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EVALUATION OF COMMERCIAL POTTING MIXES FOR OPTIMIZING GROWTH OF CITRUS IN CONTAINERS

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Abstract. **Optimal plant growth is crucial in research experiments as well as in nursery operations. Two major factors that influence plant growth are soil mix and fertilizer. Use of commercial soil mixes would be desirable for smaller operations which often lack facilities for mixing and sterilization. Several commercial potting mixes were compared to the UC (University of California) mix for growing citrus plants in our greenhouses at the Citrus Research and Education Center in Lake Alfred, FL. The UC mix is part of the UC system that uses a peat moss based soil mix and fertigation for nutrient supply. Commercial mixes were compared against the original UC mix using the UC system. A fertilizer formulation was used that was previously adjusted for Ca content in the irrigation water. Plant growth and soil pH were measured, and plants were monitored for nutrient deficiencies. Two mixes were found to be comparable to the UC mix in terms of plant growth and lack of micronutrient deficiency. No commercial mixes were found to give better plant growth or fewer deficiency symptoms than the original UC mix. The choice of mix appeared to affect mostly the soil pH and development of deficiency symptoms.**

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Good plant growth and freedom from micronutrient deficiencies are crucial in greenhouse experiments in which differences among treatments are shown in plant growth and disease symptoms many times show as patterns on the leaves (Nauer et al., 1967b). Micronutrient deficiencies can mask or otherwise interfere with the development and observation of these symptoms. It is therefore very important to develop a system for optimal plant growth free of micronutrient deficiencies.

Also, in nursery operations, optimal plant growth is essential for maximization of productivity. Healthy plants without deficiencies will ensure optimal graft take, will sell at better prices, and will grow into more healthy and vigorous trees once they are planted in the field.

The University of California (UC) system for growing plants in containers was developed in the 1940s by the University of California to meet the need for more efficient production of ornamental plants in nurseries (Baker, 1957). The resulting system addressed the major issues found to limit nursery production: diseases, salinity, and toxicity. Answers were found in a system using a peat moss-based soil mixture that was easily replicated, fertigation and sanitary measures.

The first report on the use of the UC system for growing citrus in containers was by Nauer et al. (1967a). Problems with micronutrient deficiencies, especially copper, were encountered, as well as with the bulkiness of the fertilizer, and the precipitation of nutrients in the concentrated mixture (Nauer et al., 1967b). Higher pH values of the soil caused micronutrient deficiencies in the plants and the use of a high fraction of peat moss in the UC mix apparently caused a low availability of micronutrients due to binding to the peat, even at low pH.

Eventually these problems were solved by reducing the amount of peat moss in the mixture, and by formulating a liquid fertilizer that prevented precipitation of nutrients and maintained the pH of the soil at a favorable level (Nauer et al., 1967b). The UC system for growing citrus has been successfully used at the Rubidoux indexing facility of the University of California for over 40 years.

Due to the advantages of using the UC system for growing citrus in containers, namely nutrient availability, pH adjustment possibilities, soil mix uniformity, and disease prevention, it has been adopted successfully by several citrus research organizations throughout the world. Modifications have been made in each case to adjust the system to locally available ingredients for the potting and fertilizer mixes, and the water quality at hand.

In Moncada, Spain, optimal plant growth was obtained using a 2:1 mixture of peat and siliceous sand by volume, combined with an elaborate nutrient supply through the potting mix, a fertigation system and foliar applications (Ballester-Olmos, personal communication). At the Citrus Research Institute in Antalya, Turkey, a favorable soil pH of 6.0-6.7 was obtained in a high pH mix containing sand of calcareous origin (pH 8.2-9.1) and available water with a pH of 7.8, by using pH-reducing ingredients such as ammonium nitrate and potassium nitrate (Roistacher, personal communication). At the Citrus Research and Education Institute in Belize, excellent plant growth was obtained by using the system outlined by C.N. Roistacher (1991), and adding chelated micronutrients to the fertilizer mix. Extremely low pH values down to 3.5 were found in the soil after one year, and these were corrected by replacing ammonium nitrate by calcium nitrate in the fertilizer mix.

