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Propagation of Eucalyptus Nursery Seedlings

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The very small size of eucalyptus seed, along with accompanying contaminants, makes them difficult to handle and stratify. A simple method of stratifying and propagating eucalyptus from seed is described and illustrated. Tree Planters' Notes 37(2):3-7; 1986.

Most eucalyptus nursery stock in the United States is produced as container seedlings. Although Hunt (2) has reported some comparative trials between bareroot and container outplanted seedlings, most commercial and public agency nurseries use some form of container.

The seeds of all species of eucalyptus are very small and generally mixed with the chaff from the inside of the seed capsule (figure 1). It is difficult to separate the seed from chaff because of their similar sizes and weights. This creates problems in using any kind of seeding equipment to discharge 1, 2, or 3 seeds per container opening or at a predetermined spacing in a nursery bed. Thus, common practice is to broadcast seed in trays, then pick out the small germinates and transplant them into containers. These are then grown for one season before being planted out in the field.

Another problem involves the need for moist stratification of some seeds, not only for some species but also for some provenances of a single species. Doran and Gunn (1) reported that seed of *Euc. glaucescens Maid. & Blakeley.* (Tingiringi gum) from the Mt. Tingiringi provenance requires no stratification.

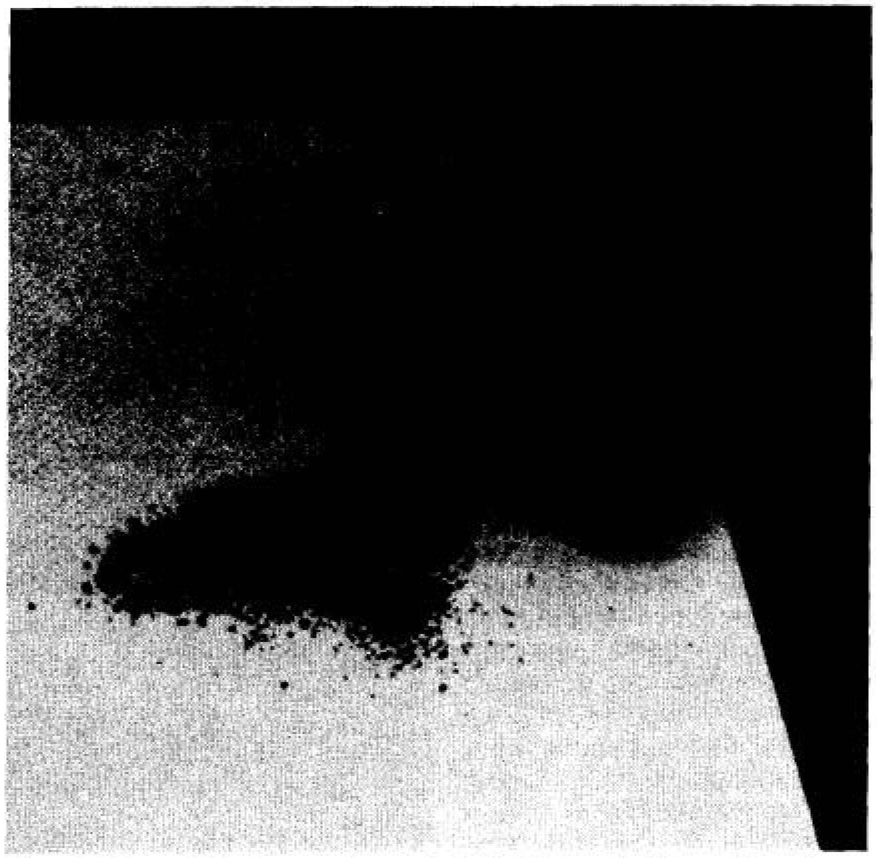

Figure 1—*The small* Eucalyptus urnigera *seed mixed with the trash of the seed capsule.*

Germination rate and number of seedlings for the Tinderry Range provenance are significantly increased by a 14-day cold moist stratification. Seed from the Guthega, Mt. Erica, and Mt. St. Gwinear provenances of this species need a pretreatment cold moist stratification of 42 days. This influence of cold on germination is of particular interest to those attempting to grow eucalyptus in areas of considerable winter frosts. Doran and Gunn report that *E. glaucescens* is one of the most cold tolerant of the eucalyptus.

Attempts to give eucalyptus seed the usual stratification by soaking them in water, then refrigerating them, results in a gooey mess that is almost impossible to handle. It was due to this situation that an alternate procedure was developed.

Methods of Stratification and Seeding

Because of the very rapid growth of both roots and tops of seedlings, we use Tinus Rootrainer book-type containers. We use a commercial potting medium (W. F. Grace Company forestry mix).

The Tinus containers are arranged in boxes and filled with the forestry mix. A small pinch of eucalyptus seed is placed in each book cell opening (figure 2), then dusted with 5 percent captan and covered lightly with the potting mix and quartz ("chicken grit," No. 2) rock (figure 3). These boxes of seeded containers are then set outside in the open midwinter (December through January) and allowed to stratify naturally (figure 4). The mean minimum temperature during these 2 months in our southwest Oregon region averages 34 °F or slightly below. Seed begin to germinate by mid-April to May first (figure 5). Seedlings can be grown for 1 year before being planted out in the field (figures 6 and 7).

There are numerous species of eucalyptus that require no stratification. However, there is a dearth of information on specific requirements for seed from various provenances. Thus, all species that have been used in our screening program for cold tolerance have been treated in the above manner. No definitive data are given on germination because there is no simple,

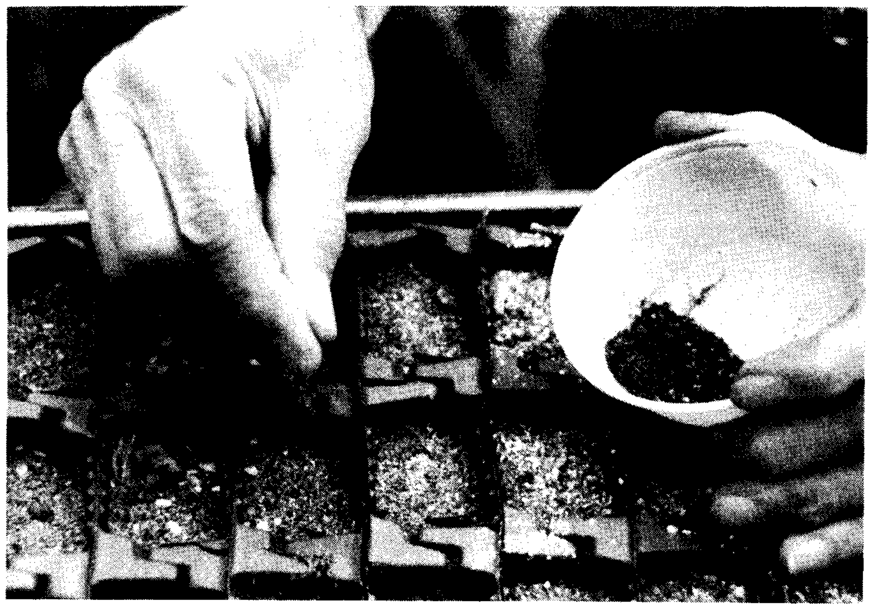

Figure 2—*Placing a small pinch of seed into the opening of Tinus Rootrainer plastic containers.*

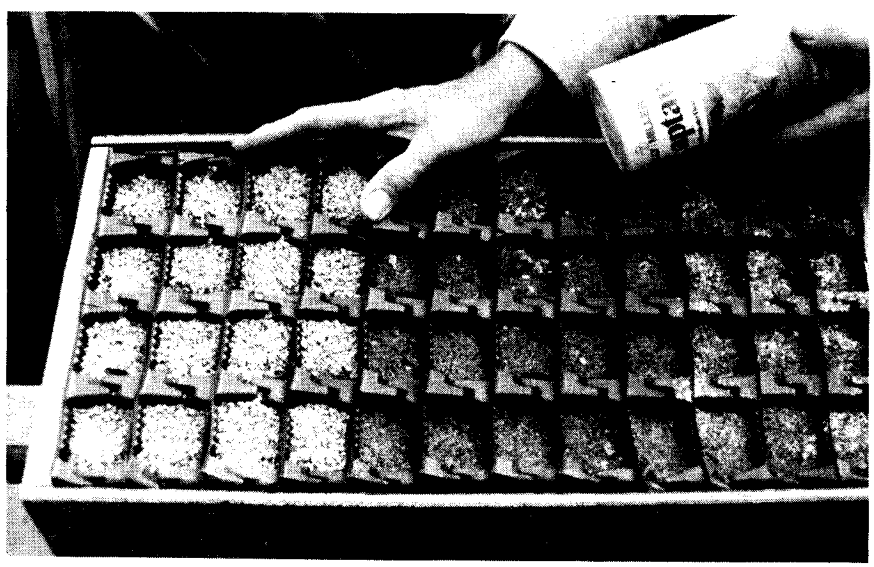

Figure 3—*Dusting seed with 5 percent captan prior to covering with potting mix and "chicken grit." Containers on the left show the "chicken grit"—No. 2 quartz rock—used to protect the seed.*

