ROOTING AND GRAFTING IN A FOREST TREE IMPROVEMENT PROGRAM

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In a program of tree improvement involving the breeding and selection of superior specimens, various techniques are necessary for success. Among these is the technique of asexual propagation of selected trees principa11y by rooting and grafting. Progeny resulting from asexual propagation are extremely valuable in tree improvement work since, unlike seed or sexually developed progeny, these will be identical in genetical makeup to the source or "parent" tree. If our techniques are successful we then can have, theoretically, ten, a hundred, or even ten thousand genetically alike trees all derived from one parent tree.

Propagation by rooting or grafting is in a sense a tool which simplifies and hastens the work of the tree geneticist. Using these techniques he can, by establishing arboreta, concentrate numerous strains of various tree species into a comparatively small area. Here he then can intensively and with little lost time aid effort conduct highly profitable breeding studies.

Rooting

Rooting or cuttage, as it is sometimes called, is one method of propagating asexually strains of forest trees. Basically it is a simple technique involving merely tire planting of short stem or root sections in a medium such as sand, peat moss, water, or even just soil. After a period of 2 or 3 weeks to even 12 months roots may develop at the base of the cutting, giving rise to a tree genetically alike to the original. Many of you, no doubt, have at one time or another placed stem sections of willow in a glass of water in the early spring. Before long, flowers appeared and then a week or so later, roots began to form along the basal ends immersed in the water. This is a very supple example of rooting. Generally, however, propagation of forest tree species by root or stem cuttings is a bit more difficult.

The natural rooting ability, of a tree is dependent upon two main factors. First, and probably most important, is the species. Some, such as those belonging to the genera Salix and Populus root very easily and quickly. Others, including many hardwoods and some conifers, root moderately well. The most difficult, however, are the coniferous species and particularly those of the genus Pinus. There will also be considerable variation among individuals within a species regardless of age or condition.

Secondly, the age of the tree mill determine to a large extent how well cuttings from it may strike roots. Material from seedlings, on the whole, roots readily even from some difficult species of pine using little or no preplanting treatment. However, as cuttings are taken from older and older individuals the percentage to strike roots sharply

decreases until an age is reached at which it is extremely difficult to obtain a satisfactory number of successful cuttings. This is a serious limiting factor when we consider rooting for use in a tree improvement program in which, more often than not, trees approaching maturity are the subjects for asexual propagation.

It has been suggested by several investigators that age itself is not the determining factor but rather the proximity of the cutting material to the root system. Larsen, in his work with aspen and gray poplar in Denmark, found that stem cuttings taken from shoots developed from root cuttings gave 80 to 100 percent rooting in about 2 weeks. The age of the parent trees seemed to have no effect upon the ease of rooting.

Stoutemeyer, O'Rourke, and Steiner found that stem cuttings taken from the upper portions of honey locust trees rooted with difficulty except in the case of very young seedlings. They found, however, that cuttings from shoots grown from root cuttings or from shoots arising as stump sprouts rooted with ease.

As another example, Toole, working with the mimosa tree found that stem cuttings taken from shoots produced by rooted root pieces gave a considerably higher rooting percentage than did stem cuttings taken from shoots developed by rooted stem pieces.

These results strongly suggest, then, that the closer the stem cutting to the parent root the greater will its ability to root be. The belief is that one or more root-promoting substances are synthesized or are accumulated in the root system and are present in decreasing amounts in stem material the further removed it is from this source.

At this point I would like to discuss briefly how roots originate on a cutting. Those roots that develop on a stem or root cutting are commonly considered as being adventitious roots. Normally, in the formation of a lateral root the root pericycle is the point of origin. The cells of this tissue become meristematic to produce the young root. However, roots generally encountered in the propagation of cuttings are considered adventitious in that they do not arise from the root pericycle. Two types of roots are involved. Roots which develop from callus tissue as at the base of a cutting are regarded as "wound roots". As the callus develops with its own vascular tissue, wound roots may develop from the continuation of the cambium into this region. The second type is that developed from the so-called "root germ" located in the pericycle or, in older material, in the secondary phloem. Root germs are often located in the area of the node although in some genera, such as Salix and Populus, they may be between nodes.

Next, I would like to consider the part played by hormones or auxins in the rooting of cuttings. It has been known for some time that root inducing substances are produced by developing buds and young leaves in the presence of light and are subsequently translocated downward. Softwood cuttings will root much more readily if one or two leaves are left attached. Horticulturists emphasize that a cutting

should have at least two buds or nodes, one for the region of rooting and one for the top shoot. It is believed that one or more growth substances are required for root formation. Several synthetic compounds have been discovered which will promote root development. Most common among these are indole-acetic acid, indole-butyric acid and napthalene acetic acid. Cuttings can be treated by immersing their bases into very weak solutions of these substances for several hours before planting. Commercially, these auxins are mixed with talc in powder form for practical usage. On the whole, use of these auxins has greatly aided in the rooting of cuttings, especially of formerly difficult material and when used on material that roots readily without treatment rooting is faster with much better root development. Often, however, application of an auxin does not seem to have any beneficial effect.

