Tree Planters' Notes
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Tree Planter's Notes, Vol. 39, No. 4 (1988)

Comparison of Three Soil Fumigants in a Bareroot Conifer Nursery

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*Nursery soil was treated with dazomet (Basamid®), metam sodium (Soil Prep®), or methyl bromide-chloropicrin (Dowfume MC-33®) or left untreated (control). All three chemical treatments resulted in reduced levels of pathogenic fungi in the soil and improved survival of ponderosa pine (*Pinus ponderosa *Dougl. ex Laws.) seedlings and stand density. Seedling growth was the same regardless of treatment in the first growing season. Some growth differences were seen after the second growing season. Height and caliper variations were least with the dazomet treatment. Utilization of these chemicals in conifer nurseries is discussed.* Tree Planters' Notes 39(4):16-22 ; 1988.

Preplanting fumigation of soil with methyl bromide-chloropicrin (MB-C) fumigant has been used routinely in many forest nurseries. The purpose of fumigation is to rid soil of pests such as pathogenic fungi, nematodes, insects, and weeds. MB-C, however, can be hazardous to apply, and treatment costs are high (over $1,000 per acre); availability of MB-C fumigant in the future may be limited as well.

Alternative chemicals or cultural practices for control of soilborne pests need to be developed so that nursery managers will have several effective options for soil treatment. A test comparing two different chemicals, metam-sodium and dazomet, to MB-C, for control of pathogenic fungi is described. Growth of seedlings in the variously treated soils is also reported.

Metam-sodium (Soil Prep®, Vapam®, Metam®, Nemasoll®, and others) is a water-soluble liquid. It decomposes into the toxic gas methyl isothiocyanate after it is applied to the soil. It must be watered or injected into the soil and the soil surface sealed for 48 hours by rolling, tarping, or watering. Rates of 100 gallons per acre in conifer nurseries have resulted in significant reductions of the pathogenic soil fungi *Fusarium* spp, *Pythium* spp and *Phytophthora* spp (3).

Dazomet (Basamid Granular®,) is a dry, granular material. Like metam-sodium, it decomposes into methyl isothiocyanate gas following contact with moisture in the soil. Dazomet is applied to the soil surface and incorporated by tilling or discing; the soil surface is then sealed by rolling, watering, or tarping. Rates of 250 to 350 pounds per acre are recommended for control of most pathogenic fungi and germinating weed seeds.

Methods

Plots treated with metamsodium, dazomet, or MB-C, and control plots were established at the USDA Forest Service Bend Nursery in August 1985. Chemical products, application rates and times of application are listed in table 1. Treatment plots, each 300 square feet (12 by 25 feet), were replicated four times in a randomized block design.

In the treated areas, soil was watered and kept at or near field capacity for 2 weeks before

Table 1—*Application rates and times of application for soil fumigants tested at Bend Nursery, August 1985*

Trade name	Active ingredient	Rate	Application date
Dowfume MC-33	Methyl bromide–chloropicrin	350 lb/ac	September 15
Soil Prep	Metam-sodium	109 gal/ac	August 30–31
Basamid Granular	Dazomet	350 lb/ac	August 30

The authors thank Susan Skakel, former manager of the Bend Nursery, who helped plan and implement this study, and Mahlon Hale, Mandy Muller, and other Bend Nursery personnel who assisted throughout, as well as Ellen Michaels Goheen and Keith Forry of USDA Forest Service, Forest Pest Management who performed the lab work necessary for assaying pathogen levels and assisted with data collection.

treatment to allow pest propagules (fungal spores, insect eggs, and weed seeds) to imbibe water and become more sensitive to chemicals. Methyl bromide-chloropicrin (2.4 pounds Dowfume MC-33 per plot) was applied to each of four plots by a contractor, along with operational fumigation at the nursery. It was injected, and the treated soil was covered with tarps for 48 hours. Metam-sodium (.75 gallons of Soil Prep in 185 gallons of water per plot, the equivalent of 1 inch of water) was sprinkled on each of four plots over a 4-hour period. Dazomet (2.4 pounds Basamid Granular per plot) was spread on the soil surface of each of four plots, incorporated by roto-cultivator to the depth of 6 inches and then sealed by 1/4 inch of water, applied by hand. No chemical was applied to the remaining four control plots.

Pathogen populations. Populations of two genera of common pathogenic soil fungi, *Fusarium* and *Pythium,* were measured at three times: (a) before treatment, (b) after treatment, and (c) prior to sowing. Soil was collected from three locations in each plot; samples from each location were composites of five cores, 0 to 6 inches in depth. Soil was taken from approximately the same three locations in each plot at each of the three sample times. Dilutions of each soil sample were plated on Komada medium, which is selective for *Fusarium* species, and cornmeal agar amended with pimaricin, which is selective for *Pythium* species.

After incubation, the numbers of fungal colonies were counted on each soil dilution plate and a determination of propagules per gram of ovendry (OD) soil was made. Treatment effectiveness was determined by comparing populations (measured as propagules per gram of OD soil) of each fungus before and after treatments.

Seedling survival. The number of live and dead ponderosa pine seedlings was counted in eight subplots (1 square foot) in each treatment plot in October of the first growing season. Counts from the subplots were pooled, and the percentage survival was calculated for each treatment plot. Seedling density (number of live seedlings per square foot) was also determined.

Seedling morphology. Thirty surviving seedlings from each treatment plot were randomly selected and dug after the first growing season, following budset in October. Stem caliper and shoot height were measured on each seedling, and average caliper and shoot height were calculated for each plot. Roots were clipped from the shoots at the cotyledonary scar, and all roots were combined to get a combined root weight (fresh) and a combined root volume (volume determined by water displacement). Combined weights and volumes of the shoots were also measured. Stem volumes and root-to-shoot ratios (R:S) were calculated for each plot. Two R:S values were calculated, one based on fresh weights and the other on volume.

After the second growing season, 10 surviving seedlings from each treatment plot (40 per treatment) were randomly selected and their calipers and shoot heights measured. Average cal-

Table 2—*Fusarium populations (propagules per gram of ovendry soil); comparisons between four different treatments at three different sampling times*

	Pretreatment	Posttreatment	Presow
Control	843 a	1160 a	311 a
MB-C	1126 a	22 a	0 a
Metam-sodium	554 a	483 a	616 a
Dazomet	543 a	615 a	332 a

Means in each column followed by the same letter do not differ significantly at the .05 probability level according to Duncan's new multiple range test.

iper and shoot height were calculated for each plot. These measurements were used to calculate a stem volume for each plot. Density counts were not taken in the second year. Second-year densities were assumed to be similar to first-year densities since little or no mortality was observed after the first growing season.

Statistical procedures. Treatments were compared for all measures using analyses of variance and Duncan's new multiple range test. Differences at the .05 level are considered significant.

Results and Discussion

Pathogen populations.

Fusarium. When treatments are compared with each other at each sample time (pretreatment, posttreatment, presow), it is seen that populations of *Fusarium* were lower (although not significantly) in MB-C soils compared to the other treatments at both posttreatment and presow times (table 2).

Within each treatment, significant reductions in *Fusarium* populations between pre- and posttreatment samples were seen only in the MB-C treatment; populations were reduced drastically following treatment and were still extremely low at sowing time (presow measurement) (fig. 1). With metamsodium and dazomet, population changes were not statistically significant.