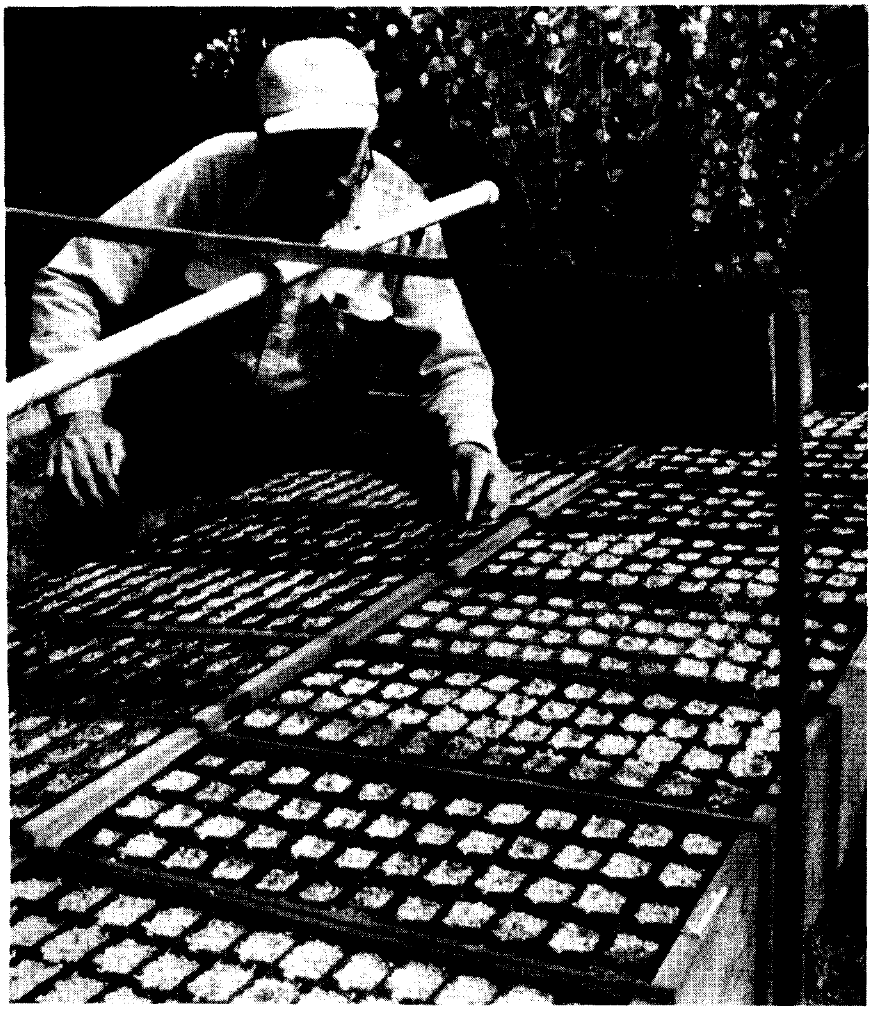

Figure 4—*Boxes of seeded containers set outside for natural stratification and germination.*

economic way to count the number of seeds placed in each container opening. The seed and chaff particles in some species are so similar as to be largely indistinguishable. Excess seedlings in container openings are plucked out. Transplanting some of them into vacant openings has been only partially successful.

Areas with subtropical or at least more moderate winter temperatures could use the same procedure. Seed can be watered and stored in the containers in boxes or trays and placed in a cold storage room at 32 to 38 °F for the required stratification period.

Advantages of this simple procedure include 1) only dry materials are handled, 2) no second handling of the seed in the stratification process is needed, and 3) the germinates do not need to be transplanted from trays to containers. Some two dozen species of eucalyptus have been grown successfully with the procedure during the past decade of our screening trials for cold tolerance.

Figure 5—*Emerging seedling in late April.*

Figure 6—*Opened-up book of Tinus container showing rooting ball of 1-year-old seedlings.*

Figure 7—*One-year-old seedlings of Urnigera gum* (Eucalyptus urnigera) *in specially made nursery boxes.*

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A Practical Method for Production of Paulownia tomentosa[1]

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A practical method for producing Paulownia tomentosa *planting stock in the nursery is presented. The maximum mean seedling height (85 centimeters) was obtained from seedlings thinned to 20 per square meter, and the maximum root collar diameter (1.6 centimeters) was obtained from seedlings thinned to 10 per square meter. Unthinned beds yielded 200 to 300 seedlings per square meter with an overall mean height of 37 centimeters and a mean root collar diameter of 0.4 centimeter.* Tree Planters' Notes 37(2):8-11; 1986.

Expectations of significant returns from exports of Paulownia tomentosa logs cut from naturalized trees have spurred interest in its cultivation. Experimentation and planting trials were initiated in the 1970's by several private entrepreneurs as well as researchers at the University of Kentucky to determine the suitability of paulownia as a highvalue species for surface mine reforestation (3,7). As paulownia exports increased, the potential of planting specifically for timber production gained widespread publicity (6). During this time researchers worked at developing techniques for storing and germinating seed, seedling production, and outplanting (1,4). Unfortunately most of the successful methods developed for producing planting stock incorporated greenhouses or other facilities not normally available for widespread use. The utilization of artificial environments raised the cost of seedlings far above the costs of most other tree species ($0.55 per seedling). These costly methods were used because many of our normal nursery practices led to total failures or at best sporadic successes when applied to paulownia. To date, even nursery practices developed specifically for paulownia have proved less than adequate (1). Because of these failures, it became increasingly apparent that new tactics were needed if a successful means of producing low-cost paulownia planting stock was to be established.

In 1981 a study was initiated to determine a practical method of producing various types of paulownia planting stock. The study was undertaken with the premise that the methods and equipment utilized would allow not only tree nurseries but many landowners to produce their own planting stock. The search for a successful procedure meeting the above criteria led to the incorporation of a technique commonly used by tobacco farmers in the southeastern United States. Tobacco seed are very small, as are paulownia seed, and many of the same problems are encountered in nursery bed production of both species. A summary of successful procedures derived from this study is given below. Specific study methods and results will also be discussed.

Procedures

The procedures outlined here are general guidelines for nursery bed production of paulownia planting stock. Individual situations may necessitate minor changes or additions to these procedures; however, the techniques employed for germinating the seed should produce adequate results over a wide geographical range.

Nursery beds should be located in areas with good drainage. Maintenance of sandy or heavy loam soil is imperative, for the young plants are susceptible to waterlogging. A minimum soil porosity of 50 percent, with a noncapillary porosity of at least 10 percent is recommended (8). Soil pH should be maintained between 5 and 8. Avoid locating beds in frost pockets. Early autumn frosts can injure the succulent foliage of this plant, and extreme winter cold can lead to root collar wounding and rootstock mortality.

The beds should be cultivated in early spring and covered with clear plastic (4 mil). Methyl bromide should be applied to kill unwanted seeds, nematodes, and fungi harbored in the soil. After the danger of frost has passed, the plastic can be removed and fungicide (such as

[1] The research reported in this paper was supported by the McIntire-Stennis Cooperative Forest Research Program. The paper is publication 85-8-107 of the Kentucky Agricultural Experiment Station.

[2] The author thanks Bert Marshall for his assistance in caring for the plant beds.

captan 50 W) incorporated to a depth of 10 to 15 centimeters. The beds should be raked to produce a relatively smooth surface. Fertilizer should also be applied at this time. Detailed fertilizer requirements are not known for *Paulownia tomentosa*; however, the need for certain micronutrients has been expressed by several workers. The following fertilizer regime proved successful under our soil and climatic conditions: a slow-release NPK fertilizer such as Osmocote (14-14-14) at 400 grams per square meter, a slow-release micronutrient additive such as Micromax at 80 grams per square meter, and gypsum and dolomite at 200 grams per square meter each. A single fertilizer application should be sufficient for the entire growing season and should not produce any significant problems with the dormant or germinating seeds. After the beds are moistened, seeding can be undertaken at a rate of approximately 0.2 gram per square meter. Scattering the seed can best be accomplished by hand on a windless day.

