Holland, Belgium, and France).

Looking to the future, layering of ornamental woody plants is likely to decrease further as technology develops. The major limiting factor is the area and cost of land required. However, stooling for rootstocks will remain a standard propagation method. Further innovations in machines, fumigation, pesticides, and overall plant health will produce even greater improvement in quality and yields. Layering procedures are part of a wonderful history in the European nursery industry, but there are specific circumstances, even with today's changing technology, where layering will still have its virtues for many decades to come.

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AVOCADO CLONAL ROOTSTOCK PROPAGATION

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BACKGROUND

Until 10 years ago, nearly all orchard-bound avocado trees raised in California were on seedling rootstocks. Clones were used only for fruiting scions such as Hass, Fuerte, and Bacon. Since 1977, however, some half million trees have been planted on clonal rootstocks. It's my guess that avocado tree production today is split about fifty-fifty between seedling and clonal rootstocks. How has this come about?

The stimulus for the newer commercial technologies came from Dr. George Zentmyer who was working toward the solution of a serious disease, avocado root rot, which first came to avocado growers' attention during the late 1940's. During the 1950's it occurred to industry leaders that this disease, caused by *Phytophthora cinnamomi* (Pc), was a serious threat to the entire avocado industry. Zentmyer, in a search for tolerant rootstocks,

found that a factor for Pc tolerance occurred in the Duke cultivar, and that the tolerance factor was transmitted through a certain proportion (25%, more or less) of the Duke's seedling progeny. Since the transmission was partial only, and specific to certain seedlings, it became a priority of the highest order to clonally propagate the best of these seedlings.

Fortunately, the basic technology was at hand. Ted Frolich, working with rootstock specialist, Dr. F. F. Halma, in the 1940's had discovered that stem tissue of avodado rooted well provided that the stem was etiolated. This discovery, coupled with Ted's expertise, enabled Zentmyer to utilize some two thousand clonally rooted avocado trees (grown by Frolich) in order to evaluate and select the best of his Pc-tolerant candidates (1).

Commercial nurserymen responded to these developments in the early 1970's when it became clear that the Halma-Frolich-Zentmyer group had discovered something really significant, that these discoveries offered a possible solution to the avocado root rot threat.

At Brokaw Nursery we endeavored to duplicate Frolich's technique with limited success. We tried variations on the technique, and, in the course of time, struck upon a procedure that has enabled us to produce more than 100,000 of these trees in a single season. While incorporating Frolich's basic discoveries, this technique departs sufficiently from his procedures that we were able to patent the process for avocados (U.S. Patent No. 4012866).

The purpose of this paper is to describe the practical application of this newer process. It will not cover general avocado tree production practices, such as general phytosanitary precautions, etc., as these were outlined in an earlier paper (2).

THE PROCESS

Seed Selection, Treatment, and Planting (Duration: approximately 3 weeks). We use large, vigorous seeds in this process because the plant, in all its propagation phases, will receive much of its energy and hormonal supply from this source. We have found that the very best seeds are from West Indian (i.e. 'Waldin') or West Indian × Guatemalan (i.e. 'Lula') sources. Certain Guatemalan seeds may be used as well, such as 'Hazzard' and 'Fourth Generation Hass.'

After heat treatment the seeds are scarified on the basal end, bedded for sprouting, and selected for planting into polyethylene bags with drainage holes, which are especially designed for the purpose (Figure 1). They are planted with the apical end flush with the sides of the containers.

For bedding, planting, and rooting we use a peat-perlite blend.

