Tree Planters' Notes
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Cover: Aspen meadow in Grand Mesa-Uncompaghre-Gunnison National Forests, Colorado (photograph by R.E. Grossman, USDA Forest Service, Collbran, CO).

Comments

Our New Editorial Policy Is Working!

We have now completed almost 2 years of publishing under our new format and editorial policy. From all accounts it has been a resounding success. We greatly appreciate your favorable comments and support throughout the transition process. I'd like to offer a few comments in retrospect.

The goal or the new editorial policy of peer-reviewing (by referees) some of the articles was to improve the manuscripts and increase the reputation of TPN. This has been achieved, I believe. Numerous comments from the nursery profession have reinforced this. Although some of our readers were not even aware or quite sure of our refereed status, the change-over has been a delicate balancing act. We are still focused intensely on practical "how-to" and equipment articles. These remain the bread and butter of TPN, and although they are not currently peer reviewed, they are reviewed closely by the editorial board consisting of myself, Tom Landis, Clark Lantz, Ron Overton, and Bob Karrfalt, as well as Rebecca Nisley, the managing editor. We are, in fact, helping authors to write articles for the journal. Many nursery managers are taking the time to write up "administrative studies," but we could always use more. We also hope the handsome new format will serve as an enticement for potential authors to take the time to submit manuscripts to us. We certainly do not want the peer-review process to restrict anyone from submitting practical articles.

I am also pleased to say that we are receiving manuscripts from new sources, including international organizations and previously unpublished authors in the reforestation community. We really appreciate your interest in the journal.

In addition to new sources of manuscripts, we are getting manuscripts regarding species that have not been the subject of many published articles. For example, in this issue we present an article on blue oak by McCreary and Tecklin, on hackberry by Anderson and Tauer, and on shortleaf pine by Barnett. Shifting the focus from the everpopular loblolly pine and Douglas-fir is, in my mind, a positive thing.

Our new "Comments" section has stirred up some interest-but it could be more effective I believe. We would like to hear from you. This section of the journal can be a valuable sounding board for airing important issues.

Our special features on the America the Beautiful National Tree Planting Program and on tropical reforestation have been instrumental in presenting a group of articles about current topics in reforestation.

Continuation

We plan to continue to present special features in response to arising needs. Some topics of interest for future issues include reforestation of wetlands, urban forestry phasing techniques, and possibly, more international reforestation features.

We appreciate your continued support and encourage you to send in your manuscripts.

Robert Mangold
Editor-in-Chief
Cooperative Forestry
USDA Forest Service
Washington, DC

Calculating Filled and Empty Cells Based On Number of Seeds Sown per Cell: A Microcomputer Application

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A personal computer and commercially available software can be used to quickly estimate filled and empty cells in a container nursery if germination and seeds sown per cell are known. Calculation formulas for LOTUS™or QUATRO PRO™ are provided, as are seeds per cell recommendations. Tree Planters' Notes 44(2):49-52; 1993.

Managers of container seedling nurseries sow multiple seeds per cell to increase the probability of having at least one germinant per cell. This ensures that their greenhouses are fully stocked so that seedling contracts may be filled. However, this practice wastes valuable seed and necessitates thinning extra germinants at an additional cost. Multiple sowing, therefore, should be minimized. Many factors influence how many seeds per cell to sow, including species, seed size, seed availability and cost, type and accuracy of sowing equipment, sowing and thinning labor costs, and germination data reliability. The primary factor, however, is greenhouse germination percentage. When germination percentage is known or assumed, nursery managers use various rules of thumb or rely on the probability tables found in Tinus and McDonald (1979) to determine the number of expected empty cells. These tables are complete, sometimes cumbersome, and currently unavailable to new managers. Fortunately, the percentage of empty cells can be obtained using a hand-held calculator (Schwartz 1993). Taking this procedure one step farther, the probability tables of Tinus and McDonald (1979), showing both filled and empty cells, can be recreated on a personal computer.

Microcomputer Application

This LOTUS™ microcomputer application may be used to provide instant data for sowing decisions. The application as presented here calculates up to 5 seeds per cell but could be expanded for any number desired. Enter a germination percentage and the matrix displays the probability of having cells with 0, 1, 2, 3, 4, and 5 germinants when sowing 1, 2, 3, 4, or 5 seeds per cell. In addition, three other calculations are displayed: 1) percentage of cells requiring thinning, 2) number of extra germinants to be thinned per 100 cells, and 3) marginal percentage return (the gain in number of cells containing a germinant for each additional seed sown in 100 cells). This dramatically shows the results of increasing seeds per cell. Data are useful in determining the cost:benefit ratio in sowing additional seeds per cell. In this application, percentage calculations have been rounded to whole numbers.

One additional calculation is provided. This application enables the user to enter either whole or fractional numbers of seeds per cell and determines the probable number of empty cells for any germination percentage. For example, 2 seeds per cell may yield too many empty cells and 3 seeds may be too liberal, so try 2.5 seeds per cell. Calculating seed requirements based upon fractional seeds (that is 2.5) enables accepting either two or three seeds per cell and therefore speeds up sowing operations.

To use this application in a LOTUS or QUATRO PROT™ file, set the following column widths:

A = 12, B = 4, C = 6, D-H = 5, I = 6, J = 15

Set the range format of C7 as percentage with two decimal places and C11..H15 as percentage with zero decimal places.

Refer to table 1 and enter the following range labels:

Range	**Label**
A1-	Calculations for optimizing seeds per cell
A5-	Germination % =
A6-	Seeds per cell =
A7-	Empty cells =
C8-	Probability of occurrence
D9-	Germinants per cell

A10, A19-	Seeds/cell
CIO-	Empty
A11, A20, D10-	"1
A12, A21, E10-	"2
A13, A22, 1710-	"3
A14, A23, G10-	"4
A15, A24, 1-110-	"5
C18-	Thinning required
C19-	Cells
D19-	Germinants
J9-	Marginal return
J10-	per 100 seeds

The probabilities of cell occupancy are determined by binomial expansion $(X = Y)^N$, where X^N = *the* probability of all seeds germinating, Y^N = the probability of an empty cell, and N = the number of seeds per cell.

Enter the following range formulas:

Range	**Formula**
C 7-	(1-C5/100)^C6
C11-	1-D11
D11-	(C5/100)^A11
C12-	+C11^A12
D12-	2*(C5/100)*(1-C5/100)
E12-	(C5/100)^A12
C13-	+C11^A13
D13-	3*(C5/100)*(1-C5/100)^2
E13-	3*(C5/100)^2*(1-C5/100)
F13-	(C5/100)^A13
C14-	+C11^A14
D14-	4*(C5/100)*(1-C5/100)^3
E14-	6*(C5/100)^2*(1-C5/100)^2
F14-	4*(C5/100) ^3*(1-C5/100)
G14-	(C5/100)^A14
C15-	+C11^A15
D15-	5*(C5/100)*(1-C5/100)^4
E15-	10*(C5/100)^2*(1-C5/100)^3
F15-	10*(C5/ 100)^3*(1-C5 / 100)^2
G15-	5*(C5/100)^4*(1-C5/100)
H15-	(C5/100)^A15
J12-	(C11-C12)*100
J13-	(C12-C13)*100
J14-	(C13-C14)*100
J15-	(C14-C15)*100
C20-	0
C21-	+E12*100
C22-	(E13+F13)*100
C23-	(E14+F14+G14)*100
C24-	(E15+F15+G15+H15)*100
D20-	0
D21-	+E12*100
D22-	(E13*100)+(F13*200)
D23-	(E14*100)+(F14*200)+(G14*300)
D24-	(E15*100)+(F15*200)+(G15*300) +(H15*400)

Example of Sowing Calculations

Input. Go to range C5 and for "Germination % =" enter 65 (table 2).

Output. The effect of sowing multiple seeds per cell is displayed in ranges C11 through H15. With the above input (65% germination) and 1 seed sown per cell, there will be 35% empty cells (range C11) and 65% cells (range D11) with 1 seed. This is an excessive number of empty cells. If 2 seeds were sown per cell there would be 12% empty, 46% with 1 germinant, and 42% with 2 germinants. Still an excessive number of empty cells. The "Marginal Return" column indicates that by sowing a second seed per cell, 23% additional cells become occupied (range J12). The effects of sowing a third, fourth, and fifth seed per cell are similarly shown. The third seed adds 8 additional occupied cells (range J13), and the fourth seed 3 more cells (range J14). Sowing another 100 seeds, the fifth seed per cell, only contributes 1 additional occupied cell (range J15), an effort that is hardly worthwhile. If a value such as 4 is entered in range C6 ("Seeds per cell =") the percentage of "Empty cells =" is displayed to two decimal places in range C7 (1.50%).

Thinning requirements are also displayed per 100 cells sown. Sowing 2 seeds per cell will require thinning one germinant from 42% of the cells (range C21) for a total of 42 extra germinants (range D21). The third seed per cell will require thinning 72% of the cells (range C22) and a total of 99 germinants per 100 cells sown (range D22). The fourth and fifth seed thinning calculations are also displayed.

Recommendations

At the University of Idaho Research Nursery, for a given germination percentage, we strive to use a seeds-per-cell value that produces fewer than 1.5% empty cells. With 98.5% filled cells, requested numbers of seedlings are usually met or exceeded with a 10% oversow. The recommendations are based upon this premise when using a precision seeder with reliable greenhouse germination data.

Table 1- *Range labels for sowing calculations*

LOTUS range columns

	A	B	C	D	E	F	G	H	I	J
1	Calculations for optimizing									
2	seeds per cell									
3										
4										
5	Germination % =									
6	Seeds per cell =									
7	Empty cells									
8			Probability of occurrence							
9					Germinants per cell					Marginal return
10	Seeds/cell		Empty	1	2	3	4	5		per 100 seeds
11	1									
12	2									
13	3									
14	4									
15	5									
16										
17										
18			Thinning required							
19	Seeds/cell		Cells	Germinants						
20	1									
21	2									
22	3									
23	4									
24	5									
25										

Table 2 -*Example of calculations for optimizing seeds per cell*

LOTUS range columns

	A	B	C	D	E	F	G	H	I	J
1	Calculations for optimizing									
2	seeds per cell									
3										
4										
5	Germination % = 65									
6	Seeds per cell = 4									
7	Empty cells = 1.50%									
8			Probability of occurrence							
9					Germinants per cell					Marginal return
10	Seeds/cell		Empty	1	2	3	4	5		per 100 seeds
11	1		35%	65%						
12	2		12%	46%	42%					23
13	3		4%	24%	44%	27%				8
14	4		2%	11 %	31 %	38%	18%			3
15	5		1 %	5%	18%	34%	31 %	12%		1
16										
17										
18			Thinning required							
19	Seeds/cell		Cells	Germinants						
20	1		0	0						
21	2		42	42						
22	3		72	99						
23	4		87	162						
24	5		95	226						
25										

Seed lot germination percentage	Recommended seeds per cell
98-100	1.0
95-97	1.5
88-94	2.0
82-87	2.5
76-81	3.0
70-75	3.5
65-69	4.0
60-64	4.5

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Effect of Root Form on 10-Year Survival and Growth of Planted Douglas-fir Trees

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Douglas fir seedlings (Pseudotsuga menziesii *(Mirb.) Franco.) were planted with three root form treatments including C-roots ("correctly" planted controls), L-roots, and]-roots. After 10 years, there were no significant differences in outplanting performance between the three root form treatments on a good site in western Oregon. The results are in agreement with those of other studies, which suggests that when no other confounding planting errors are present, deformed root systems play a less dramatic role in subsequent field performance than is generally thought. These results in no way imply that poor planting is acceptable.* Tree Planters' Notes 44(2):53-57; 1993.