Maintenance of a moist environment during germination and initial seedling development is one of the most important steps for ensuring successful germination and establishment. Desiccation for even short periods can be fatal during the early development of the radicle. Desiccation of radicles has been observed between irrigations during afternoons when temperatures were high and relative humidities were low. The small seeds on the soil surface are able to support only one attempt at radicle emersion, making the microenvironment surrounding the seed critical. A soil amendment, mulch, or a covering over the bed is necessary to maintain an adequate moisture regime. Trials with soil amendment or mulch have led to sporadic results. This is due to movement of the mulch, amendment, and/or seed by wind or by the direct impact of water from precipitation and irrigation.

Maintenance of the proper environment, while avoiding the problems mentioned above, can be accomplished by covering the nursery bed with a spunbonded polyester or nylon canvas, commonly known as a "tobacco plant bed cover" (figure 1). This covering suspended above the bed allows light, which is necessary for paulownia seed germination, to filter through while alleviating the adverse effects of water and wind. The covering disperses the incoming water droplets, allowing only a fine mist to reach the soil surface and provides a warm, moist, and undisturbed environment at the soil surface (figure 1). This type of covering is used extensively in the United States for growing tobacco transplants. Light-weight cotton or cheesecloth could also be used, but the synthetic material is much less expensive and readily avail-

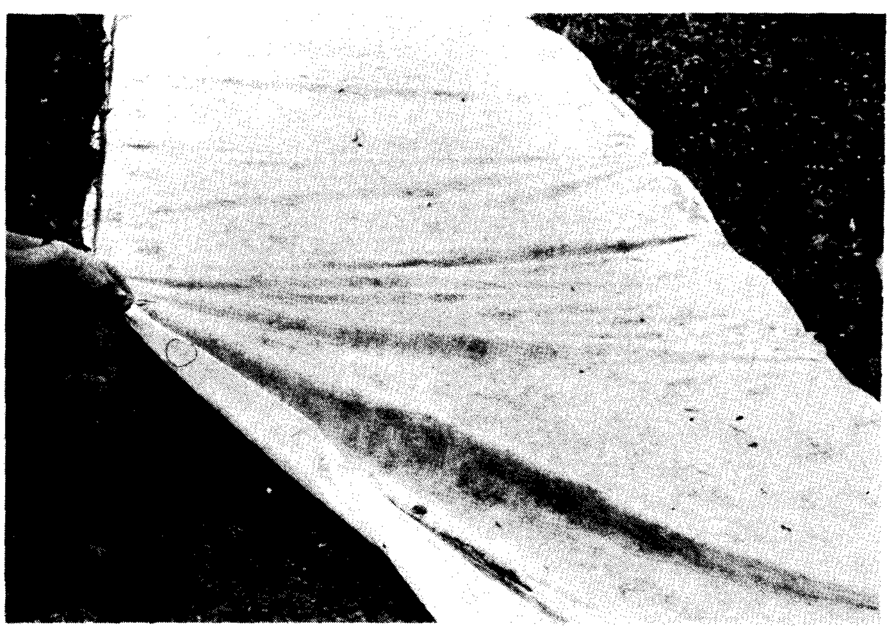

Figure 1—*Paulownia plant bed with tobacco plant cover suspended above the soil surface. Seedlings are less than 1 centimeter high.*

able. The covering can be suspended over the soil surface by a series of arched wires placed along the center line of the bed, by attaching it to a wooden frame surrounding the plant bed, or by a very small amount of straw spread over the soil. If the covering is allowed to contact the soil the plants will grow through the cover and it will not be possible to remove the cover without damaging the seedlings. The covering can be removed when the seedlings average 4 to 8 centimeters in height.

Seedling density is important in producing good planting stock. Thinning should be completed when plants average 20 centimeters in height. Postponing the thinning leads to small spindly plants. Thinning is necessary for proper development, but the specific level depends upon the type of planting stock being produced. Thinning is best accomplished by hand, leaving the most vigorous seedlings intact. Thinning levels will be discussed in a later section.

Overhead irrigation can be used to ensure maintenance of a moist seed bed. Overwatering, however, can quickly lead to seedling decline. Irrigation should be reduced in September. Normally, either entire root systems or root cuttings should be used as planting stock. The use of bareroot seedlings is not recommended. Leaves should be allowed to abscise prior to pruning the main stem at the groundline. Rootstocks should overwinter in the beds, covered with 5 cm of a mulch such as sawdust. Mulch is necessary when ground temperatures are expected to fall below 0 °C. The rootstocks can be outplanted in the spring or allowed to grow a second year in the nursery bed or moved to a transplant bed to produce 2-0 or 1-1 planting stock, respectively. A good review of handling procedures for paulownia planting stock is given by Kundt (S).

Study Methods

The 1.2- by 15.2-meter beds were elevated 20 centimeters above groundline and were composed of equal parts sand, topsoil, and sawdust. In mid-April the beds were covered with 4-mil-thick plastic and treated with methyl bromide (two 1-pound cans of Brom-O-Gas). One week later the plastic was removed. Fertilizer and seed were then scattered over the bed as described in the procedures section. A supplemental fungicide treatment was not applied in 1981. However, captan 50 W was incorporated to a depth of 10 to 15 centimeters in 1982. The seeding rate of 0.2 grams per square meter equaled approximately one-half cup for the 1.2- by 15.2-meter bed. In 1981 three-quarters of the bed was covered with a spunbonded polyester canvas suspended approximately 2 to 10 centimeters above the bed surface, and the remainder left uncovered. Overhead irrigation was necessarily increased on the uncovered portion of the bed.

In 1982 four thinning treatments were applied when mean seedling height was 20 centimeters. Various portions of the bed were hand thinned, leaving 10, 20, and 100 seedlings per square meter, and an unthinned control. Total height and root collar diameters were measured at the end of the growing season.

Results and Discussion

1981. The seeds in the uncovered portion of the bed failed to germinate or were desiccated after germination even though they were irrigated daily. The direct impact of water droplets from both precipitation and irrigation allowed much of the seed to be washed into concentrated areas or buried by the shifting soil. Seed burial resulted in reduced germination by decreasing the level of light reaching the seeds to below that necessary for germination.

The covered portion of the bed produced approximately 300 plants per square meter with a mean height of 30 centimeters. However, over the course of the growing season, the seedlings stagnated and portions of the bed exhibited dieback. Pathological investigation identified a root decay fungus (*Rhizoctonia* sp.) and an anthracnose fungus (*Colletotrichum* sp.). Therefore, the initial methyl bromide treatment was supplemented with captan 50 W in 1982 to provide continued protection against fungal invasion.

1982. The thinned seedlings had increased height and root collar diameters compared with the unthinned seedlings (table 1). The unthinned treatment yielded approximately 200 seedlings per square meter with a mean height of 37 centimeters and a mean root collar diameter of 0.4 centimeter. There was no dieback in the unthinned treatment as in 1981, possibly due to the increased protection afforded by captan 50 W. Root collar diameters and observed root sizes were inversely related to seedling density. Between the thinned treatments, diameters ranged from 0.5 centimeter (100 per square meter) to 1.6 centimeters (10 per square centimeter). Average height ranged from 85 to 61 centimeters for the 20 and 100 seedlings per square meter treatments. The 20 seedlings per square meter treatment also produced the smallest range (10 centimeters) in seedling height.

The thinning level selected depends upon the type of planting stock required. A thinning level with a high residual density can be employed if 1-0 or 1-1 seedlings or rootstocks are to be outplanted. However, if 2-0 stock is being produced, one of the heavier thinning levels should be utilized. Subsequent thinnings may also be necessary if 2-0 stock is being produced. Regardless of the planting stock being produced, tops of seedlings should be pruned at groundline for outplanting as well as for increasing winter survival.

Table 1—*Response of* Paulownia tomentosa *to various thinning levels*

	$10/m^2$	$20/m^2$	$100/m^2$	Unthinned
Mean height (cm)	76	85	61	37
Range height (cm)	63–92	81–91	52–65	21–63
Root collar diameter (cm)	1.6	1.1	0.5	0.4

Conclusions

Although establishing *Paulownia* plantations is still a popular idea, past planting failures have caused many to become disillusioned with the species. As with any new species, it will take time to successfully determine all the techniques necessary for plantation culture. However, the procedures outlined in this article should help to rectify some of the problems normally encountered during seed germination and planting stock production. Beckjord (2) has compiled further information on plantation culture; however, it must be realized that the cultivation of paulownia is a recent phenomenon in the United States and only long-term results will determine the effectiveness of our current recommendations.

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Improved Handtools for Site Preparation

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Manual site preparation will continue to play an important role in reforestation efforts in the years ahead. New, more efficient handtools are now available that can make this labor-intensive, expensive task more cost effective. Tree Planters' Notes 37(2):12-14; 1986.

Hand scalping for site preparation before planting trees is a common practice in reforestation. Hand scalping is labor intensive and expensive, but it is well suited for steep slopes. Production rates are usually low, but workers are able to select the most favorable microsites for the tree seedlings.