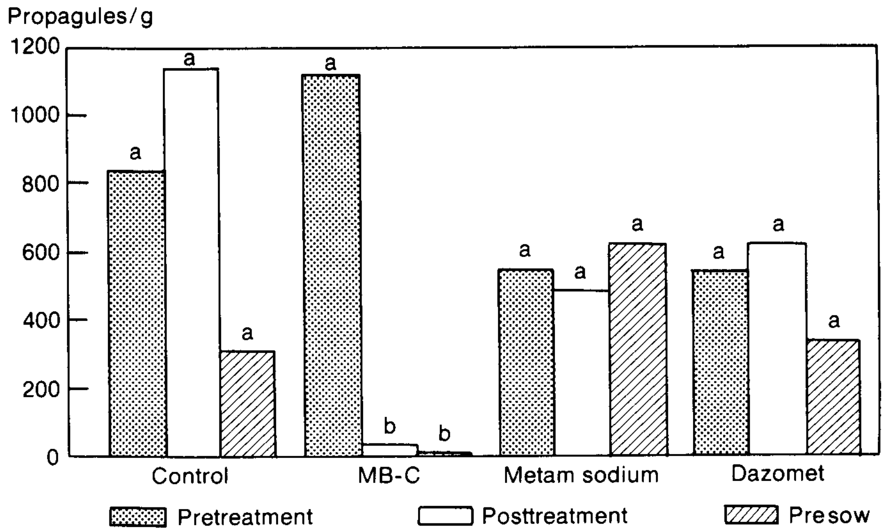

Figure 1—Fusarium *populations before and after treatment with the fumigants methyl bromide–chloropicrin (MB-C), metam-sodium, and dazomet. In each cluster of bars, bars with the same letter do not differ significantly according to Duncan's new multiple range test (P < .05).*

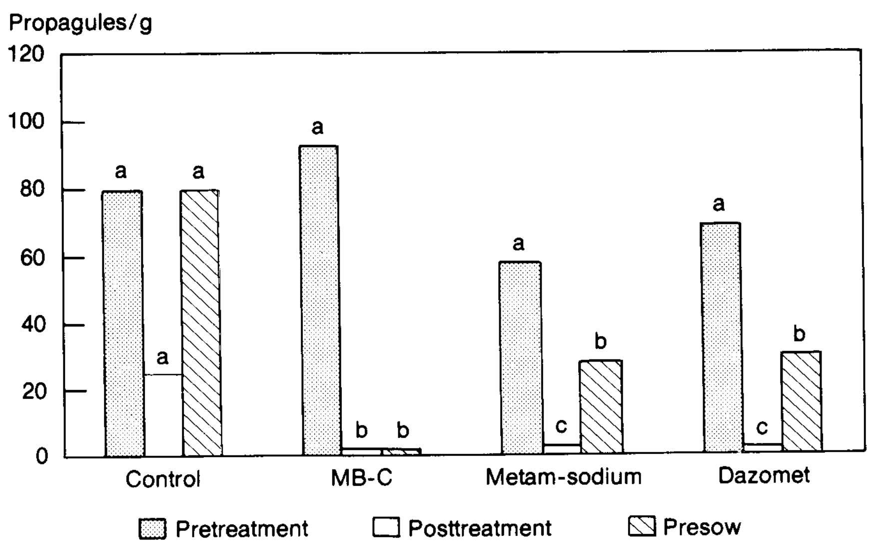

Figure 2—Pythium *populations before and after treatment with the fumigants methyl bromide–chloropicrin (MB-C), metam-sodium and dazomet. In each cluster of bars, those with the same letter do not differ significantly according to Duncan's new multiple range test (P < .05).*

Pythium. When treatments are compared with each other at each sample time, treated soil had significantly lower populations of *Pythium* at posttreatment and presow times than did

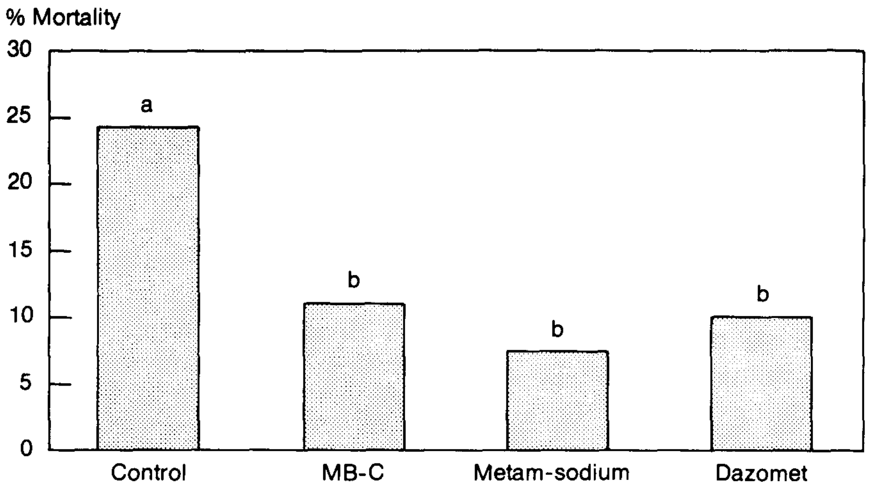

Figure 3—*Ponderosa pine seedling mortality in the first growing season. Bars with the same letter above them do not differ significantly according to Duncan's new multiple range test ($P < .05$).*

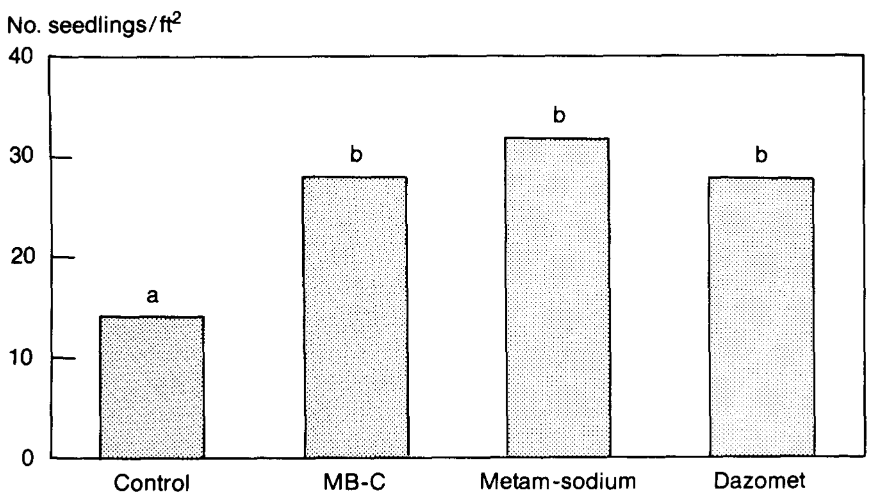

Figure 4—*Ponderosa pine seedling density after the first growing season. Bars with the same letter above them do not differ significantly according to Duncan's new multiple range test ($P < .05$).*

untreated soil (table 2). And, although not statistically significant, populations in MB-C plots were much lower than populations in either dazomet or metam-sodium plots.

Within each treatment, significant reductions in *Pythium* populations between pre- and posttreatment samples were seen for all treatments except the check (fig. 2). With MB-C, populations of *Pythium* were reduced to zero and were still near zero at sowing time.

With metam-sodium and dazomet, populations were reduced to near zero immediately following treatment; they then increased, although the levels at sowing were still significantly lower than the levels seen before treatment (table 3). It is interesting to note that a gradual increase in populations of *Pythium* in both metam-sodium and dazomet treatments occurred between treatment in the fall and sowing the next spring. This may be due to incomplete eradication of *Pythium so* that population increases resulted from inoculum remaining in the soil after treatment. Recolonization of pathogen-free portions of the soil (such as the top few inches where chemical concentration was probably greatest) by inoculum in portions of soil that were untreated or received less chemical may have also occurred.

Pythium appears to be more sensitive than *Fusarium* to dazomet and metam-sodium. This may be due to differences in cell-wall thickness of resting spores or differences in other mechanisms that allow fungi to withstand toxins. It may also be the result of a higher proportion

Table 3—Pythium *populations (propagules per gram of ovendry soil); comparisons between four different treatments at three different sampling times*

	Pretreatment	Posttreatment	Presow
Control	85 a	29 a	85 a
MB-C	98 a	0 b	2 b
Metam-sodium	63 b	3 b	31 b
Dazomet	73 b	2 b	34 b

Means in each column followed by the same letter do not differ significantly at the .05 probability level according to Duncan's new multiple range test.

Table 4—*First-year seedling morphology*

	Shoot ht (cm)	Caliper (mm)	R:S wt	R:S vol	Stem vol (mm³)
Control	8.9 a	2.8 a	.50 a	.42 a	181 a
MB-C	9.6 a	2.5 a	.63 a	.54 a	154 a
Metam-sodium	8.5 a	2.5 a	.50 a	.47 a	146 a
Dazomet	9.1 a	2.7 a	.50 a	.39 a	176 a

Means in each column followed by the same letter do not differ significantly at the .05 probability level according to Duncan's new multiple range test.

