Citrus Nursery Operations

D. A. Newcomb

Summary

Nursery practices for any particular operation need to be adapted to the soil, climate, and water supply of the location. The rootstock and scions being grown may have an influence on the procedures that will be most efficient and produce the best trees. There are, however, certain over-riding basic criteria that need to be taken into consideration in every citrus nursery. These taken in retrospect are quite obvious but since some of them are occasionally overlooked they are briefly summarized below.

1. A well-drained soil, preferably of light-medium to medium texture, protected from flooding and excessive wind. It should be free of citrus-attacking *Phytophthora* and injurious nematodes. If this condition cannot be met the soil should be fumigated.

2. An adequate supply of irrigation water free from excessive salinity or toxic elements. It also should not be contaminated by *Phytophthora* or nematodes which might attack citrus. If well water is not available it may be desirable to chlorinate ditch or lake water. Surface water in a citrus area is often subject to contamination by *Phytophthora* or nematodes that are damaging to citrus.

3. Carefully selected seed from true-to-type trees free from psorosis virus. The seed should be properly heat-treated to eliminate the possibility of infecting the seedbeds with *Phytophthora.*

4. Budwood from sources selected for trueness-to-type with demonstrated fruit quality and productivity. Bud source trees should be indexed to determine freedom from known viruses or bud transmissible diseases.

5. Careful drastic culling and grading of the seedbed-stock at the time of transplanting from the seedbed to the nursery row. The acceptable seedlings should be graded into 2 or 3 sizes and be planted in separate rows in order to obtain uniform growth in the nursery. It is only with uniform input that a uniform product can be achieved.

6. To me the most important idea to follow for a successful citrus nursery is to forget about relating expense to the cost of the whole operation, but carefully consider the cost of each operation in relation to the quality of the finished tree. In our experience the best tree that can be grown is the cheapest to produce.

Introduction

The production of citrus nursery stock is a business and as such it must be profitable. The goal of a successful operation should be to produce the best possible product at the lowest possible cost. Since this may imply a conflict between quality and cost, many businesses settle for lower quality to decrease cost, and in fact may have to make this compromise to meet competition.

A citrus nursery is different in this respect. There have been many dismal failures when expense was cut, with the result that not only the quality of the trees suffered, but at the same time, the percentage yield of salable trees dropped so low that the net cost of producing a tree exceeded the market value. It has been our experience that if tree quality is emphasized regardless of cost, the resulting rapid growth and high yields of top quality trees will actually reduce the cost per tree.

It is desirable that all the trees in a row reach each stage of growth at the same time so that all the trees will be ready to receive each step of care at the same time. More labor will usually be spent on a backward tree than one that grows normally. In addition to costing more, such a tree may end up as a discard or second-grade tree.

The cost of producing citrus nursery stock in California has increased only slightly during the past 20 years in spite of a four-fold increase in the hourly cost of labor and other substantial cost increases. It was possible to avoid an increase in cost by development of new methods which not only reduced labor but produced better trees.

Nursery Operations

The procedures for producing a citrus nursery tree discussed here are related to 2 main objectives. The first is improvement of nursery sanitation which is related to plant quality and eventual success of the orchard. The second covers some methods of improving both the plant growth and the efficiency of the nursery operation. Both factors are related to achieving a high yield of healthy, vigorous, uniform plants that require a minimum of attention in the nursery.

Phytophthora species that attack citrus roots are a world-wide problem and every possible precaution should be taken to keep them out of the nursery. Most citrus orchards sooner or later become infected, but orchards planted with trees free of *Phytophthora* make better growth and have higher production for many years when compared with orchards planted with *Phytophthora*-infected trees (19).

It is difficult to collect citrus seed fruit and to extract seed in volume without introducing *Phytophthora*. For this reason, all seed produced by Willits & Newcomb is treated by immersion in a hot water bath at 125°F for 10 minutes (10). Heat-treated seed will produce healthy plants free from *Phytophthora* and other damping-off fungi when planted in clean soil (9).

