VOICE: How many cuttings were your getting from the butterfly root?

BILL BRUMBACK: You can cut the root into only a few sections. It used to be thought that you could not move that plant. However, it has been shown that you can cut them up into pieces and they will come back.

VOICE: What are the germination requirements for trillium seeds?

BILL BRUMBACK: Trillium is a two-year plant. Seeds need a cold period so that during the subsequent warm period the root will grow out. You then need another cold period to release the shoot inhibition. The leaf the first year will be a single leaf. By the third year you will see the three-leaf whorl.

PROPAGATION OF HERBACEOUS PERENNIALS BY ROOT CUTTINGS

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Why propagate by root cuttings? It is a relatively cheap and simple way to propagate perennials and is the only way to propagate some cultivars asexually. In comparison to propagation by shoot cuttings, it is less costly because root cuttings do not require expensive humidification or misting systems and bottom heat is unnecessary. Many root cuttings will regenerate new plants without any added heat. Most commercially grown perennials are field-grown, mechanically harvested, and shipped bare-root. This facilitates the taking of roots as the plants are being prepared for shipping. For plants with thick, fleshy roots the sticking of roots can be mechanized. This year we installed Bouldin and Lawson equipment that allowed us to reduce the time it takes to stick 20,000 oriental poppy roots from 2 or 3 days to less than one full day. Paper cutters are used to trim soft rooted plants, such as phlox, which saves a considerable amount of time.

There are many plants that produce underground shoots which can be treated in the same manner as root cuttings (Tables 1 and 2). The main difference between the two is that underground shoots have preformed buds or bud initials which produce shoots readily in propagation, whereas roots have to develop buds. Hartmann and Kester discuss root bud development in their book, *Plant Propagation: Principles and*

Practices (3), therefore I will not elaborate on the physiology and anatomy of propagation by root cuttings.

Source of roots. We use two field-grown sources for roots: 1) saleable plants, and 2) stock plants. Field-grown plants are superior to pot grown plants because in pots the roots are matted and twisted together. It is also difficult to tell in a pot-grown root ball the polarity of the roots.

1) Saleable plants. It has been the standard practice for us to remove a few roots for propagation at the time that plants are being shipped. As this is done with discretion it does not affect the plant in either its appearance or performance. The disadvantages of this method are: a) It slows down the shipping process; b) Not all plants flower the first year from root cuttings, therefore rogues can be propagated without us knowing it; and c) Propagation time is determined by harvesting/shipping times.

2) Stock plants. This has several advantages: a) Roots can be taken when it fits the propagation schedule; b) Rogues can be eliminated before propagation; and c) Some plants produce better roots for propagation from two-year-old plants, such as *Geranium cinereum* 'Ballerina' (2).

We are moving more to stock plants and may eventually only use this technique. We already do this on those kinds of plants that we sell in pots, such as *Anchusa azurea* cultivars and *Cynoglossum nervosum*.

A word of caution when planting stock from a plastic container. It is essential to trim the roots that ring the bottom of the pot, otherwise it will be very difficult to obtain straight roots. Plants from flats, ground beds, or peat pots are a better source.

Types of roots. As far as productivity in handling is concerned, there are two basic types of roots, those with thick fleshy roots, such as, oriental poppy, *Anchusa*, and *Cynoglossum*; and those with soft, flexible roots, such as, *Phlox*. Thick roots can be stuck in a preformed hole, permitting mechanization, while soft flexible roots need to be placed vertically in the soil and the soil brought up against the root.

Polarity. The majority of plants propagated by root cuttings will produce shoots only at the proximal (top) end of the root. The proximal end is the end closest to the crown of the plant. Therefore, it is essential to plant the root with the proximal end up. Otherwise the shoot will try to develop at the end buried in the soil, and if it does not rot before reaching the surface of the soil it will produce a mechanically weak plant which is hard to plant with an automatic planting ma-

chine. Many books on perennials or plant propagation recommend laying the roots horizontally so as to overcome the problem of polarity. We have found this to be impractical and again it is hard to plant a liner which has shoots at right-angles to the root. The practice of making a straight cut at the proximal end of the cutting and a slanting cut at the distal end is also too time consuming. With care and developing a routine of always repeating the same motions, such as always putting roots down in the same direction, the problem of "upside-down" roots can be overcome.