The majority of forest nursery personnel and tree planters would agree that root deformation during planting is detrimental to the development of the tree. In fact, tree planting contracts often have specifications against root deformation and current reforestation manuals cite J-roots and L-roots as unsatisfactory (Rose 1992). Common problems attributed to root deformities are increased mortality, moisture stress, disease incidence, and decreased wind firmness. However, despite such widespread acceptance of the drawbacks of root deformation during planting, there is uncertainty surrounding this belief.

In an early study, Cheyney (1927) found there was very little difference between seedlings of 3 species with balled roots and with expanded roots. In another early study, Rudolf (1939) found that root deformity in forest plantations had little effect upon mortality. Rather, trees with the majority of their roots in a single plane had greater mortality and poorer growth than those with their roots spread out, regardless of root deformation. Sutton (1969) noted that the relationship between root form and tree performance in conifers was not well understood.

In more recent research, Woods (1980) found no significant differences in survival or height growth after 7 years for loblolly pine *(Pinus taeda* L.) planted with their roots in five configurations. In a study with 4 species, Schantz-Hansen (1945) found no significant differences in survival or root de velopment between planting methods, including a "careless" method in which the roots were placed in an abnormal position. Mexal and Burton (1978) found that deformation of the taproot in loblolly pine was not correlated with seedling growth 4 years after plantation establishment. In a study with several northwestern conifer species, root system deformation was found to be unrelated to tree growth (Long 1978).

Some researchers have contributed data to support the negative effects of root deformation. Brissette and Barnett (1988) concluded that J-rooted loblolly pine seedlings had lower survival and growth. However, from their results, it appeared that mortality and growth were more likely related to planting depth. The J-rooting treatment resulted in seedlings with roots 5 cm shallower than the straight treatment, but when roots were placed at similar depths, survival of J-rooted trees was actually greater than that of straight-rooted trees. This suggests that shallow-planted trees, especially those which are J-rooted, are less likely to perform well. In another study, Lacaze (1968) found that average heights among control, J-rooted, and L-rooted Norway spruce *(Picea abies* L.) seedlings differed significantly with the control having the greatest growth. However, the maximum difference between treatments was only 7 cm. Bergman (1976) cited root deformation as having a negative effect on reforestation. However, he refers to seedlings that have been deformed in containers before being planted to the forest.

Despite some evidence indicating that root deformation is not harmful to seedling development, the evidence is still unclear and many reforestation personnel and researchers are reluctant to forsake their belief in root deformation's detrimental effects In a 24-year study, Hunter and Maki (1980) found no significant differences in survival and growth between straight- and curl-rooted loblolly pine trees, yet the authors stated that they believed curl-rooted trees go through a period of high susceptibility to blowdown between the ages of 3 and 5. Gruschow (1959) found that 67% of excavated young loblolly pine trees had deformed roots but that growth was not related to root form. However, this author made it a point to speculate that seedlings with deformed roots are probably more susceptible to disease and that increased attention should be given to "correct" planting of seedlings. Grene (1978) claims that field performance may be misleading and that root deformation leads to reduced root growth and stability, despite concluding that root strangulation is a myth and finding evidence that root deformation decreases over time.

The objectives of this study were to evaluate the effect of root form on the growth and survival of Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) seedlings in a coastal environment. Most research on root form has focused on southern pine species and on spruces. This study will include more data on northwestern species and will contribute to further understanding of the long-term effects of root form at the time of planting.

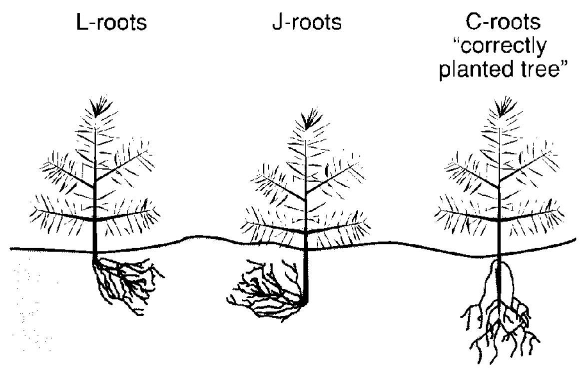


Figure 1—*The three root-form treatments.*

Methods

Two-year-old (2+0) Douglas-fir seedlings were grown at the USDA Forest Service's Humboldt Nursery in northern California. All seedlings were lifted on January 30, 1981, and graded to operational specifications. Seedlings were placed in cold storage before they were outplanted between March 10 and April 14, 1981.

The study area was located in the eastern portion of Coos County, Oregon, on land managed by the U.S. Department of the Interior's Bureau of Land Management. The site is at an elevation of 700 m, with a south aspect and 30 to 50% slope. Soils in the area are generally deep (with an average top soil depth of 60 to 90 cm). The site has a moderate site index and an average annual precipitation of 170 cm. The summer months are fairly dry, with an average of less than 5 cm of precipitation from July through September.

The three root-form treatments included C-roots ("correctly" planted controls), L-roots, and J-roots. All seedlings were planted with a shovel. At each planting spot, a 10- x 18- x 30-cm-deep hole was dug. The seedling was suspended over the hole and the pre-determined root configuration was formed by putting the roots into a J or L shape or leaving the roots suspended naturally for the C-roots (figure 1). Soil was carefully filled in around the root system so the desired root configuration would remain. All seedlings were protected from animal browsing with mesh tubes.

The experimental design consisted of a randomized complete block design with four blocks of 100 trees each. Each block consisted of four rows of 25 seedlings planted on a 3 x 3 m spacing. The root treatment at each planting spot was determined randomly until there were approximately equal numbers of each treatment in each block (33 seedlings per treatment block). Seedlings were measured for height and survival at the end of the first five growing seasons. In addition, 3 randomly chosen trees, one of each root form, were excavated in June 1984 to observe root configurations. After the tenth season, trees were again measured for survival and height as well as diameter at breast height (DBH).

Data were analyzed using analysis of variance (ANOVA). Tests for normality, linearity, and constant variance of the residuals were performed to ensure the validity of these assumptions. Fisher's protected least significant difference (FPLSD) procedure was used to determine significant differences in data among root-form treatments at the a 0.05 level. Statistical Analysis System (SAS Institute 1982) software was used for analysis of all data.

Results

This study produced no evidence that root form influenced survival or growth of Douglas-fir. After 10 years, there was little difference in outplanting performance among the three root-form treatments (table 1). Differences in survival, growth, height, and diameter were nonsignificant ($\alpha <= 0.05$) among

Table 1-Means of seasonal survival and means and standard errors (SE) for seasonal height and 10-year diameter at breast height (DBH) of control (C), J-rooted, and L-rooted Douglas fir seedlings outplnnted in Oregon

	Control seedlings	J-rooted seedlings	L-rooted seedlings	SE
Survival (%)				
Initial	100	100	100	
1981	100	98	96'	
1982	88	87	87	
1983	88	85	81	
1984	87	85	81	
1985	87	85	81	
1990	87	83	80	
Total height (cm)				
Initial	24.1	22.6	24.1	0.64
1981	36.5	34.3	35.3	0.81
1982	67.5	63.2	65.7	1.73
1983	109.1	105.8	99.5	3.79
1984	148.5	145.9	136.3	5.04
1985	195.9	192.6	180.7	6.71
1990	649.7	634.5	626.6	16.65
DBH (cm)				
1990	9.3	9.2	8.8	0.24

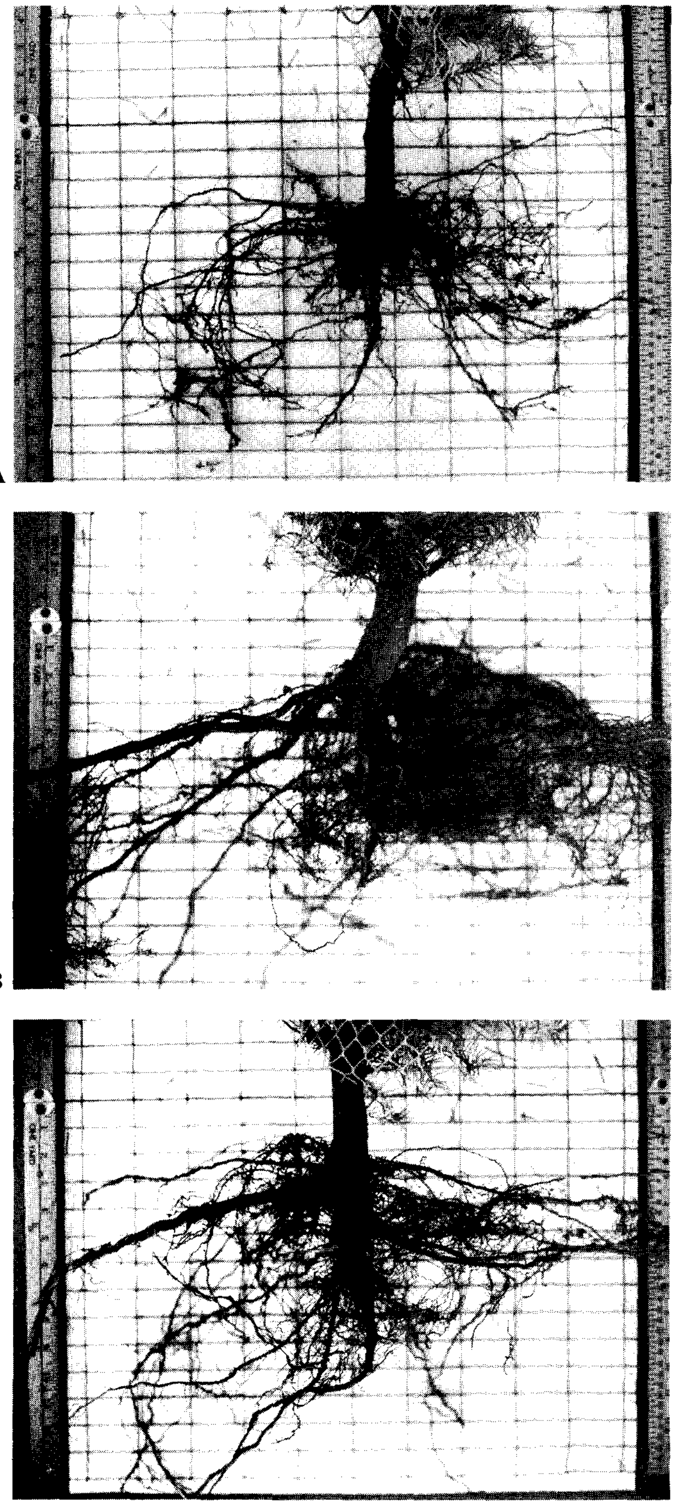
Means within each year followed by an asterisk differ significantly ($\alpha <= 0.05$) from the controls (Fisher's protected LSD procedure),

treatments every year with the exception of firstyear survival (1981), where the L-rooted trees had significantly lower survival than the controls. However, this significance is not particularly meaningful given that the survival of 96% for L-rooted trees is well within acceptable stocking standards. Although not statistically significant, the L-rooted trees consistently exhibited a trend toward reduced survival and growth as compared to the controls and J-rooted trees. This trend, however, may have little impact on the overall yield and quality of the mature stand. Furthermore, this reduced survival and growth may not be entirely attributable to root configuration, because the J-rooted trees, which were the most deformed, tended to perform better than the L-rooted trees.