Our contacts with land managers indicate that hand scalping will continue and may even increase as timber harvesting moves to steeper sites that make mechanical site preparation more difficult or impossible.

Because hand scalping will continue to play an important role in reforestation efforts in the foreseeable future, Forest Service Timber Management asked the Missoula Equipment Development Center (MEDC) to undertake a search for more efficient and effective handtools that would help reduce hand scalping costs.

Initial investigation uncovered a unique handtool that had been developed by Gordon Reinhart, a Forest Service fire management officer on the Umatilla National Forest in Pendleton, OR. This tool, known as the Reinhart grubbing tool, was developed initially for fireline construction but is also used for scalping. A tool that can quickly and efficiently scrape away vegetation to mineral soil to build fireline is also a good tool for site preparation. Reinhart's grubbing tool was constructed using afire shovel and reversing a shortened blade and replacing the shovel handle with an adze handle (figure 1).

Joe Bruzda, a former Forest Service employee, redesigned the Reinhart grubbing tool and began manufacturing his version under the name Fyr-Tamer (figure 2).

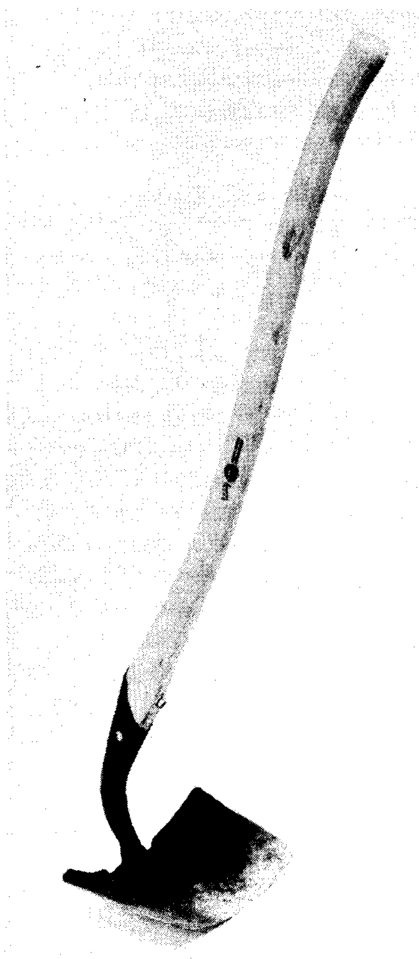

Figure 1—*Reinhart grubbing tool.*

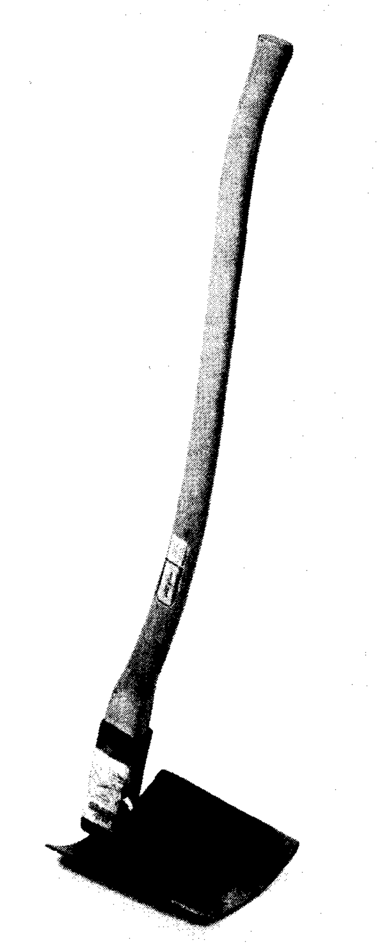

Figure 2—*Fyr-Tamer.*

To determine how scalping tools like the Reinhart grubbing tool and the Fyr-Tamer compared to conventional tools for site preparation and fireline construction, MEDC conducted two evaluations.

In the first, the Reinhart, Fyr-Tamer, and a tool built by MEDC called the modified Reinhart (figure 3) were sent to Forest Service planting crews on ranger districts in four western regions for evalua-

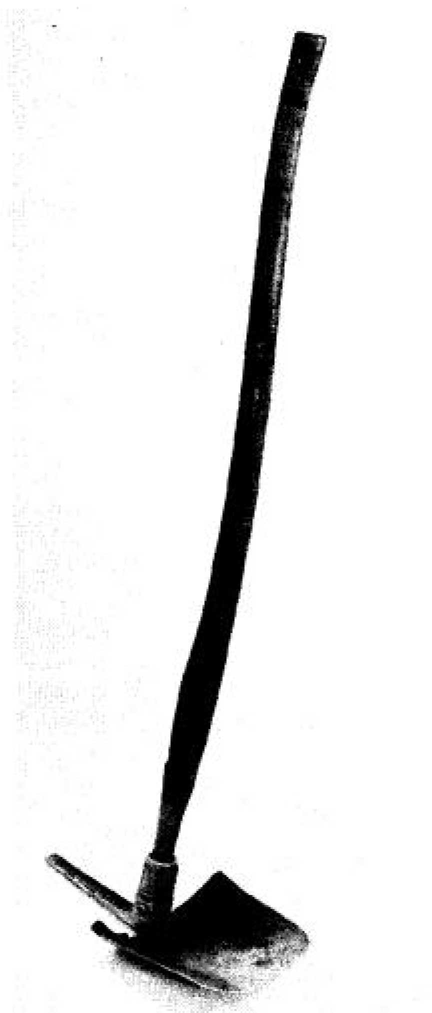

Figure 3—Modified Reinhart grubbing tool.

Figure 4—Combination tool.

tion. The Reinhart was modified by using an entrenching toolhead with a number 0 shovel blade welded to it and replacing the handle with an adze hoe handle.

Responses to all the tools were favorable. Most crew members preferred these tools to those they had been using. Increases in production of up to 30 percent were reported.

In the second evaluation, Center personnel compared these three new tools with the adze hoe, Pulaski, super Pulaski, and McLeod for performance and human energy cost efficiency. The results indicated that the Reinhart, modified Reinhart, and Fyr-Tamer are as efficient or more so than these conventional tools for digging fireline.

The evaluation further suggested that although the three new tools were efficient, they did not represent the optimum design possible. Field users had identified some deficiencies in the tools. As a result, MEDC designed a "combination" tool (figure 4) that corrected these shortcomings with a longer handle and a blade that had a more modified curve to increase efficiency and production.

A followup field evaluation of this "combi" tool indicated it is much closer to an optimum design for a scalping tool. The Center worked with a toolmaker to refine the design for actual production. Manufacturing specifications were written and 300 "combi" tools were produced for fireline construction evaluations during the

1985 fire season. This tool should be available from the General Services Administration by the spring of 1986 for under $30.

Construction drawings for the Reinhart grubbing tool and the modified Reinhart tool may be obtained from the Center (request drawing number MEDC-674). The Fyr-Tamer is available from Fyr-Tamer Distributing, 30144 East Woodward Rd., Troutdale, OR 97060; (503) 695-4778.

For land managers faced with replanting steep sites, these new handtools represent a more efficient, cost-effective means for site preparation.

Effect of Various Nutrient Regimes and Ectomycorrhizal Inoculations on Field Survival and Growth of Ponderosa Pine (*Pinus ponderosa* var. *scopulorum* Engelm.) Container Seedlings in Arizona[1]

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Pinus ponderosa *var*. scopulorum *Engelm. container seedlings raised under four nutrient and three mycorrhizal inoculation treatments survived well in the field. Trees inoculated with forest duff survived better than noninoculated seedlings. Generally, seedlings raised under high nitrogen regimes had greater growth.* Tree Planters' Notes 37(3):15-19; 1986.

In the Southwest--Arizona, New Mexico, and southwestern Colorado--reestablishment of Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm.) is difficult because precipitation is erratic during critical periods of the year. Nursery stock can be planted successfully when proper procedures are followed (6,14). Initial growth of planted seedlings, especially bareroot stock, is very slow (5). Seedlings that grow slowly are subject to predation by a host of biotic agents, primarily browsing mammals and insects. Hastening juvenile growth reduces the time trees are susceptible to damaging agents.

Inoculating the roots of many tree species with mycorrhizal fungi has improved survival and growth, especially when the symbionts are ecologically adapted to the site (9). In North Dakota, Riffle and Tinus (13) found that survival, stem diameter, current height increment, and biomass of ponderosa pine seedlings were increased, after 2 and 3 years, for seedlings inoculated with pine duff, *Rhizopogon roseolus* (Corda) Hollos, or *Suillus granulatus* (L.: Fries) O. Kuntze.