Efforts to produce *Phytophthora*-free seed would be wasted unless the soil in the seedbeds is also free from *Phytophthora* and can be kept so. In the past, virgin land free from *Phytophthora* and citrus nematodes has generally been available for nurseries, but now it is often necessary to use land that has been exposed to contamination from previous citrus plantings or from nearby citrus. California regulations for growing certified citrus nursery stock call for soil fumigation with a minimum of 300 pounds of methyl bromide per acre, immediately covered with 1 mil thick polyethylene tarp (24). The methyl bromide may be supplemented with 150 pounds of chloropicrin to improve the kill of *Phytophthora*. This treatment is effective for eliminating nematodes, *Phytophthora* and weed seed.

Willits & Newcomb uses rigid precautions to prevent reintroduction of *Phytophthora* into the nursery after fumigation. The nursery is completely fenced and the gate is kept locked when no work is in progress. Workmen entering the nursery change into clean shoes which are kept in lockers at the entrance. They treat their shoes with Bordeaux powder at frequent intervals. Tools are sterilized and many other procedures are followed to reduce the hazard of contamination. When reservoirs are used for irrigation water they are treated each month with copper sulfate (11). Birds are always possible carriers of *Phytophthora* but unfortunately the cost of screening for birds is prohibitive.

Production of uniform seedbed-stock starts with the correct spacing of the seed in the beds. If the seedlings are crowded, the first to germinate will shade the later ones, causing them to be retarded. Willits & Newcomb have had best results with about 24 seed per square foot for the larger-leafed types of rootstocks such as sour orange and rough lemon. The smaller-leafed types such as 'Carrizo' and 'Troyer' citrange and 'Cleopatra' mandarin do well with 36 seed per square foot. The seed should be spaced evenly.

Often the solution of one problem leads to other problems. Seedbeds planted in fumigated soil often fail to grow normally. The seeds germinate and grow uniformly for a time but soon some areas become retarded or completely stop growing. In other parts of the beds the growth is normal. For many years this was an unsolved problem, but we now know that the seedlings which grow well have endogone mycorrhiza on the roots, while the plants that grow poorly do not, as shown by recent work by Kleinschmidt and Gerdemann at the University of Illinois (8). Apparently the fumigation dosage specified for control of nematodes and *Phytophthora* is not high enough to completely kill the mycorrhiza leaving spots where it survives. Dr. Martin at the University of California at Riverside had previously shown that the seedlings with retarded growth were failing to pick up phosphorous from the soil, and that growth could be improved by making heavy applications of phosphate fertilizers to the soil prior to planting (12, 13, 14, 15). This was effective with certain varieties, including rough lemon, *C. macrophylla*, trifoliate and trifoliate hybrids. Other varieties, such as 'Cleopatra' mandarin, sour orange and sweet orange, made only a partial response. The growth of these varieties on fumigated soil was still depressed 25% to 50% of normal in affected areas as compared with spots where growth was normal. The plants that were depressed started to grow normally after the soil around them was inoculated with mycorrhiza. In one trial, cultures of mycorrhiza of the endogone species supplied by Dr. Gerdemann of the University of Illinois were used. In other trials soil containing citrus roots from the spots in the nursery where the plants were growing normally and where the examination had shown the presence of mycorrhiza on the roots was mixed into the top 2 inches of soil near the affected plants. Studies are now under way to learn the best method of inoculating seedbeds with mycorrhiza in order to avoid the problem of depressed growth following fumigation. Both treatments were successful. It is interesting that in sterile plant mixes which contain a low percentage of clay, plants may grow well without mycorrhiza when irrigated with nutrient solution.