Table 5—*Second-year seedling morphology*

	Shoot ht		Caliper		Stem vol
	cm	cv	mm	cv	(mm³)
Control	19.8 ab	3.7	6.6 a	11.9	2257 a
MB-C	18.4 b	6.0	5.3 b	4.9	1352 c
Metam-sodium	20.7 ab	9.5	5.7 b	9.0	1760 abc
Dazomet	21.7 a	1.6	6.0 ab	3.3	2042 ab

Means in each column followed by the same letter do not differ significantly at the .05 probability level according to Duncan's new multiple range test. cv = coefficient of variation.

of Pythium propagules being in a sensitive stage (for example, zoospores or germinating resting spores) than Fusarium propagules at the time of treatment.

Mortality. At the end of the first growing season, seedling mortality was significantly lower in treated areas compared to untreated (control) areas. Average mortality in treated plots was about one-third of mortality in check plots (9.6% versus 24.5%). There were no real differences in mortality among the three chemical treatments (fig. 3).

Seedling stand. The number of surviving seedlings per square foot was significantly higher in treated areas than in untreated (control) areas. Treated areas averaged about 50% more seedlings than control areas. The highest number of seedlings per square foot was found in the metam-sodium treatment. Seedling numbers were identical in MB-C and dazomet areas (fig. 4).

Seedling morphology. At the end of the first growing season, various morphological measurements were made. The average shoot height and root-to-shoot ratios were slightly higher for seedlings from MB-C plots than other treatments. Caliper and stem volume were highest in control and dazomet seedlings. However, for all measurements-height, caliper, R:S (weight), R:S (volume), and stem volume-differences were not significant (table 4).

At the end of the second growing season, some significant differences in morphology were seen between treatments. Total height was greatest in dazomet-treated plots and lowest in MBC-treated plots. Similar to the first growing season, caliper and stem volume was highest in control and dazomet treatments; differences between these treatments and MB-C were significant, however (table 5).

The amount of variation in second-year seedling height and caliper was least in dazomet plots (see coefficient of variation, table 5). This lower variation has been observed in Douglas-fir seedlings as well, at another nursery in the Pacific Northwest, following dazomet treatment (5). Seedling height varied the most in metam-sodium plots and caliper varied the most in check plots.

Larger caliper and stem volumes seen in check seedlings in both the first and second year are most likely due to greater water and nutrient availability for individual control seedlings as a result of lower bed density. Similar conclusions were drawn by Boyd (2), who found that density effects concealed true fumigation effects. It is uncertain why second-year height and stem volume of the dazomet seedlings are greater than those in the MB-C treatment in this trial, even though first year densities were identical. This differs from the results found by Tanaka et al. (4), who observed that fumigation with similar rates of MB-C resulted in larger 1+0 seedlings compared to dazomet or check seedlings grown under similar bed densities.

Conclusions

Based on results from this trial, it appears that the two "new" products, dazomet and metam-sodium, perform as well as the more commonly used methyl bromide-chloropicrin fumigant in terms of seedling survival and growth. Although pathogen populations were not reduced as much with either product as they were with MB-C, seedling survival and size surpassed or equaled those seen with MB-C. Similar results have been reported for these products in other conifer nurseries in the Pacific Northwest (1, 3, 5). Seedlings grown in dazomet-treated soil showed greater uniformity of height and caliper than seedlings in other treatments.

Operational use of dazomet and metam-sodium at the Bend Nursery would be warranted from an economical as well as a disease control standpoint. The per-unit chemical cost of applying dazomet is similar to that of MB-C. The per-unit cost of applying metam-sodium, at 100 gal/acre (the rate used in this test), is less than that of MB-C. The acute toxicities and handling hazards of dazomet and metam-sodium are considerably lower than that of MB-C. Dazomet has been used operationally in several conifer nurseries in 1986 and 1987; application technology is developed and fairly well-refined so that the material can be applied easily and effectively. Efficient, cost-effective methods for applying metam-sodium in conifer nurseries have not yet been worked out; since the material is best applied through the irrigation system, some modifications of existing systems must be made before this chemical can be used operationally.

Weather conditions, soil characteristics, and the kinds and amounts of soilborne pathogens at each individual nursery will undoubtedly influence the ease of application, duration of treatment and effectiveness of these materials. Ideal rates and application techniques will need to be developed at individual nurseries to ensure maximum pest control.

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Use of the Inventory-Monitoring System for Shortleaf and Eastern White Pine Cone and Seed Crops at the Beech Creek Seed Orchard

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Cone and seed crops of eastern white pine (Pinus strobus *L.) and shortleaf pine (*P. echinata *Mill.) seed orchard trees were monitored with an inventory-monitoring system. Survival curves for the crops were developed showing the cone efficiency and when losses were occurring in the orchard trees. Cones of one species were analyzed. Results of this study allow the seed orchard manager to evaluate orchard productivity and to develop more* cost-effective *pest management programs.* Tree Planters' Notes 39(4):23-29; 1988.

In June of 1981 at the Beech Creek Seed Orchard, Nantahala National Forest, USDA Forest Service, Murphy, NC, we began to use the inventory-monitoring system (IMS) developed by Bramlett and Godbee (1). This system involves periodic inspection of sample trees and branches to measure the survival of the initial cone crop and to predict expected cone and seed yields at maturity. The data collected allow the orchard manager to calculate the cone efficiency of the orchard and to determine when losses are occurring. At maturity, cone analysis of a sample of the cones in the IMS is used to evaluate the seed production efficiency of the sample trees. Collectively, the information can then be used to determine what corrective procedures need to be taken to bring cone and seed production efficiency levels up to an acceptable level.

Two species, each from a different geographical source, were monitored using the IMS. The methods used with each species shall be described separately.

Methods

Study I. The inventory-monitoring system was first used to study eastern white pines *(Pinus strobus* L.) from a North Carolina source. The stratified clone procedure was used to estimate the orchard productivity.

Clones were classified on the basis of cone production, that is, being either poor, moderate, or good cone producers. Then a proportion of the clones were randomly selected to represent each production class based on previous knowledge of the cone production of each clone. Thirty-nine sample trees (ramets) were selected representing 8 good, 5 moderate, and 3 poor cone producers. Ideally, three ramets would have been selected from each production class, but due to logistical problems a few clones were represented by only one or two ramets.

A total flower count was made on the sample trees as soon as possible after flowering was complete, and then sample branches were tagged. These sample branches were then counted periodically throughout the life-cycle from flower to mature cone. The branches were selected throughout the flower-bearing portions of the trees so as to be a good representative sample of the flower crop in all crown positions.

Subsequent counts were made of the sample branches only, and from this information inferences were made regarding the total flower and cone crops. Four to eight sample branches per sample tree were selected with 1 to 25 flowers per branch. This represented from approximately 28% of the total tree count for the good producers, to as high as 100% on the low producers.

Thus, there was a fairly large percentage of the total tree flowers represented by the sample branches. This would not have been possible in a year with a heavy flower crop.

The 39 sample trees were about 2.5% of the eastern white pines from the North Carolina source. This number of sample trees is not quite up to the recommended minimum of 48 trees, but because of the relatively poor flower crop of 1981, this number should be more than adequate.

Study II. The IMS technique was next used to study shortleaf pines from a Kentucky source. The stratified clone procedure was used to choose the sample trees.

Thirty-five sample trees were selected representing 6 good, 4 moderate, and 2 poor cone producers. All clones were represented by three ramets with the exception of 1 clone. Six to 8 sample branches were selected per sample tree, with each branch bearing 1 to 25 flowers. Nine to 100% of the total tree count was encompassed by the sample branch count.

The 35 sample trees represent about 2%, of the shortleaf pines from the Kentucky source.

Results and Discussion

Study I. The history of the 1981-82 flower/cone crop from the eastern white pines from the North Carolina source at the Beech Creek Seed Orchard is presented in figure 1 (all the sample trees studied) and figure 2 (random sample of 18 of the original 39 ramets used to calculate the data in figure 1). Both graphs differ very little except that an additional conelet count was made in July for figure 2.