Time of year for taking roots. Many perennials can be propagated from roots at different times of the year. We do most of ours when it is most convenient, that is in the fall as the plants are being dug from the field. We start with oriental poppies in early September and finish with cooler stored phlox in late December or early January. Some exceptions to fall propagation mentioned by Hill (5) are *Primula denticulata* cultivars in March through May, and *Anemone pulsatilla* in June, July or August (6). *Geranium cinereum* 'Ballerina' is propagated at Blooms Nursery in England during February in outdoor frames (2).

Taking roots. When taking roots we remove the roots close to the crown. On a saleable plant we can take 3 to 10 roots without making it unsaleable. The roots are either snapped off or cut off with a sharp knife. Each root length can be cut up into suitable lengths, each section of which will produce a new plant. The second section of phlox roots are much thinner than the first and therefore we group more roots in each cluster. After taking roots we lay them down in a flat taking great care to lay them in the same direction. At this time the flats are put in plastic bags and placed in cold storage at 34 to 38°F until it is convenient to stick the roots. Root pieces can be kept in storage for several weeks without harming them. If storage molds develop we stick the roots immediately. We have not found it necessary to treat with fungicides.

One way to propagate rare plants that can be propagated by root cuttings, without disturbing the root system, is to pot the plant in a narrow pot with a large drainage hole and then plunge the pot in sand. One or more roots will eventually grow into the sand. These roots can be removed for propagation without disturbing the plant (5).

Length of root pieces. Root pieces are usually taken 2 to 3 in. long, although some fleshy roots, such as, *Anchusa*, can be taken with pieces ¼ in. long (5). This is valuable when roots are in short supply. We cut thin roots with a well-sharpened paper cutter. Thick, fleshy roots are fastened in bundles with

rubber bands spaced down the roots to facilitate cutting the roots into even lengths. The rubber bands are removed just prior to sticking the roots and it is at this time that most mistakes are made with putting roots upside down.

Methods for growing root cuttings. 1) *Individual pots.* We use Nu-pot 25's extensively. These are blow-molded pots with tops 2½ in. across and 3 in. deep and a tray to fit the pots. They are very convenient for mechanization. We have used peat pots in the past and we found that Fertil Pot #008 to be the best with Jiffy Pot #425 a fair substitute. Individual pots provide inventory accuracy and enable us to ship some crops directly to the customer with those items that grow too large in field production. Disadvantages of individual pots are the cost of the pot and the need to grow them in a heated greenhouse. It also takes longer to prepare a plant for field planting when it has been pot grown.

2) *Flats.* We have used wooden flats for years, but they break, rot, and need to be disinfected as they carry fungi, bacteria, and liverworts. We are replacing wooden flats as needed with rigid plastic flats. These are expensive initially, however they are unbreakable in normal use, and will eventually be more economical than wooden flats. The advantage of flats is that they are suitable for mechanization. Disadvantages are the initial high cost, the cost of disinfesting the flats, also the need for heated frame or greenhouse space.

3) *Multipots.* These are used extensively by some large wholesale growers for root cuttings. They are space efficient and can be mechanized, but they produce a very tight root ball because of the confined space. We cannot produce the quality of plant we sell with multipots.

4) *Frames.* Heated and unheated frames when used for direct sticking are usually very inefficient in terms of productivity of workers, and the sticking of roots is determined by the weather. They do require less heat than greenhouses, especially when well insulated. Another problem is the need to pasteurize the soil on a regular basis.

5) *Polyhouses.* Direct sticking in ground beds is used extensively at Walters Gardens which is said to be the largest perennial grower in the world. The advantage of this method is that it is a really high volume technique because roots can be packed in closely and the time needed to prepare the resulting plants for field planting is very short. The disadvantages are that ground beds have to be pasteurized and also it is back breaking work sticking roots in the ground.

