vember when the leaves drop. The cuttings are then packaged in a sausage roll. We cut plastic into strips and put sphagnum moss on it and roll the cuttings up in it We have a package that can be easily taken out in the spring and planted. The cold storage is kept at 28 to 30°F over winter We have found that late planting, the first or second week of May, produces more growth than early planting.

MICHAEL DIRR· How do you handle double breaks and does it hinder growing a straight trunk?

JOERG LEISS: In our case the terminal breaks are flowers, so we end up with the shoots from the second node. We normally do what we do when we graft — just knock one break back. Growing a straight tree is the easiest thing.

PROPAGATION OF SOUTHERN PINES BY CUTTINGS

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For the past 30 years, forestry in the southeastern United States has been devoted to genetic improvement of pine trees (21). Major interest in tree improvement has concerned loblolly pine (*Pinus taeda* L.) though longleaf (*Pinus palustris* Mill.), slash (*Pinus elliottii* Engelm. var. *elliottii*) and shortleaf (*Pinus echinata* Mill.) pines are also important. Straightness of bole, branching characteristics and large volume are a few of the traits being examined. Improvement of these desired traits has been through the process of sexual propagation; that is, through controlled breeding to produce improved progeny for successive generations (15). Recently, there has been an increased effort among research foresters to capture these desired traits through asexual propagation by rooting. Since pines in general are difficult to root (18), obstacles have been encountered.

Asexual propagation by rooting allows for a greater recovery of the genetic potential of a tree more quickly than through sexual propagation. As a result of this advantage, research in the area of improving the rootability of the southern pines is being pursued. Grigsby (5) was the first to report rooting success with loblolly pine, but he could not successfully repeat his results. Subsequent research has revealed that quantity of mist, use of fungicides, adjustment of hormone concentrations in rooting powders and girdling prior to remov-

al of cuttings from the ortet were important for attaining repeatable rooting success (4,6,8,9,16,20) Important factors in rooting southern pines (specifically loblolly pine) to be discussed in this report include age of ortet from which the cuttings are obtained, time of year of rooting, environment during rooting, pretreatment of the branch to be cut and cuttings prior to sticking, and treatment of the cuttings during rooting.

Age of ortet. The age of the ortet from which the cutting is obtained is extremely important. In other conifers such as *Tsuga diversifolia*, *Abies concolor* (water controls only), *Pinus strobus* and *Pinus radiata* (10,12,18), it has been observed that rooting declines as the age of the ortet increases. Results (unpublished) within International Paper Company demonstrated similar trends in southern pines Cuttings from one- to two-year-old ortets had rooting percentages from 60-80. They exhibited vigorous root systems averaging three or more main roots per rooted cutting. After three years of age, rooting percentages declined to 30-50 percent of cuttings along with the quality of the root system. Usually 1-3 main roots occurred per rooted cutting.

Time of Year. Seasonal variation in rooting southern pine has been investigated but discrepancies exist. Reines and Bamping (14) showed that optimal rooting of slash and loblolly pine occurred from September through January. They suggested that carbohydrate levels during that period play an important role in the rooting process. In work reported by Bower and van Buijtenen (1), cuttings collected in May from both greenhouse- and field-grown ortets rooted best. Work at International Paper Company has shown optimal rooting of cuttings to occur from early October through early February. Cuttings stuck earlier than October or later than February will receive daytime temperatures that can be detrimental. With the exception of the results of Bower and van Buijtenen (1), cuttings stuck during the dormant season have rooted best.

Although rooting appears to be more successful during the winter months, a problem can occur with growth of the propagules produced during this time. Cuttings rooted during the winter months and receiving and 18-20 h photoperiod will undergo an out-of-phase dormancy change when placed in natural day lengths the following spring (3). This induced quiescence is unavoidable, and it can affect subsequent growth and development for a year or more following outplanting.

Environment. Environment is another very important parameter affecting rooting. A chamber to maintain high humidity conditions around the cuttings was developed by Hare (8) and later modified by van Buijtenen (20) These chambers are

equipped with nozzles to provide the cuttings with a fine intermittent mist at fairly precise intervals.