Several techniques have been developed to improve the growth of the plants. One method has been to extend the season for the growth of the seedlings in the seedbeds. Under California conditions seed planted in unheated beds does not begin to germinate until the soil warms up in April. The growth period ends about the first of November when the soil becomes cool. This leaves about 7 months of growing weather. This period can be extended at least 1 month by planting the seed in late January and covering the beds with polyethylene. The daytime soil temperature can be raised from a normal of around 50°F the first of February to from 60 - 65°F. On the first of March the daytime temperature of exposed soil will be from 60 - 63°F. Under the polyethylene it will be from 70 - 75°F. In April the normal soil temperature will be in the 65 - 75° range and it will be necessary to cut holes in the polyethylene to start ventilation and hardening of the plants to avoid injury from heat on warm days. As soon as soil temperatures reach 90 - 95°F the polyethylene should be completely removed. The additional growing time obtained in this way may produce seedlings as much as 25% larger at the end of the growing season than those without protection. This extra size is highly desirable in order to give the seedlings a good start when they are transplanted and to have vigorous seedlings when they are ready to bud.

Under desert conditions some protection from wind and sun is desirable while the seedlings are young. One-quarter inch mesh wire cloth is ideal for this purpose. It is placed over the beds which are planted in the bottom of wide, flat-bottom furrows. Willits & Newcomb have standardized on furrows that are 3 feet wide and 6 inches deep. The wire cloth is supported by 1" x 3" strips of wood placed across the beds at 4 foot intervals. The polyethylene mentioned earlier is laid over the wire and glued at each strip of wood. After the polyethylene is removed and as the seedlings grow the wire is elevated by placing 2" x 4" blocks of wood under the ends of the strips. When the seedlings begin to touch the wire it is removed, usually in June, and the seedlings complete their growth in full sun. Seedlings grown in full sun have smaller, thicker leaves and heavier stems than those grown in semi-shade. They survive and grow well when transplanted.

In California it is the custom to transplant seedbed-stock in the spring 1 year after planting the seed. Our practice is to prune the seedlings to a height of 14 inches 1 week before digging. This initiates the sprouting of the buds and conditions the plants for transplanting. The plant roots are undercut with a knife and as the seedlings are removed from the soil they are graded. Any seedlings less than 14 inches in height are discarded along with any crooked or weak plants, and the rest are graded into 2 sizes - regular and large. Size grading before transplanting is the basis for a uniform nursery, with the advantage that every tree in the row can be treated the same. This is a crucial operation for a successful nursery.

Transplanting the seedlings from the seedbeds to the nursery row is another critical operation. Some varieties such as 'Troyer' and 'Carrizo' citrange, trifoliate, and sour orange tolerate transplanting well, while rough lemon, sweet orange and 'Cleopatra' are more subject to loss of water (hydrostatic shock) during transplanting (7). *C. macrophylla* is very susceptible to water loss and under adverse conditions of transplanting many plants may fail to survive transplanting. We have found that seedlings packed with moist sphagnum moss in lightly ventilated containers have arrived at their destination in satisfactory condition. Some of our shipments have gone half-way around the world without losses.

The survival of seedlings during transplanting depends a great deal on the climatic condition at the time. In desert areas with a low humidity transplanting must be very carefully done. Very low humidity with a slight wind and either a chilling or a high temperature condition can dessicate the seedlings beyond the point of recovery. The roots should not be exposed to air or direct sunlight for more than a minute or 2 while transplanting. The soil at the planting site should be moist prior to planting. As the seedlings are planted the roots should be tightly packed in the soil and watered immediately. In areas where humid conditions prevail seedlings may be exposed to the open air in the shade for some time without damage. However, under any circumstances, the less shock the seedlings receive during transplanting the quicker they will recover and commence to grow again.

Machines are often used to plant citrus seedlings. In our case the machine opens a groove in the soil while the operators place the seedlings by hand. As the machine advances the soil is pressed around the roots. Our machine adds a quart of water to the soil as each seedling is planted so that the roots are packed into moisture-saturated soil. Irrigation water is applied immediately after planting each row of trees. The seedlings are planted in the bottom of the irrigation furrow. The irrigation water leaches away the salts which accumulate by evaporation during dry seasons. The salts can also be leached out by using sprinkler irrigation. With care we normally expect close to 100% survival of the plants, even under desert conditions.

