seem to help. At higher concentrations we get tissue damage but again with no improvement in rooting.

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MODERATOR TEAGUE: Thank you. Ted. Next we will hear from Mr. Paul Moore, University of California, Riverside, who will continue the discussion on citrus propagation. Paul:

PROPAGATION AND GROWING CITRUS NURSERY TREES IN CONTAINERS

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The field propagation of citrus nursery trees is an old practice. Successful nursery techniques are well established and reasonably standardized throughout the citrus producing areas of the world. Until recent years, citrus nurserymen have shown but little interest in growing their trees in containers. Orchardists have been equally hesitant about planting container-grown stock. However, within the last decade, certain developments related to nursery tree certification, land and labor availability, automation, and transportation costs have generated a new interest in container-growing systems for citrus.

For many years, the University of California, Citrus Research Center, has been growing trees in containers for research purposes. Thousands of such trees have been planted in our orchards and have performed as well as field-grown nursery trees. The consequence of our favorable experiences was a decision to discontinue our field nurseries in favor of container growing. Some of the advantages which led us to this decision are listed below:

Advantages:

1. *Standardized soils*

   Soil mixes can be standardized for physical and nutrient characteristics. Flexibility in selecting mixes tailored for specific needs is also possible.

2. *Pest-free soils*

   Steam sterilization or pasturization guarantees freedom from soil-borne diseases, pests and weeds.

3. *Fertility control*
   Frequent applications of dilute fertilizer solutions through the irrigation system and ease of manipulating fertilizer amounts and ratios bring about optimum growth.
4. *Lower space (land) requirements*
   A space requirement of one square foot per tree, including working aisles between beds, is satisfactory compared to three or four square feet per tree in field growing.
5. *Shorter growing cycles*
   By using plastic greenhouses, growth rates are increased and the effective annual growing season is prolonged. Budded trees ready for planting to orchard locations can be grown in 14 to 18 months from seed planting. Two to three years are required for field growing.
6. *Lower frost protection costs*
   The high concentration of trees under plastic permits automated temperature control at lower labor and fuel costs per unit area than are required under field conditions.
7. *Permanent growing site*
   Container-growing permits the use of a permanent location and eliminates the usual practice of moving to new ground for each successive nursery.
8. *Potential automation*
   Proper system design can automate irrigation and temperature control.
9. *Salinity control*
   Under a combination of field conditions, including the use of irrigation waters containing from 250 ppm or more of dissolved salts applied in furrows between the nursery rows, injurious saline conditions may develop. The use of well-drained soil mixes and irrigation practices, which include adequate leaching, eliminate this hazard in container-growing systems.
10. *No setback when transplanting to field.*
    Balled trees experience a temporary setback when moved from the nursery to the orchard. The growth of container trees is uninterrupted by transplanting. Although the younger container grown nursery trees are usually of smaller caliper when planted in the orchard, after one season in the field, they frequently make up the size difference because no recovery period is required.

Special precautions

Container-growing is not free of problems and certain hazards must be recognized, anticipated, and preventive measures taken to avoid them. Some of the problems which have been experienced are (1) correct pH control, (2) micronutrient deficiencies, (3) rootbinding, (4) salinity, and (5) root diseases.

The first three problems are associated with the limited volume of soil used in conveniently sized containers. Salinity is associated with poor irrigation or fertilization practices, and root diseases with inadequate sanitation control.

1. *pH control*

   The optimum pH range for citrus lies between 5.5 6.5. pH values above 7.0 adversely affect micronutrient uptake. Poor growth occurs in soil with values below 4.5. Approximate pH of the soil solution can be determined by periodically collecting and testing the leachate that runs out of the drainage holes of the container. Soil pH can be regulated by varying the ratio of calcium nitrate and ammonium nitrate in the liquid feed program. Calcium nitrate will increase pH and ammonium nitrate will lower it. A liquid feed program will be discussed later under the caption "Liquid Feeding".

2. *Micronutrient deficiencies*

   Micronutrient deficiencies can be prevented by additions of appropriate amounts of micronutrients to the soil mix and by controlling pH within the desirable range discussed above. Amounts used in our mixes will be discussed under "Soil Mixes".