Several observations can be made from the data. This group of eastern white pines had a low to moderate amount of flowers initially. Many flowers aborted between flowering in May and

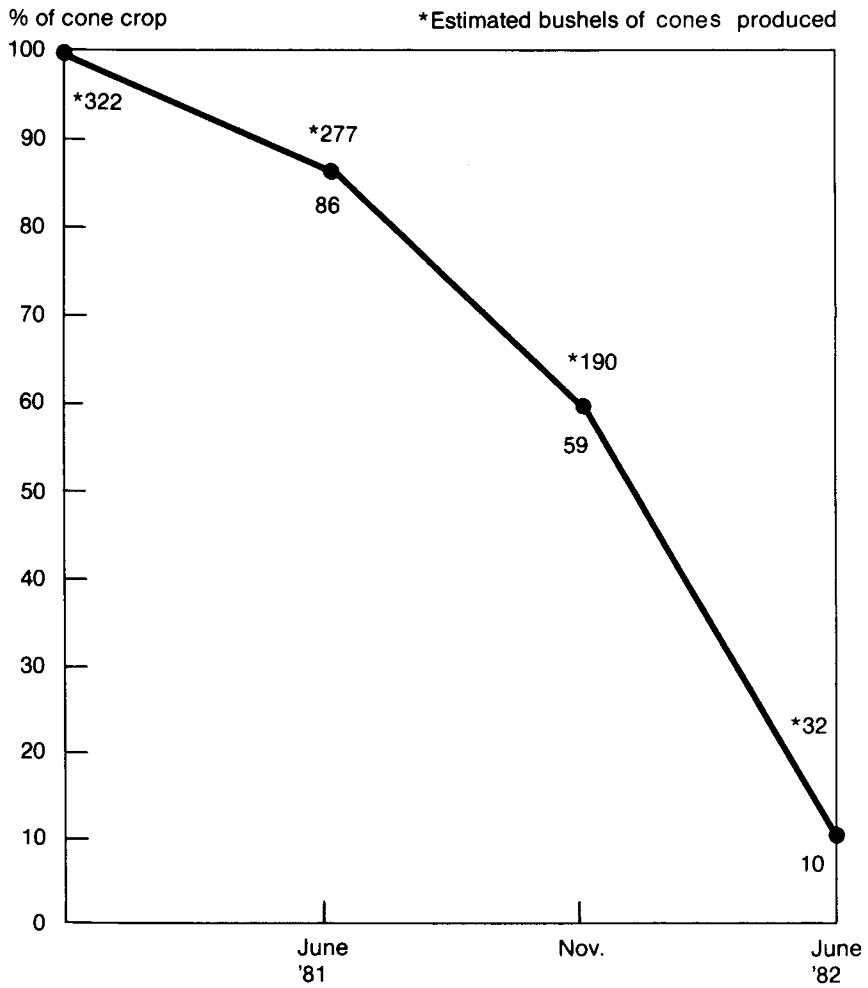

Figure 1—*Cone efficiency and estimated bushels of eastern white pine cones at the Beech Creek Seed Orchard (1981–82 cone crop; all sample trees).*

the count made in July (about 30`%, see fig. 2). This may have been due to the poor pollen crop, but the only way to substantiate that claim would be to count pollen grains per ovule, which was beyond the scope of this study.

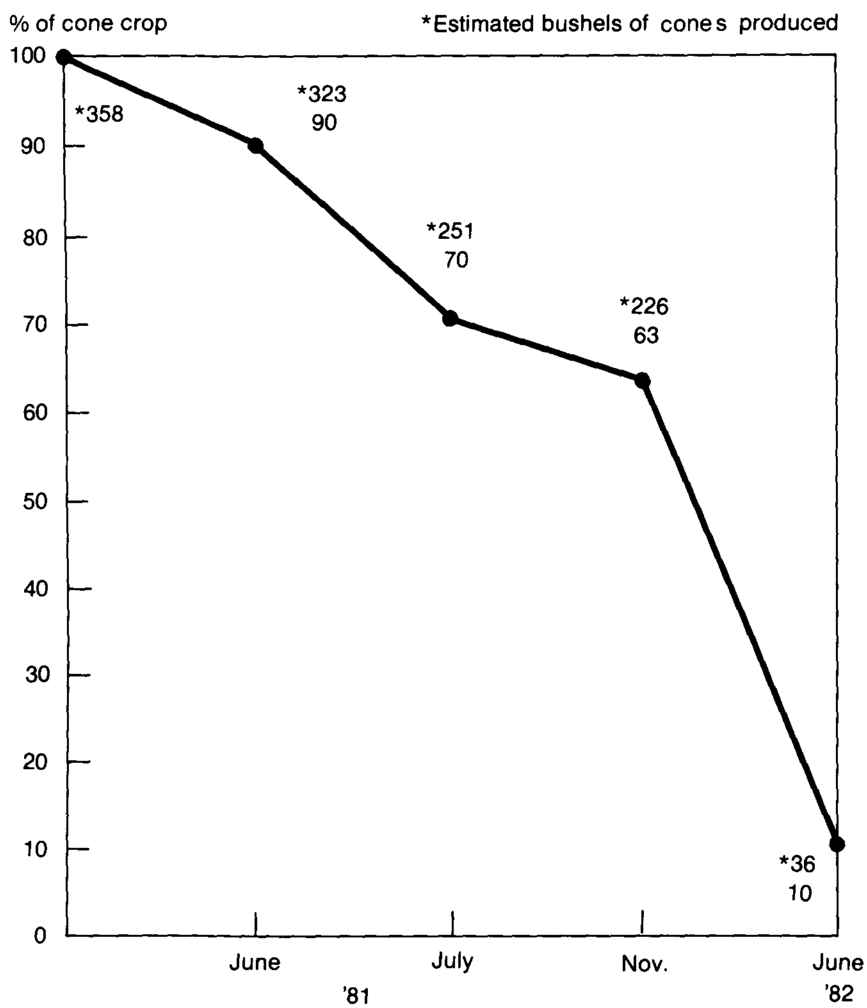

Figure 2—*Cone efficiency and estimated bushels of eastern white pine cones at the Beech Creek Seed Orchard (1981–82 cone crop; random sample, 18 of 39 ramets).*

The trees retained about 60% of their conelets into the winter. This cone efficiency value is quite acceptable considering that no effort was made to protect the conelets from insect attack during this period.

The curves for November 1981 to June 1982 (figs. 1 and 2) show a gradual loss in cones until April, when the curves drop off drastically. These curves are only approximations because there was not time to do a cone count in early April. It is known from past history and from the life cycle of one of the major cone-attacking insects—the white pine cone beetle, *Conophthorus coniperda (Schwartz)*—that the majority of cone loss during this period occurs during the spring and early summer.

Because the cone crop was so poor, no pesticide was applied to protect the cones from the white pine cone beetle. The results of no protection is dramatic (fig. 1 and 2). At this point the study was terminated because 90% of the cone crop was gone and little valuable information could be realized between June and the maturation of the cones in August.

Study II. The cone efficiency of the 1982-83 flower/cone crop from shortleaf pines from a Kentucky source was excellent (figure 3). Losses were minor throughout the crop's life cycle. Cone efficiency values above 60%, are generally acceptable in southern pine seed orchards. The 89% survival we obtained is probably near or at the peak efficiency that could be expected.

One of the primary reasons for using the IMS is to estimate cone and seed yields. Figure 3 shows the estimated number of bushels one could expect to harvest from this shortleaf pine orchard. With the IMS data, there were 510 bushels of cones predicted. In actual field harvest, this source yielded 517 bushels. Needless to say, we were quite pleased with the estimate derived from the IMS data. The small crop of white pine cones in study I was not harvested, and therefore the comparison between field results and predicted values could not be made.

Cone analysis of a small sample of the cones collected from the IMS at maturity yielded the data presented in figure 4. Due to economic restraints it was not possible to perform complete cone analysis on all cones, and only one cone per clone was used in the IMS. Thus the seed efficiency values are derived from a rather small sample. The value of 69% seed efficiency is quite high considering that the biological maximum is thought to be around 90%. Values above 55% indicate good management practices are being used at the seed orchard (2).