Because of the proven success of using the UC system for growing citrus in containers in other locations, an experiment was conducted at the Citrus Research and Education Center in Lake Alfred, Florida to establish a modified UC system adapted to local water quality and the lack of facilities and labor for the production of a custom mix. Commercially made mixes, including some of the commercial mixes currently used at CREC, were tested against the UC mix. Criteria for selecting commercial mixes included continuity in the availability and quality of the mix. Our objective was to obtain a commercially available potting mix containing peat moss that was best suited for optimal plant growth without causing micronutrient deficiencies using our current greenhouse fertilizer formulation.

Materials and Methods

Nine commercial mixes were compared against the UC mix described by Roistacher (1991). The choice of commercial mixes tested was based on their aeration and drainage characteristics as provided by the manufacturer (also see Table 1). The mixes tested were: Fafard 2, Fafard 2P, Fafard 3, Fafard 3B, Fafard 4, Fafard 4P, Fafard Citrus Mix (Fafard, Agawam, Massachusetts), Promix BX (Premier, Dorval, Quebec, Canada), Metromix 500 (Scotts, Marysville, Ohio), and the UC mix.

Thirty Duncan grapefruit (*Citrus paradisi* Macf.) seeds were planted in each mix, with 15 seeds in each of two 4-liter containers. Seed germination was recorded after one month, and 12 seedlings from each soil mix were transplanted individually into 2.5-liter pots containing the same soil mix in which they germinated. Grapefruit was chosen for this experiment because of its sensitivity to micronutrient deficiencies when grown as seedlings for biological indexing. The plants were placed in a production greenhouse with limited air temperature control: evaporative cooling to prevent temperatures over 38°C and heating to prevent temperatures below 15°C.

A Dosmatic (Dosmatic, Carrollton, Texas) injector (1/100 fertilizer/water) was used to fertigate the plants with every watering. The liquid fertilizer consisted of a solution of ammonium nitrate (39.1 g/liter) and potassium nitrate (12.0 g/liter) following the UC-system as described by Nauer et al. (1967b) and Roistacher (1991). Calcium nitrate was omitted from the fertilizer, because of the comparable content of Ca in the irrigation water. Potassium phosphate (1.5 g/liter) was added to this solution to provide necessary P, and Microplex (Miller Fertilizer and Chemical Company, Hanover, Pa., 4.25 g/liter) to provide micronutrients. Microplex contains Mg (5.43%), B (0.5%), Co (0.05%), Cu (1.5%), Fe (4.0%), Mn (4.0%), Mo (0.1%) and Zn (1.5%) in chelated form.

Table 1. Composition of the commercial mixes and the UC mix.[z]

	UC	Fafard 2	Fafard 2P	Fafard 3	Fafard 3B	Fafard 4	Fafard 4P	Fafard CM	Promix BX	Metro Mix 500
Initial soil pH	5.6	6.9	6.2	7.0	6.6	6.8	6.7	6.4	5.7	5.0
Peat moss (%)	50	70	60	32	45	40	30	50	75-85	12-22
Perlite (%)	—	20	40	8	10	-	10	40	+	—
Vermiculite (%)	—	10	—	20	14	30	30	10	+	20-35
Bark (%)	—	—	—	40	31	30	30	—	—	40-50
Fine sand (%)	50	—	—	—	—	—	—	—	—	—
Wetting agent	—	+	+	+	+	+	+	+	+	n/a
Nutrients	+	+	+	+	+	+	+	+	+	+

[z]The pH of all mixes was measured at the beginning of the experiment, using the local tap water. All other data for the commercial mixes were obtained from the manufacturer. Type and composition of nutrients and wetting agents in the commercial mixes are not specified by the manufacturer. Nutrients in the UC mix are given in Roistacher (1991).

Plants were trained to a single shoot. Plant height was measured five months after planting. The pH of the drainage water was measured as described by Roistacher (1991) to obtain soil pH after five months. Initial soil pH was measured in the same fashion from one sample of each mix. Also, the pH of the irrigation water was measured. Micronutrient deficiency symptoms were evaluated at five months after planting using the following rating system: 0 for dark green healthy leaves; 1 for slightly chlorotic leaves without visible patterns; 2 for leaves with slight deficiency patterns, but with all parts green; 3 for leaves with clear deficiency patterns including chlorotic areas; 4 for leaves with clear patterns and visible growth reduction.