Mist quantity and distribution within the rooting bed affects cutting survival and rootability (4). The following formula has been developed to calibrate mist fall where volume = volume collected in a circular cylinder in milliliters, $\pi = 3.14$, r^2 = the square of the radius of the container, and time = mist collection time in minutes:

$$\text{millimeters/hour} = \frac{600 \bullet \text{volume}}{\pi r^2 \bullet \text{time}}$$

When mist fall is quantified using the above formula and correlated with rooting, optimum rooting has been obtained with a mist precipitation rate around 0.1mm/hour. This quantity is very close to that reported by Grigsby (5).

Other environmental parameters are important to the rooting process and are listed in Table 1. Supplemental CO_2 and extended photoperiod have not been determined as essential, and further work should be pursued to establish their effect on rooting.

Table 1. Summary of techniques for successful rooting of southern pines

Environment	1	Mist chamber — polyvinyl, roof not essential, sides may be essential
	2	CO_2 supplement — 1500-2000 ppm
	3	Intermittent mist — 0 1mm/hour
	4	Medium — 1 1 perlite-vermiculite
	5	Bottom heat — 80°F.
	6	Air temperature — maintain as close as possible to 80°F day and 62°F night
	7	Supplemental light — incandescent light used to extend natural day length to 18-20 hours
Age of Ortet	1	Young material roots better than old material, cuttings from ortets 0-3 years old root around 60%, cuttings from greater than or equal to 4-year-old ortets root around 35%.
Pretreatment Before Sticking	1	Hedging — used to increase cutting material and possibly slow down maturation
	2	Girdling ortet — two months before collecting
	3	Cytokinins — increase axillary bud induction
	4	Hare's rooting powder before sticking
	5	Rooting is optimum from October 1 through February 1 — further work needed
Treatment During Rooting*	1	Hoagland's nutrient solution — every other day until foliar run-off
	2	$AgNO_3$ — 250ppm biweekly

*Rooting time is around 3-4 months

Pretreatments. There are several mechanical as well as chemical pretreatments that can be applied to improve rooting.

In slash pine, Hare (9) showed that girdling in mid-summer can significantly improve rooting from cuttings obtained that fall; however, throughout the season girdled cuttings always rooted better than non-girdled cuttings. It may be that the *effect of girdling on rooting is similar to the cause for seasonal* rooting observed by Reines and Bamping (14); that is, both effects result from increased carbohydrates in the stem.

Hare (8) developed a pretreatment rooting powder that significantly influenced subsequent pine rooting behavior. The ingredients in the powder consist of two forms of auxin, a fungicide, an anti-gibberellin, and sucrose. The influence of the components of Hare's powder on growth of resulting rooted cuttings has not yet been tested. Also, the exact combination of ingredients causing improved rooting has not been fully tested. Greenwood *et al.* (4) found that cuttings from trees more than four years old rooted better with one-half strength formulation of Hare's powder. Thielges and Hoitink (16) observed in eastern white pine an increase in rooting by the use of fungicides alone.

Hedging, another pretreatment technique, has been suggested to improve rooting by arresting or slowing down maturation (10,13). This could be an essential technique for genetic improvement of pine through asexual propagation. Many timber-growing companies now seek to make selections of superior trees at age 5 in order to speed up the genetic improvement process. After the selections are made, scion material from these selections are grafted into specially designated clone banks. If hedging begins on this grafted material immediately after banking, maturation should be slowed down or arrested with stabilized rooting percentages. Despite the appeal that hedging may have, it has not been fully established whether maturation is actually affected by hedging in southern pines. Regardless of whether or not hedging is affected, hedging is a reasonable practice from the standpoint of accessibility of cuttings.

Hedging can also be used as an ortet pretreatment to induce outgrowth of axillary buds in the base of each needle fascicle bundle. This process can produce virtually unlimited cutting material from a single genotype. Besides hedging, foliar sprays of cytokinins and other plant growth regulators have been effective in inducing axillary bud outgrowth (2,7,11,19).

