8. James River Limestone Company, Inc. Buchannan, Virginia 24066.

9. Soil Science Booklet, O.M. Scott and Sons, Marysville, Ohio.

10. Yeager, T.H. and D.L. Ingram. 1983. Influence of dolomitic limestone rate on growth of holly, juniper, and azalea. *The Woody Oranmentalist:* 8(6).

INFLUENCE OF JUVENILITY AND MATURITY IN PROPAGATION

,FRED T. DAVIES, JR.

Department of Horticultural Sciences
Texas A & M University
College Station, Texas 77843

Importance of juvenility and maturity in propagation. Why are juvenility and maturity important in propagation? In a schematic representation of a 100 year old tree there are three zones of maturation: (1) a juvenile zone at the crown and base of the tree: (2) a transition zone; and (3) a mature zone or region (Figure 1). Any propagules taken from the base of this tree will have juvenile characteristics and be potentially easier to root, regardless of the chronological age of the propagule. The transition zone of the tree is comparable to puberty in humans with both juvenile and mature characteristics. In general, transition zone material will not flower and propagules taken from this region root less readily than juvenile material, yet more readily than mature material. The mature zone is characterized by the ability to flower and set fruit, but frequently there is a drastic reduction in rooting potential. Characteristically, a plant will not express its commercial potential until after it has reached a mature stage. Hence, as propagators we have an interest in learning to manipulate these three physiological stages of growth either to enhance rooting by causing a reversion back to the transition or juvenile condition, or to encourage earlier flowering, fruit bearing, or expression of other desirable mature characteristics by speeding up the maturation process.

Physiological condition vs. chronological age. It is the physiological condition, not the chronological age which determines a plant's capability to form adventitious roots (ARF). A sucker, which may have developed 50 years ago at the base of this 100 year old tree in the juvenile zone, will have a greater chance of rooting than a 5-month-old shoot that has recently developed in the mature region. It is the physiological age, the internal chemistry of the plant, that determines successful rooting.