The extraction efficiency average of 73% was obtained from a much larger sample (10 cones per clone), but the results may be less representative than

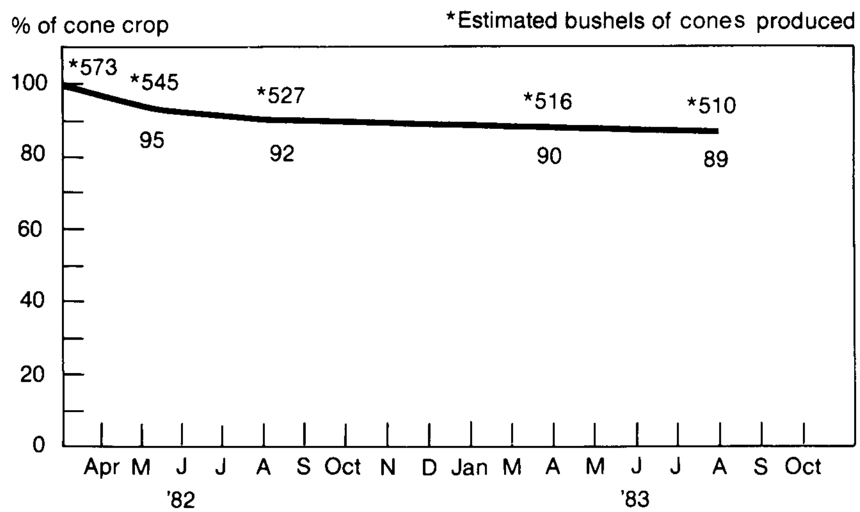

Figure 3—*Cone efficiency and estimated bushels of the shortleaf pine cone crop at the Beech Creek Seed Orchard (1982–83 cone crop).*

expected extractory efficiencies for several reasons. First of all, the cones were collected 1 week earlier than normal in order to avoid interfering with production cone collections. Thus the IMS sample cones were not quite mature and subject to case hardening.

Secondly, shipment of the cones was delayed, restricting natural cone opening prior to receipt at the cone analysis service. Actual field results from the bulk cone collections in this shortleaf source yielded nearly 1 pound of seed per bushel of cones. This figure indicated a more acceptable extraction efficiency than was predicted with the IMS sample cones.

Germination was not tested by the cone analysis service, but the general orchard collections from this shortleaf source yielded seed that showed 80% germination (fig. 4).

From closer analysis of the cone analysis data (table 1), several observations can be made:

1. An average of 79 developed seed per cone were extracted.
2. The average seed potential for this shortleaf seed orchard was 101, which is

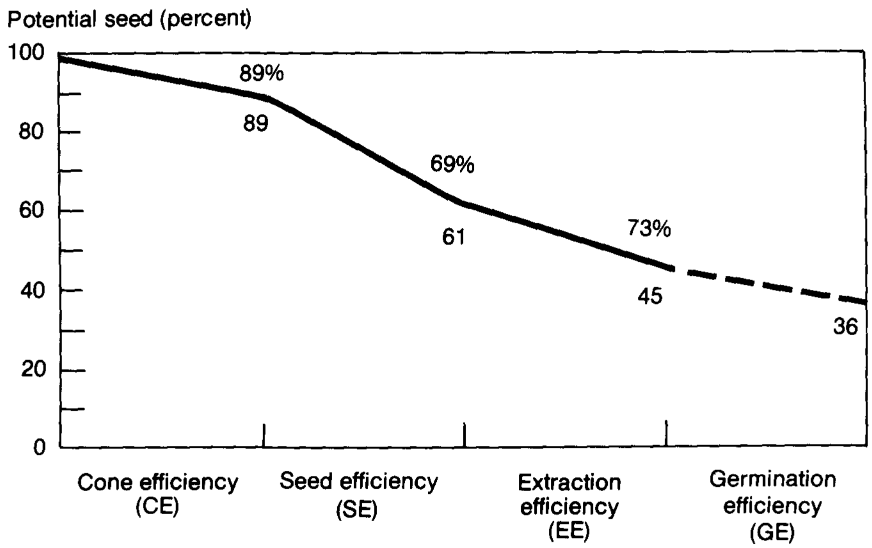

Figure 4—*Seed orchard-to-nursery efficiency of the 1982–83 shortleaf pine seed crop.*

slightly higher than the expected average of 88 to 90. The range was from 80 to 148, possibly indicating that those clones in the upper end of the range have some loblolly parents in their pedigree. Clone 42 in particular has longer needles and produces much larger cones than those normally characteristic of a shortleaf pine. It has also been suggested that the seed orchard environment, with the cultural regimes practiced there—for example, fertilization, thinning, subsoiling, etc.—may increase seed potential much like these practices increase flowering potential.

3. The average percentage of first-year aborted ovules was 21%, with over 80% of the clones having 16% or less first-year abortions. These abortions are caused mostly by a lack of viable pollen and/or by feeding by nymphs of the leaffooted pine seed bug—Leptoglossus corculus (Say) (2). These first-year abortions seldom fall below 10 to 15% in any given year.
4. The number of second-year ovule abortions was quite small, indicating that we had excellent control of the seed bugs early in the second growing season.
5. The average percentage of developed seed was 79%, with 87% of these developing into full seeds.
6. As already mentioned the average seed efficiency was 69%. This value is expressed as the ratio of filled to potential seed. The loss of 31% of the potential seed can be broken down as follows: 21 % of the loss was from first-year abortions and has already been discussed, 10% of the loss was from second year abortions acrd empty seeds with both of these conditions brought about primarily by seedbug feeding. Another cause of empty seeds may be embryo abortions brought about when recessive lethal genes combine (3, 4).

The pattern and general trends shown by these results can be closely correlated to the pest management program during the 1982-83 cone crop development, which is summarized here.

* The first pesticide application to this seed orchard was in February 1982, when carbofuran (Furadan 10-G) was applied at 4 ounces per inch dbh. Azinphosmethyl (Guthion 2L) applied at 3.5 gallons per 500 gallons of water) was sprayed on July 13 and monthly until September. The carbofuran should have protected the flower and conelet crop early in the growing season, yet there were moderate levels of first

Table 1—*Clonal and overall averages 1982–83 Kentucky shortleaf cone analysis summary*

Clone	TD	DS%	EE%	A1%	A2%	SEP	FL%	SE%
15	74	80	16	16	4	80	95	76
16	26	17	82	82	1	90	87	14
17	74	82	86	18	0	108	92	76
22	82	72	73	28	0	124	87	62
23	74	92	55	8	0	90	93	86
27	96	87	80	13	1	112	92	79
30	70	90	46	10	0	90	93	83
32	83	83	46	13	4	98	67	55
36	80	84	88	16	0	88	88	74
37	103	87	87	13	0	102	91	79
40	80	80	51	20	0	86	71	57
42	111	91	96	9	0	148	93	84
Overall averages	79*	79†	73*	21†	.75†	101†	87†	69†

* Average of 120 sample cones (12 clones).
† Average of 12 sample cones (1 cone clone).
TD = total developed seed, DS% = %d eveloped seed, EE% = extraction efficiency, A1% = % first-year abortions, A2% = % second-year abortions, SEP = seed potential, FL% = % filled seed, SE% = seed efficiency %.

year ovule abortions. Possibly the carbofuran did give partial control, but its value may be questionable.

* Monthly spraying of azinphosmethyl (Guthion) after July 1982 and fenvalerate (Pydrin) beginning in midMay 1983 gave excellent control until the cones reached near full size in July 1983. Following a scale insect outbreak, entomologists recommended that we discontinue spraying with fenvalerate and use malathion instead. If the damage from seedbugs had occurred during the early summer, (during fenvalerate protection periods), then one would expect to have substantial numbers of second-year ovule abortions. Seedbug feeding on full-sized cones caused empty seeds rather than aborted ovules, thus one can assume the majority of the seedbug feeding occurred during July and beyond. Again empty seeds may not all be caused by seedbugs, but can also be caused by lethal gene combinations. Thus with 13% empty seed being extracted there was either a problem in late-season seedbug control, a problem with recessive genes, or a combination of these factors. However, 87% filled seed is very good seed yield, and it is doubtful that there is much opportunity for improvement.

Conclusion

it appears that the IMS is a valuable tool for seed orchard managers. If used on a continuing basis, orchard managers can evaluate both short and longterm changes in orchard productivity. When used in conjunction with cone analysis the manager can pinpoint when and where losses are occurring, and then determine if additional measures to protect the crop(s) are cost effective enough to justify the increased management costs.

As we build up several years of data, our ability to accurately predict seed yields will be greatly increased, as will our knowledge of the most crucial time periods in seed protection.