Though not quantified, there was observed to be little or no difference in the number, length, or distribution of major lateral roots among the three root-form treatments for seedlings excavated in June 1984 (figure 2). The original taproot on the J-rooted seedling appeared to have quit functioning. The trees in each treatment seemed to be anchored stably in the ground.

Discussion

The results of this study are in agreement with those of other studies, which have found root de-



A B C

Figure 2—*Root systems of seedlings excavated in June 1984: A— Control. B—J-rooted. C—L-rooted.*

formation at the time of planting to have no adverse effects. Owston and Stein (1978) found that initial deformities did not seem to hamper the development of a strong root system for bareroot Douglas-fir and noble fir (Abies procera Rehd.) seedlings. Seiler et al. (1990) found that J-rooting did not significantly lower the water potential of loblolly or eastern white pine (Pinus monticola Dougl.) seedlings. They state that tree planters should be primarily concerned with planting seedlings quickly and at the correct depth. They warn that instructing planters to avoid J-roots by pulling back up on the seedlings when they are placed in the planting hole may do more damage than good because the end result could be shallower root placement. In a study by Schultz (1973), there was no indication that early growth of slash pine *(Pinus* elliottii Engelm.) was inhibited by deformed roots, and, after 12 years, root deformation was no longer visible.

Some researchers have even found favorable effects of root deformation on seedling development. Hay and Woods (1974a) found that dry weights of loblolly pine seedlings with deformed roots increased at a faster rate than those with straight roots. They attribute this to the proliferation of lateral roots in the upper soil zones, which may have enhanced the nutrient and water absorption capacity of the seedling and stimulated stem and foliage growth. In other studies, Hay and Woods (1968, 1975, 1978) reported that the development of extensive lateral root systems in seedlings with deformed roots seems to be promoted by carbohydrates accumulated above taproot curvatures. In addition, Hay and Woods (1974b) found that root systems of large saplings (on a weight basis) in 4- to 6-year-old plantations showed more deformation characteristics than did the roots of small saplings. They note that although large, hard-to-plant seedlings could have an initial growth advantage, large saplings probably developed extensive shallow root systems, which could utilize nutrients in the fertile upper soil layers more effectively than the deeper taproots of "correctly" planted saplings. In a study by Huuri (1978), seedlings planted with balled roots actually had better stability than the control trees. The author concludes that there appears to be no risk of Scotch pine *(Pinus* sylvestris L.) plantations being jeopardized by root deformation.

The results of this study cannot lead to any firm conclusions concerning root form. Given the variability of the data, this study had a low statistical power to detect the measured differences between treatments. However, although the trend was very weak, the biological order of results in terms of height and survival (C > J > L) concurs with the practical forester's expectation.

This study, like other applied research of its kind, was set up as a simulated operational test to examine long-term effects of root form. However, this study could not simulate deformed planting with the occasional air pocket, exposed roots, non-perpendicular shoot orientation, extremely deep or shallow planting holes, and other common planting errors that accompany operational J- and L-rooting of seedlings. In other words, if other confounding errors of poor planting are eliminated, and all other factors are kept equal except root form, there *is* a possibility that J- and L-rooted seedlings will become established and grow as well as correctly planted seedlings.

Conclusion

These results indicate that seedlings in this study were not adversely affected by variations in root form at the time of planting. This conclusion is based on the results of seedling performance on one specific site with relatively favorable growing conditions. On a harsher site, the differences be tween root forms may be more dramatic. Therefore, no widespread conclusions can be drawn from the data. This study in no way implies that "sloppy" planting is acceptable nor does it suggest that root form should be ignored. However, this study does add to the literature that suggests that when all other factors are equal, root form of planted bare root seedlings plays a less dramatic role in subsequent field performance than some foresters may have thought.

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Presowing Treatments Affect Shortleaf Pine Seed Germination and Seedling Development

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Two experiments using 6 half-sib families of skortleaf pine (Pinus echinata Mill.) *were conducted to provide better information on seed stratification needs. Results from laboratory and nursery germination tests and evaluations of seedling development in the nursery indicate that stratification for 15 days was adequate when germination conditions were nearly ideal. However, results from the studies indicate that the speed of germination was much slower when germination temperatures and daylengths were lower than optimum. Under these conditions, 45 days of stratification were needed to achieve uniform rates of germination. The more adverse the germination conditions were, the more important it was that stratification was longer. Seeds that germinated early produced larger stock than those that germinated later. Predictions of seed gerurination in nurseries can be improved by determining the typical environmental conditions at the time of sowing and by requesting that germination tests be conducted under corresponding conditions.* Tree Planters' Notes 44(2):58-62; 1993.

Shortleaf pine *(Pinus echinata* Mill.), the most widely distributed southern pine species, is planted extensively in Arkansas and Oklahoma. Little research has focused on the production of high-quality seeds, and much less information is available on appropriate technology for producing shortleaf pine than for loblolly pine (P. *taeda L.)* seeds. Because information on shortleaf pine seed quality, nursery culture, and regeneration techniques has been limited, the gaps have been filled by using data from loblolly pine (Barnett et al. 1986). The research reported here is part of an effort to develop information specific to shortleaf pine.

Prompt, uniform germination and early establishment are essential to producing shortleaf pine seedlings of consistently high quality. Overcoming seed dormancy is one of the major steps toward ensuring prompt, uniform germination. Typically, stratification (moist prechilling) of conifer seeds is done after an 8- to 24-hour period of moisture imbibition. However, recent studies show that length of water soaking may affect germination of species such as longleaf pine (P, *palustris* Mill.) (Barnett and Pesacreta 1990). Fully imbibed seeds are nor many placed in polyethylene bags and held at temperatures of 1 to 4 /C (34 to 38 /F). The length of stratification varies according to the extent of dormancy in the seeds.

Although stratification treatments are routinely applied to shortleaf pine seeds, few studies provide specific guidelines. Seidel (1963), working a single seed lot, found that germination speed increased progressively with duration of stratification up to 60 days. Barnett and McGilvray (1971) tested 16 separate lots representing various geographic sources and years of collection. They found that freshly collected seeds were much less dormant than stored ones. In these tests, germination speed of stored seeds continued to increase through 56 to 70 days of stratification.

The objectives of this study were to determine the effects of various pregermination treatments on germination of shortleaf pine seeds tested under optimum laboratory and more adverse laboratory and seedbed conditions, and on seedling develop ment at the time of lifting.

Materials and Methods

General protocol. The general protocol for the two experiments reported here was to use 6 half sib families from the USDA Forest Service seed or chard at Mt. Ida, Arkansas. Shortleaf pine seeds were stored at - 4 /C (25 /F) before use, and all empty seeds were removed by flotation in ethanol (Barnett 1971). In addition to evaluating a range of pretreatments (after 16 hours of water imbibition), seeds were tested under 3 conditions:

1. Ideal conditions-22 /C (72 /F) and 16-hour photoperiod, as indicated by standard germina tion tests (Association of Official Seed Analysts 1980).

2. Adverse laboratory temperatures-15 /C (60 /F) in test 1 and 18 /C (65 /F) in test 2-and a 12-hour photoperiod.
a. Field nursery conditions.

The seeds were germinated and tested at the Alexandria Forest Center forest nursery near Pineville, Louisiana. Experimental design in the nursery was modified to reflect operational practices and consisted of two replications of 4 rows each (50 seeds per row) oriented across 1.2-m (4-foot) beds and spaced 15 cm (6 inches) apart; the result was a sowing density of 269 seeds per mz (25 seeds per square foot). Sowing was done during the first week of April. Depending on latitude and annual climatic variation, nursery beds in early April more nearly approximate the 15 /C (60 /F) and 12-hour photoperiod conditions than standard laboratory conditions.

Test 1. Seeds from the 6 half-sib families were subjected to 0, 30, and 60 days of stratification. A fourth treatment was 60 days of stratification plus a subsequent 3-day aerated water soak. Germination of 200-seed samples for each of the 6 families, 4 treatments, with 3 locations of 3 replications each, was measured 3 times a week for 28 days. Responses to treatments were evaluated by determining germination percentages and values. Germination values reflect the speed of germination and are expressed as the peak value of the maximum cumulative percentage of germination divided by the number of days from sowing (Czabator 1962). Germination of the seeds sown in the nursery was measured weekly. Those that germinated during each 1-week period were marked with plastic rings of a specified color so they could be identified and remeasured later on in the growing season. Germination counts in the nursery were made weekly until germination was complete. Percentages of nursery trees were computed by taking the number of germinants produced 60 days after sowing in the nursery relative to the total seed sown for each nursery plot. In addition to germination, seedling mortality that occurred up to early June and seedling heights and diameters at lifting in the following winter were measured and development was related to the time of germination by tracking the plastic ring color of individual seedlings.

Test 2. Seeds from the same half-sib families were evaluated as in test 1, but from different samples. Three replications of 200-seed samples were subjected to 8 treatments: 0, 15, 30, and 45 days of stratification with and without 3 days of aerated water soaks following stratification in 3 lo cations. Aerated water soak treatments were com bined with each length of stratification in this test to better evaluate this combined treatment at shorter periods of stratification. Germination tests were conducted under the same 3 sets of condi tions as described in test 1, except that the ger mination test temperature was increased to 18 /C (65 /F)-from 15 /C (60 /F) in test 1-in the less favorable laboratory testing environment. Post germination seedling development in the nursery was not followed in this test.

Differences in germination response and seedling development resulting from the treatment applica tions were tested for statistical significance at the 0.05 level by analyses of variance. Orthogonal sin gle degree of freedom tests were conducted to evaluate differences among locations. Germination data were averaged across locations to evaluate dif ferences among stratification regimes.