Trees require mycorrhizae to absorb adequate water and nutrients, especially phosphorus (7,8,10,11). Greater absorption is likely due to a larger surface area of the roots resulting from the formation of the fungal mantle and from mycelia that emanate from the mantle and permeate the soil. In addition, mycorrhizal roots remain functioning for longer periods of time, whereas uninfected roots are ephemeral (1).

Root to shoot ratios have long been considered an important factor in determining initial survival of planted ponderosa pine. Cornett (3) has shown that root to shoot ratios (ovendry weight basis) are inversely related to amounts of foliar N, P, and K applied. Thus, if a formula for producing seedlings with short, compact tops and well-developed mycorrhizal root systems could be found, survival and growth in the field should be improved. This field study tested the survival and growth of containerized seedlings raised under four nutrient regimes and inoculated with forest duff or *Pisolithus tinctorius* (Pers.) Coker & Couch (Pt).

Methods

Seedlings. Ponderosa pine container seedlings were raised in the Bureau of Indian Affairs' greenhouse at McNary, AZ, following general guidelines from Tinus and McDonald (15).[2] Trees were raised in Tinus Rootrainers (492 cubic centimeters) manufactured by Spencer-Lemaire, Ltd., Canada. Seedling substrate consisted of equal parts of peat moss and vermiculite inoculated with forest duff, Pt, or no inoculum (3). Duff was collected from an 85-year-old ponderosa pine stand in central Arizona on a 6- to 8-percent slope with a southwest aspect. Recent litterfall layers were discarded, then humus layers (down to mineral soil) were collected. The material was prepared as inoculum by passing it through a 1.3-centimeter screen. All inocula were mixed with the substrate immediately prior to filling and seeding containers at a rate of 8 percent duff by volume.

Basidiospores of Pt were collected in 1979 from a dry site in Jackson County, OR, at an elevation of approximately 600 meters. The spores were stored dry at a temperature of 2 to 4 °C until used as inoculum. At that time, 100 milligrams of Pt spores was suspended in a 2-liter solution of distilled

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[1] The research reported here was conducted at the Rocky Mountain Forest and Range Experiment Station's research work unit at Flagstaff in cooperation with Northern Arizona University.

[2] Seedlings were raised by Cornett as part of a Ph.D. research project at the University of Arizona, Tucson. However, this study was not a part of the dissertation.

water to which 0.75 milliliter of the surfactant Tween 80 was added. The mixture was then returned to cold storage. Spores were applied at a rate equivalent to 0.1 milligram per 0.09 square meter of exposed substrate when the containers were filled. This was done by mixing the appropriate amount of suspension in several liters of water, then pouring it over vermiculite. The treated vermiculite was then mixed well with the rest of the substrate and the containers were filled (3).

Seedlings were watered with Peters soluble fertilizer (15-30-15) applied as a foliar spray three times a week for 6 weeks and two times a week for 5 weeks. Fertilizer treatments were calculated to supply 30, 45, 60, and 75 parts per million (ppm) nitrogen. Peters' Stem (containing S, B, Cu, Fe, Mn, Mo, and Zn) was added in equal amounts to each of the four treatment solutions along with equal amounts of iron chelate (sodium ferric diethylenetriamine pentacetate, 10 percent by weight). Fertilization was begun 4 weeks after seed were sown.

Root to shoot ratios and mycorrhizal infection rates at the end of the greenhouse experiment are listed in table 1. After the greenhouse experiments (3), 240 of the seedlings were planted on the Fort Valley Experimental Forest, approximately 24 kilometers northwest of Flagstaff, AZ.

Site. The study site is on level terrain at an elevation of approximately 2,225 meters. Soils are silt loams derived from basalt parent material. Most of the mature ponderosa pine overstory had been removed in the 1960's. Tree cover now consists of pole-sized ponderosa pine originating in 1919. Ground cover is primarily Arizona fescue (*Festuca arizonica* Vasey) and mountain muhly (*Muhlenbergia montana* (Nutt.) Hitchc.).

In 1976, grass openings were sprayed with a mixture of dalapon (6.63 kilograms active ingredient (ai) per hectare) and atrazine 80-W (5.6 kilograms ai per hectare) before bareroot seedlings were planted. The planting was a failure because of poor quality nursery stock. In 1982, a small opening about 15 meters by 15 meters, still free of live grass, was selected for this study.

The study consists of four randomized blocks, each with 12 rows of five trees. Each row was randomly selected for planting with seedlings raised under one of the regimes (combination of nutrient and inoculation treatment) shown in table 2.

Trees were planted with planting bars at a spacing of 0.9 meter by 0.9 meter at the end of July 1982. There was a space of 0.9 meter between blocks. After planting, mesh plastic seedling protectors were placed around each tree and secured with two wire pins.

Measurements. Seedling survival was recorded periodically in 1982 and 1983 with the following notation: 1 = alive-growing, 2 = alive-not growing, and 3 = dead. Seedling heights were measured in the spring of 1983 before growth began and in the fall after growth ceased.

Table 1—*Root to shoot ratios and extent of mycorrhizal infection for container ponderosa pine seedlings raised in the greenhouse under various nitrogen supplementation regimes and inoculation treatments*[1]

Treatment	Root/shoot ratio (ovendry weight) (g/g)	Mycorrhizal infections (percent short roots infected)
N supplementation		
30 ppm	0.916 a	40 a
45 ppm	.926 a	26 b
60 ppm	.770 a	20 b
75 ppm	.758 b	22 b
Inoculation		
Control (none)	.725 a	14 a
Duff	.741 a	16 a
Pt	.707 a	16 a

[1]Means with the same letter in common are not significantly different (P = 0.05) as determined by analysis of variance. Differences in means determined by Student-Newman-Keuls multiple range test.

Table 2—*Effect of greenhouse N supplementation and inoculation on growth characteristics and survival of ponderosa pine outplanted in Arizona*

Greenhouse treatment[1]	Total height[2] (cm)	Height growth[2] (cm)	Survival[3] (%)
30 ppm N			
Control	15.5 bc	5.8 d	90 a
Duff	16.5 d	5.2 cd	95 a
Pt	12.9 a	3.3 b	95 a
45 ppm N			
Control	14.6 b	4.4 c	90 a
Duff	17.5 de	5.1 cd	100 a
Pt	15.8 cd	3.1 a	80 a
60 ppm N			
Control	19.2 e	6.1 d	85 a
Duff	15.0 b	3.2 ab	100 a
Pt	15.8 bcd	5.7 d	95 a
75 ppm N			
Control	15.4 bcd	6.0 d	85 a
Duff	18.0 e	5.2 cd	95 a
Pt	19.5 e	5.5 cd	90 a
Mean	16.3	4.9	92

[1]Pt = *Pisolithus tinctorius*.
[2]Treatments followed by the same letter are not significantly different (P = 0.10) as determined by analysis of variance (LSD = 0.05).
[3]Treatments with the same letter in common are not significantly different as determined by Chi square.

Table 3—*Field survival rates of ponderosa pine container seedlings averaged by greenhouse treatments*[1]

Treatment[2]	Survival (%)
N supplementation	
30 ppm	93 a
45 ppm	90 a
60 ppm	93 a
75 ppm	90 a
Inoculation	
Control	88 a
Pt	90 ab
Duff	98 b

[1]Treatment values with the same letter in common are not significantly different (P = 0.1) as determined by Chi square.
[2]Pt = *Pisolithus tinctorius*.

Because of interaction between nutrients and inoculation treatments, and heterogeneous variance among the treatment combinations, total height and height growth for the 12 treatment combinations were analyzed by randomized block analysis of variance, followed by heterogeneous variance LSD pairwise multiple comparisons when a significant overall F test of treatment differences was first observed (2). Survival was analyzed with Chi square techniques.

Results and Discussion

In spite of the fact that seedlings were enclosed by protectors, 28 percent of the trees were browsed by elk (*Cervus elaphus*), which knocked the protectors over. Nevertheless, overall survival (92 percent after one and a half growing seasons) was excellent (table 2). Individual treatment means did not differ significantly (table 2); however, results averaged across nutrient levels showed that seedlings inoculated with forest duff survived significantly better than noninoculated trees (table 3).

Even though significant treatment effects were observed for both total height and height growth (P = 0.05), the interaction of nutrient level and inoculation treatment clouds the analysis of individual effects of added nutrients and inoculation. Generally speaking, height growth was greatest under high N regimes (table 2), although noninoculated seedlings exhibit high growth rates for the lowest N level. Seedlings inoculated with Pt exhibited less growth for the two lowest N levels than for the two highest levels. Seedlings inoculated with duff grew equally at all but 60 ppm N. Patterns of total height response were similar except that total height of noninoculated seedlings was high only at 60 ppm N.