The experiment was set up and analyzed as fully randomized (Lauckner and Fielding, 1991). Duncan's multiple range test with a confidence level of 0.95 was used to differentiate treatments using soil pH, plant length and deficiency ratings.

Results

Germination, plant growth, soil pH, and deficiency symptom data are given in Table 2. Data for germination were not analyzed statistically, because of the small number of experimental units (2) in the germination period. The pH of the irrigation water was 7.0.

Fafard 4, 4P, 2P, Citrus Mix, and Promix BX gave similar or higher germination rates as compared to the UC mix. Germination rates in Fafard 2, 3, and 3B were considerably lower than that of the UC mix. Significantly higher plant growth as compared to that in the UC mix was not found in any of the commercial mixes. Significantly lower plant growth was only found using Fafard 3B. Soil pH of most commercial mixes was higher than that of the UC mix, and only Metromix 500 had a significantly lower soil pH. The UC mix, as well as Promix BX, Metromix 500 and Fafard 3B had soil pH within the range for optimal citrus growth. Deficiency symptoms were found using all mixes but Metromix 500. However, the UC mix and Fafard 4 did not differ significantly from Metromix 500 in deficiency symptom ratings.

Discussion

Compared to the UC mix, none of the commercial potting mixes gave higher plant growth. Only Fafard 3B gave a significantly lower growth than the UC mix. However, average deficiency symptoms were significantly more severe than those when using the UC mix, except for Fafard 4 and Metromix 500. This indicates that the soil mix does not affect plant growth as much in terms of plant length, but more the development of micronutrient deficiencies.

Micronutrient availability is influenced considerably by soil pH (Baker, 1957), a higher pH decreasing the micronutrient availability to plants. For citrus, a soil pH within the range of 5.5 to 6.5 is preferred, with better micronutrient availability at the lower side of the range (Roistacher, pers. comm.). This trend was also found in this experiment. However, plants grown in Fafard 4 had very few deficiency symptoms even with a final average pH of 6.6, indicating that soil factors other than pH also affect micronutrient availability.

In previous experiments, using the original UC-fertilizer formulation, soil pH tended to increase steadily and level off at pH 7 in different commercial mixes. This was caused by the excess calcium supplied by the fertilizer and irrigation water. Since the supply of calcium by the original formulation of the UC fertilizer is 64.7 ppm, calcium was omitted from the fertilizer mix. This new formulation was used in this experiment and no signs of calcium deficiency were observed in the plants.

In our experience, when evaluating soil mixes it is important to consider the interaction between mix and fertilizer formulation and their effect on the soil pH. This experiment has shown that Fafard 4 and Metromix 500 were the most comparable with the UC mix, but only with the fertilizer composition used in this experiment, which was adapted to the local water quality. It can be expected that pH and nutrient availability change when using a different fertilizer mix. The quality of the irrigation water also plays an important role. In our case, for example, calcium was found to be present in sufficient amounts in the irrigation water. Therefore, there is no guarantee that these two mixes will perform as well in other locations, and evaluation of different mixes is suggested before adaptation elsewhere.

Soil pH can be adjusted over time by changing the composition of the fertilizer used. Nauer et al. (1968b) compared the effect of two fertilizer compositions on the pH of the soil, and found that fertigation with calcium nitrate (599 ppm), magnesium sulfate (240 ppm) and potassium sulfate (150 ppm) increased the soil pH from 5.9 to 7.8 in 11 months, while a fertigation with ammonium nitrate (599 ppm), potassium chloride (560 ppm) and ammonium phosphate (120 ppm) decreased the pH from 5.9 to 4.4 in the same period of

Table 2. Germination, growth, nutrient deficiency and soil pH of 'Duncan' grapefruit planted in commercial potting mixes.[z]

	Germination[y] (%)	Soil pH[x]	Plant ht.[x] (cm)	Deficiency symptoms[x,w]
UC mix	50	5.4 e	47.1 abc	0.6 b
Fafard 2	30	7.1 a	42.8 bc	1.5 a
Fafard 2P	57	7.2 a	44.9 abc	2.1 a
Fafard 3	30	6.7 b	48.0 abc	1.8 a
Fafard 3B	33	6.5 c	30.2 d	1.6 a
Fafard 4	63	6.6 c	46.9 abc	0.7 b
Fafard 4P	53	6.8 b	52.2 a	1.6 a
Fafard Citrus Mix	53	7.1 a	51.0 ab	1.8 a
Promix BX	63	5.9 d	51.0 ab	1.6 a
Metromix 500	47	5.1 f	41.0 c	0.0 b