Results and Discussion

Results indicate that the seed lots tested were not nearly as dormant as those reported in earlier studies by Seidel (1963) and Barnett and McGilvray (1971). Data from the previous studies indicated that stratification for at least 56 days was needed to obtain prompt germination. The 6 half-sib seed lots used in the current study did respond dif ferently to treatments. Some families germinated well without stratification while others needed con siderable prechilling. Because there was no logical explanation for response differences among seed lots, the lots were averaged to get a representative sample. Seeds tested under standard laboratory conditions and in nursery beds did not respond in total germination to periods of stratification beyond 30 days in this study (table 1). Germination per centages of seeds tested at 15 /C (60 /F) tempera tures and shorter photoperiods indicated that they did benefit from the longer prechilling treatments. Germination in both of the less favorable environ ments (15 /C [60 /F] and nursery) was lower with out stratification than the 22 /C (72 /F) condition, and the germination tests indicate the environmen tal conditions of 15 /C (60 /F) were more adverse than those occurring in the nursery seed beds. Data from other tests show that if the field condi tions had been colder, seeds would have lower germination rates in treatments providing shorter stratification (McLemore 1969). The additional aer-

Table 1-Germination percentages and values for shortleaf pine seed lots subjected to different germination conditions and various lengths of stratification (0 to 60+ days)

Germination conditions	Germination % Day 0	Day 30	Day 60	Day 60+	Ave.	Germination value Day 0	Day 30	Day 60	Day 60+	Ave.
Ideal lab (22 /C)	80	91	90	88	87 c	14.9	31.3	34.2	25.7	26.5 c
Adverse lab (15 /C)	0	17	62	70	37 a	0	0.6	5.7	8.0	3.3 a
Nursery	45	79	76	77	67 b	2.1	9.6	11.4	12.6	8.9 b
Average	42 a	62 b	76 c	78 c		5.9 a	13.8 b	17.1 d	15.4 c	

The germination data are means of two 100-seed samples from 3 replications of 6 different half-sib families. The 60+ treatment consists of 60 days of cold stratification (2 /C) plus 3 days of aerated water soaks at 24 /C, Means within and across germination percentage and value columns followed by the same letter are not statistically different at the 0.05 level.

ated water soak treatment following stratification did not improve total seed germination over that of 60-day stratification, except when tested at 15 /C (60 /F).

In the nursery, germination peaked during the second week after sowing, but seedling mortality continued to increase as the seeds germinated later in the season (table 2). Mortality of seedlings that germinated in the fourth and fifth weeks averaged 27 and 56%, respectively. It is also interesting to note that seedlings lifted from the nursery during this late germination period were considerably smaller than, and were never able to compete with, those from early-germinating seeds. Seed stratification did result in stock at the end of the growing season that was statistically larger (156 versus 118 mm in height and 3.9 versus 3.2 mm in diameter) than from untreated seeds (0 days of stratification), but there were no size differences due to varying lengths of stratification pretreatments.

In test 2, treatments of 0, 15, 30, and 60 days of stratification were evaluated with and without a subsequent aerated water soak treatment (table 3). The seed lots used in the study showed little additional response in total germination to stratification beyond 15 days, although response did vary by seed lot. Apparently the seed orchard seeds evaluated in these tests were less dormant than the of stratification, although this dormancy may have been influenced by storage. Seeds from orchards are generally larger, and studies with loblolly pines indicate that large seeds tend to germinate faster than small ones, probably because they are less dormant as a result of less seed coat constraint (Barnett 1991, Dunlap and Barnett 1983).

Germination of unstratified seeds was better at the ideal laboratory conditions of 22 /C (72 /F) and 18-hour photoperiod than at more adverse laboratory conditions of 18 /C (65 /F) and 12-hour photoperiod or at nursery conditions. In this test, the more adverse laboratory and nursery conditions were about equal in effect, that is, they reduced germination by about 18 percentage points in the 0-day stratification treatment (table 3). This similarity in response reflects the similarity of the lab oratory conditions (18 /C; 65 /F) to the temperature of the seed beds. The 3 additional days of aerated water soaking improved overall germination of seed of the 0-day treatment by 7 percentage points over the regular stratification treatments, but this difference was not statistically significant (table 3).

Speed of germination of stratified seeds, as determined by germination values, continued to increase with additional lengths of treatment (table 3). Al though total germination percentage did not in crease with longer periods of stratification, germination values did improve, reflecting an increasing rate of germination. Germination values were con sistently greater for the tests conducted at 22 /C (72 /F) than for those conducted at 18 /C (65 /F).

One interesting result of these tests is the deter mination that predictions of performance on nurs

Table 2-Mortality and seedling size of shortleaaf pine seedlings at lifting as related to the time of germination,

Time after sowing Days	Week	Germination per week (%)	Mortality of germinants (%)	Seeding size (mm) Height	Diameter
8-10	1	6	12	157	4.1
13-17	2	52	13	160	4.0
20-24	3	30	18	144	3.5
27-31	4	10	27	118	3.1
34-38	5	2	56	115	2.7

Seeds were sown April 2, 1985, m two replications of four 50-seed rows for each of six half-sib families. Size measurements were made in early January 1986.

Table 3-Germination percentages and values for shortleaf pine seed lots of test 2 subjected to different germination conditions

	Days of seed pretreatment								
Germination Conditions	0	15	30	45	0+	15+	30+	45+	Ave.
Germination percentage									
Ideal lab (22 /C)	61	86	92	94	68	88	92	95	84 b
Adverse lab (18 /C)	44	92	92	94	45	87	92	94	80 ab
Nursery	42	80	87	83	54	77	86	85	74 a
Average	49 a	86 c	90 d	90 d	56 b	81 c	90 d	91 d	
Germination values									
Ideal lab (22 /C)	8.7	33.4	42.6	55.4	16.1	44.3	59.1	91.7	43.8 b
Adverse lab (18 /C)	4.9	22.6	28.3	33.2	8.6	25.7	34.8	71.8	28.7 a
Average	6.8 a	28.0 c	35.4 d	44.3 a	12.3 b	35.0 d	46.9 a	81.8 f	

The germination data are means of two 100-seed samples of 3 replications of 6 different half-sib families. The length of pretreatment followed by (+) indicates stratification followed by 3 days of aerated water soaking. Means within and across columns followed by the same letter are not significantly different at the 0.05 level.

ery beds based on germination tests can be improved by measuring the environmental conditions at the time of sowing and then closely duplicating those in the seed testing laboratory. Soil-temperature data can be accumulated over several years with relatively inexpensive monitoring equipment. With this background information, germination tests can be conducted under conditions that reflect typical seed bed conditions.

Previous studies indicate that soaking seeds in aerated water is a short-term substitute for stratification. Soaking shortleaf pine seeds in continuously aerated water at 10 /C (50 /F) stimulated germination as much as colder soaks and did so more quickly (Barnett 1971). This technique provides a rapid stimulatory effect on shortleaf pine seeds, but it is not a replacement for more effective stratification treatments. There was no demonstrated advantage of using aerated soaks after lengthy periods of stratification.

Conclusions

Stratification is essential to obtain prompt and uniform germination. The length of treatment varies by seed source and length of storage, but the total germination of orchard collections of shortleaf pine seeds did not respond to stratification beyond 15 days. However, speed of germination continued to increase with stratification up to 45 days. There were major differences in seed performance due to the environmental conditions under which they germinated. Seeds without stratification germinated very poorly under the more stressful conditions of nursery beds or lowered laboratory temperatures and daylengths. These data confirm other studies showing that the optimum length of stratification increases as germination conditions become more adverse, that is, 15 and 18 /C (McLemore 1969). Temperatures of 22 /C continue to be the most optimum for germination.

Seeds that germinated first in the nursery produced larger seedlings than those that germinated later. Late germinants were typically small; they could not compete with those that germinated earlier and many died or became culls.

In spite of many attempts to find better predictors, germination percentages from laboratory tests conducted under optimum conditions are normally used to predict seed performance in nurseries (Barnett and McLemore 1984). Nursery managers who have difficulty in predicting seed germination can improve their estimates on their nursery beds by determining typical environmental conditions at the time of sowing and by requesting that their seed germination tests be conducted under those conditions as well as standard laboratory ones.

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Taylorilygus pallidulus (Blanchard): A Potential Pest of Pine Seedlings

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Taylorilygus pallidulus *(Blanchard) is a cosmopolitan insect that has been found in pine nurseries in the United States, South Africa, and Guatemala. A caging study in South Africa demonstrated that this insect may be responsible for malformation of the terminal shoots (bushy tops)* of *young seedlings* of *maritime pine* (Pinus pinaster *Ait.). The morphological distortions of young pine seedlings are indistinguishable from those caused by* Lygus *spp. Due to its wide range,* T. pallidulus *is potentially a world-wide pest* of *conifer seedlings.* Tree Planters' Notes 44(2):63-67; 1993.

Pine seedlings with "bushy tops" were noticed at two nurseries in the southern Cape Province in South Africa in September 1991 by members of a U.S. tour group. These "bushy-top" seedlings exhibited multiple leaders, malformed shoots, and needle distortion. About 1% of Monterey pine *(Pinus radiata* D. Don) seedlings at the Witfontein Nursery showed such symptoms; 2% of slash pines *(P. elliottii* Engelm.), 4% of Monterey pine, and 5% of maritime pine (*P. pinaster* Ait.) at the Lottering Nursery showed such injury.

These "bushy-top" symptoms were identical to those caused by *Lygus spp.* on pine seedlings (Holopainen 1986, Schowalter et al. 1986, South 1986). Plant bugs similar to *Lygus spp.* were found at the Witfontein Nursery but these were later identified as *Taylorilygus pallidulus* (Blanchard) (voucher specimens were deposited in the U.S. National Museum of Natural History). As a result, a caging study was established at George, South Africa, to determine if *T. pallidulus* could cause young pine seedlings to form multiple leaders. Data from a trapping study conducted in Georgia, USA, were reviewed after examining the results from the caging study.

Materials and Methods

Caging study. This study was conducted at the Saasveld Forestry Research Center at George, South Africa. Soil from the Witfontein Nursery was sterilized and placed into 20 plastic trays of approximate dimensions 30 x 30 x 20 cm (height). Seeds of maritime pine and Monterey pine were each broadcast sown into 10 trays on September 30, 1991. Water was applied with sprinklers and humidity was kept high during germination. Each tray was placed in a separate cage. For each species, five random cages were used to release in sects. On November 5, 1991, 6 adult *T. pallidulus* were placed into each of the 5 cages containing Monterey pine. Another 6 adults per cage were added on November 12. On November 13, 5 adults were placed into each cage of maritime pine and another 2 adults were added on November 28. A total of 354 Monterey pine and 270 maritime pine seedlings were exposed to the insects. Control cages, where no insects were placed, protected 509 Monterey pine seedlings and 267 maritime pine seedlings. Differential germination percentages resulted in unequal seedling counts between the two species. Damage to seedlings was assessed on January 5, 1992. Each seedling was classified as either normal or showing signs of damage. Data were analyzed using a chi-square test.