In addition to auxin treatments, several investigators have used solutions of plant nutrients, sugars, and vitamin B_1 but results have been inconclusive for any practical application. It is generally agreed, however, that an accumulation of plant foods in the cutting, particularly in its base, will aid in root formation and development. The girdling of shoots to be used as cutting material of various fruit and ornamental trees has been found to greatly improve their rooting abili ty. The shoots are girdled with a knife or with a tight band of wire during the growing season and after several months severed aid planted. I tried this method with sapling shortleaf pine. A fine wire was looped around the base of the current shoot in late August and tightened, cutting through to the wood. The wire was left in place. The following January the girdled twigs were severed for planting. By this time their bases had swollen to almost twice the diameter of the stem immediately below the girdle. All were treated with a comm ercial auxin powder, and planted in coarse sand with bottom heat. However, none rooted although callusing was very good.

Mirov, in California, has had considerable success in rooting numerous pine species. However, he finds that age of the parent tree is a major factor. He has obtained a high percentage of rooting when cuttings from comparatively young trees are used. He believes time of year, physiological condition of the shoots, temperature of the rooting medium, and the relation between the temperature of the atmosphere and that of the rooting medium as the prime factors in the rooting of pine cuttings. He considers a proper combination of these conditions far more important than the action alone of some root inducing auxin such as indole-butyric acid.

Doran, in Massachusetts, took cuttings from a 30 year-old white pine in late winter handling separately those from the upper and those from the lower crown. Both lots were treated with various concentrations of indole-butyric acid solution as well as with a solution of sucrose. He obtained the highest percentage of rooting, 70 percent, with the cuttings from the lower one third of the crown which had been treated with a fairly strong solution of indole-butyric acid. Untreated cuttings from either the upper or lower third of toe crown failed to root. Throughout the experiment cuttings from the lower third rooted much better than did those, from the upper third of the crown. Those treated with sucrose appeared to root somewhat better than those lacking this treatment. At any rate, sucrose treated cuttings lived longer, rooted or not.

Other investigators, especially in Europe, appear to agree with Doran that pine cuttings from the lower crown root better than those from the upper crown. Lateral and slow growing shoots are to be preferred to terminal and succulent material. It is interesting to note that in grafting the opposite holds true, better results being obtained when fast growing shoots from the upper crown are used.

Dorman, here in the Southeast, has done considerable work on the rooting of southern pines, particularly slash and longleaf. He has used about 270 chemical treatments under several different environments both in the nursery and in the greenhouse. Cutting material was collected in the spring, summer, and winter. He obtained about 30 percent rooting although some individual trees yielded as high as 56 percent His results also show the importance of age. Cuttings from young trees rooted well without any treatment and gave almost 100 percent rooting with treatment. The oldest tree used was 28 years of age. October and early November appeared to be the best time for the collection of cuttings. Use of auxins aided rooting but their value was not fully established, When mineral nutrients, vitamin B_1, and sucrose were added to the treatment solution survival and possibly rooting was increased with summer cuttings. He feels, however, that further study should be given to this phase of the problem. Various combinations of environmentwere tried but no definite conclusions were reached as to which was best. He believes that the effects of environment are great and that much more work is needed along this line.

I have made several large scale attempts at rooting shortleaf pine in connection with the littleleaf disease of this species but without success. Various treatments arid combinations of environment have been tried using trees 10 years of age and older. Another experiment was begun in August of last year. Three trees about 30 years of age were selected in the vicinity of Athens, Georgia to provide cutting material. Every 3 weeks 25 cuttings are taken from the lower crown of each tree, treated with a commercial auxin powder, and planted in a sand-peat moss medium with bottom heat. In addition, 25 cuttings are taken from randomly selected 2 to 4 year-old seedlings located along roads and in clearings. This experiment will continue for at least, one year with the primary purpose of determining the best time for collecting shortleaf pine cuttings in that area.

Let us now briefly summarize what is generally known regarding the rooting of cuttings from forest trees. First, the ease with which a tree will root will depend considerably upon the species. And also individuals within a species will differ in this character. When we desire to propagate older material, as in a tree improvement program, age of the tree becomes a highly important factor. A young tree roots readily but this ability is quickly lost as the tree gets older. Of course, we do not know whether or not age is only an indirect effect controlling the proximity of the shoots to the root system. As shown in several previous examples the closer the shoots to the parent root system the better the rooting of these shoots. Other evidence to support this theory comes from those who find that cutting material taken from the lower crown of a tree will root much better than that from the upper

crown. The physiological condition of the cutting as reflected in the time chosen for collection is another important factor. Indications are that fall to early winter may be best. However, the specific time will vary from year to year and from area to area. Highly important but as yet somewhat vague are the environmental conditions under which cuttings should be rooted. And, finally, use of root inducing substances appears to be beneficial in the rooting of cuttings. And some evidence indicates that the use of nutrient solutions, sucrose, and vitamin B1 as a preplanting treatment may be of value.