Root to shoot ratios of the seedlings used in this study were inversely related to N application rates but not to mycorrhizal fungi. A similar finding for ponderosa pine inoculated with Pt was reported by Trappe (16). However, results from this experiment tend to minimize the importance of root to shoot ratios as a factor in the establishment of ponderosa pine container seedlings in the Southwest. Seedlings raised under the lowest N regime had a root to shoot ratio, before planting, of 0.916 but did not survive better than seedlings raised under the highest regime, which had the lowest root to shoot ratio (0.758). A similar conclusion was reached by Racey et al. (12), who found top length, stem diameter, top volume, and root volume to be better indicators of nursery stock quality and potential growth performance than top to root ratios for red pine (*Pinus resinosa*) bareroot seedlings. Tinus and Ronco[3] found little correlation between root to shoot ratios of container seedlings and field survival in Arizona and New Mexico.

Root to shoot ratios and mycorrhizae may be more important in improving survival under conditions more adverse than those in this study. During the first year after these seedlings were planted, more than 635 millimeters of precipitation fell on the study site. Almost 102 millimeters of rain fell in the first month after planting. Normal precipitation for the year in this area is about 559 millimeters.

In the same area, Cornett (4) found that significantly more of the ponderosa pine container seedlings inoculated with *Suillus granulatus* survived than did controls during an abnormally dry year.

Although in this experiment there was not a strong effect on survival rates by inoculation treatments, there is an indication that survival is improved by inoculation with forest duff, presumably because of the presence of native mycorrhizal fungi. Growth of seedlings was not improved by inoculation treatments.

[3] Unpublished data on file, Rocky Mountain Forest and Range Experiment Station, Flagstaff, AZ 86001.

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Tree Planter's Notes, Volume 37, No. 2 (1986)

Raspberry *(Rubus idaeus* L.) Competition Effects on Balsam Fir *(Abies balsamea* (L.) Mill.) Seedlings in Northern Maine[1]

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The effects of competition from raspberries on the growth and nutrient quality of the foliage of balsam fir seedlings were evaluated. Seedlings overtopped by raspberries were smaller than open-grown seedlings. Root collar diameters averaged 5.5 and 8.2 millimeters in the overtopped and open-grown seedlings, respectively. Foliar analysis revealed higher P (0.18 versus 0.16 percent) and lower K (0.59 versus 0.80 percent) concentrations in the open-grown seedlings than in the overtopped seedlings. Nutrient proportions in both groups of seedlings deviated from proposed optimum levels. The foliar analyses indicated K deficiencies in the open-grown seedlings and possible luxury consumption of Ca in both groups. Tree Planters' Notes 37(2):20-23; 1986.

Clearcutting is common in the spruce-fir stands of northern Maine. A dense cover of raspberries frequently becomes established following clearcutting, and can suppress small spruce and fir seedlings (2, 6). This may increase the time required for these stands to reach merchantable size.

Foliar analysis is often used to evaluate the nutritional status of forest trees (22). Critical levels have been established for the essential elements in many species (15). However, examination of individual nutrient concentrations alone is inadequate to characterize the nutrient status of a tree. Maximum growth occurs only when the proper ratio among nutrients occurs in combination with optimum concentrations (20). Work with black spruce (*Picea Mariana* (Mill.) B.S.P.), white spruce (*P. glauca* (Moench) Voss), and Scotch pine (*Pinus sylvestris* L.) has led to the proposal of an optimum nutrient proportion (expressed as a weight relation to nitrogen) of: N = 100, P = 13, K = 65, Ca = 6, Mg = 8.5, S = 9, and Fe = 0.7 (8-10, 22, 23).

In this study, foliar analysis and growth data were used to investigate the impacts of raspberry competition on the growth and elemental composition of balsam fir seedlings.

Materials and Methods

This study was conducted in township T5R12, located between Chesuncook Lake and Baxter State Park at 46° N. and 69° W. in northern Maine. The climate in this region is continental. Total annual precipitation averages 92 centimeters, with snow falling between November and March (4). Soils of the Telos (coarse-loamy, mixed, frigid Aquic Haplorthod) and Monarda (coarse-loamy, mixed, nonacid, frigid Aeric Haplaquept) series were characteristic of the study area.

The uncut stands in the area were approximately 60 years old and originated following the spruce budworm outbreak of 1913-19 (19). Red spruce (*Picea rubens* Sarg.) and balsam fir were the principle components. Scattered eastern white pine (*Pinus strobus* L.), paper birch (*Betula papyrifera* Marsh.), and black spruce also were found. The stands were fully stocked, with the overstory basal area averaging about 28 square meters per hectare. Abundant advanced spruce and fir regeneration existed in the understory.

Five adjacent clearcut strips were located in 1979. The strips had been harvested with mechanical feller-bunchers during the winter of 1974-75. The strips were approximately 30 meters wide, oriented northeast-southwest, and were separated by strips of uncut timber 45 to 60 meters wide.

Two groups of 10 balsam fir seedlings were selected in each clearcut strip in October 1979. Half the seedlings were overtopped by raspberries, whereas the remainder were free to grow.

The total height and the root collar diameter of each seedling were measured. Seedlings were then severed at the root collar, and seedling age was determined by

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counting the annual rings. The current year's foliage was collected from each seedling and put together with the foliage from all other seedlings within each group.

These composite foliage samples were dried at 70 °C and ground in a Wiley mill to pass a 0.84-millimeter screen. Nitrogen was determined by a micro-Kjeldahl procedure (14). Phosphorus was determined by the vanadomolybdate-HNO_3 procedure following dry ashing at 500 °C (5). Ten milliliters of 0.33 M magnesium acetate was added to the ground sample and evaporated prior to dry ashing to prevent volatilization of P. Cations were determined following dry ashing at 550 °C. Calcium and magnesium were determined by atomic absorption, and potassium was determined by flame emission spectrophotometry. Sulfur was determined colorimetrically following a nitric-perchloric acid digest (5).

The student's *t*-test was used to determine differences in age, height, root collar diameter, and foliar nutrient concentrations between open-grown and overtopped seedlings (11).

Table 1—*Age, height, and root collar diameter and nutrient concentrations in the foliage of balsam fir seedlings growing in clearcuts in northern Maine*[1]

Seedling condition	Age (yr)	Height (cm)	Root collar diam. (mm)	Nutrient conc. (%)					
				N	P	K	Ca	Mg	S
Overtopped	6.2 a	36.2 a	5.5 a	1.30 a	0.16 a	0.80 a	0.51 a	0.11 a	0.12 a
Open-grown	6.4 a	47.9 a	8.2 b	1.27 a	0.18 b	0.59 b	0.57 a	0.10 a	0.11 a

[1]Values in a column with the same letter are not significantly different (Alpha = 0.05).

Results and Discussion

The average age of both the overtopped and the open-grown seedlings was 6 years (table 1). Thus, the regeneration present in these 5year-old clearcuts originated from seedlings that existed in the understory at the time of harvest. Such advanced regeneration is a common feature in spruce-fir stands in eastern North America (1), and is the principle source of regeneration following clearcut harvesting (3).

The open-grown seedlings in this study were larger than those overtopped by raspberries (table 1). Competition from raspberries appears to have retarded the growth of these seedlings, particularly with respect to diameter. Similar results have been reported by Holt and coworkers (7).

Nutrient concentrations in the foliage of the sampled seedlings are presented in table 1. Significant differences were found in P and K concentrations between overtopped and open-grown seedlings. Nutrient proportions in the two groups of seedlings and comparisons with proposed optimum values are presented in table 2. The nutrient ratios in both groups of seedlings deviated from the proposed optimum proportions.

Although statistically significant, differences in P concentrations were relatively small. Lowry and Avard (12) found no difference in f concentrations among crown classes in black spruce. However, van den Driessche (21) reported higher P concentrations in suppressed trees. It is doubtful that the differences found in the present study are biologically significant. Phosphorus concentrations were above critical levels (15), and the ratio of P to N is very close to the optimum value in both groups of seedlings (table 2).

Table 2—*Nutrient proportions in the foliage of balsam fir seedlings growing in clearcuts in northern Maine compared with optimum values (N set at 100)*

Nutrient	Overtopped	Open-grown	Optimum value[1]
N	100	100	100
P	12.3	14.5	13
K	61.5	46.5	65
Ca	39.2	42.3	6
Mg	8.3	7.7	8.5
S	9.1	8.6	9

[1]van den Driessche (1976).

Large and statistically significant differences in foliar K concentrations existed between the overtopped and open-grown seedlings, with higher K concentrations in the overtopped seedlings. Similar results have been reported with black spruce (12) and red pine (*Pinus resinosa* Ait.) (13). In addition, the K to N ratio in the open-grown seedlings was the only nutrient proportion that deviated below the optimum by more than 10 percent, thus indicating a severe K deficiency. Growth dilution in the open-grown seedlings may be responsible for these differences.