Trapping study. In 1987, an insect trapping study was installed at the Carters Nursery in Chatsworth, Georgia, USA. Twelve white sticky traps (Rebelll®) were placed throughout the nursery (each location was usually further than 15 m from the end of the nurserybed and at least 15 m from an adjacent cover-crop or fallow field). Each trap was positioned in a bed of loblolly pine *(Pinus taeda* L.) seedlings and was hung from a bent piece of rebar so the bottom of the trap would be about 30 cm from the ground. Traps were monitored from May 20, 1987, until August 30, 1987. The traps were usually inspected on Monday, Wednesday, and Friday, and the number of tar nished plant bugs *(Lygus lineolaris* (Palisot de Beauvois)) and T. *pallidulus* were recorded at each inspection. Apart from anatomical differences, the species differ in color: adult *T. pallidulus* (figure 1)

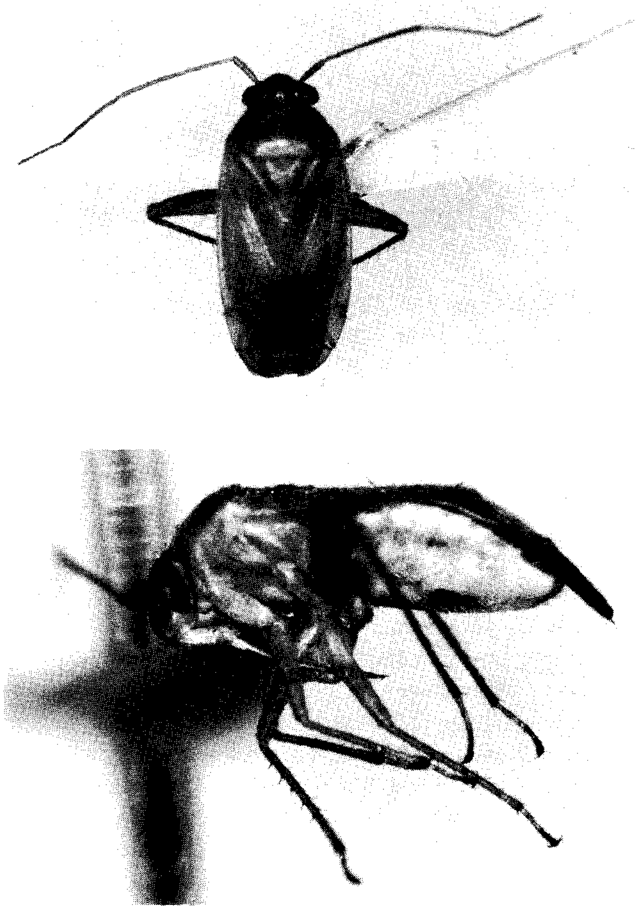


Figure 1-Taylorilygus pallidulus; *life* size = 4.5 to 5.0 mm (photograph courtesy of T.A. Henry, USDA ARS, Washington, DC).

are green whereas *L. lineolaris* are yellowish-green to brown. Once a week, the traps were cleaned with mineral spirits and retreated with Tangle-trap®. Seedlings were sampled by placing a counting frame (30 cm bed width) over the nursery bed and counting every seedling within the frame. The sampling was repeated six times at each insect trap. A total of 7,244 loblolly pine seedlings were evaluated for morphological distortion on July 10.

Results

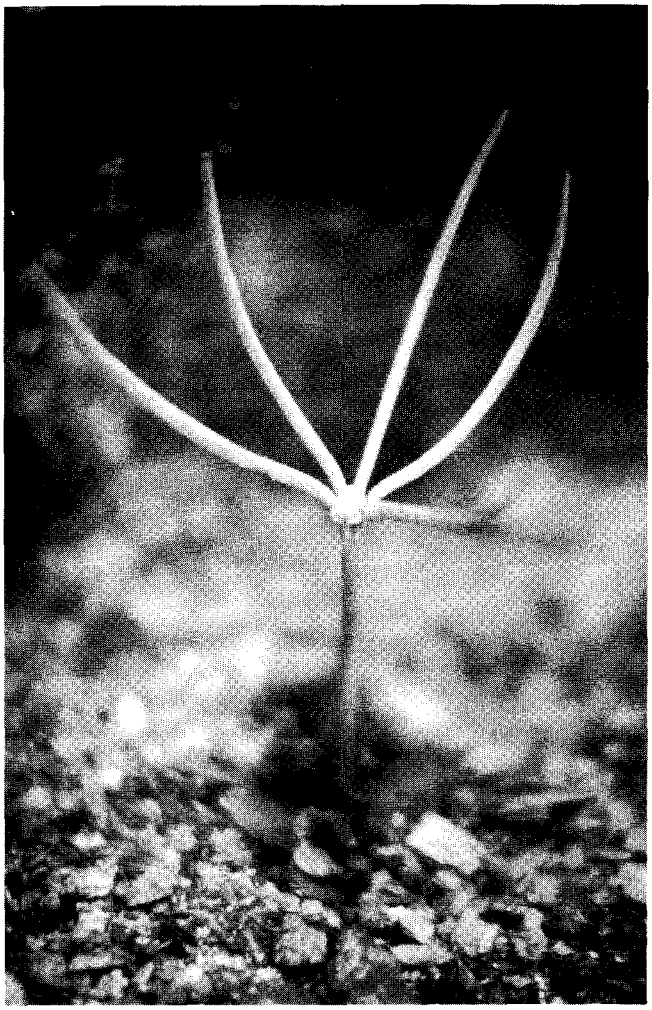
Soon after the insects had been introduced into the cages, the growing tip of the epicotyl of some seedlings died. These seedlings started sprouting multiple leaders with deformed needles. Damaged seedlings were very similar in appearance to those observed in September 1991 at the Witfontein and Lottering nurseries. Examples of malformed maritime pine seedlings associated with *T. pallidulus* infestation are shown in figure 2.

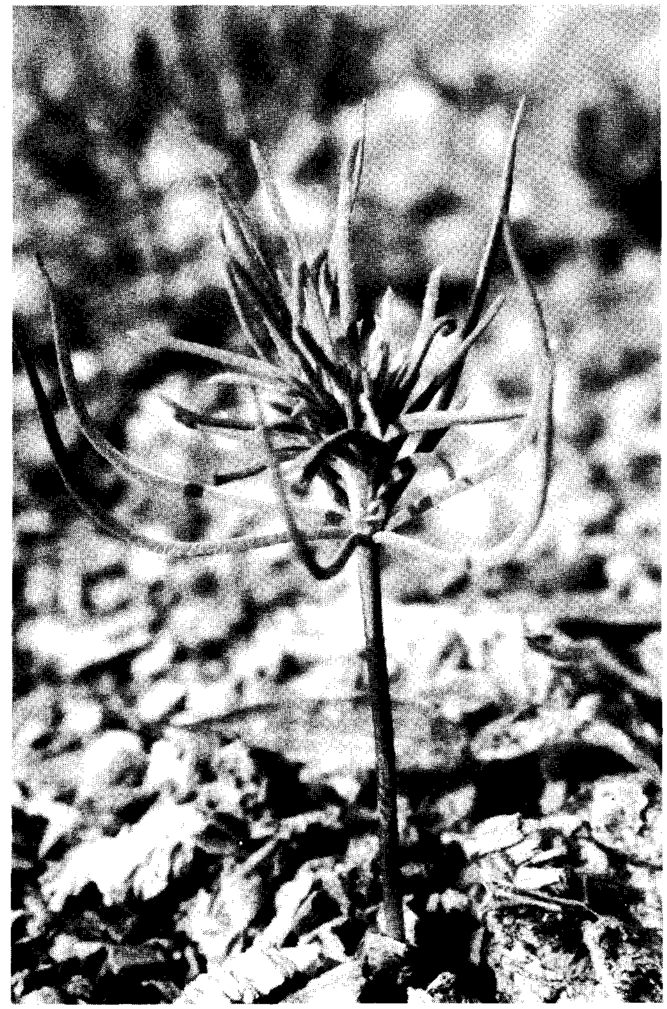
Monterey pine and maritime pine differed in their sensitivity to *T. pallidulus.* Only 2.8% of the exposed Monterey pine seedlings developed "bushy tops"; this was not significantly greater than 2.0% observed in the control cages. However, 27% of the maritime pine seedlings were malformed compared to 0.7% of the controls (chi-square = 77; $P < 0.001$). The reason for the difference between species is unexplained.

The results from the trapping study at the Carters Nursery in Georgia are shown in figure 3. The number of *T. pallidulus* caught exceeded the number of *L. lineolaris* caught during several periods during May, June, and July. On June 22, the average number of *T. pallidulus* recorded per trap was 11.9. Morphological distortion of loblolly pine began to appear during the first week of June, and by July 10, 9.7% of the seedlings were malformed.

Discussion

Before 1959, *Taylorilygus pallidulus* was better known under the name *Lygus apicalis* Fieber (now considered a junior synonym). Although several species of *Lygus* are known to cause multiple leaders in pine nurseries in the northern hemisphere (South 1991), no reports have been found on *T. pallidulus* being associated with damage to pine seedlings. This association is not too surprising because *T. cupressus* (Taylor) and *T. complexus* (Taylor) are known to feed on cypress (Taylor 1947). It has been previously assumed that "bushy top" seedlings of southern pines were solely due to injury from *L.* lineolaris (Bryan 1989; South 1991). However, *T. pallidulus* is also present in the southern United States (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, and Texas) and can be associated with similar damage of pines. In some areas, the spring population levels of *L. lineolaris* will be greater than for *T. pallidulus* (Snodgrass et aL 1984), but population levels can be similar in the fall (Young and Lockley 1990). At the Garters Nursery in Georgia, both *T. pallidulus* and *L. lineolaris* were trapped in seedbeds. However, although 10% of the loblolly pine seedlings showed morphological distortion associated with these insects, it is difficult to say which species could be responsible for most damage.





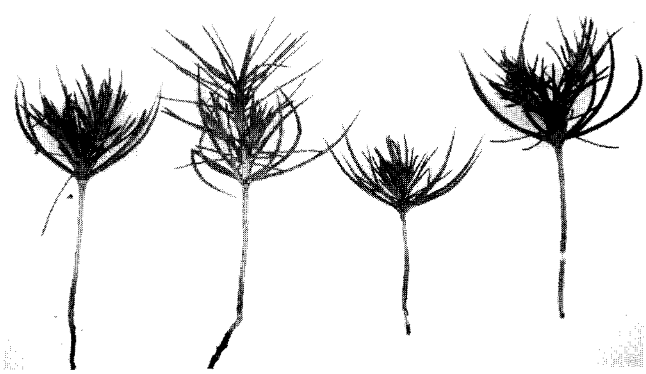


Figure 2-*Symptoms of damage associated with* Taylorilygus pallidulus *infestation on* Pinus pinaster.