It is customary in California to bud citrus nursery stock 8 to 10 inches above the ground. The seedlings are wrapped with aluminum foil to a height of 12 inches to prevent the sprouting of suckers (6). This also protects the trunk from sunburn and makes it possible to apply herbicides mechanically without injury to the plants. When the seedlings are ready to bud, the wrap is removed, exposing the trunk which is smooth and easy to bud.

After the seedlings are budded they are bent over and tied to the trunk below the bud. The top of the seedling is left attached until the budling has reached full size. Growth which sprouts from the seedling is cut off at frequent intervals. This results in vigorous, rapid growth of the bud with a minimum of other attention.

Weed control is an important element in any nursery operation. Soil fumigation with methyl bromide kills the weed seed in the soil and makes it possible to operate a weed-free nursery. The few weeds resulting from seeds blown in by the wind can easily be pulled by hand or sprayed with weed oil from time to time. Where soil fumigation is not used, a preplant treatment with Treflan (trifluralin) incorporated in the soil, followed by a pre-emergence surface treatment with Princep (simazine), has given equally good control of weeds in seedbeds. The same materials are effective when transplanting seedlings, but the Princep should be applied to the surface of the soil prior to transplanting. With these treatments it is not necessary to cultivate the soil.

Mechanical devices can be an aid in reducing costs when nurseries are grown on a large scale. Many operations can be performed quickly at the right time with a minimum of cost by adapting fertilizer spreading, spraying, dusting, and trimming equipment to the correct height and space requirements.

Propagating Material

The best of care would be wasted unless the nursery is grown with disease-free propagating material. The California Citrus Foundation operated by Willits & Newcomb maintains a collection of trees for production of citrus seed and budwood. This program was initiated originally in 1947 for the purpose of creating a supply of true-to-type, disease-free propagating material, which included commercial selections of citrus then being used in California. This material was primarily for use in the Willits & Newcomb nursery. At first it was produced on a small scale, but requests from growers as well as from experiment stations led to expansion of the program.

Today, 50 acres are devoted to plantings for the production of budwood and seed. The Foundation depends heavily on the Citrus Variety Improvement Program of the Agricultural Experiment Station and Citrus Research Center of the University of California at Riverside (18, 20, 21, 22), and the U.S. Department of Agriculture at Indio, California, for source material which is used for propagating mother trees. These trees are planted in the Foundation's orchards and entered as candidates in the California Department of Agriculture Citrus Registration Program. Trees in orchards for seed production are being indexed for psorosis in the new California program for registration of seed trees (3).

Each tree is labeled with a code number which identifies the exact source of the scion and rootstock. The propagation program is subject to California State Quarantine Regulations covering tristeza, and to the California Citrus Registration and Certification Program (1, 2, 16, 17). Any tree found to be off-type, showing symptoms characteristic of stubborn disease or infected with a virus is immediately removed from the planting. Small off-type branches and twigs are removed by pruning.

Propagating material is produced at 2 locations - at Thermal, California, under interior desert conditions and at Arvin, California, in the San Joaquin Valley, with a more moderate climate. Both locations are in tristeza-free areas protected by continuous tristeza eradication programs. These locations are separated by mountain barriers and open desert from the tristeza-infected coastal zone of Southern California. Environmental conditions and cultural practices provide freedom from bacterial and fungus diseases and from pathogenic nematodes.