Treatment during rooting. There are several treatments which improve cutting survival during rooting. One treatment is the use of nutrient amendments. For southern pines, Hoagland's solution in the concentration shown in Table 2 is a widely used nutrient amendment.

Another useful treatment to maintain sanitary conditions in the bed is silver nitrate (4). When 250 ppm silver nitrate is used biweekly, it can be effective in reducing large algal accumulation However, when mist is adjusted properly, algal growth should not be a serious problem.

Table 2 Hoagland's solution for vegetative propagation of southern pine by cuttings

Macronutrients	in 4 liters
$Ca(NO_3)_2 \cdot 4\ H_2O$	2 35 grams
KNO_3	1 01 grams
$MgSO_4 \cdot 7\ H_2O$	0 99 grams
KH_2PO_4	0 27 grams
NH_4Cl	0 54 grams
Micronutrients[1]	4ml of stock solution
Iron chelate[2]	4ml of stock solution
[1] Micronutrient Stock Solution	grams per 1 liter
H_3BO_3	2 86
$MnCl_2 \cdot 4\ H_2O$ (manganous chloride)	1 81
$ZnSO_4 \cdot 7\ H_2O$ (zinc sulfate)	0 22
$CuSO_4 \cdot 5\ H_2O$ (cupric sulfate)	0 08
$H_2MoO_4 \cdot H_2O$ (molybdic acid)	0 02
[2] Iron Chelate Stock Stolution	
Sequestrene 330 Fe	13 0

CONCLUSIONS

With the increased effort to improve southern pine genetics and to reforest with this improved stock, vegetative propagation by means of rooted cuttings is attractive. Since rooting percentages are low, further work to increase rootability is needed. With the information provided here, one should have the basic techniques to obtain rooting percentages of 30-50 from cuttings of southern pine trees greater than three years old. Since the rooting response of southern pine is slow (requiring two to three months) compared with more easily rooted plant species, the need exists for more careful environmental control than is common with many plant cultivars of horticultural interest.

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CAMERON SMITH: Could you explain Hare's rooting powder?

THOMAS MARINO: IBA at 1% is the auxin. The powder also contains PPZ, Algar 85 as an anti-gibberellin; sucrose and captan 10W as the fungicide. If you want the formula I will send it to you.

BILL SNYDER: Are the roots on one side or distributed around the cutting?

THOMAS MARINO: It is variable The older the cutting the more prone the roots are to be on one side.

BRUCE BRIGGS. Did you remove any of the needles when you put the cuttings in? Did you do a leaching experiment for 12-24 hours? In Japan they have obtained a good rooting response with some pines after leaching

THOMAS MARINO: We left the needles intact and, no, we have not tried leaching.

PROPAGATION AND PRODUCTION OF *RHUS TYPHINA* 'LACINIATA', CUTLEAF STAGHORN SUMAC

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The cutleaf staghorn sumac is a very hardy form with bright green leaves, deeply cut foliage and good fall coloration. It is sometimes referred to as fern leafed sumac.

The propagation and growing of this attractive plant is not a very common practice in midwestern nurseries. This creates a good demand and we are always sold out before our season is over. There are only a few nurseries who grow it.

The procedures described are our own methods and derived from a trial and error procedure over a period of more than ten years. We have found it to be a somewhat difficult and inconsistent subject but by using large numbers and being persistent, we have always had a crop of plants for sale.

Growing conditions. It is one deciduous item we can grow and produce to saleable sizes in one season's growth. Our growing season in Southern Minnesota is normally about 115 days with precipitation averages of nearly 30 inches per year.

Our soils are a silt-loam type and very moisture retentive We do not irrigate them or use any herbicide or chemical fertilizers during the growth period. We try to apply cattle manure to our nursery about every other year.

We harvest this crop in early November when they are completely dormant They are taken to the root cellar and stored until we can grade them, usually in December. The plants will grade out into four sizes, from 9-12 inches to 3-4 foot.