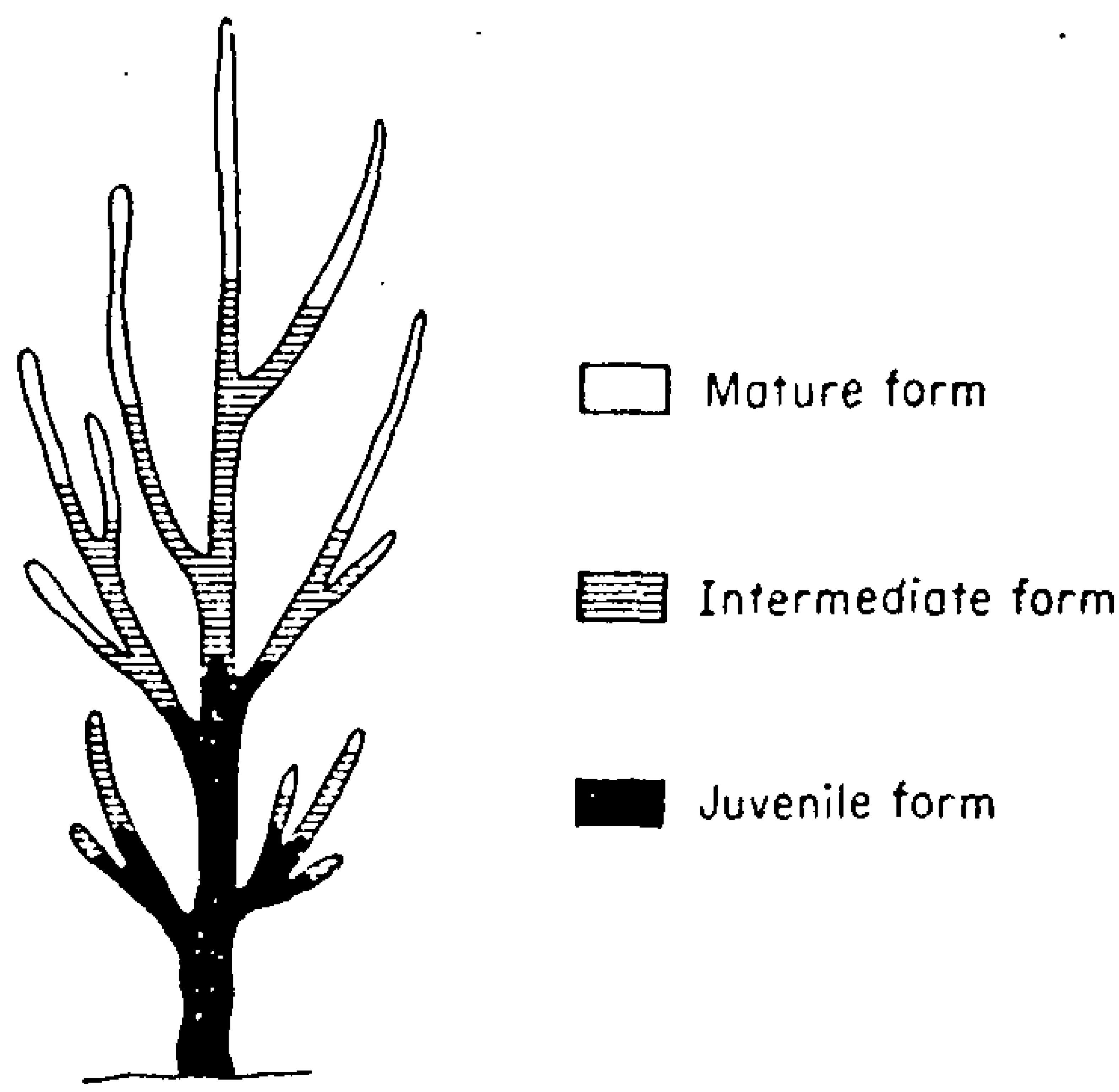

Figure 1. Schematic representation of a 100 year old tree with a juvenile, intermediate (transition) and mature zones.

Type of wood selected. There are a number of conditions, or factors, that need to be considered in the rooting of cuttings. One critical factor is the type of wood selected: hardwood, semi-hardwood, softwood, or herbaceous. Stock plant conditions are particularly important when we compare rooting between easy-to-root juvenile and difficult-to-root mature materials. Again, we are considering the physiological conditions of the stock plant such as carbohydrate/nitrogen ratio, auxin, and rooting co-factor content.

Physiological condition of stock plant and rooting. Certain plants show strong morphological (physical) differences between the juvenile easy-to-root form and the mature more difficult-to-root materials. Examples are aralia (*Dizygotheca elegantissima*) with differences in both leaf size and the number of leaflets per compound leaf; English ivy (*Hedera helix*), and creeping fig (*Ficus pumila*), with sharp differences in leaf morphology and actual plant form (shrub vs. trailing vine ground covers). Junipers are an example of a woody plant species that has mature scale-like foliage at the top and more juvenile needle-like foliage at the base of the plant.

Adventitious rooting — organized developmental process. The formation of adventitious roots (ARF) is an organized developmental process that entails sychronization of internal chemical changes and subsequent structural changes.

Structural aspects of juvenile vs. mature material. Juvenile material forms less structural material, such as sclereids and fibers, which help support the shoot system by making the tissue stronger. As a plant gets older the amount of sclereids and fibers increases since a larger and more mature plant needs greater support. Some researchers have felt that sclereids are actual physical barriers to the rooting process, hence they have tried to correlate sclereid formation with decreased root formation.