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Propagating Black Willow From Cuttings in the Lower Rio Grande Valley, Texas

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Cuttings of black willow (Salix nigra) *with diameters* of 0.9 to *4.5 cm and lengths of about 50 to 150 cm were* rooted success-*fully in the field in the Lower Rio Grande Valley, TX.* Tree Planters' Notes 39(4):30-32; 1988

Black willow *(Salix nigra* Marsh.) is common in wet areas that are not permanently flooded in the eastern United States (6). The plant is also referred to as S. *humboldtiana* Willd. in the Lower Rio Grande Valley of south Texas and northeastern Mexico (3, 7). It grows rapidly, reaching 20 m in height, along levees, riverbanks, ponds, and resacas (former river channels that have become oxbow lakes). The Altamira *oriole—Icterus gularis* (Wagler) (2)—and perhaps other species of birds (7) use this tree for nesting sites.

The U.S. Department of the Interior, Fish and Wildlife Service is planting willow cuttings adjacent to resacas and the Rio Grande River in south Texas. Notes in the literature state that most willows can be grown from cuttings (4, 12). Nokes (11) stated that black willow would root from either root or stem cuttings set out in early spring before the buds leafed out. Maisenhelder and Heavrin (9) advised taking cuttings from 1- to 3-year-old seedlings or sprouts. These cuttings should be 50 cm long and from 1 to 2 cm in diameter at the small end. McKnight (10) also stated that cuttings should be from established young trees, preferably not more than 3 years old.

Briscoe (1) obtained a 67% survival rate with cuttings rooted between September and March, with March the best month (87 to 100% success). He used cuttings 40 cm in length and 0.5 to 4.8 cm in diameter. He had better success with butt-cuts (basal 40 cm) than second-cuts (next 40 cm). The mean heights of cuttings rooted in February and March were 115 to 150 cm after 5 months.

Maisenhelder (8) similarly stated that height growth of black willow averages about 120 cm the first year. Briscoe (1) suggested that cuttings with a large diameter might survive and grow better than smaller ones, and that longer cuttings might survive better than shorter ones.

Past research on black willow propagation has been confined to the lower Mississippi floodplain. A search of 18 files in the DIALOG database produced no titles on black willow propagation specific to south Texas. We conducted field trials to obtain information on desired diameter, length of cuttings, and expected survival in the Lower Rio Grande Valley.

Methods

Cuttings of black willow were rooted at a site adjacent to a resaca for 2 successive years. The site was located south of McAllen near the Pharr Settling Basin and about 1,100 m north of the Rio Grande River. The soil was a Matamoros silty clay, with the top 38 cm typically a calcareous, moderately alkaline, moist silty clay (5). The slope was less than 2%.

Cuttings were taken from trees of various ages adjacent to the resaca. Three hundred and ninety-four cuttings were placed in the margins of three ditches in late February 1985. The ditches were about 30 to 200 m from the edge of the resaca. One hundred and sixty-two cuttings were placed in the side of the ditch closer to the resaca (15 to 200 m from the edge) in late February 1986. All ditches were about 0.3 m deep.

Cuttings were watered once after planting. Survival checks were made on May 16, 1985, June 9, 1986, and January 9, 1987. Diameter of the cutting and length of the aboveground

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Table 1—*Survival of black willow cuttings*

Cuttings planted		Survival							
		3 mo.		11 mo.		16 mo.		23 mo.	
Date	N	No.	%	No.	%	No.	%	No.	%
Feb. 85	394	75	19	—	—	18	4.5	18	4.5
Feb. 86	162	93	57	84	52	—	—	—	—

Table 2—*Size of successful cuttings*

Date planted	Diameter (cm)			Above-ground length (cm)		
	Mean	SD	Range	Mean	SD	Range
Feb. 85	3.5	0.6	2.5–4.5	91	12	65–104
Feb. 86	2.1	0.6	0.9–3.0	52	13	20–109

portion of the cutting were measured on June 9, 1986. Height of the live growth was measured on January 9, 1987. Precipitation records were kept at the Santa Ana National Wildlife Refuge, which is 10 km to the east.

We did not control the depth to which the cuttings were placed. Most were placed upright, to about 30 cm depth, and cuttings were typically 130 cm in total length. Several cuttings that assumed a more horizontal position after several months rooted nevertheless.

Results

Seventy-five (19%) of the cuttings planted in 1985 were alive after 3 months, but only 18 (4.5%) remained alive at the 16- and 23-month checks (table 1). No cuttings died between the latter two checks in 1985. At the 16-month check, mean diameter of live cuttings was 3.5 cm and mean above-ground length of successful cuttings was 91 cm (table 2). Heights of the live portion of the cuttings ranged from 85 to 200 cm (mean = 158, standard deviation = 42) after 23 months.

Ninety-three (57%) of the cuttings planted in 1986 were alive after 3 months, and 84 (52%) survived 11 months (table 1). At the 3-month check, mean diameter of live cuttings was 2.1 cm and mean above-ground length of successful cuttings was 52 cm (table 2). Heights of the live portion of the cuttings after 11 months ranged from 40 to 320 cm (mean = 165, standard deviation = 62). The plants had not yet dropped their leaves on January 9, 1987.

Discussion

Cuttings with diameters of 0.9 to 4.5 cm, and lengths of about 50 to 150 cm were rooted successfully. We have rooted black willow cuttings of up to 10 cm diameter adjacent to the water's edge at another site. Briscoe (1) suggested that larger and longer cuttings may be preferable, but our results were not as good as those obtained with shorter and smaller diameter cuttings. The smaller diameter cuttings placed in the ground in 1986 had much greater rooting success (52% vs. 4.5%). A greater portion of the 1986 cuttings were from smaller, presumably younger, trees.

The 1986 plantings had a smaller percentage of subterminal cuttings. Few basal cuts were used in either planting. The 1986 cuttings were placed in a ditch that was closer to the resaca, where soil moisture may have been slightly higher than the site where the 1985 cuttings were planted. Precipitation, however, was 179% greater in 1985 for both the 2-month (66 vs. 37 mm) and 8-month (530 vs. 296 mm) periods after cuttings were placed in the ground.

Other possible reasons for the great difference in rooting success between the 2 years may include differences in physiological conditions of the parent trees when cuttings were taken or other differences in climatic or soil conditions. Overall, results were not as good as that reported for the lower Mississippi floodplain (1, 8, 9).

Additional studies are needed to determine the optimum month for rooting cuttings, diameter and length of cuttings, depth at which to set cuttings, age and size of parent trees, and basal versus subterminal cuttings. Until these studies are completed, we recommend rooting cuttings in January or early February in the Lower Rio Grande Valley, and taking basal cuttings from smaller size seedlings and sprouts. Cuttings should be set 40 cm into the ground, either in a hole punched with a planting rod or in the slit made with a subsoil plow as recommended by Maisenhelder and Heavrin (9).

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Tree Planter's Notes, Vol. 39, No. 4 (1988)

Graded Northern Red Oak Planting Stock: Dimensions and Outplanting Performance

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Data on the initial stem diameter and height growth of graded 1 + 0 and 1 + 1 northern red oak stock (Quercus rubra *L.) are presented. If shoot clipping or prescribed burning is to be used after planting, grading of stock appears to be of little use.* Tree Planters' Notes 39(4):33-35; 1988.

Northern red oak is a valuable hardwood with a range extending over much of eastern North America. In Ontario, the species occurs on many site types, but at the northern part of its range it is most often found in dry ecoclimates on shallow-to-bedrock sites, on soils derived from glacial till. Good growth of red oak can be expected on these sites, in the absence of strong competition from sugar maple *(Acer saccharum* Marsh.) and American beech *(Fagus grandifolia* Ehrh.). However, regeneration of red oak stands is a problem in that acorns are a preferred food source for squirrels, and deer exert a strong browsing pressure on any recently established stems. The problem is compounded in the absence of fire, which often acts as a control upon competition.

With management foresters from the provincial Ministry of Natural Resources, I have initiated tests of a variety of silvicultural techniques to enhance the regeneration of red oak, generally following the prescriptions suggested by Johnson (2). We incorporated herbicide and burning treatments to control competition into a replicated (blocks = 3) shelterwood and underplant system using 1 + 0 and 1 + 1 red oak stock. (Each "cell" within a treatment received 64 trees at 2-m by 2-m spacing.) Due to the variability in size and quality of red oak stock obtained from the nursery, we felt it necessary to grade, measure, and apportion the stock to the treatment "cells" in order to avoid bias to one type, size or class of stock. The following information on initial dimensions of this graded stock may be of use to forest managers who deal with the regeneration of red oak forests.