6) *Field beds.* For large fleshy roots this can be a successful method. We don't practice this technique because we feel

that it is not reliable. New England weather is too unpredictable. A few years ago we had a winter we call the "freeze-dried" winter, where the top few inches of soil became totally void of moisture. This was due to a lack of precipitation, abundant sunshine, 10 to 20°F below zero temperatures and 30 to 40 mph winds. Many long established plants succumbed; outdoor root cutting propagation would have been a disaster.

Composts. One of the keys to successful root cutting propagation is that the compost must be able to hold moisture, but must also have perfect drainage. High nitrogen fertilizers should be kept to a minimum until good shoot and root systems have been developed. Our basic container compost contains per cubic yard the following:

8 cu ft peat moss
8 cu ft #2 vermiculite
8 cu ft coarse perlite
3 cu ft coarse sand
20 lb dolomitic limestone (aiming for a pH of 6.0 to 6.5)
1 lb double superphosphate (0-20-0)
1 lb Micromax trace element mixture.

For oriental poppies we add 3½ lb Osmocote (18-6-12) slow release fertilizer and for most other plants we add 1 pound of potassium nitrate. We add chelated iron to the soil for *Anchusa azurea* 'Little John', as an iron deficiency develops when we use our regular mix.

For outside beds or frames a compost of 3 parts peat moss, 2 parts grit (very coarse sand) and a 1 in layer of pasteurized loam — forked in — has been recommended by Blooms Nursery (2).

Sticking the roots. We try to get the proximal end about ¼ in below the surface of the soil. Roots sticking above the soil will dry out at the tip; this inhibits bud formation. Shoots produced from roots buried too deep will frequently rot before or after they break the surface of the soil. For thin roots we use two or more roots together which produces a larger crown. We have two basic techniques for sticking roots, based on the type of root.

1) Firm, fleshy roots: For either pots or flats we mix the compost mechanically and feed it to a flat-filling machine. The filled trays are passed by conveyor to a mechanical dibbler where holes are dibbled; then the flats proceed along a slow-moving conveyor where workers on either side of the belt put in roots. The holes and the roots have to be uniform otherwise the depth would be unacceptably inconsistent. The flats are stacked on wagons and transported to a growing house.

2) Soft flexible roots: We have not been able to devise a method for mechanizing the sticking of soft roots; only the mixing of the compost is mechanized. Flats are filled by hand, making a row of soil, putting down either clusters of roots against the soil and then putting in another band of soil; this is repeated until the flat is filled. Our fastest workers can stick a flat in six minutes, but an average worker takes 10 to 15 minutes. As we grow about 35,000 phlox a year this way we would really like to figure out a way to mechanize this operation.

Growing environment. 1) *Temperature.* Generally the faster a plant is produced, the warmer the initial temperature. A plant, such as *Catananche*, will produce new shoots in 2 to 3 weeks, whereas, phlox takes 3 to 4 months. We produce fast-growing plants at 50 to 60°F night temperature and 35 to 40°F for slow growers. Those items that are sold directly from a pot to a customer are the faster growing types, and those that are planted in the field are the slower growers.

2) *Watering and fertilizing.* Composts are kept on the dry side and liquid fertilizer is not applied until new roots and shoots have developed.

3) *Pests and diseases.* Roots decay quickly if the soil is kept too wet. If an area of disease starts it can usually be stopped with a drench of a broad spectrum fungicide, such as Banrot.

Aphids are the worst enemy of emerging shoots because they can cause severe distortion of the new shoots. Prevention, with a regular spray program including an insecticide, is recommended.

4) *Light.* Light is unnecessary until the shoots begin to emerge. We frequently stack flats of root cuttings and cover them with plastic when greenhouse space is short. A careful watch must be kept, for once the shoots begin to grow the flats must be spread out. After the shoots emerge they should be placed in bright light to prevent etiolation which weakens the shoots.