3. *Rootbinding*

   Rootbinding resulting from holding trees in containers too long is a distinct hazard. We have experimented with several can sizes and have standardized on a nominal "2 gallon" (actual capacity about 1.4 gallons) container, 8½" in diameter and 8½" deep. Citrus can be grown in these for as long as one year without root binding. After one year, the trees should be planted into the field or re-potted into larger containers.

4. *Salinity control*

   Dissolved salts from fertilizer or saline irrigation water sources must be kept within the tolerance range for citrus. One way to achieve this is to pursue a liquid feed program which applies dilute fertilizer solutions frequently in sufficient amounts of irrigation water to cause some leaching with every watering. We periodically run conductivity tests on the leachate collected for pH determinations and aim to maintain the soil solution below 3 millimoles/cm.

5. *Disease prevention*

   Steam sterilization is the first line of defense against soil-borne diseases and pests but carelessness in sanitation control may allow the reintroduction of disease organisms. Frequently, introduced pathogens will cause more extensive damage in sterilized soils than they would in non-sterilized soils. Strict measures should be followed to prevent contamination of tools, hoses, soil, and growing premises.

One system of container growing

It is recognized that there are many successful variations that can be used to grow quality citrus nursery stock. The system described herein is one that has been used with satisfactory results by our nursery for the past two years. The soil mix selected is one used successfully for several years by a group performing virus indexing, a program demanding vigorous plant growth free from micronutrient or other leaf patterns that would interfere with the reading of virus symptoms. The liquid feed program was also proven by the virus indexing group.

Soil Mix

The soil mix described below combines good physical characteristics, with good internal drainage, good soil moisture retention and moisture release characteristics, and adequate starting levels of nutrients.

The initial addition of phosphorous as single super-phosphate, calcium as calcium carbonate lime, and magnesium as dolomite lime appears to provide satisfactory amounts of these elements for at least one year. Nitrogen and potassium are provided in the original mix and supplemented by the liquid feed. Micronutrients are provided in the original mix.

Dry Mix

The following materials are mixed dry in a cement mixer for two or three minutes.

Materials	*Amount per cubic yard*
Canadian peat moss	10 cu. ft.
Fine sand	10 cu. ft.
Redwood shavings	7 cu. ft.
Single super-phosphate	2½ lbs.
Calcium carbonate lime	1¼ lbs.

To the dry mix, add the following ingredients in sufficient water (15 - 25 gal.) to insure good distribution of the nutrients through the soil but not enough to cause drainage of free water from the mix. Agitate the mixture sufficiently to keep the dolomite in uniform suspension.

Materials	*Amount per cubic yard*
Potassium nitrate	4 oz.
Potassium sulfate	4 oz.
Dolomite lime	3¾ lbs.
Micronutrients (see below)	1 gal. stock solution

Micronutrient stock solution

Materials	Amount/gal distilled water	Appx. ppm in soil (dry basis)
Copper sulfate	1.9 oz.	25 Cu
Zinc sulfate	0.8 oz.	10 Zn
Manganese sulfate	0.6 oz.	10 Mn
Ferrous sulfate	2.2 oz.	25 Fe

Liquid feed

Several variations of liquid feed formulas could give satisfactory results. Only two are suggested below:

Liquid feed A

Material	Amounts per 100 gal. water *applied*
Calcium nitrate	4 oz.
Ammonium nitrate	4 oz.
Magnesium sulfate	4 oz.
Potassium nitrate	1⅓ oz.

Liquid feed B

Material	Amounts per 100 gal. water *applied*
Ammonium nitrate	8 oz.
Potassium chloride	3¼ oz.

Calcium nitrate may be substituted for part or all of the ammonium nitrate for pH control purposes. Since calcium nitrate contains approximately 16% nitrogen and ammonium nitrate 33%, twice as much calcium nitrate should be substituted for each unit of ammonium nitrate.

Note that the amounts are per 100 gallons *applied.* If proportioners are used, proper ratios of concentrate to applied amounts should be calculated.

pH control can be obtained by varying the ratio of calcium nitrate to ammonium nitrate. Calcium nitrate will tend to raise and ammonium nitrate to lower pH values.