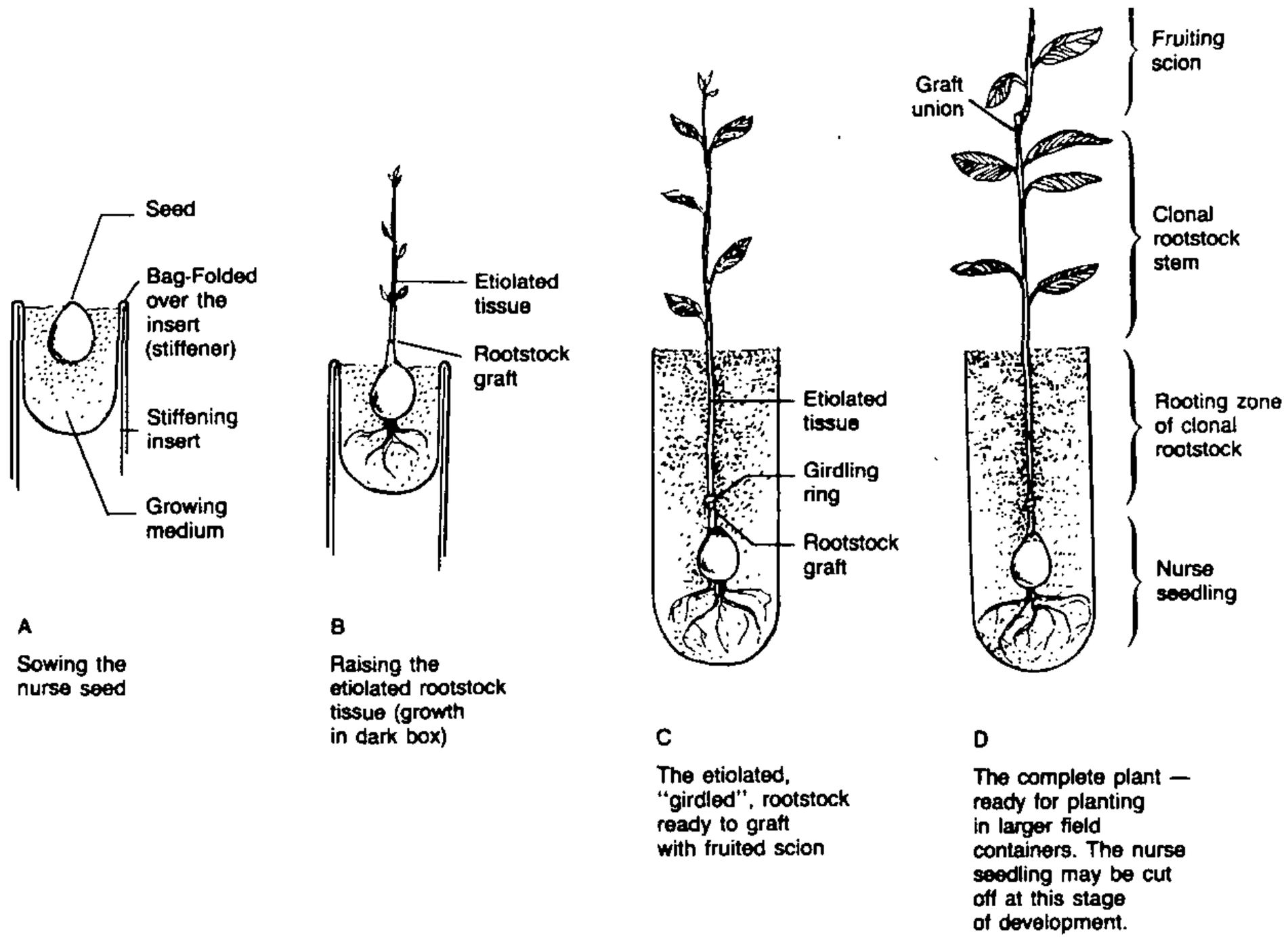

Figure 1. Use of the propagating bag. The 12 inch (30 cm) long poly bag is used for all propagation stages. At seed sowing, rootstock grafting, and etiolation it is in the "folded" state and supported by a disposable insert which serves as a stiffener. After "girdling," the bag is extended, the insert discarded, and the bag is filled to the brim with a growing medium.

Propagating the Rootstock. The seed and seedling will be henceforth referred to as "nurse seed" and "nurse seedling" since their sole function is to temporarily sustain subsequent grafts which will serve as rootstock and fruiting scions of the producing adult avocado trees. The nurse seedlings will die in the process.

Once the nurse seedling has grown to a height of approximately 10 in. it is ready for a rootstock graft. Any convenient grafting technique will serve. At our nursery we use a simple split stem and wedge-shaped scion, but a whip graft and sundry variations will serve equally well. The only special requirement is that the graft be placed low on the seedling stem. We want the roots to originate as near as practicable to the nurse seed but on the rootstock shoot which will emerge from the rootstock graft.

After the rootstock bud has emerged, possesses obvious vigor, and is ¼ to 1 in. (0.5 to 3 cm) in length, it is transferred to a dark chamber for etiolation. Within the chamber it is allowed to grow to a height of approximately 14 in. (35 cm), at which time it is removed for hormone application, girdling, and bag extension, the extended bag finally to be filled to the brim with a suitable propagation medium (Figure 1).

Hormones are applied by brush to the etiolated tissue to a height of approximately 6 inches above the nurse seed. We use an alcohol-water solution of 2000 ppm IBA and 1000 ppm NAA. This hastens rooting but is not essential to the success of the process.

Once the hormone solution has dried, we encircle the rootstock scion at its base with a loosely fitting metal ring ¼ in. (½ cm) or more in width that has no gaps. In practice we use a "C"-shaped metal band that is clamped around the original rootstock graft. If it fails to close completely we add another whose gap is opposed to that of the first (Figure 2).