T.Pallidulus is a cosmopolitan insect and can be found in Africa, Asia, Europe, South America, North America (Carvalho 1959), and Australia (Room and Wardhaugh 1977). Therefore, this insect is a potential pest of pines throughout the warmer parts of the world. For example, the senior author observed "bushy-top" seedling at a pine nursery in Guatemala in March 1992. *Pious oocarpa* Schiede seedlings with damage similar to that associated with *T. pallidulus* were observed at a nursery at Huehuetenago. The level of damage was approximately 1%. Several specimens of *T. pallidulus* were found feeding on weeds adjacent to the nursery. Therefore, managers of pine nurseries in the northern hemisphere should be aware that certain plant bugs besides *Lygus* may be causing shoot deformation. In addition, nursery managers in the southern hemisphere who have "bushy-top" pines should check to see if adults of *T. pallidulus* are feeding on newly germinated seedlings.

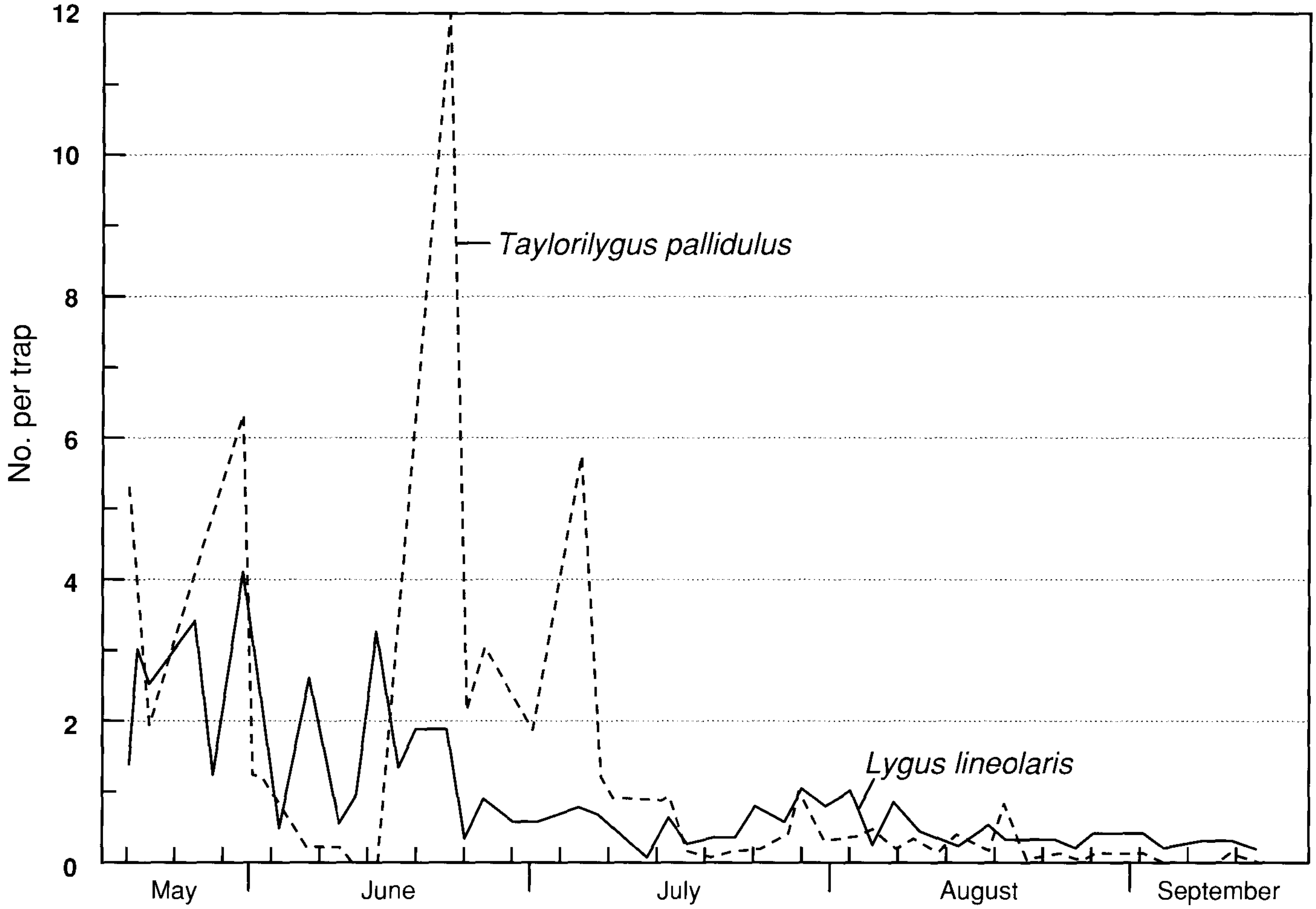


Figure 3-Recorded trapping of Taylorilygus pallidulus *and* Lygus lineolaris *at the Carters Nursery in 1987.*

Acknowledgments

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Fertilization Affects Growth and Incidence of Grey Mold on Container-Grown Giant Sequoia

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Different formulations of commercial soluble fertilizers were tested on container seedlings of giant sequoia (Sequoiadendron giganteum *(Lindl) Buchholz). The 28-14-14 formulation, followed by the 10-52-10, 35-5-10, and 8-20-30 formulations, resulted in seedlings with adequate dimensions (height of 26 cm and collar diameter of 7 mm). As far as grey mold caused by* Botrytis cinerea *Pers. ex Fr. was concerned, 0-15-40 and 8-20-30 formulations produced seedlings in excellent sanitary state. In the container nursery conditions of the Association Foret-Cellulose (AFOCEL) experiment station, from now on, giant sequoia seedlings will be provided with the 28-14-14 formulation from May to July and then with the 8-20-30 formulations from August to September, in order to obtain seedlings with desirable growth characteristics and disease resistance.* Tree Planters' Notes 44(2):68-72; 1993.

In producing vigorous container seedlings of giant sequoia *(Sequoiadendron giganteum* (Lindl) Buchholz) for outplanting, there are two main difficulties. After 7 months of growth, it is hard to obtain a majority of seedlings above the minimum height of 15 cm. Grey mold, caused by *Botrytis cinerea* Pers. ex Fr., damages giant sequoia seedlings throughout the growing season. More than 30% of seedling production at the Association Foret-Cellulose (AFOCEL) nursery has been at times affected by grey mold.

Controlled-release fertilizers supply major and minor nutrients in the growing medium but meet seedlings' needs only during the first several months. At the beginning of the growing season, if temperatures are very high, nutrients can be released in excess compared to seedlings' needs, causing "burning," whereas, later in the season, nutrients are liable to be insufficient. Therefore, it becomes necessary to add fertilizer, and watering is the most commonly used method of applying fertilizer in France. To obtain a balanced fertilization, formulations used must contain major nutrients (N, P, K) as well as minor nutrients (Lemaire *et al.* 1989).

Botrytis is a facultative parasite, living either as a saprophyte on decaying organic matter or as a parasite on living tissue. Moreover, it is a polyphagous pathogen and can be found on a great number of plants, ranging from shrubs to cut flowers and trees. It is also ubiquitous, growing everywhere from greenhouses to the natural environment when conditions are favorable. Two environmental factors favor its spread-high relative humidity (> 98%) and warm air temperature (15 to 20 /C) (Lamarque 1979). Consequently, rainy and mild springs and autumns promote favorable environmental conditions for *Botrytis* proliferation. Chemical control of this fungus involves protective treatments using both systemic and contact fungicides alternatively at low concentration (2 parts to 1,000 parts water), as well as treatments with systemic fungicides at high concentrations (4 parts to 1,000 parts water) (James and Woo 1984). However, although sensitive fungus strains disappear, resist ant fungus strains spread, thus making this control method difficult or even ineffective (Gillman and James 1980).

Botrytis is principally found in vineyards in France, and prophylactic management strategies against *Botrytis* in woody plant nurseries can draw inspiration from wine-growing practices:

1. Growing density is low; as soon as seedling twigs touch each other, growing density is reduced from 250 seedlings/m^2 (25/foot^2) to 125 seedlings/m^2 (12.5/foot^2).
2. Diseased twigs or seedlings are systematically destroyed.
3. Seedlings are transported from greenhouse to outside as early as possible because a prolonged stay in greenhouse favors abundant tender and succulent shoots, which are less resistant to spore germination (Peterson et al. 1988).

4. Low-nitrogen fertilizer (Bourdier 1986) is used to minimize foliage development.

In the experimental nursery of AFOCEL station in Malissard, we tested various formulations of commercial soluble fertilizers during the growing season to find a fertilizer that would enable us to produce container-grown giant sequoias of sufficient height that were also relatively disease free.

Growing Regimes

Seeds came from a natural stand of the center of the native distributional range of giant sequoia in the United States, from a region called Black Mountain in southern California near Randsburg (36/ N and 118/ W), between 1,170 m (3,838 feet) and 2,070 m (6,791 feet).

On February 1, 1990, seeds were stratified for 6 weeks in moist cold at 4 /C in the AFOCEL station's cold chamber. On March 15, 1990, seeds were set out in small trays (15 X 40 cm, or 0.5 X 1.3 foot) filled with a 1:1 (vol/vol) mixture of peat moss and pine bark. They were watered with a fungicide solution-oxyquinoleine (Cryptonol)-at 0.2%) and placed under a tent made of a transparent plastic sheet at 20 /C in the glass-covered greenhouse.

Seedlings were transplanted when cotyledons were horizontal and the first bud was visible (April 1990) into bottomless Fertiss containers. These 250-cm3 tube-like containers (5.5 X 11 cm, or 2.1 X 4.3 inches) are made of nonwoven synthetic material that roots can penetrate (figure 1). They were filled with a 1:1 mixture of peat moss and pine bark. Containers were set up in bottom less AFOCEL-Stamp trays (40 X 60 cm, or 1.3 X 1.9 feet) made of plastic, each containing 60 Fertiss containers side by side.

Once transplanted, young seedlings stayed under a tent in the greenhouse. The tent was removed when roots penetrated the nonwoven walls. During this period, water was supplied by subirrigation through a wadded cloth, and protective fungicides at low concentration (2 parts to 1,000 parts water) such as benomyl (Benlate), thiophanate-methyl (Pelt44), dichlofluanide (Euparene), iprodione (Royal), and procymidone (Sumisclex) were applied alternatively once a week. Seedling growing density was reduced from 250/m2 (25/foot2) to 125/mz (12.5/foot2) as soon as first twigs touched each

Figure *1-Seedlings of giant sequoia transplanted into bot tomless containers of nonwoven synthetic material (Fertiss) in the greenhouse.*

Container seedlings, still in AFOCEL-Stamp trays, were carried to an outside growing area at the be ginning of July 1990. Daily irrigation by sprinkling was done on an as-needed basis. Fungicide treat meats were completely stopped at that time.