Typical propagation sequence

Compared to field growing, one advantage of the container system which also utilizes plastic growing structures is the great flexibility one has in performing the sequential operations such as seed planting, budding and forcing. One can perform any of these at almost any time of the year. The preferred cycle in areas climatically similar to Riverside, California is:

1. Sow seed in seedbeds containing the soil mix described above in March or April. Seed should be spaced to allow about three to four square inches per seed.

2. Transplant seedlings into 2-gallon containers from July to September. We have standardized on a tapered, flexible pot. These pots nest and require relatively little storage space. They also have a smooth, non-corrosive wall and the plants can easily be removed at planting time by inverting the pot and tapping the rim. They can be steam sterilized and appear to be reusable for at least three growing cycles, thereby reducing the container costs per tree.

3. The more vigorous, commonly used rootstock varieties such as Troyer citrange, Carrizo citrange, Rough lemon, *Citrus macrophylla,* and sweet orange are ready for potting first. They will be ready to bud as early as September but can be held until the following March when it is easier to force buds. In a warm plastic house, September buds can be forced to produce plantable trees by June or July of the second growing season. March budding will give plantable lemons, grapefruit, or oranges by July or August but normal planting schedules dictate orchard planting the following spring.

The cycle is longer when the dwarfing stock, *Poncirus trifoliata,* the trifoliate orange, is used. The above sequence is followed through transplanting but budding is best performed in the spring after the seedlings start their spring growth. Scions grow more slowly on trifoliate stocks and will require a full year to 15 months after budding to attain planting size.

Budding and grafting techniques

Our budding techniques are similar to those used in field propagation but some modifications have been made to accommodate smaller stock seedlings. Field grown rootstock seedlings may be 18 to 24 months old at budding time and will have attained a caliper of ¼″ to ⅜″.

Under our container-growing sequence, rootstocks are transplanted when they are four to five months old. The vigorous growing varieties may be budded as young as six months. In nearly all cases, they will have been budded before they are one year old. Caliper will range from ⅛″ to ¼″. For these smaller stocks, we prefer a veneer or chip bud over the conventional shield bud.

We have also used the "microbud" technique which was probably first used by Ian Tolley of Renmark, South Australia. Microbudding uses only the small bud, seldom more than 3/16″ long, without any surrounding wood or bark tissue. It is inserted beneath the stock bark into an inverted "T" cut. The advantage of microbudding is that very small stocks or very small budwood can be utilized when either situation must be met. Polyethylene tape is used to wrap the buds and is removed after they have healed in.

Tip grafting may be used under greenhouse conditions. One of the larger lemon plantings at the University's South Coast Field Station was propagated in this manner.

Buds are forced into growth by either of two methods of lopping. (1) cutting off the rootstock seedling above the bud or (2) bending the seedling back upon itself and tying into position like an inverted "U" with the upper bend a few inches above the bud. The first method is performed after the bud has healed in The second may be done immediately following budding or after the bud has healed in. In the second method, the portion of the lopped seedling which remains above the bud is left until the bud has grown to a height of 28″ to 30″ and then removed by a clean, smooth cut.

When the buds have reached a height of 30″ to 36″, they are tipped at about 28″ to induce lateral shoots or "head" development.

Orchard performance

Certain prejudices against container-grown citrus trees are held by growers. Their greatest concern is about root-binding and its effects on future root development and fruit production. Properly handled, that is held no longer than one year in 2-gallon pots or moved up to egg cans or 5's if longer holding periods become necessary, the trees will develop normally and be equivalent to those from field-grown, balled nursery stock. We have planted several thousand trees grown in No. 10 cans, full gallon cans, egg cans, and 5's. All have grown normally. Some have been dug up two, three and five years after planting and found to have root systems comparable to those grown from balled nursery trees.

Anticipated changes

We have an experiment in progress which compares the early orchard performance of nursery trees grown in three container sizes, No. 10 cans, 2-gallon pots, and 4-gallon egg cans. Three soil types, fine sand, UC soil mix "H", and a local Ramona sandy loam, were used in each of the three can sizes. Although the experiment is still in progress, three trends have been observed:

1. The larger container sizes required less frequent irrigation and thus would have lower maintenance labor costs where hand watering is performed.

2. The trees from the 4-gallon containers had more extensive root systems at planting time and have developed more extensive root systems in the orchard site during the first three months following planting. There are still no apparent size differences between tops. As yet there are no consistent differences in top growth due to container size or soil mix.