What factors control a plants ability to regenerate from root pieces? This was discussed by Heuser (4) at the IPPS meeting in 1977 and is also covered by Hartmann and Kester (3). It appears that it is controlled by hormone concentrations. Cytokinin concentrations at the proximal end have been found to be higher than normal in roots developing buds. Auxins, which are normally found in roots, prevent bud formation and therefore their affects have to be "swamped" by higher cytokinin levels. I am not aware of any studies to find out if cytokinin treatments can stimulate rooting on plants that do

not normally initiate buds. It would be an interesting study for a research organization.

Table 1. Perennials that can be propagated by underground shoots.

Achillea spp.	*Macleaya cordata*
Aegopodium podagraria	*Mentha* spp.
Anthemis spp.	*Monarda* spp.
Artemesia spp.	*Physalis alkekengii*
Asperula odorata	*Polygonatum* spp.
Aster spp.	*Polygonum* spp.
Campanula spp.	*Rodgersia* spp.
Chrysanthemum spp.	*Sanguinaria canadensis*
Convallaria majalis	*Saponaria officinalis*
Coptis trifolia	*Schizostylis coccinea*
Coreopsis verticillata	*Uvulara* spp.
Geranium spp.	*Yucca* spp.
Helianthus spp.	Also many ferns, grasses and bamboos.
Lysimachia spp.	

Table 2. Herbaceous perennials that can be produced from root cuttings.

Acanthus spp.	*Geranium* spp.
Ajuga spp.	**Gypsophila* spp.
Anemone spp.	**Helleborus* spp.
**Arabis* spp.	*Lobelia* spp.
Anchusa azurea	*Matthiola tristis* var. *vallesiaca*
Asclepias tuberosa	*Mertensia maritima*
Brunnera macrophylla	*Morisia monanthos*
**Campanula* spp.	*Papaver orientale*
Catananche caerulea	*Phlox decussata*
Centaurea spp.	**Phlox subulata*
**Crambe* spp.	*Pulsatilla* spp.
Cynoglossum nervosum	*Primula denticulata*
**Dicentra* spp.	*Primula mistassinica*
**Dictamnus albus*	*Scabiosa caucasica*
**Drosera* spp.	**Senecio pulcher*
Echinacea purpurea	*Stokesia laevis*
Echinops spp.	*Symphytum* spp.
**Echioides longiflorum*	**Taraxacum albidum*
**Epilobium angustifolium*	**Trollius* spp.
Erodium spp.	*Verbascum* spp.
Eryngium spp.	*Viola pedata*
Gaillardia spp.	**Weldenia candida*

Those marks with an asterisk (*) have been reported in various lists but I have no experience with them. I am somewhat doubtful that some of these can, indeed, be propagated by root cuttings; however, if I get the opportunity I will certainly try them.

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CLONAL DIFFERENCES IN PROPAGATING CONIFERS

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At the University of Connecticut we have been working on the development of new forms of dwarf conifers. The dwarf plants we develop are not the result of hybridization, but are seedlings obtained from mutations found on various conifers. These mutations, called witches'-brooms, produce seed that yield plants which are 50% normal and 50% dwarf.

We have 20,000 seedlings at our nursery that range in age from 2 to 21 years. Most of these seedlings are from witches'-brooms found on: two *Larix* species, one *Picea* species, one *Tsuga* species, and six *Pinus* species.

Although we could obtain dwarf shrubs by merely grafting scions from the witches'-brooms, we prefer to collect and grow seeds from the brooms. We do this because with seedlings we obtain a highly variable population from which we could select some unique forms.

Although the variation among seedlings obtained from witches'-broom is, most likely, similar to the variation obtained with normal seedlings, the compact growth of the dwarf shrub makes it easier to discern a short-needled plant from a medium or long-needled plant or a blue-green plant from a green plant. Other variations that are not easily noticed on a normal seedling become more obvious on the dwarf. As a consequence, the dwarf shrubs obtained from witches'-brooms offer a wide range of variation in growth patterns.

Our objectives in this project are to select, from these progenies, shrubs that are aesthetically pleasing and different from those currently available. We evaluate them for at least 6