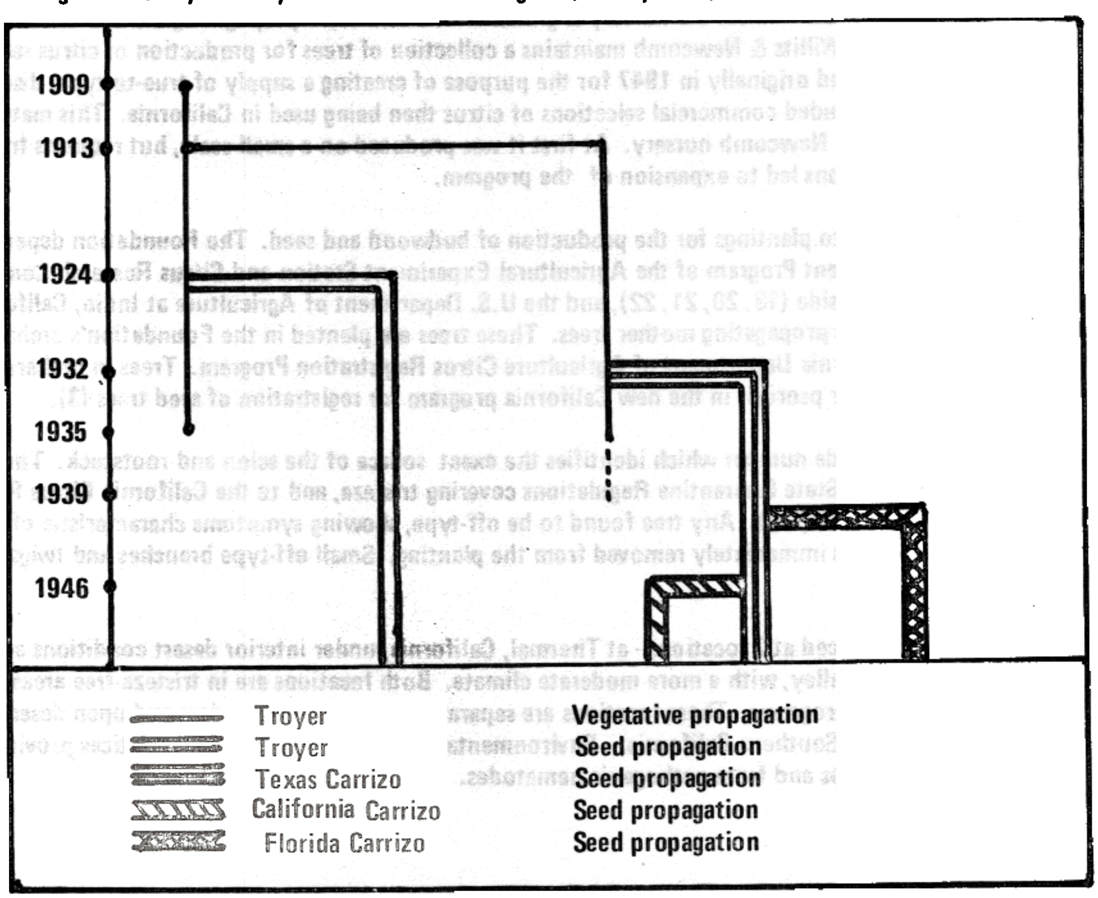
While the conditions under which budwood is produced by the California Citrus Foundation are designed to assure freedom from recognized virus diseases, the problem of producing budwood free from stubborn disease, *Spiroplasma citri*, remains to be solved. Field spread of stubborn disease has been demonstrated in California by research agencies. At this time neither the vector nor the source of the stubborn inoculum has been identified. Selections apparently free of stubborn are now being grown under insect-free conditions, using greenhouse and screenhouse facilities. Plants of these selections will be maintained under screen as sources of budwood that hopefully will be free of all viruses and mycoplasma-like organisms. These plants will be indexed periodically by the California Department of Agriculture to confirm their virus-free status.