This work was supported financially by the Canada-Ontario Forest Resource Development Agreement, which is funded jointly by the Canadian Forestry Service and the Ontario Ministry of Natural Resources.

Materials and Methods

Northern red oak stock was obtained in the spring of 1986 from the Ontario Ministry of Natural Resources Midhurst Nursery, near Barrie, Ontario (Ontario Site Region 6E). The 1 + 0 stock was initially planted with 8 cm between acorns and 14 cm between drills. It was lifted in the fall of 1985 and overwintered in cold storage. The 1 + 1 stock was transplanted by hand to a 45-cm by 45-cm spacing and lifted in the spring of 1986. Neither stock was root pruned. Stock was grown in a loamy, medium-fine sand of moderate fertility (data on file, Midhurst Nursery) and a pH of 6.8.

Before outplanting, stock was graded according to the criteria of Stroempl (5). This four-grade system is similar to that used by Johnson (1), but it also takes into account stem form and the health of buds and roots in addition to seedling size. Seedlings of grades 1 to 3 are considered acceptable for planting; grade 4 seedlings are culled. Stem diameters were measured with a vernier-scale caliper at 2 cm above the root collar (root collar diameter, RCD). Seedlings were then outplanted according to the experimental design described in the Introduction. Planters were instructed on depth and method of planting; operational heights (ground to tallest shoot) were then recorded. Further information on treatment effects upon subsequent growth and survival of outplanted oaks is presently being compiled.

Results and Discussion

Even the 1 + 1 stock obtained from Midhurst Nursery failed to reach the minimum root collar diameters recommended for planting by Stroempl (5), 8 mm, and Johnson (1), 10 mm (table

1). In fact, both the 1 + 0 and 1 + 1 stock used here would be classified by Johnson and others (3) as "small" 1 + 0 stock. This may reflect year-to-year or geographic variation in climatic conditions at the nursery. Of more interest is the fact that very little variation occurs in stem diameter or height (table 1) for either the 1 + 0 or 1 + 1 stock between grades, possibly because of the emphasis of the grading system on stem form, or because of the small size of the stock itself. This is true for stem diameter even when grade 4 cull stock is considered (table 1). Thus, if clipping (3) or prescribed burning (4) is to be used to enhance single-shoot growth, then it is probably not necessary to grade red oak stock beyond removing culls. This is partially confirmed by field observations on the growth of the outplanted 1 + 0 and 1 + 1 red oak stock (table 2).

In comparing 1 + 0 and 1 + 1 red oak stock, it might appear from the data on stem diameters that it is not worthwhile to transplant 1 + 0 stock. However, although stem diameter is only slightly larger in the 1 + 1 stock (table 1), regardless of grade, it is enough to place the older stock marginally in the "large" seedling class (RCD basis) of Stroempl (5). (The 1 + 0 stock is only slightly above the range given by Stroempl (5) for "small" stock.) The height data presented in table 2 give a better illustration of the added effect of an extra year in the nursery; the 1 + 1 stock is approximately twice as high as the 1 + 0 stock. This is indicative, too, of the generally larger root systems found on the 1 + 1 stock. This is an important criterion to consider, especially if root pruning is contemplated as suggested by Johnson (1). It is also likely that seedlings with large root systems and a minimum diameter of 8 mm (5) will be better able to withstand the effects of prescribed burning.

The beneficial effect of using the larger 1 + 1 stock, even in a

Table 1—*Stem diameter at 2 cm above root collar and initial height after outplanting (ground to tallest shoot) of 1 + 0 and 1 + 1 northern red oak nursery stock, by grade*

	Root collar diameter (mm)		Initial height (cm)	
	1 + 0	1 + 1	1 + 0	1 + 1
Grade 1				
Mean ± SE	6.8 ± .07	7.6 ± .19	22.5 ± .5	50.8 ± 1.2
Range	4.8–10.3	4.5–12.3	12–46	26–70
N	182	68	177	66
Grade 2				
Mean ± SE	6.6 ± .06	7.8 ± .10	24.5 ± .4	46.4 ± .6
Range	4.1–10.9	4.4–13.7	10–55	25–80
N	322	264	310	268
Grade 3				
Mean ± SE	6.7 ± .06	7.8 ± .11	25.9 ± .9	42.6 ± .6
Range	4.2–10.3	4.3–13.8	13–63	21–67
N	321	245	83	240
Grade 4*				
Mean ± SE	6.5 ± 0.9	—	—	—
Range	4.3–10.2	—	—	—
N	130	—	—	—

*Not acceptable under Stroempl's system of grading (6), included for information only.

Table 2—*Dominant shoot growth for the 1987 growing season in 1 + 0 and 1 + 1 northern red oak nursery stock, by grade*

	Mean shoot growth ± SE (cm)		
	1 + 0	1 + 1	Difference
Grade 1	24.2 ± 3.1	40.7 ± 7.8	16.5
Grade 2	22.8 ± 2.1	36.9 ± 3.0	14.1
Grade 3	36.6 ± 6.1	31.0 ± 3.7	−5.6

Seedlings were underplanted in spring 1986 beneath a residual stand of tolerant hardwoods. These hardwoods resulted from a shelterwood cut (fall 1985) that removed 50% of the basal area of the timber at the site.

situation where burning or clipping is not considered, can be seen in table 2. Although variation in 1987 dominant shoot growth occurred between grades, the added year in the nursery appears to have substantially enhanced field performance, at least in terms of height growth. This is true for both grade 1 and grade 2 stock.

Regardless of assigned grade, many seedlings suffer top mortality and dominance is often assumed by a rapidly growing branch initiated at a lower lateral bud. To avoid poor stem form, operational clipping or burning should be considered. This statement must be qualified by the fact that very little is known about the minimum size of stem diameter required to withstand an operational burn. This is an important consideration because the mortality of red oak seedlings in a burn is directly related to root collar temperature (2). Of course, in a competition-free situation where burning or clipping is not contemplated, stem form is of utmost importance and stock should be graded at the nursery. This assumes a correlation of seedling stem form with stem form at a later age, a likely event barring major browse or environmental (e.g., ice) damage. If grading is undertaken, the recommendations of Stroempl (5) should be followed; particular attention should be paid to the quality and size of terminal buds.

The grading system employed in this study was derived principally from a morphological grading system for 2 + 0 red oak stock. The study discussed here employed 1 + 0 and 1 + 1 stock, mainly because of availability. Morphologically, both stock types fit the criteria described by Stroempl (5) quite well, although, possibly because of transplanting (1 + 1), there were seedlings in all grades that went below the cull size specified by Stroempl (5), which is 4.5 mm. In Ontario nurseries, transplanting red oak is used primarily to enhance root growth; to obtain maximum root development and RCD, 1 + 2 stock is usually grown. However, even with 1 + 1 stock, increased height growth is possible (table 2), but decreased or reduced diameter growth may be noticed. Thus, the minimum cull diameter given by Stroempl (5) may be too high when 1 + 1 (or 1 + 0) stock is being considered. Due to cost and the reduced growth associated with transplanting, 2 + 0 red oak stock that has been undercut to increase root fibrosity (1) may be a more desirable stock type.

Forest managers dealing with red oak stock in Ontario and similar climatic zones can expect good survivorship of red oak seedlings that are planted carefully. Older, larger stock is preferred; it should be graded and culls discarded at the nursery if shoot clipping or burning after planting will not be considered. If either of these is contemplated, grading may be of little benefit.

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Pregermination Treatment Hastens Emergence of Loblolly Pine Seedlings

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A pregermination treatment in which loblolly pine (Pinus taeda *L.)* seeds were *placed in a warm, lighted, aerated water bath was tested* as a *method* to *hasten germination. The treatment significantly reduced the time between sowing and emergence, but did not affect the variation in emergence timing. Seedling morphology was not significantly affected by the pregermination treatment.* Tree Planters' Notes 39(4):36-38; 1988.

The germination of loblolly pine *(Pinus taeda* L.) can be hastened by seed stratification (2, 3). Rapid germination is necessary to avoid seed loss due to heavy rains, reduce the period of susceptibility to certain diseases, improve crop uniformity, and increase seedling size.