Origin of adventitious roots. Another factor is the actual origin of adventitious roots from stem cuttings. With many easy-to-root species, adventitious roots will originate from phloem ray parenchyma cells, which are located in the phloem region. The phloem is involved with transporting photosynthates such as sugars and growth regulators to other parts of the plant. In the phloem tissue there are parenchyma cells capable of undergoing cell division, which must occur for rooting to take place. The phloem region acts as a "loading zone" where sugars and metabolites can be utilized in the rooting process. Difficult-to-root plants often form roots from callus tissue. Both juvenile and mature stem cuttings will form *de novo* roots by dedifferentiating cells into meristematic zones where cells actively start to divide. Root initials are then formed, followed by root primordia. During the final stage, root primordia elongate through the stem and penetrate through the periderm. The key factor in ARF is the capability to dedifferentiate and form root primordia. It is this capability to form primordia that separates difficult vs. easy-to-root plants (2). Once primordia are formed they can exert tremendous pressure in penetrating through the stem. Only in carnation has a layer of fibers been shown to retard root elongation.

Rooting studies in mature and juvenile *Ficus pumila*. A study was done comparing ARF between juvenile and mature *Ficus pumila* (Table 1). The key difference between juvenile and mature materials was that juvenile cuttings formed roots more rapidly. However, once primordia were formed, there was a comparable time period between the elongation phase of primordia in both juvenile and mature material (7 vs. 8 days) to the point where 100% rooting occurred, indicating that it is in the early stages of rooting, that genetic capability, not the elongation of primordia that is most critical (Table 1). In growth regulator studies, 1000 mg/liter IBA-K gave optimal rooting for the juvenile and 3000 mg/liter gave optimal rooting for mature *Ficus pumila* cuttings (1). There is a 2 to 3x increase in the amount of auxin needed to get a comparable rooting response with the mature material, and even then ARF occurs much more rapidly with juvenile material. Most likely the mature form does not have as much auxin or there may be some chemical breakdown of auxin occurring more rapidly compared with juvenile material.

Table 1. Time of adventitious root formation in juvenile and mature leaf-bud cuttings of *Ficus pumila* L. treated with IBA.

	Juvenile	Mature
Anticlinal cell divisions of ray parenchyma	day 4	day 6
Primoridia	day 6	day 10
First rooting[a]	day 7	day 20
Maximum rooting[b]	day 14	day 28

[a] Based on 25% or more cuttings with roots protruding from stem.
[b] Based on 100% rooting and maximum root number.

Auxin, other factors, competent cells. Auxin is certainly a factor. However, we know that not all plants respond to auxin, such as difficult-to-root plants. Auxin may not be the sole limiting factor determining why plants do not root. Most likely there are other chemical factors that limit rooting. Forestry researchers use the term "competent cells." Competent cells have the genetic capability to form adventitious roots. These may include phloem ray parenchyma cells or callus cells that undergo successful cell division and dedifferentiation. For successful rooting, then, there are a number of factors such as competent cells, auxins, carbohydrates, substrates for energy reactions, and cell wall formation. There are also chemical complexes. Rooting co-factors are phenolic compounds that act synergistically with auxin to enhance ARF. It is now thought that rooting co-factors form complexes with auxins and certain enzymes to enhance the rooting process.

Seasonal effects, plant age, and rooting. Seasonal effects on stock plants is another factor in comparing easy and difficult-to-root material. Increased rooting during peak seasonal periods is associated with increased cambial activity. In juvenile *Ficus pumila* the controls show a seasonal response; and when auxin is applied, the seasonal response is overcome (3). With mature, difficult-to-root *Ficus*, rooting occurs with controls only during the months of April and May, and rooting percentage is low. When auxin is applied, rooting is enhanced in the mature material, but the seasonal response is not overcome, and the winter months have much lower rooting compared to spring.

Shoot RNA and rooting. How does the shoot system influence the rooting process? Shoot RNA is part of the genetic material of a plant involved in producing proteins that act as enzymes and serve as catalysts for driving chemical reactions.

We wanted to study how shoot RNA might be involved in the rooting process. During periods of low rooting there were very low levels of shoot RNA produced (Table 2). During periods of high rooting there are much higher levels of RNA produced. Somehow, shoot RNA is involved with the rooting process. Comparing easy vs. difficult-to-root material, the juvenile has greater RNA activity than mature material.