Our plan is to continue maintaining and enlarging the collection of those citrus varieties for which there is sufficient interest. New introductions are made by vegetative means when it is possible to secure disease-free material that complies with quarantine regulations. When vegetative material cannot be introduced, nucellar seedling budlines of polyembryonic cultivars are developed when possible. In either case sufficient numbers of plants of each introduction will be grown and fruited to determine that it is true-to-type before offering it for distribution.

It is unreliable to depend upon seedlings for the purpose of making new introductions without using the precaution of growing a sufficient number of seedlings to identify the variants. There are many examples of variants arising from using seedlings to introduce particular varieties to a new location. In one instance we selected what we considered 4 uniform seedlings of 'Carrizo' citrange. We cut buds from each seedling and grew about 40 trees. When the trees came into fruiting 3 distinct types were apparent. One composed about 50% of the planting and each of the others about 25%. Perhaps it would be valid to assume that 2 of the seedlings were true-to-type and the other 2 were variants. How much better it would have been to have grown 40 seedlings to the bearing stage and then to have carefully selected the dominant type.

The diagram which follows illustrates the history of the development of 'Troyer', Florida 'Carrizo' and California 'Carrizo' citranges from the original cross pollination of 'Washington' navel orange with trifoliate in 1909 as reported by Savage and Gardner (23).

Fig. 1. History of Troyer and Carrizo Citranges* (Family Tree)



*Data from E. M. Savage and F. E. Gardner. 1965. Citrus Ind. 46(2):5, 6, 7, 26.

It is recognized that there are differences in 'Troyer' citrange, California 'Carrizo' citrange and Florida 'Carrizo' citrange (4, 5). In each case where a clone has produced seedlings with characteristics different from those produced by the original clone, there has been a propagation by seed rather than by vegetative means. This illustrates the need of thorough testing of the characteristics of seedling trees before accepting them as being identical to their mother.

The creation of a collection of virus-free citrus varieties for production of budwood and seed can be beset with many difficulties. In our case we have established 5 budwood source orchards at Thermal, California, during the past 25 years. In each case we used great care to limit the introductions to the cleanest, true-to-type source material available at that time. Of these 5 mother blocks only 1 now remains. The other 4 have been abandoned because of the number of trees it had been necessary to condemn and remove for various reasons, including infection with exocortis or stubborn disease, mutation prone lines, and other reasons.

In maintaining budwood trees it is undesirable to cut heavily for budwood. Heavy cutting may result in a flush of new growth that may mask the true characteristics of the tree and depress flowering and fruiting. To avoid this we use "budwood increase blocks". Under California regulations buds may be cut from registered trees and be budded into "registered increase blocks" for the purpose of producing registered budwood (2). The increase blocks are eligible for bud cutting for a period limited to 18 months after budding. Nurseries grown from "registered increase stock" are ineligible for further budwood production.

Performance of Rootstock Varieties in the Nursery

The behavior of rootstock varieties in the nursery may vary in different ways depending upon the environment. I shall give a few examples to illustrate this point as it is important to recognize that a nursery program that works well in one situation may not work in another.

For example, near the coast in California where the weather is cool, even in the summer, it normally takes 3 years from the time the seed is put in the ground until a lemon tree on macrophylla root is ready to dig. In the warm interior valleys it is general practice to transplant 1-year-old macrophylla seedlings in early spring, bud them in July or August, and have trees ready to dig the following spring, 2 years from planting the seed. In tropical areas or under greenhouse conditions the same plant may be produced in a little over 1 year from seed.

There are great variations in the rates of growth of different rootstocks under different temperatures. Some rootstocks grow best in a rather narrow range of temperature. 'Cleopatra' mandarin, which is a slow-growing plant in California nurseries, has outgrown 'Troyer' citrange and *C. macrophylla* in outdoor seedbeds in a warm, humid, tropical valley near Chilpancingo, Mexico. On the other hand it grows very slowly compared to 'Troyer' citrange and *C. macrophylla* in the Coachella Valley of California where the average daily maximum temperature is 108°F during July and August.