Grafting

Now we shall consider the second method of asexual propagation applicable to forest trees - grafting, including budding. This technique differs from rooting in that the resultant tree will be a composite of two trees, or consisting of a scion and a stock. The stock may be a seedling or an older tree onto which the scion is grafted. The scion may be any part of another tree such as a shoot or twig, a bud, a patch of bark, or even a section of root. Then, it is by means of the scion that we multiply a specimen; the stock merely serves as its base or as its root system.

Many different methods of grafting can be used such as the cleft, the bottle approach, budding, the side, and the whip graft. Actually, they are merely variations of joining the scion to the stock. The basic principle of grafting is the growing or fusing together of the cambium of the stock with that of the scion and then the development of continuous xylem and phloem from stock to scion so that eventually the two parts function as one.

As in the case of rooting, the ability of a tree to graft easily depends largely on the species. Most hardwoods are not difficult to propagate in this manner. Some conifers such as arborvitae, juniper, and cypress also graft fairly well. Pines, however, are somewhat more difficult. Again, as in rooting, individual trees within a species will vary greatly in how well they graft.

Fortunately, age does not appear to be a dominant factor in the grafting of trees. Often fairly old trees will graft as easily as seedlings although more commonly younger trees will graft somewhat better. Age is important only in that it influences the vigor of the material. Often this effect can largely be overcome by fertilizing a year or two prior to grafting. When shoots are employed as scions the more vigorous ones graft best and hence terminals and those from the upper crown are more suitable. The cambial activity, then, of the scion and stock will determine to a large degree whether or not a graft will be successful. For this reason grafting is generally done In late winter in the greenhouse, or in early spring in the field when the first flush of growth occurs.

I should now like to cite a few examples of grafting of pines. In the west, Mirov has done much of the successful work with this species. He was able even to intergraft several species such as Pinus albicaulis or Pinus ponderosa, Pinus lambertiana on Pinus radiata, and Pinus torreyana on P. ponderosa. He concluded that apparently there will be

no difficulties in intergrafting all the species of Pinus. He used the common types of grafts such as the cleft, the side, and the approach graft as well as an unusual type for pine -- budding.

In this latter method he removed a needle bundle from the scion tree along with a shield of bark and cambium about 3/4" long and about 1/2" wide. He next inserted the shield into a slit made on the stem of the stock seedling, tied the graft and covered the whole with a bell jar for one month. Later when union was assured the jar was removed and the stock plant gradually pruned back to force development of the dormant bud within the needle bundle. He pointed out the advantage of this method in propagating particularly desirable seedling trees. While they might give only 2 or 3 cuttings or grafting twigs they would provide several dozen needle bundles.

In Wisconsin, Riker working with white pines selected for blister rust resistance has had considerable success in grafting this species. His method was to place potted 2 year-old transplants in a warm greenhouse in early January with continuous light for a period of 48 hours. When new growth began to appear on these stock trees twigs were collected from the select trees in the field and the grafts made.

Here in the South, Jackson, investigating the possibility that a virus might be involved as the causal agent of the littleleaf disease of shortleaf pine made a large number of successful grafts. He obtained a fair degree of success with such grafts as the stem and root approach. A very high percentage of union was obtained with bark patch grafts whereby a small shield of bark and cambium was taken from the stem of one tree and grafted onto the stem of another. However, none of these particular types of grafts are applicable to breeding work which require the formation of a separate and distinct tree such as can be made with a cleft or side graft using twig material.

Later, on the same project, I made a number of successful cleft grafts using this species by utilizing sprouts developed from 5 year-old seedling stumps as stock material. Scion twigs were taken from both healthy and littleleaf trees ranging in age from 27 to 42 years. The purpose of this experiment was to determine whether the exuded resin between the cut surfaces of the stock and scion hindered fusion by the formation of a "pitch barrier". Three treatments were applied to both the stock and scion stems to hold back or remove the resin from the cut surfaces until the graft was securely tied. The results showed that the untreated or control group was most successful with 25 percent of the grafts making union. Apparently the treatments used to remove the resin destroyed the exposed tissue hindering fusion. The scion trees showed a great difference in grafting ability irrespective of age or apparent vigor. Six such trees were used, 3 vigorous healthy specimens and 3 littleleaf trees exhibiting poor shoot growth, yellowed and short needles. Two of the healthy and one of the littleleaf trees failed to produce a single successful graft. One healthy scion tree gave 23 percent, while one littleleaf tree gave 23 percent and another, 34 years-old gave 43 percent success.