Experimental Design

On July 4, 1990, we used a randomized complete block design with 2 blocks. There were 30 trees in each treatment block combination. We tested 5 for mutations of concentrated soluble fertilizers made commercially by Plant-Prod (Fertil France Company).

Control
35-05-10
00-15-40
OS-20-30
10-52-10
28-14-14

Fertilizers were applied by watering (6 liters of solution composed of 5 parts fertilizer to 1,000 parts water per 30 seedlings). Treatments were identified by N-P-K balance: for instance, 28-14-14 meant the fertilizer whose N-P-K balance was 28-14-14.

Applications took place after morning sprinkling until saturation with a watering can. Fertilization was initiated on July 5, 1990, after seedlings were carried to the outside growing area. Fertilizers were applied once a week until August 30, 1990, for a total of 9 applications. Overall quantities of nutrients applied per seedling at the end of the 9 applications were calculated according to fertilizer compositions given by Plant-Prod (table 1).

Measurements

Four traits were measured: height from soil level to tip of the terminal bud in centimeters on July 3, 1990 (initial measurement) and September 4, 1990

Table *1-Overall quantities of nutrients per gram of N-P-K fertilizer at the end of 9 applications*

Treatment (N-P-I()	Nitrogen (g)	Phosphorus lg)	Potassium Cg)	Total lg)
Control	0	0	0	0
35-05-10	3.15	0.45	0.9	4.5
00-15-40	0	1.35	3.6	4.95
08-20-30	0.72	1.8	2.7	5.22
10-52-10	0.9	4.68	0.9	6.48
28-14-14	2.52	1.26	1.26	5.04

(final measurement); root collar diameter in millimeters on September 4, 1990; and a rating for amount of disease on October 22, 1990. Seedlings received a rating of **1** if they were disease-free or **2** if they had *Botrytis* symptoms (typical brownish necrosis).

Analysis of variance for the two factors was performed on all collected data according to general linear models procedure based on Fisher's method and tables (Dagnelie 1970). Differences among means were evaluated using the test of additivity from Tukey and Kramer (Dagnelie 1970), designed specifically for comparisons based on the studentized range.

Results

On July 3, 1990, mean heights of different treatments were not significantly different (table 2). This first measurement ensured that the initial seedling population was homogeneous. The treatments had significant differences for height when measured on September 4, 1990. The treatment producing the tallest seedlings was treatment 28-14-14. Block effects were non-significant. There were also significant differences in height growth. The best treatment was 28-14-14, which produced excellent growth. Treatments 10-52-10, 35-5-10, and 8-20-30 produced superior growth as well. The treatment producing the largest diameter seedlings was 28-14-14 followed by 8-20-30 and 10-52-10

Overall differences among treatments were significant.

For percentage of disease-free seedlings, all treat ments exceeded control but differences among treatments were not always significant. Only 0-15-40 and 8-20-30 formulations showed signifi cantly higher percentages than the other 4

Table *2-Effects* of six *fertilizer treatments on container seedlings* of *giant sequoia grown in Valence, France*

Treatment (N-P-K)	Height (cm) 7/10/90	Height (cm) 9/4/90	Growth	Root collar diameter (mm) 9/4/90	% Disease-free seedlings 10/22/90
Control	13.4 a	15.5 d	2.15 c	4.9 be	70 b
35-05-10	13.3 a	20 be	6.7 b	5.7 be	98 b
00-15-40	15.7 a	18.1 cd	2.4 c	5.9 b	100 a
08-20-30	14.4 a	19.7 cd	5.3 be	6.3 ab	100 a
10-52-10	15.1 a	22.4 ab	7.3 ab	6.1 ab	95 b
28-14-14	15.6 a	26.4 a	10.8 a	6.9 a	95 b
Average	14.5	20.3	5.7	5.9	93

Values in columns with no letters in common differ significantly.

One of the two most concentrated nitrogen formulations (28-14-14) produced the tallest seedlings (26 cm height and 7mm collar diameter). The relatively unexpected response of treatment 35-5-10 might be due to the low phosphorus and potassium contents of the fertilizer. Formulations 10-52-10, 8-20-30, and 0-15-40 also exceeded the control (figures 2 and 3). This experiment confirms nitrogen as the major element that has the highest

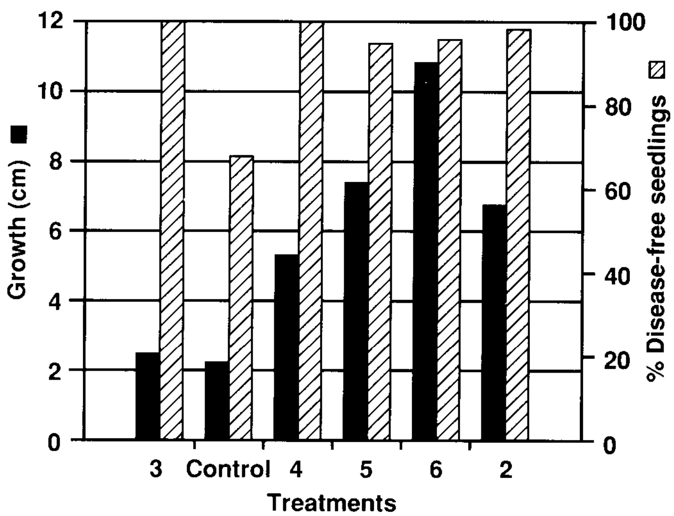

Figure *2-Fertilizer treatment effects on seedling growth and percentage of discase-free seedlings of giant sequoia ranked according to increasing N contents in the fertilizer (treatment 2 = 35-5-10, 3 = 0-15-40, 4 = 8-20-30, 5 = 10-52-10, 6 = 28-14-14 N-P-K).*

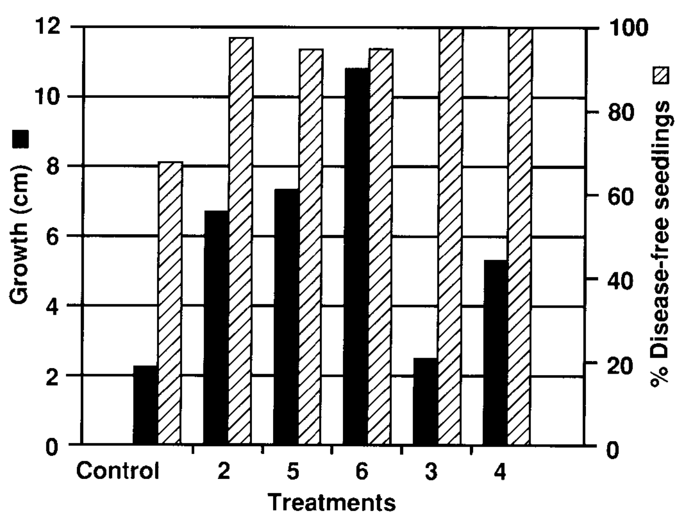

Figure *3-Fertilizer treatment effects on seedling growth and percentage disease-free seedlings of giant sequoia ranked according to increasing K content in the fertilizer (treatment 2 = 35-5-10, 3 = 0-15-40, 4 = 8-20-30, 5 = 10-52-10, 6 = 28-14-14 N-P-K).*

control on the vegetative growth, provided that the other nutrients are present in enough quantities.

Discussion

As far as *Botrytis* damages are concerned, we recorded slightly different trends. July and August 1990 were particularly dry and hot months and therefore unfavorable to *Botrytis;* on the other and therefore favorable to this fungus. In July and August, all seedlings were healthy, but during September and October, some lots were covered with brownish necrosis typical of the disease. All formulations appeared to give good protection from *Botrytis* damage. Therefore, seedling resistance to *Botrytis* seemed to be related to the quantity of mineral elements available, with a tendency toward good results with less nitrogen and more potassium.

If effects of nutrient nature and quantity on growth have long been investigated, it is not the case for their effects on disease resistance; literature dealing with this subject is scarce and contradictory: facing a given fertilization, each species reacts differently in interaction with each disease, which may be either favored or unfavored. According to Podger and Wardlaw (1990), even seasonal or ephemeral nutrient deficiencies contribute to spring needle-cast affecting Monterey pine *(Pinus radiata* D. Don.). On the other side, Patila and Uotila *Scleroderris* canker can be associated with increased growth due to fertilization. A rich manure favors *Botrytis* on vineyards, but has the opposite effect on giant sequoia seedlings; keeping giant sequoia seedlings growing thanks to a suitable fertilization seems an effective practice against *Botrytis.* Grape vine as a "frugal" plant seems to bear far better with a low-nitrogen fertilization regime compared to giant sequoia, a "greedy" plant, which grows better under higher nitrogen regimes. Indeed, the control in this study shows more disease than other treatments.

Other work (Lepp and Edwards 1984) demonstrates an inhibitory role for iron in the germination of spores from *Botrytis cinerea* on tomato. Potassium, which plays an important role on osmotic pressure regulation in cells, could reinforce natural cell barriers towards *Botrytis* and explain better results towards disease resistance with more potassium and less nitrogen (Lafon et al. 1988)

Conclusion

In our growing conditions, the 28-14-14 formulation produces tallest seedlings, whereas the 8-20-30 formulation gives better disease protection. The difference between 95% disease-free seedlings (28-14-14) and 100% disease-free seedlings (8-20-30), although small, may possibly appear important in mild and rainy years. That is why providing

seedlings with the 28-14-14 formulation from May to July and then the 8-20-30 formulation from August to September should give the best compromise

between seedlings of target growth and disease characteristics. Our conclusions are obviously provisional and need to be confirmed by other similar and complementary experiments.

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Top Pruning Improves Field Performance of Blue Oak Seedlings

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Large 1-year-old container-grown seedlings of blue oak (Quercus douglasii *Hook. & Arn.) were top pruned at the time of field planting and compared to both large and small unpruned controls. After two growing seasons, top-pruned seedlings were significantly larger and had significantly greater height and caliper incremenu than either other seedling type. Seedlings planted early (December 15) also had higher survival rates and tended to grow slightly more than those planted 6 or 12 weeks later. These results suggest that blue oak seedlings should be planted early in the season, and that those with large tops should be top pruned before outplanting.* Tree Planters' Notes 44(2):73-77; 1993.

Blue oak *(Quercus douglasii* Hook. and Arn.) is one of several species of native California oaks that is reported to be regenerating poorly in portions of the state (Muick and Bartolome 1987, Bolsinger 1988). This deciduous white oak is endemic to California and grows primarily in the foothills surrounding the Central Valley. Although it has little commercial value other than for firewood, the blue oak is a tremendously important component of California's natural landscape and is vital to numerous wildlife species. In recent years there has been considerable concern about habitat loss in blue oak woodlands and public support for conservation efforts.