3. For the first two months after transplanting to the orchard, trees in the local Ramona soil, which is similar to the orchard soil, dried less rapidly and required less frequent ir-

rigation than trees grown in either the sand or soil mix.

These very limited results suggest that further studies should be undertaken to obtain more precise data on the interrelationships between container sizes, container soil-orchard soil interactions, and the first year's performance of trees in the orchard.

MODERATOR TEAGUE: Thanks for a very interesting discussion, Paul. Now, are there any questions?

VOICE: Paul, would you comment further about these microbuds? You say you have to force them out real fast.

PAUL MOORE: Yes, they are so small that the callus around the cut will bury them if they're not forced into growth rapidly. One way of doing this is to actually lop the seedling at the same time you bud. That is, insert the bud and lop it at that time. The bud will heal and will force a little more rapidly than if you allowed, say three weeks for it to heal, and then lop it.

BRUCE BRIGGS: Did you try to use any liquid hormones sprayed on the avocado leaves to help stimulate root formation up the stem?

CRAWFORD TEAGUE: We've never used any hormones in avocado propagation at all; they seem to be useless on avocados.

VOICE: Have you had any success in rooting kumquats and other difficult citrus?

TED FROLICH: We have worked with kumquats some; we find that, unlike other citrus, we have to cut the tree back hard to get very rank thorny, angled shoots; we can root such wood but when we get it rooted we still don't get a very good plant — not nearly as good a plant as if you bud it on another rootstock. Kumquats are rather poor on their own roots. We would recommend against it.

CRAWFORD TEAGUE: We've budded kumquats on Troyer citrange and Trifoliate orange; they make very fine trees.

GENE BACIU: What varieties of citrus seeds produces the fastest growing seedling in the nursery?

PAUL MOORE: Usually the acid types of citrus, such as Rough Lemon or *Citrus macrophylla,* grow very rapidly. Also some stocks, such as Troyer and Carrizo citrange produce very good trees in contrast to the more dwarfing stocks like Trifoliate orange. The most rapid growing would be Rough Lemon, *Citrus macrophylla,* and Rangpur lime — very vigorous rootstocks. The Rangpur lime is very subject to brown rot gummosis, so is not a preferred stock. Rough Lemon is resistant to gummosis and is commonly used in the ornamental trade because of its rapid growth. Troyer citrange is resistant to these root disorders and is also a vigorous rootstock, imparting a couple degrees of frost resistance to the tree and produces good quality fruit, too.

VOICE: Are commercial citrus growers reluctant to use nursery trees grown in containers?

PAUL MOORE: Yes, there is a reluctance; I think it stems from the feeling that anything grown in a container is apt to be pot-bound and will not give good performance. This is one reason why I spent a little time with the slides showing that normal root systems can develop from container-grown trees; when moved out properly I don't believe the commercial grower has anything to fear from this. We might design a better shaped pot. I think the ideal container would be two pots deep and one pot in diameter. This would give something that is similar to the size of a balled and burlapped commercial tree, and in fact I could have shown you some pictures of trees that were grown in a double egg can, one on top of the other, with excellent root development — no twisting roots — that would be every bit as good as from a field-grown nursery tree. Maybe before the prejudice is overcome, however, the commercial citrus nurseryman may have to go to a pot that is, conceivably, a better shaped pot in the mind of the orchardist.

CRAWFORD TEAGUE: I might point out that we're growing quite a few thousand container-grown trees, and we're also putting them out in our own groves. If we're not afraid to use them, and if we can show good trees in the field after several years, perhaps most of our customers will go along with this procedure — but they're very reluctant to change.

RON HUROV: What are the problems associated with growth of avocado cuttings once they're rooted?

TED FROLICH: They just seem to be tempermental for about a year or two. If any thing happens to defoliate them, the plants will die. On the other hand, if you have a seedling, you could pick all the leaves off it but it will just grow new leaves and every thing will be fine; an avocado cutting in its early stages — for a year or two — is a very tempermental thing. If we cut them back to graft them, we very often lose them. Once they get up to a certain point, they grow just as well as seedlings; we don't know basically what the trouble is.