Barnett (1) developed a method to germinate pine seeds to prepare them for "fluid drilling." The objectives of this experiment were (a) to adapt this method to traditional sowing methods used in the nursery and (b) to test the method's effects on the speed and uniformity of seed germination and, in turn, the morphological characteristics and uniformity of the resulting seedling crop. We have termed this treatment "pregermination" because germination is initiated prior to sowing. Because emerging radicles would be damaged using traditional sowing methods, Barnett's procedures were modified so that the germination process was stopped when the seed coat cracked, prior to emergence of the radicles.

Materials and Methods

Loblolly pine seeds used in this test were from two half-sib families provided by International Paper Company (IPCO) One family was from a first-generation seed orchard (family I) and the other came from a second-generation orchard (family II).

All seeds were stratified for 60 days. Half the seeds also were given a pregermination treatment for 3 days, which consisted of an aerated water bath at 24 °C. The water bath was kept under constant fluorescent lighting. Seeds were sown by hand on May 5, 1985, at IPCO's nursery near Bluff City, AK. Plot size was 0.6 m by 1.2 m (bed width), with 240 seeds sown per plot (2

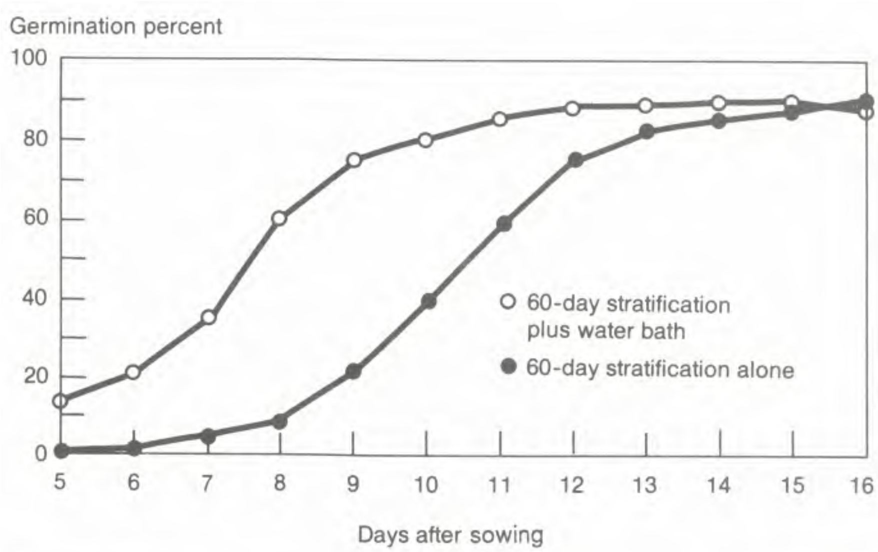

Figure 1—*Cumulative germination curves for family I seed stratified for 60 days, with and without pregermination (warm soak) treatment.*

cm apart in rows 15 cm apart). Treatments were replicated six times. Germination was monitored daily from May 10 until May 21. Seedlings were lifted from each plot in December 1985 and measured for height, diameter, shoot dry weight, and root dry weight. Separate analyses of variance for germination and morphological characteristics were conducted or each family.

Results and Discuss

The pregermination treatment significantly hastened germination for both families (figs. 1 and 2, table 1). Mean time to emergence was reduced by 3 days for family I, and by about 2 days for family II. Despite the more rapid germination, the uniformity of emergence was not affected. The standard deviation for days to emergence was not reduced by the pregermination treatment (family I, SD = 1.76 and 1.71 for pregermination and control, respectively; family II = 1.62 and 1.62). Therefore, placing seeds in the warm water bath was equivalent to "sowing" 3 days earlier. Because the uniformity of emergence was not improved by the pregermination treatment, seedling uniformity was not affected (SD for diameter, family I = 1.01 and 1.02 for pregermination and control, respectively; family II = 1.16 and 1.06). Therefore, results from this and other studies (4) suggest that in order to improve seedling uniformity, the uniformity of emergence must be increased.

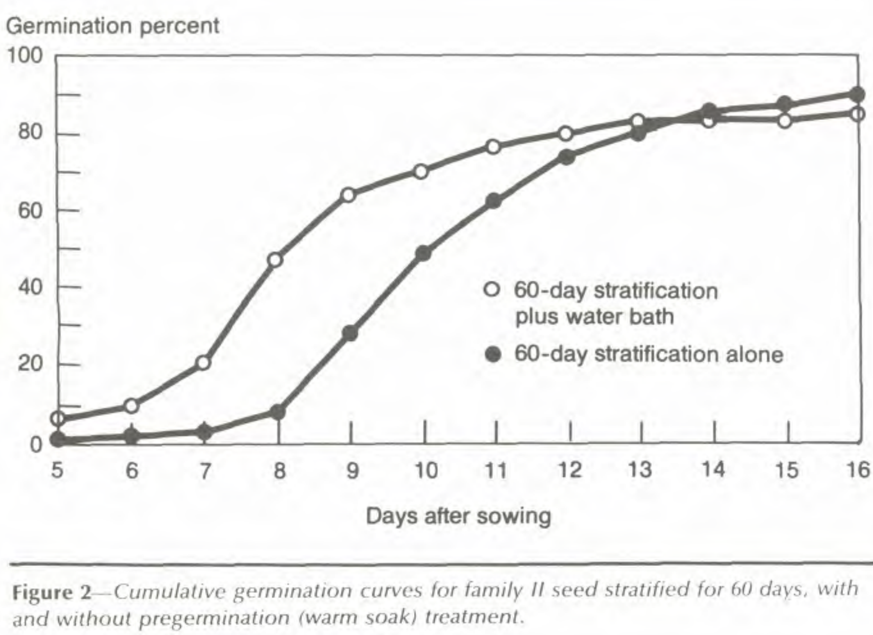

Figure 2—*Cumulative germination curves for family II seed stratified for 60 days, with and without pregermination (warm soak) treatment.*

In a previous study, a similar pregermination treatment increased seedling diameter by 1.4% for each day emergence was accelerated (3). In this study, however, while diameters of pregerminated seedlings averaged 1.5 and 2.3% higher per day for family I and family II, respectively, these differences were not significant at the 5% level (table 2). Root dry weight and shoot—root ratio showed even greater relative increases for both families, but were not significant at the 5% level.

Summary and Conclusions

The pregermination treatment (aerated, lighted, warm water bath) tested in this experiment significantly reduced the time required for germination when computed as days after sowing. However, if one considers day 0 to be the day seeds were placed in warm water, the pregermina-

Table 1—*Seed germination and seedling survival results for pregermination treatment (60-day stratification followed by warm soak) and control (60-day stratification alone)*

	Family I			Family II		
Variable	Warm soak	Control	P>F	Warm soak	Control	P>F
G-50 (field)*	8.2	11.0	0.0001	8.8	10.5	0.0041
G-50 (total)†	11.2	11.0	0.3632	11.8	10.5	0.0103
Germination %‡	91.5	92.0	0.7174	85.6	89.2	0.0291
Tree percent§	86.9	86.7	0.9744	76.1	88.0	0.1454

G_{50} = number of days required for 50% of the seed to germinate.
*Days counted from sowing for both treatments.
†Days counted from beginning of warm soak for pregermination treatment.
‡Total germination 16 days after sowing (percent of seed sown).
§Total live trees at end of season (percent of seed sown).

Table 2—*Seedling morphology results for pregermination treatment (60-day stratification followed by warm soak) and control (60-day stratification alone)*

	Family I			Family II		
Variable	Warm soak	Control	P>F	Warm Soak	Control	P>F
Diameter (mm)	3.80	3.64	0.0674	3.81	3.65	0.3844
Height (cm)	22.9	22.9	0.9445	22.4	22.9	0.5613
Shoot wt. (g)	2.75	2.69	0.6837	2.83	2.94	0.6131
Root wt. (g)	0.90	0.67	0.1043	0.85	0.78	0.2893
Total wt. (g)	3.65	3.35	0.1749	3.69	3.72	0.9011
Shoot/root (g/g)	3.29	4.07	0.0644	3.37	3.77	0.0571

tion treatment did not hasten germination. Rather, the warm water bath caused the germination process to begin sooner. Although early field emergence may influence seedling morphology, the differences were not significant in this study. This treatment may, however, reduce the time between sowing and seedling establishment, which would make a washout by heavy rain less likely. This procedure will be most effective if the pregermination treatment is coordinated with proper field conditions. If rainy weather delays field sowing, the "pregerminated" seeds will either have to be chilled or redried in order to delay germination until the seedbeds dry out.

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