[z]Mean separation within columns by Duncan's multiple range test, 5% level.
[y]One month after planting.
[x]Five months after planting.
[w]0 = healthy plants; 4 = leaf deficiency symptoms and reduced growth.

time. This change of pH was due to the presence of pH-increasing (calcium nitrate) and decreasing (ammonium nitrate, ammonium phosphate) ingredients in the fertilizer mixes (Hanan, 1998). The effect of the fertilizer composition on soil pH can only be seen on a long term basis and constant monitoring of the soil pH is therefore crucial when plants are grown for extended periods of time.

Fafard 4 and Metromix 500 would be acceptable alternatives to the UC mix, with the use of Fafard 4 resulting in a higher germination rate, and with the use of Metromix 500 giving a more favorable pH and, although not statistically different, causing no micronutrient deficiencies in the plants.

Seedling growth was compared with that obtained at the Rubidoux indexing facility in Riverside, California (Roistacher, 1991). Growth of grapefruit in our greenhouse using the UC mix was 2.17 cm/week, compared to 2.5 cm/week in California. However, instead of measuring plant growth as the time needed to reach 1 m, plant height was measured as height reached after five months. We expect that the growth in our greenhouses will compare to that in California when measuring growth in the same fashion.

In our experiment we have compared only a small fraction of all commercially available potting mixes. Fafard 4 and Metromix 500 have been found to be most comparable to the UC mix and superior to the other tested mixes, based on seed germination, plant growth, soil pH and the absence of micronutrient deficiencies. Plant growth data did not reveal any correlation with the soil characteristics given in Table 1. Perhaps there are interactions between ingredients, but a more probable explanation would be that soil mix manufacturers only reveal limited information on their mixes, and do not provide information on the composition of initial fertilizers, pH-regulating components, or types of wetting agents used. It is therefore more difficult to predict or explain soil mix performance using commercial mixes based on information provided by manufacturers. For example, the mix produced specifically for citrus by Fafard (Citrus Mix) was not the best performing mix in our experiment. This can be avoided when using a self-made mix where all ingredients are known, like the UC mix.

It is advisable to test more mixes against these two for further optimization of the system, and for comparison of different uses (germination, seedling growth, different plant species).

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DIVERSITY OF FROST PROTECTION METHODOLOGY

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Abstract. **Diversity of frost protection methodology is broad when viewed over a long period. Heating methodology is especially diverse. A rule is apparent: growers used readily available materials. Prunings were burned during frosts at the height of the Roman Empire. A broad spectrum of heater types began to appear in more recent centuries. Wood, charcoal, oil, gas, and other fuels were burned in heaters so diverse in design that one's imagination is staggered. Development in design and management continues in some areas of the world in contrast with local opinions that such methods are of only historical interest. Wind machines of various shapes and sizes began to appear in the early part of the 20th Century in response to concerns about air pollution and labor availability. These solutions include the helicopter. Orchard covers, later row and individual plant covers were tried and found effective. Irrigation, the current choice in citrus, was in use in the form of flooding during the earliest days of the past century. Smudges, fogs, steam, heated irrigation, and windbreaks have been tried and in most cases, used effectively. The probability that a freeze will occur in a particular year is low. Authors have published extensive explanations and models. They have advised use of alarms, forecasts, site selection, satellite images, and networking in conjunction with a recommendation to limit attention to the method du jour. Most authors implied the field of work was mature and additional change seemed unlikely. In a longer view change, at times rapid, is an apparent characteristic of the field. Diversity of methodology and grower ingenuity suggests that change will characterize the future as it has the past. Diversity abounds.**

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This is a philosophical summary aimed at the grower, production manager, and especially the consultant. It is too easy to ignore the possibility of a freeze during a warm series of years, and to forget the rich diversity of methods available for frost control when a single method, sprinkler irrigation, is so widely used.