Some selections of trifoliate orange react differently to climate. In the hot San Joaquin Valley, 'Beneke' trifoliate outgrows 'Rubidoux' trifoliate when they are planted side by side. In the Coachella Valley where the temperature is higher, the situation is reversed, and 'Rubidoux' grows faster than 'Beneke'.

Other differences in behavior of the plants, such as reaction to various soils or susceptibility to insects and mites, may be as pronounced as sensitivity to climate. It is well known that some varieties of rootstocks are sensitive to high lime content in the soil. Trifoliate and some of the trifoliate hybrids will scarcely stay alive in some high lime soils, while rough lemon, sour orange and 'Cleopatra' mandarin seem to flourish. Some seedlings such as trifoliate, 'Troyer' and 'Carrizo' citrange are preferred hosts to certain mites.

The acceptance of buds by the plant and the ability of the seedling to push the growth of the bud varies with the variety of the seedlings. In our experience 'Cleopatra' mandarin, even as a small seedling, will strongly support the growth of the bud. 'Troyer' and 'Carrizo' citrange, *C. macrophylla* and *C. volkameriana* are all good in this respect. Sweet and sour orange, *C. amblicarpa* and some of the citrumelos may produce an uneven growth of the buds. Sometimes some of the buds will stay green but be delayed in sprouting. Sometimes there will be a lag of weeks or months. Some of the buds will start growing but stop after a few inches growth. We do not yet understand the cause of this.

Another characteristic that differs greatly between seedling varieties is the percentage of gametic seedlings. While all seedbeds and lined-out seedlings should be carefully examined to remove plants that may not be typical, the necessity of this operation is much greater in some varieties than others. 'Cleopatra' mandarin, rough lemon, 'Rangpur' lime, and *C. macrophylla* seedbeds will have a high percentage of true-to-type seedlings. 'Troyer' and 'Carrizo' citrange and trifoliate may produce a small but perceptible number of off-types. *Citrus taiwanica* and 'Sacaton' citrumelo consistently produce up to 50% or more off-type plants. Most of the off-type seedlings will be less than average size and can be eliminated easily by an experienced nurseryman.

These examples of differences in behavior are given to indicate the need of experience in the nursery under local conditions in order to adapt the nursery program to the particular situation.

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ROOTSTOCK SHORT COURSE

11:30 Discussion
Wednesday, September 26

Questions for Mr. D. A. Newcomb

question: How much do you sell a citrus tree for?

answer: For 20 years the price of a nursery tree was $2.75. The last trees we have sold the prices have gone up to $3.00.

question: In many of your nursery operations from the seed bed to the budded tree, you showed the use of hedging and topping devices to maintain uniformity. Do you attempt to sterilize or in any way clean the cutting blades on these things to minimize transmission of exocortis by mechanical means?

answer: Our drivers are all instructed to clean the sickle bar completely with Purex (a type of bleach) after they complete trimming 1 row of nursery stock. Of course all of the budwood used in this nursery comes from registered stock but we never know when something might happen. All of the propagators carry a bottle of Purex or Clorox with them in their budding kit to sterilize their tools also. Our people conducting irrigation are not given shovels anymore either for fear that they may stick them in the ground in one place and carry a disease or some sort of organism with them into another place where the shovel might be stuck in again and transmit disease in this fashion so all of the irrigators have is a valve for turning on the water faucets. Each row is irrigated independently. We keep traffic down to a minimum, we keep the gate locked so that no one comes in or out of the area. As a consequence of these precautions it has now been over 2 years since we have found any phytophthora in the nursery.

question: Did you say that you are using mycorrhiza in an attempt to stimulate the growth of citrus seedlings in fumigated plant beds and if so what type are you using and how are you using them?

answer: Yes, we are working with mycorrhiza in a joint project with the University of Illinois, however, at this time we are not really sure what is the best application technique that will work. We are now trying to coat the seeds as this would be a very favorable technique.