An extremely high Ca to N ratio was found in both the open-grown and the overtopped seedlings. The values were between 6 and 7 times greater than the suggested optimum value. When data from other studies of balsam fir are used to construct nutrient proportions, high values for the Ca to N ratio are also obtained (16, 17, 24).

Because of an imbalance in the age structure of the spruce-fir forests in the Northeast, attributed to the cyclic nature of outbreaks of the spruce budworm, *Choristoneura fumiferana* (Clemens), a softwood timber shortage has been predicted for this region (18). Regeneration delays induced by raspberry competition would exacerbate this shortage. The research presented in this paper has shown that competition from raspberry plants reduces growth and affects tree nutrition of balsam fir seedlings, which could contribute to the timber shortfall problem. Additional work is needed in this area. In particular, the optimum nutrient proportions in balsam fir foliage need to be identified.

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Tree Planter's Notes, Volume 37, No. 2 (1986)

Performance of Fall- and Spring-Planted Bareroot and Container-Grown Red Pine (*Pinus resinosa* Ait.)

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*Red pine (*Pinus resinosa *Ait.) styro-plug, 2-0, 3-0, and 2-2 seedlings were planted in the fall and spring. After four field seasons for the spring-planted seedlings and three for the fall-planted seedlings, survival and height growth of the container seedlings was similar to that of the 2-0 and 3-0 seedlings. The 2-2 transplant stock generally outperformed all the other stock classes. Planting season had no significant effect on survival of container stock. Average annual height growth was better on spring-planted trees than on fall-planted trees, irrespective of stock class.* Tree Planters' Notes *37(2):24-26; 1986.*

Recent symposia on artificial regeneration and intensive management in the Lake States, plus projected needs for softwoods, have stimulated interest in intensive management of red pine (*Pinus resinosa* Ait.) plantations *(2).* Research needs include documentation of the survival and growth of bareroot and container seedlings on various sites. There is also renewed interest in the prospect of fall planting to widen the existing reforestation window. This paper compares the performance of bare-root and container red pine seedlings planted in the spring and fall in east central Minnesota.

Materials and Methods

Three types of nursery-grown bareroot stock *(2-2* transplants and *3-0* and *2-0* seedlings) and styro-plug container-grown seedlings were planted in spring and fall *1980.* These results include four growing seasons for spring-planted trees and three growing seasons for fall-planted trees.

The prior cover type on the study site consisted of quaking aspen (*Populus tremuloides* Michx.), paper birch (*Betula papyrifera* Marsh.), and red maple (*Acer rubrum* L.). After the harvest of commercial trees in *1979* the area was scarified by root raking. The soil is a moderately well-drained Ahmeek-Ohmega sandy loam underlain by a fine, sandy loam fragipan.

The styro-plug containers *(35* cubic centimeters rooting volume) were seeded in November *1979,* grown in a greenhouse, and placed outside in May *1980* until planted. Both spring- and fall-planted containers were from the same greenhouse crop. Spring-planted bareroot trees were lifted from the nursery and stored for about 1 week under refrigeration before being planted. Spring planting of bareroot stock was on May *14* and container stock on June *3, 1980.* Fall-planted bareroot stock was planted on the same day it was lifted from the nursery. All fall planting was done on September *23, 1980.* Container stock was planted using a Potti-putki planting tube. The bareroot stock was planted using a standard planting bar.

Measurements taken of sample seedlings at time of planting indicated that the quality of all stock was within acceptable standards except the high shoot to root ratio of fall-planted *3-0* stock (table 1).

A randomized block design was used with four replications of each treatment combination (stock x season). Each treatment combination had *50* trees per replication for a total of *1600* trees in the entire study.

Evidence of browse damage by snowshoe hares (*Lepus americanus* Erxleben) was noted in October *1980.* To reduce further browse damage, mesh plastic netting was placed around each seedling.

Primary vegetative competition on the site was quaking aspen and balsam poplar (*Populus balsamifera* L.), various willow species (*Salix* spp.), grasses, and sedge. The trees were chemically released in August *1982.*

Survival and height measurements are summarized in table 1. Height growth was calculated as the average per growing season.

Results

Planting season comparisons. Spring-planted bareroot stock had significantly greater survival and

[1] The authors thank the Potlatch Corporation, Minnesota Wood Products Division, for its help in conducting this study. This article is University of Minnesota Agricultural Experiment Station Science Journal Series Paper No. 1989.

height growth than stock planted in the fall. Season of planting had no significant effect on survival of container stock but, similar to bareroot stock, mean annual height growth was less on fall-planted trees (table 2). Heights at the end of the measurement period are also shown in table 2 but keep in mind that the spring-planted stock had an additional growing season in the field.

Table 1—*Physical characteristics of stock at time of planting (N = 20)*[1]

Stock type	Stem diam. (mm)		Shoot ht. (cm)		S/R ratio[2]	
	Spring	Fall	Spring	Fall	Spring	Fall
Container	1.6 d	2.1 d	9.5 c	9.7 b	2.3	1.1
2–0	3.0 c	3.1 c	7.5 d	6.1 c	3.6	3.1
3–0	3.7 b	4.0 b	16.7 b	23.2 a	4.1	6.7
2–2	5.5 a	7.1 a	20.1 a	24.7 a	4.3	3.9

[1]Means within a column and planting season with the same letter are not significantly different (P = 0.05).
[2]Shoot to root ratio based on ovendry weight.

Table 2—*Comparisons of mean survival, mean height, and mean annual height growth of spring- and fall-planted red pine stock types*[1]

Planting season	Container	2–0	3–0	2–2	Average
Mean survival (%)					
Spring	82 ay	91 axy	82 ay	97 ax	88
Fall	73 ax	74 bx	51 by	85 bx	71
Mean height (cm)					
Spring	59 az	76 ay	72 ay	102 ax	81
Fall	33 by	36 by	34 by	59 bx	43
Annual height growth (cm)					
Spring	12 ay	17 axy	17 axy	22 ax	17
Fall	4 by	10 bx	6 by	12 bx	8

[1]Bareroot seedlings were planted in the spring on May 14, 1980; containerized seedlings on June 3, 1980. Seedlings were planted in the fall on September 23, 1980. Means within a column (a, b, c) or across a row (x, y, z) followed by different letters differ significantly (P = 0.05).

Planting stock comparisons. Survival of the container and bareroot stock was similar, with two exceptions. Survival of spring-planted 2-2 stock was significantly higher than the 3-0 and container stock. Survival of fall-planted 3-0 stock was significantly lower than the other types of stock (table 2).

Height differences were not consistent between spring- and fall-planted seedlings. Average height of spring-planted container stock was significantly shorter than that of the spring-planted bareroot stock. But, the height of fall-planted container stock did not differ significantly from that of the 20 and 3-0 stock. The 2-2 stock was significantly taller than all other stock types at the end of the measurement period, as it was at the time of planting; however, it did not necessarily grow faster than the 2-0 and 3-0 stock (table 2). The mean annual height growths of spring-planted container, 2-0 and 3-0 stock did not differ statistically. Average annual height growth of fall-planted container and 3-0 stock was substantially less than either the 2-0 or 2-2 stock.

Height comparisons between the various stock types were affected by both the hare browsing and the subsequent use of the plastic mesh, which restricted height growth in some instances. In order to remove the effects of those influences, damaged trees were not included in the height summary and analysis.

Conclusions

Spring planting resulted in superior survival and growth rates for the 2-2, 3-0, and 2-0 stock in comparison to the fall-planted bareroot stock. Results similar to these have been documented in other studies of red pine regeneration (3, 4, 6). Seedlings grown in styro-plug containers had similar survival rates irrespective of planting season, but spring-planted containers grew at a faster rate than those planted in the fall.

Survival and height growth of the container seedlings was comparable to those of the 3-0 seedling stock. Survival of container stock was similar to that of 2-0 seedlings, but fall-planted 2-0 stock grew at a substantially faster rate. As a result of acceptable field performance, similar to that found in this study and others, use of containerized seedlings as a supplement to bareroot stock has been increasing in the Lake States (1). Survival and height growth of the 2-2 transplant stock was as good as or better than that of the other stock types. The superior performance of red pine transplants over seedlings is well documented in the literature (4-6).

It must be noted that this study encompasses a single planting season and set of environmental conditions. Comparisons such as these must be repeated through time under various conditions. The results, however, do provide supportive data and aid in evaluation of stock type and planting season.