F. C. Galle, in cooperative work with the Tennessee Valley Authority in Tennessee has been very successful in grafting pines. His method is to pot stock seedlings during the fall and winter and place them in a cool section of the greenhouse for about 30 days or until root growth is resumed at which time they are grafted. The graft used is a modified side graft. The newly grafted trees are then placed into a bed of moist peat moss in a propagating box with bottom heat. The box is kept closed for about 30 days after which it is gradually opened and the stock pruned back. The grafted trees are then planted out during the spring.

In addition, the Tennessee Valley authority has many grafting projects underway at its nursery at Norris, Tennessee. White pine, loblolly and shortleaf pine, and red cedar have been grafted with a high degree of success. Grafted white pines only one foot in height have many female flowers, the scions having come from large trees. Also improved varieties of Chinese chestnut and black walnut have been grafted for use as nut trees.

I might also mention an example of the grafting work being done in Europe. Larsen, in Denmark, tells in correspondence of the successful grafting of pine both in the greenhouse and in the field. He uses 4 to 5 year-old potted seedling stock and emphasizes that they must be in perfect condition to be used for grafting. The scion material is collected in late winter when yet dormant and stored in a cool cellar until early spring when the stock trees have begun growth. The grafts are then made. He points out that the scion material must not be as advanced in development as the stock when the graft is made. He reports that he has obtained 70 to 90 percent success in the greenhouse and about 65 percent in the field.

Rooting or Grafting -- which to use?

Having now discussed both techniques of asexual propagation useable in a forest tree improvement program we may well ask which shall we use. Is rooting a more practical method or is grafting? Actually, I believe, both techniques have their place in a program such as this. I shall, therefore, as a conclusion to this paper on rooting and grafting discuss the major advantages and disadvantages of each.

Rooting is often advantageous when cost is considered. Assuming equal success, this method will be less expensive than grafting since basically it is a simple technique. However, when grafting is more feasible and successful, as with older material, we may find the cost of rooting comparatively high and that of grafting low. Similarily, differences among species as to their rooting and grafting ability will influence the unit cost.

Rooting will be a more practical form of vegetative propagation for many species, particularly when young trees are involved. Some species, however, will be better suited for grafting at any age.

I believe the greatest advantage of grafting lies in the fact that age of the parent tree is not a vital factor. Most past and current work strongly suggests that the ability of a tree to graft easily is not dependent directly upon the age of the specimen. Rather, as previously pointed out, this ability depends more upon the vigor of the scion tree at the time of grafting. A relatively old tree will generally be too low in vigor for suitable grafting but it can be re juvenated considerably by proper applications of fertilizers one or two years prior to grafting. In fact, if necessary, the tree can even be supplied with water. On the other hand, it has been repeatedly demonstrated that the rooting capability of a tree decreases sharply with age. Young trees of many species, as eastern white pine for example, root readily when under 10 years of age. Beyond that point, however, rooting becomes more and more difficult and eventually almost impossible.

Another advantage of grafting may lie in the early flowering character of material propagated in this manner. Reports seem to indicate that grafted trees will produce flowers and fruit in a shorter period than will trees developed from cuttings.

Cuttings often develop one-sided or unbalanced root systems so when planted in the field they may eventually be highly susceptible to windthrow. However, this condition can often be prevented by better preplanting treatment of the cutting to stimulate more abundant and uniform root development.

It is sometimes impossible to successfully outplant rooted cuttings taken from exotic or distantly located :Material because of different soil conditions. By grafting this material on local stock we can, however, overcome this difficulty. Such a problem might easily arise in developing an arboretum for both native and exotic species.

When it is desirable that the propagated tree be genetically alike to the parent both in the roots and in the top then the use of rooting is a necessity. Also, it has been found that in grafting the stock may adversely affect the above ground portions. In some instances dwarfing of the top may result due possibly to incompatibility between stock and scion.

Thus, we find that both rooting and grafting have their advantages and disadvantages when used for propagation in a tree improvement program. Which method to use, however, for a specific propagation problem will depend upon the purpose in mind and many factors local in character. It is possible that the disadvantage of age as regards rooting may be overcome somewhat by combining this technique with grafting. If age itself is not the determining factor in the rooting of cuttings, as some work suggests, but rather the proximity of the prospective cutting material to the parent root system, it may then be possible to first make a few grafts and after one or two years root cuttings from these grafted trees. In this manner we might obtain successful rooting even though the original parent tree were quite old. This would be especially useful when many progeny would be required.

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