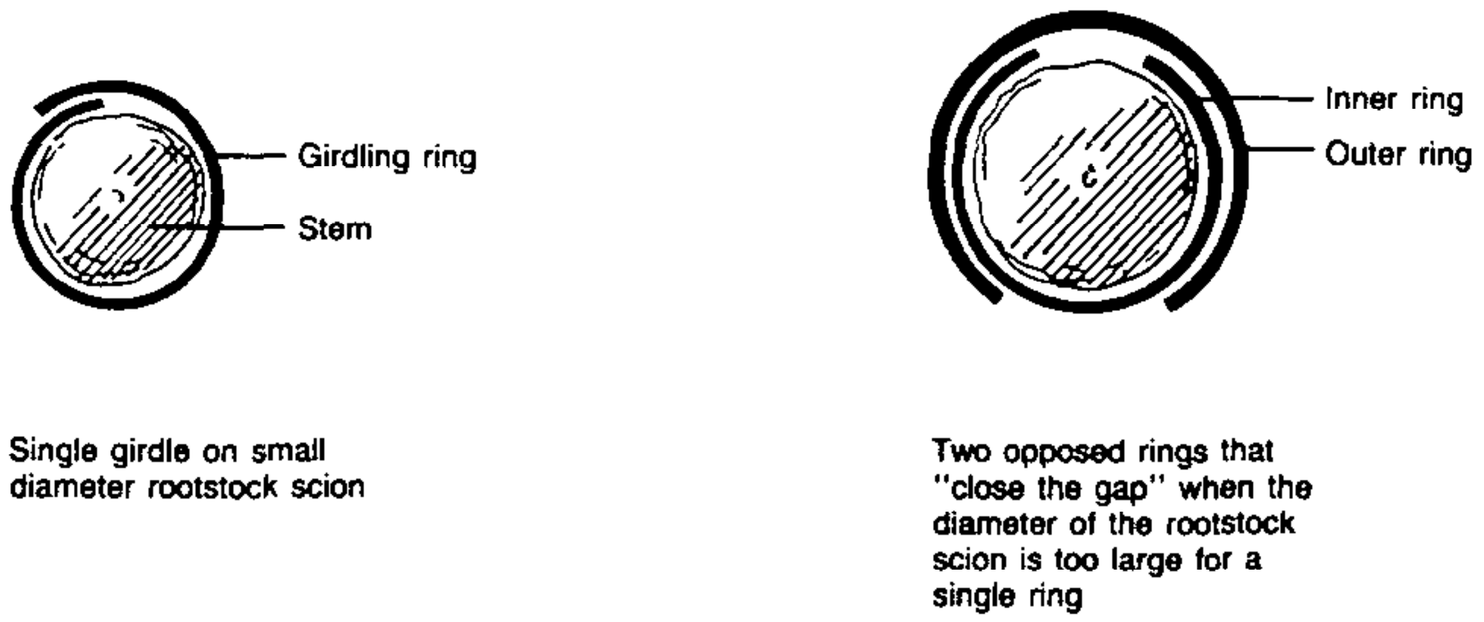

Figure 2. Girdling rings. In practice, the gaps of these rings are closed tight with pliers or other suitable instrument, taking care not to crush the cortex of the stem.

The purpose of this ring, which we call a "weaning girdle," is to gradually constrict and extinguish the life from the nurse seedling after our propagations have been completed. The nurse seedling normally dies within a year, when the tree is still in the nursery. In some cases it is tenuously alive at time of delivery, but never have we seen one with life after two or three years from seed planting.

Other types of metal strictures may be used as well. Broad washers may serve, since they also require substantial overgrowth by the stem to reestablish any connection between nurse seedling and the grafted rootstock. Rubber or plastic will not reliably serve. They are apt to be overgrown, thus allowing reconnection of the nurse tissue with the clonal rootstock stem.

Once the hormone is applied and weaning girdle is in place, our bag is extended (Figure 1) and filled with the propagation medium. We are now ready to graft a fruiting scion onto the clonal rootstock stem. This may be done immediately onto the etiolated tissue, or it may be delayed until roots have emerged.

Propagating the Fruiting Scion. This operation is straightforward and may be accomplished by any appropriate technique. We use the same wedge graft that was described above for rootstock grafting.

In practice, we graft fruiting scions at a height of 8 to 10 in. (20 to 25 cm) so that in case of graft failure (some 3 to 15% of grafts may

fail) we can regraft at a lower height. We pinch sprouts (shoots on the rootstock) but are careful not to completely remove them below the basal ring. (The live shoot stubs, with their basal buds, maintain "sap" movement up and down the rootstock stem. I believe that in the process they preserve a functional hormone balance.)

The grafted plants are usually kept in the greenhouse for a period of 6 to 10 weeks, frequently sorted to prevent shading, and then transferred to a shade house.

After two weeks in shade and a few days in open sunlight they are ready to be planted into the larger 3½ gal. containers (14 liters) in the field, or outside growing grounds, in full sunlight. Transplanting procedures are standard and are described in an earlier publication (2). These larger outside containers previously have been filled with a soil-organic mixture which drains well, yet is somewhat cohesive and has a suitable ion exchange and water retention capacity.