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A Seedbed Comparison of Two Seed Sources of White Spruce (Picea glauca (Moench.) Voss) at the Maine State Forest Nursery

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*White spruce seedlings (*Picea glauca *(Moench.) Voss) grown from superior seed, collected in the Ottawa Valley, had significantly greater shoot heights and root lengths than seedlings grown from commercial seed from Michigan. Stem diameters and shoot to root ratios were not significantly different.* Tree Planters' Notes 37(2):2728; 1986

White spruce (*Picea glauca* , (Moench.) Voss) at the Maine State Forest Nursery, Greenbush, is grown as 3-0 stock, with 8 inches of shoot height designated as the minimum size for shipping. If an flinch plantable seedling could be produced in 2 years instead of 3, production costs would decrease considerably and fields could be put into a cover crop rotation more easily. This study was conducted to determine if the use of an improved source of seed could reduce production time for white spruce seedlings.

Materials and Methods

Ottawa Valley white spruce seed has been determined through a series of provenance tests in Canada and the United States to be a consistently superior performer under most circumstances. Teich, Morgenstern, and Skeates (5) compared Canadian sources of seed on planting sites in Ontario and found a "consistency in the origin of productive provenances." This area was the Cobourg-Beachburg corri- dor in the lower Ottawa River valley. In a more widely ranging Canadian study, Teich (4) determined again that the lower Ottawa Valley sources were generally about 20 percent taller than plantation averages. Nienstaedt (2) studied seed sources from a wider range and found that the Ontario sources were among the top ten best sources in each of the 14 outplantings used.

In the spring of 1980, 500 grams of Ottawa Valley white spruce seed (collected in Algonquin Provincial Park) were seeded by hand in a production bed at the Maine State Forest Nursery, Greenbush. The bed was given the same cultural treatments as the regular production beds, which had been mechanically seeded with a commercially collected seedlot from Michigan. Density in the beds was approximately the same, 34 trees per square foot. After three growing seasons, the trees were lifted, and 20 trees from each source were selected randomly and measured for shoot height, root length, and stem caliper at the root collar. Shoot to root ratios were calculated from these measurements.

Results and Discussion

By use of an unpaired t-test, it was determined that both shoot height and root length were significantly different for the two seed sources, whereas root collar diameter was not (table 1). Due to the non-normality of the distribution of the shoot to root ratio generated here, the Mann-Whitney nonparametric test was used to compare shoot to root ratios for the two sources. This comparison also showed no significant difference. This was not unexpected, as production of a well-balanced seedling should be evident at any stage of development.

Seedlings from the Ottawa Valley source were significantly taller than those from the Michigan source by 20.2 percent (2.16 inches), according to the results obtained from the t-test. They were taller than the flinch minimum height by 60.5 percent (4.84 inches). The smallest individual from the Ottawa Valley

Table 1—*Growth characteristics of white spruce seed from two sources (N = 20)*

Source	Shoot height (in)	Root length (in)	Root collar diameter (in)
Ottawa Valley	12.84**	14.80*	0.23 NS
Michigan	10.68**	11.30*	0.21 NS

*Significantly different at the 5-percent level (unpaired *t*-test).
**Significantly different at the 1-percent level (unpaired *t*-test).
NS = Not significantly different (unpaired *t*-test).

source was 1.5 inches taller than the minimum, whereas the smallest individual from the Michigan source was 0.25 inches shorter than the minimum.

Mullin and Bowdery (1) suggest that a sturdier, more plantable seedling may be produced by a reduction in seedbed density, perhaps a drastic reduction, to 10 seedlings per square foot. Reese and Sadreika (3) describe acceptable bareroot planting stock of 3=0 white spruce as being between 22 and 28 centimeters (8.7 to 11.0 inches) in height and acceptable 2-0 planting stock as being between 10 and 16 centimeters (3.9 to 6.3 inches) in height.

Results indicate that with a reduction in seedbed density to less than 20 trees per square foot and the use of superior white spruce seed, such as the Ottawa Valley source, the Maine State Forest Nursery may be able to produce a plantable white spruce seedling in 2 years, meeting and probably exceeding the Ontario standard for 2-0 stock and meeting the present Maine standard for 3-0 stock. A reduction in seedbed density might also reduce the number of cull trees, further decreasing production costs. These possibilities need further investigation.

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Walnuts and White Pine Can Be Grown Together Successfully

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*Small plantings of mixed eastern white pine (*Pinus strobus *L.) and black walnut (*Juglans nigra *L.) planted on the same site appear to be healthy after 15 to 18 years. These plantations are producing trees of desirable silvicultural form.* Tree Planters' Notes 37(2):29-31; 1986.

Many cultural problems await the novice landowner during the early years of walnut plantation establishment. Insect damage to leaders, epicormic sprouting, and girdling by meadow mice are a few examples. These problems may require annual corrective pruning or other cultural practices. Many landowners do not have the time, money, or patience for all this management.

The challenge presented to the forester is formidable. How do you establish a walnut plantation that will virtually take care of itself for 10 to 15 years? Usually, by then stem crowding is so apparent that even the most reluctant landowner will concede that an improvement cutting is in order. One answer to this challenge in southwest Wisconsin is the interplanting of white pine and walnut. Several plantations of this mixture were established 15 to 20 years ago, and the effectiveness of the combination is encouraging.

There has been concern about the dangers of growing white pine and walnut together in plantations. Walnut trees produce the chemical juglone (5-hydroxy-1,4-naphthoquinone), which inhibits the growth of white pine. This growth inhibition seems to occur where white pine is planted beneath an established walnut overstory with the objective of bringing the white pine through to rotation age. But evidence from even-aged (15 to 20 years) plantations of mixed white pine and walnut appears to remove this concern (figures 1 and 2).

The planting design starts with the first row being planted to pure 3-0 white pine on a 6-foot spacing. The second row is planted to white pine alternated with 1-0 walnut on the same spacing. Rows are spaced 6 feet apart. These two basic rows are replicated over and over. When a plantation is completed, each walnut is surrounded by white pine. Approximately 300 walnut and 900 white pine are needed to cover an acre.

It is very important that the plantation be kept from grass competition during the first 2 years. This is best accomplished by applying a band of simazine to each row of

Figure 1—*Fifteen-year-old mixed plantation of walnut and white pine in northwest Grant County, southwestern Wisconsin. Very little improvement has been accomplished.*

Figure 2—*Nineteen-year-old mixed plantation of walnut and white pine in northeast Rock County, southern Wisconsin. Three improvement cuts were made (1977, 1981, 1984), and the walnut crop trees were pruned to 12 feet.*

the planting. Consult your local forester for the amount of chemical to apply. The rate of application will depend on the soil type and amount of grass competition or weeds present.

This white pine-walnut plantation prescription can be planted in many areas of southern Wisconsin, and on a wide range of sites. However, it works best on a well-drained, silt loam with a soil acidity between 6.0 and 7.0. Areas to avoid are river bottoms and valley floors where prolonged periods of high humidity in midsummer are common. These conditions may produce blister rust infection in the white pine as well as bacterial and fungal infections in the walnut.

In the early years of this prescription (ages 7 to 9) a modest thinning of white pine Christmas trees can be anticipated to help defray the cost of stand establishment. From ages 10 to 15, a genetic thinning is necessary. At this time, trees with better genetic traits will express their dominance; and additional growing space will favor future development of these trees. By age 15, the stocking of the stand should be reduced from 1,200 per acre to 700. Pruning should be done to half the height of the tree, whether walnut or white pine (figures 1 and 2).

The unusual aspect of mixing a conifer and a fine hardwood is that it gives landowners options that are not possible with pure plantings. Landowners may want to favor a walnut by cutting adjacent white pine. They can favor a fast-growing white pine by cutting deformed or poor-growing walnuts. It is entirely possible to bring white pine and walnut growing on the same site to final sawlog rotation.

A 60-year-old white pine plantation in Wyalusing State Park is living testimony to just how well walnut and white pine can grow together (figure 3). This 1923 planting of white pine now has dominants over 115 feet in height and a basal area of 220 square feet. As this planting developed, many walnut volunteers began to appear throughout the plantation. Today these walnut trees are saw-timber size, with 30 to 40 feet of clear trunk. There is no apparent adverse effect from the walnut trees growing in close proximity to the white pine for 60 years.

The adaptations are limitless on the species mix of this prescription. For instance, for landowners who want to grow a desirable fuelwood species along with their walnut and white pine, it is possible to add green ash to the design. In this case, the design can be altered by substituting a green ash for every other walnut.

With high land prices and property taxes, foresters must be imaginative and innovative in their planting prescriptions. Every effort must be made to maximize returns for the landowner if we are to keep interest alive in forest management. Mixing of conifers and hardwoods is another option that foresters now have in assisting landowners to get the maximum return from a forestry investment.

Figure 3—*Sixty-year-old plantation of white pine with volunteer walnut trees in Wyalusing State Park, southwest Wisconsin.*

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