Table 2. Relationship between shoot RNA and adventitious root formation in *Ficus pumila* cuttings.

Plant Age	Rooting Level[x]	RNA
Juvenile	High	0.801
Mature	High	0.647
Juvenile	Low	0.631
Mature	Low	0.478

[x]Shoot apicies were harvested from stock plants during high rooting months of March, April, and May and during low rooting months of November and January.

Can we fool Mother Nature? So the question comes up — can we fool Mother Nature? To a degree we can. One way is by rejuvenation, which is a key factor in the concept of manipulating a plant's physiological condition to enhance rooting. Rejuvenation is commercially done by etiolation, mounding, stooling, hedging-back. During etiolation of a stock plant, part of the plant is grown in the absence of light, which causes certain chemical and morphological changes to occur. There are commonalities between etiolation and juvenility, such as less structural tissue formed by fibers and sclereids. There are higher auxin and rooting co-factor levels. A current theory is that with reduced fiber and sclereid formation, there is less lignin formed. Consequently there may be more available metabolites for forming rooting co-factors.

Mounding and stooling are used with the Malling clonal apple understock series, with pecans, and with certain other difficult-to-root material (6). In Peru they have been able to produce clonal pecan understock by girdling and then mounding and stooling stock plants (6).

In pines and other difficult-to-root species, Hare's rooting powder, containing auxins, rooting co-factors, sugar, growth retardants and fungicides, has been developed for use in pines and other difficult-to-root species. Hare's powder is used with woody plant material that is initially girdled and air-layered before removing the cutting. A low percentage of *Quercus virginiana* propagules have been rooted using this technique.

Serial cuttage. Serial cutting propagation is another rejuvenation technique. Cuttings are initially taken from a difficult-to-root plant. Only a small percentage will root. Those cuttings that do root are then grown on as stock plants in a greenhouse under optimal nutritional, water, and light regimes to encourage vegetative growth. Cuttings are then taken from these new greenhouse-grown rooted stock plants. Morgan (7) has had some success with *Quercus virginiana* using this technique.

Tissue culture. Another rejuvenation technique, which probably has the greatest commercial potential, is tissue culture (4, 5). With tissue culture we can take an explant from a mature, difficult-to-root species, manipulate the explant and subsequently rejuvenate mature material during the tissue culture phase to make it much more responsive to rooting techniques. The potential of working with mature material and successfully tissue culturing it is unlimited (4).

LITERATURE CITED

1. Davies, F. T. and J. N. Joiner. 1980. Growth regulator effects on adventitious root formation in leaf bud cuttings of juvenile and mature *Ficus pumila*. *J. Amer. Soc. Hort. Sci.* 105:91-95.
2. Davies, F. T., J. E. Lazarte, and J. N. Joiner. 1982. Initiation and development of roots in juvenile and mature leaf bud cuttings of *Ficus pumila* L. *Amer. J. Botany* 69:804-811.
3. Davies, F. T., Jr. 1982. Seasonal influence on shoot RNA in difficult vs. easy-to-regenerate plants. Beltsville Symposium VII. Genetic Engineering: Applications to Agriculture. Beltsville, Maryland pp. 9.
4. Lazarte, J. E. 1981. Woody tissue culture research. *Proc. Inter. Plant Prop. Soc.* 31:649-655.
5. Lyrene, P. M. 1981. Juvenility and production of fast growing cuttings from blueberry shoot cultures. *J. Amer. Soc. Hort. Sci. 106: 396-398.*
6. Medina, J. P. 1981: Studies on clonal propagation on pecans at Ica, Peru. *Plant Prop.* 27:10-11.
7. Morgan, D. L., E. L. McWilliams, W. C. Parr. 1980. Maintaining juvenility in live oak. *HortScience* 15:493-494.