TIMING THE PROPAGATIONS AND ENVIRONMENT

The timing of avocado propagation is critical. The nurseryman needs large quantities of fresh grafting materials when they are in optimal condition. At Brokaw Nusery we raise 8 rootstocks and 7 fruiting cultivars as standard offerings, each with its own timing requirement. Grafting material is generally available during periods of the winter so that all our propagation operations are performed in the greenhouse.

To illustrate the timing problems: in Ventura County, California, 'Duke 7' is best grafted from late October to early February. 'G755,' on the other hand, often causes problems when grafted before mid-January. 'Hass' scionwood is best from January 15th to early May. The reader can see that the timing of production is specific to cultivar and is a delicate matter if one is to achieve a high success rate with a large number of plants.

NURSE SEED ATTACHED

Our method is sometimes referred to as the NSA, or Nurse-Seed-Attached, method, and has troubled some individuals who have suspected that it is not a purely clonal rootstock.

It would be a simple matter to completely prune off the nurse portion of the baby triple-staged plant before field transfer. Indeed we would, were we not fully confident that the nurse portion would finally die while the plant is still very young. The nurse seedling does inevitably die, however, and we consider it to be of positive value during the full course of its brief existence. It assists plant development for a period of 6 to 10 months from seed sowing.

LIFE CYCLE OF THE DEVELOPING PLANT

Normally our trees are delivered for spring orchard planting at 16 to 20 months after sowing of the nurse seeds. At this time the plants have been trimmed to a height of about 38 in. (95 cm). Sometimes they are delivered in the summer at ten months, in which case they have reached heights of 30 to 35 in. (77 to 90 cm).

About six or seven months of the plant's life is spent in greenhouse, shadehouse, and in outside storage prior to transplanting in the field. The stages of development for most saleable trees may be broken down as follows:

Seed sowing to planting	3 weeks
Development of seedling	3 to 5 weeks
Rootstock bud start	4 to 6 weeks
Residence in etiolation chamber	3 to 5 weeks
Staging for scion grafting	1 to 6 weeks
Scion graft development	4 to 8 weeks
Hardening period	2 to 6 weeks
All time prior to field nursery	19 to 41 weeks (sum of the above)
Time in field	40 to 70 weeks (approx)
Total time	69 to 87 weeks (16 to 20 mo.)

FUTURE OF CLONAL ROOTSTOCK PROPAGATION FOR AVOCADOS

New avocado rootstocks are being introduced on a regular basis and I do not foresee an end to clonal propagation. As we continue to progress in our evaluations of new candidates we will inevitably find higher levels of Pc-tolerance and discover superior combinations of other horticultural characteristics—such as salt-tolerance, chlorosis resistance, controlled tree size, frost resistance, and superior cropping. Indeed, cultivar differences are already showing up in some of these areas. I expect that, down the road, we will be using specific rootstocks matched to specific fruiting cultivars and to specific soil-water quality combinations.

The stage is set, then, for a germplasm search of unprecedented proportions, as we search for the ever evasive perfect rootstocks and rootstock-fruiting cultivar combinations. It will be an exciting period for several years. It's a great time and fertile opportunity for the progressive avocado nurseryman.

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VOICE: In air-layering, do you use any dark-colored foil to cover the plastic over the root ball?

WM. NELSON: Yes, we do, using the darkest color we can find, although with the plastic alone we can get some heating, which is good unless the weather gets too hot, when there can be scorching of the roots.

VOICE: In girdling your branch for air-layering, do you not lose the entire branch if the layering is not successful? Also what time of year is the air-layering done and what size branch is used?

WM. NELSON: In southern California, where the growing season is virtually the year round, we can do air-layering successfully almost anytime. And with an active cambium at the girdled area it will callus and heal back together, even on a 3 or 4 in. diameter branch—so we do not lose it. We work with branches from about ¾ in. to 2 in. in size for our air-layering, but the branch size is not as important as some other factors. A good root system should form on air-layers in 2 to 3 months.

VOICE: Question for David Hill. What type of lighting are you using for rooting your tissue-cultured cuttings?

DAVID HILL: For the past several years we have been using mercury vapor lamps at 150 foot-candles at bench level, but now we are looking at high pressure sodium lamps, which will double the foot-candle output.

VOICE: First a comment on air-layering. We have found that a Windex type sprayer or an aerosol sprayer can be used to apply IBA solutions to the girdling cut on air layers. Now a question for Bill Nelson. What total costs per unit are involved in your air layering techniques?

WM. NELSON: For the rare, expensive, specimen trees that we air-layer on someone's property we pay the owner five dollars per tree, leaving the tree in good condition. Total costs for an air-layered plant into a container would be about $15 each. For this we would charge $40 per tree.