containing appropriate salts.

LITERATURE CITED

BAKER, K. F.
1957. The U. C. system for producing healthy container grown plants. University of California Manual 23.

BROWN, J. G., and R. K. JACKSON
1955. A note on the potentiometric determination of chloride. Proc. Amer. Soc. Hort. Sci. 65: 187–94.

CAMP, A. F., and B. R. FUDGE
1939. Some symptoms of citrus malnutrition in Florida. Fla. Agr. Exp. Sta. Bul. 335:1–55.

CAMP, A. F., and W. REUTHER
1937. Studies on the effects of zinc and other unusual mineral supplements on the growth of horticultural crops. Fla. Agr. Exp. Sta. Ann. Rept. 1937:132–35.

CLIFFORD, P. A., and W. O. WINKLER
1954. Sodium determination on Beckman DU. J. Assoc. Offc. Agr. Chemists 37(3):587–601.

DUNCAN, D. B.
1955. Multiple range and multiple *F* tests. Biometrics 11:1–42.

HATCHER, J. Y., and L. V. WILCOX
1950. Colorimetric determination of boron using carmine. Anal. Chem. 22:567–69.

JACKSON, R. K., and J. G. BROWN
1956. The determination of zinc in plant material without the use of organic extractants. Proc. Amer. Soc. Hort. Sci. 68:1–5.

KITSON, R. E., and M. O. MELLON
1944. Colorimetric determination of phosphorus as molybdivanadophosphoric acid. Ind. and Eng. Chem. Anal. Ed. 16:379–83.

LABANAUSKAS, C. K.
1966. Effects of orange leaf-washing technique on removal of surface contaminants and nutrient losses. Proc. Amer. Soc. Hort. Sci. 89:201–05.

LABANAUSKAS, C. K., W. W. JONES, and T. W. EMBLETON
1962. Effects of nitrogen, phosphorus, potassium, limestone, gypsum, and manure soil applications on soil pH and on macro- and micronutrient concentrations in Washington navel orange leaves. Proc. Amer. Soc. Hort. Sci. 80:259–67.

NAUER, E. M., C. N. ROISTACHER, and C. K. LABANAUSKAS
1967. Effects of mix composition, fertilization, and pH on citrus grown in several U.C.-type potting mixtures under greenhouse conditions. Hilgardia 38(15):557–67.

PRATT, P. F., R. B. HARDING, W. W. JONES, and H. D. CHAPMAN
1959. Chemical changes in an irrigated soil during 28 years of differential fertilization. Hilgardia 28(15):381–430.

REITZ, H. J., C. D. LEONARD, I. STEWART, R. C. J. KOO, D. V. CALVERT, C. A. ANDERSON, P. F. SMITH, and G. K. RASMUSSEN
1964. Recommended fertilizers and nutritional sprays for citrus. Fla. Agr. Exp. Sta. Bul. 536B:1–24.

REUTHER, W.
1959. A program for establishing and maintaining virus-free citrus stock. (J. M. Wallace, ed.) Citrus Virus Diseases, pp. 215–17. University of California, Div. Agr. Sci., Berkeley.

REUTHER, W., W. W. JONES, T. W. EMBLETON, and C. K. LABANAUSKAS
1962. Leaf analysis as a guide to orange nutrition. Better Crops with Plant Food (Plant Analysis, A Special Issue). 46(3):44–49.

SANDELL, E. B.
1950. Colorimetric Determination of Traces of Metals. 2nd ed. Vol. III. New York and London: Interscience Publishers, Inc.

SMITH, P. F.
1964. Effect of potassium level and substrate lime on growth, fruit quality, and nutritional status of Valencia orange trees. *In* Plant Analysis and Fertilizer Problems, pp. 332–43. (Bould, C., Prevot, P., and Magness, J. R. ed). Published by Amer. Soc. Hort. Sci. Printed by W. F. Hamphrey Press, Inc. Geneva, New York, U.S.A.

SPENCER, W. F.
1960. Effects of heavy applications of phosphate and lime on nutrient uptake, growth, freeze injury, and root distribution of grapefruit trees. Soil Sci. 89:311–18.

4*m*-11,'67 (H4007) V.L.
141

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.

The journal HILGARDIA is published at irregular intervals, in volumes of about 650 to 700 pages. The number of issues per volume varies.

Single copies of any issue may be obtained free, as long as the supply lasts; please request by volume and issue number from:

Agricultural Publications
University Hall
University of California
Berkeley, California 94720

The limit to nonresidents of California is 10 separate titles. The limit to California residents is 20 separate titles.

The journal will be sent regularly to libraries, schools, or institutions in one of the following ways:

1. In exchange for similar published material on research.
2. As a gift to qualified repository libraries only.
3. On a subscription basis—$7.50 a year paid in advance. All subscriptions will be started with the first number issued during a calendar year. Subscribers starting during any given year will be sent back numbers to the first of that year and will be billed for the ensuing year the following January. Make checks or money orders payable to The Regents of The University of California; send payment with order to Agricultural Publications at above address.