Discussion. Over a 12-year period 8,000 grafted tamarillo plants have been planted. The ultimate production of the grafted trees is superior to seedling trees. Spectacular resistance to *Phytophthora* root rots has resulted. Not all my problems were solved, however, as other diseases, such as verticillium, have taken their toll of trees in the orchard. Further work is being carried out to find stocks resistant to the other diseases encountered.

PHYSIOLOGICAL FACTORS LIMITING THE PROPAGATION OF DECIDUOUS ORNAMENTALS BY HARDWOOD CUTTINGS

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Since the initial breakthrough with hardwood cutting propagation of fruit tree rootstocks (2,4,5), the logical progression of research has extended towards the evaluation of such techniques on deciduous ornamental species. Most of such work has been done by the research groups who were involved with fruit tree rootstock hardwood propagation, and a similar trend in emphasis has been true with the N.Z. Nursery Research Centre, where extensive trials are continuing with hardwood cutting propagation of deciduous ornamentals.

The initial approach to the propagation of deciduous ornamentals by hardwood cuttings has been to impose those treatments which were successful on genera such as *Malus* and *Prunus*, to a wide range of ornamental species. Although some species have responded well to the standard treatment, others have not. Subsequent research has established a broad base from which more detailed studies can be developed. Many of the factors limiting the successful hardwood propagation of deciduous ornamentals are similar to those which were found with studies of fruit tree rootstock propagation. When evaluating the factors which limit the propagation by hardwood cuttings, it is essential that all influences are considered in combination rather than each one in isolation.

Juvenility. Although very little is understood about the components of juvenility in plants, the importance of using juvenile plant material for cutting propagation has long been recognized (6). From our recent trials, it has become apparent that the use of juvenile plant material for hardwood cutting propagation is of paramount importance. Other methods of cutting propagation can utilize material which may be temporarily juvenile because of the timing of collection, summer cutting

propagation being the classical example. Because hardwood material is one-year-old and "hardened", totally juvenile stock plants must be established for successful propagation. It is this factor more than any other, that is the key to obtaining high rooting percentages. Initial propagation trials may be conducted using less juvenile material and useful indications of the potential of the technique can be obtained, but as juvenile plants are established, further improvements in rooting performance might be expected.

Reversion to, or reinduction of the juvenile growth phase on stock plants can be achieved in several ways (6). To date the easiest and most successful has been by severely pruning the plant, leading to the development of both adventitious shoots and vigorous vegetative growth. The process of reversion to the juvenile phase may take from one to several years and appears to be species dependent. Once the mother stock plants are established, annual removal of cutting material can serve to keep the plant in the juvenile growth phase.

Expression of juvenility can be observed from several features and it is important that these can be recognized by growers contemplating hardwood cutting propagation. Plants in a juvenile growth phase produce long, strong, vegetative shoots and individual leaves may be larger than those on adult plants. With some species, leaf shape can be quite different, usually deeply lobed leaves become less lobed or even ovate (e.g. *Quercus coccinea*). Leaf senescence and shedding is usually delayed when compared with adult plants. The absence of short adult shoots bearing floral buds also indicates that reversion to the juvenile phase has been achieved.

Rooting Hormone Treatments. Most research into rooting hormone treatments for hardwood cuttings has utilized the concentrated alcohol-quick-dip technique using indolebutyric acid (IBA). It remains to be established whether this method of application is suitable for all deciduous ornamentals, especially those with tender bark and buds.

Concentrations of approximately 2,500 ppm IBA, which were optimum for some fruit tree rootstocks, have been found to be excessive for many deciduous ornamentals, consequently the re-evaluation of the basal hormone treatments constitutes one large area of current research. Problems of basal deterioration on cuttings prior to root formation have been found to be, in part, associated with excessive IBA concentrations. Therefore, when a previously untried species is treated, an IBA application of 1250 ppm might be a more satisfactory starting concentration (9).

At present, very little is known about the mode of action of IBA in promoting root formation. Traditionally it has been thought that IBA increases the total auxin content of a cutting to a threshold level required for root formation. It has also been postulated that IBA breaks down to produce IAA which is the endogenous active auxin within the plant (3). When one considers that IBA is physiologically very inactive, and that IBA is used for propagation because it is relatively stable within the plant cell (i.e. resistant to breakdown), the explanations for IBA actively in rooting promotion are in conflict with the apparent benefits of using IBA compared with IAA which is unstable. Furthermore, many cuttings will not root simply by applying IBA to the cutting base, although it has been found that if the endogenous IAA level of a cutting increases, IBA can then promote root formation (8). This suggests that IBA may have another function rather than simply elevating the total auxin level to that which is required for root formation. There is a need for basic physiological research into the mode of action of IBA in root promotion, because until this process is more clearly understood, further developments in hormone stimulated root formation may be restricted.

Basal Temperature. The combination of high basal temperatures and high IBA concentrations has been found to be the two essential stimuli for rapid root formation on fruit tree hardwood cuttings. As has been found with IBA concentrations, each species of deciduous ornamentals may have differing optimum basal temperature requirements. Excessively high basal temperatures have been found to induce basal decay prior to root formation. Prolonged high temperature storage will also deplete carbohydrate reserves within the cutting (1). While root formation may ultimately be achieved, the subsequent establishment of rooted cuttings may be poor owing to the depleted food reserves.

From studies at the N.Z. Nursery Research Centre (7), lower basal temperatures of 18°C (64°F) compared with 22°C (72°F) have shown promise with cultivars which root readily provided basal decay can be avoided. When lower basal temperatures have been associated with lower hormone concentrations, basal decay has largely been diminished and rapid root formation has been achieved.

The Time of Taking Cuttings. The timing of taking cuttings has always been an important feature of successful propagation and has a considerable influence on hardwood cutting propagation. Generally hardwood cuttings have been found to root most readily in late autumn or early spring (4,7,8). The time when cuttings are taken will also influence the subsequent IBA and the temperature response due to the interaction of these treat-

ments with endogenous factors affecting root formation. When considering deciduous ornamentals, quite different seasonal rooting responses are evident between species (see Table 1).

Table 1. Seasonal Changes in Root Formation on Hardwood Cuttings of *Betula pendula* and *Ulmus procera* 'Van Houttei'.

	Percent of Cuttings Rooted			
Species	April	June	July	August
B. pendula	70.0	75.0	37.5	12.5
U. procera 'Van Houttei'	0.0	0.0	55.0	50.0

Clearly, the optimum time for taking cuttings must be established for each species, a process which requires considerable reserves of stock material. Consequently, studies of the effect of the time of taking cuttings on root formation have been restricted but will continue as sufficient juvenile plant material becomes available.

In summary, developing hardwood cutting propagation techniques for deciduous ornamentals involves establishing juvenile stock sources and evaluating interactions among temperature, hormone, and timing treatments. As research progresses more data is being accumulated and recommendations for particular species will soon be available for growers contemplating using this propagating technique.

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