The reasons for the poor natural regeneration of blue oak are varied and complex and include browsing by deer and livestock, insect defoliation, acorn predation, and competition from introduced Mediterranean annuals. The effects of competition are exacerbated by the fact that there is often little or no rainfall in the blue oak region during the summers.

In the last few years, efforts have been initiated to develop techniques to successfully regenerate this species artificially. These have included studies on acorn collection, storage, and planting (McCreary 1990, McCreary and Koukoura 1990); methods for growing seedlings (Krelle and McCreary 1992); and techniques for planting, protecting, and maintaining seedlings in the field (Adams et al. 1991).

At present, many of the native oak seedlings produced in California are grown in small containers or "liners" and transplanted to the field when they are 1 year old. While in containers, their root growth is severely restricted, and as a result, these plants have a much different size and configuration than naturally grown seedlings. With unrestricted root growth, native California oaks typically develop a large, deep root system--often before their shoots emerge from the ground. For example, in a study at the University of California's Sierra Foothill Research and Extension Center, blue oak seedlings grown in deep boxes designed to monitor root growth had many roots over 30 cm long before the shoots were visible (Tecklin and McCreary 1991). After 5 months, average root length was nearly 90 cm, while the shoots were less than 15 cm.

When root growth is restricted, the ratio of roots to shoots decreases and the seedlings may become out of balance; that is, the roots may be too small in relation to the tops to provide adequate moisture and nutrient uptake when they are outplanted. Such seedlings may grow slowly or even die.

For many tree species, top pruning in the nursery (or just before outplanting) has been used to reduce the size of the shoot and restore a more favorable root-shoot ratio (Duryea 1984). This practice has been found to be especially beneficial for hardwoods. Cutting off part of the shoot not only reduces photosynthetic capacity, it also lowers moisture requirements by reducing the transpirational surface. This may confer an advantage to seedlings planted in an environment where soil moisture is limiting.

Although top pruning has been used successfully for several species of eastern and southern oaks (Russell 1973, Larson 1975, Adams 1984), it has not been previously tested for any California oak species. The purpose of this study was to evaluate how top pruning and planting date would affect the survival and growth of blue oak seedlings outplanted on a foothill rangeland site.

Materials and Methods

Several hundred seedlings, grown from acorns collected in fall of 1988 from 6 adjacent blue oaks near Red Bluff, California, were grown for 1 year in round, open-ended paper containers approximately 4 cm in diameter and 20 cm tall. These seedlings were kept in a greenhouse for 5 months and then moved outdoors. Before outplanting, seedlings were divided into two groups: **small seedlings,** which were between 10 and 20 cm tall, and **large seedlings,** which were between 25 and 35 cm tall. This latter group appeared to be too tall for the small containers and most likely would benefit from top pruning. The large seedlings were further randomly divided into a group that was pruned to a 15-cm top immediately after planting and a group that was left unpruned. Thus, three seedling stocktypes were compared: small seedlings, large seedlings, and pruned large seedlings. At the time, the pruning treatment seemed drastic, because it reduced seedling height by more than 60%, leaving behind a short bare stem with no branches and few visible buds.

Seedlings were planted in a bare field at the Si erra Foothill Research and Extension Center, 30 km northeast of Marysville, within a deer and cattle exclosure, on three planting dates (December 15, 1989; February 2, 1990; and March 23, 1990). The study followed a randomized complete block de sign with nine treatments and three blocks. The nine treatments consisted of all combinations of three stocktypes and three planting dates. These were randomly assigned within each block to 9 adjacent 8-seedling rows. Rows and seedlings within rows were 60 cm apart. Means of each 8-seedling row were used for ANOVA.

Before planting, the area was treated with a 1½% solution of glyphosate to remove competing vegetation. Subsequently, the plot was kept moderately weed-free with a combination of herbicides, hoeing, and hand pulling. Before planting, each planting spot was augered to a depth of 90 cm using a tractor-mounted 15-cm-diameter auger, and a 21-g slow-release fertilizer tablet (20-10-5, N-P-K) was placed about 10 cm beneath the bottom of the roots. Seedlings were planted with their paper sleeves on, but the paper was carefully folded down at the top and the seedlings were planted deep enough so that there was no chance moisture would "wick out" through exposed potting soil. The initial height and caliper of each seedling were measured soon after planting.

During the next 2 years (1990 and 1991), sur vival, leaf-out date, year-end height, and year-end caliper were recorded. Leaf-out date was also re corded in the spring of 1992. Determining year-end survival in the fall is difficult because of the highly variable leaf drop; therefore, survival in 1990 and 1991 was based on the number of seedlings that leafed out the following spring. Leaf-out date was recorded as the Julian date when the most ad vanced bud opened and began elongating. Caliper was measured 2 cm above the ground line, and height was the distance from the ground to the tip of the longest shoot when it was held straight. Averages of each of these variables were calculated for each row and analyzed using analysis of vari ance for a randomized block design. Before anal ysis, survival was transformed using an arc sin transformation to improve the equality of variances. Whenever significant differences were found for a variable, a Fisher's protected LSD test (Snedecor and Cochran 1967) was conducted to determine which means were significantly different from one another. Differences reported as significant were at the P -- 0.05 level.

Results

Table 1 lists each of the variables analyzed and the level of significance for the main effects (stock

Table 1-Level of significance among treatments for seedling responses evaluated

Seedling responses	Stocktype	Planting date	Stocktype by planting date
First year (1990)			
Survival	NS	**	NS
Height	**	NS	NS
Caliper	**	NS	NS
Height increment	*	NS	NS
Caliper increment	NS	NS	NS
Leaf-out date	**	**	**
Second year (1991)			
Survival	NS	NS	NS
Height	NS	NS	NS
Caliper	**	NS	NS
Height increment	**	NS	NS
Caliper increment	*	NS	NS
Leaf-out date	**	*	NS

*Significantly different at P <=O5 level by a two-way analysis of variance.
**Signrficantly different at P <=.01 by a two-way analysis of variance.
NS = Not significantly different.

type and planting date) and their interactions. As indicated, there were few significant differences among planting dates, but large differences among stocktypes. These are discussed individually below.

Stocktype. There were no significant differences in survival among the three stocktypes (table 2), which ranged from 78 to 83% in 1990 and 76 to 81% in 1991. Height and caliper, on the other hand, were strongly affected by top pruning. Although top-pruned seedlings were initially quite short, by the end of the second field growing season, they were the tallest of any of the stocktypes (figure 1). These differences were only significant at the .10 level of probability because the initial heights of the large pruned seedlings were so dramatically reduced. During both the first and second years, the top-pruned seedlings also had significantly greater height increments than unpruned seedlings of the same initial size class.

Caliper exhibited a similar, though less pronounced, pattern (figure 2). After the first year, the small seedlings had significantly smaller calipers than the other two stocktypes. There were no significant differences in caliper increment. By the end of the second field growing season, however, the calipers of top-pruned seedlings were significantly greater than those of either other stocktype and their caliper increments were also significantly more.

Table 2-*Survival and leaf-out date for seedlings from different stocktypes*

	Small unpruned	Large unpruned	Large pruned
Survival			
1990	78% a	83% a	83% a
1991	76% a	81 % a	81 % a
Leaf-out date			
1990	March 19 a	March 27 b	March 26 b
1991	March 14 b	March 20 b	March 6 a
1992	March 15 a	March 17 a	March 18 a

In each row, values followed by different letters differ significantly (P <= .05) according to Fisher's protected LSD test.

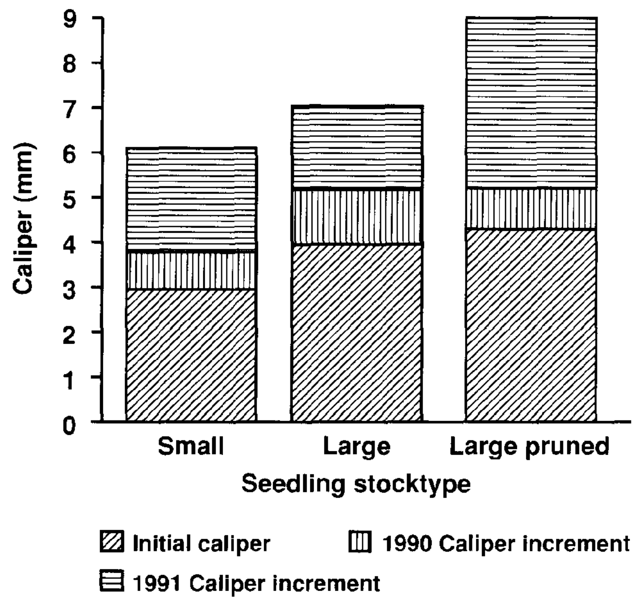

Figure 2—*Yearly caliper for different stocktypes.*

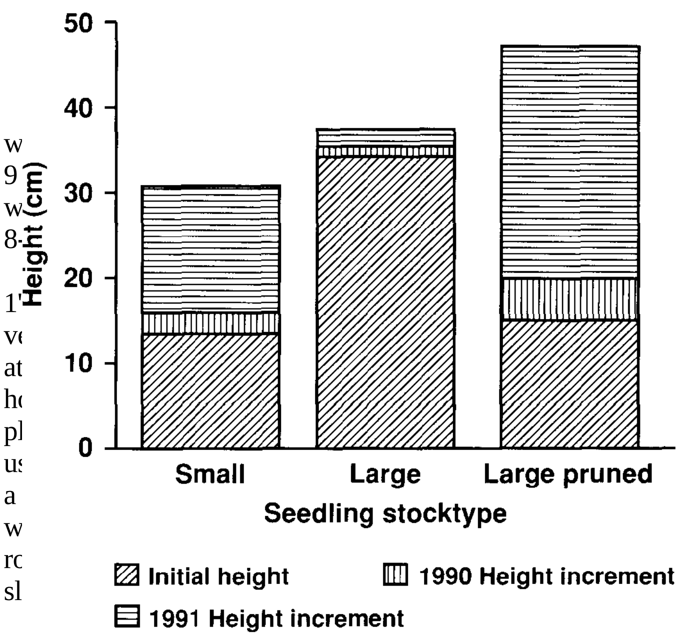

Figure 1—*Yearly height for different stocktypes.*

Leaf-out date was not consistent between years. In the first growing season, the small unpruned seedlings leafed out approximately 1 week earlier than the other two groups (table 2). During the second year, however, top-pruned seedlings leafed out over a week earlier than the other stocktypes. By the spring of 1992, all stocktypes leafed out at approximately the same time.

Planting Date. Field performance was influenced far less by planting date than it was by stocktype (table 3). In fact, there were no significant differences among planting dates for height, caliper, height increment, or caliper increment for either 1990 or 1991, although for most of these variables, seedlings planted on the earliest date had slightly higher average growth. During the year of planting, as expected, leaf-out was later for later

Table *3-Survival, leaf-out date, height, and caliper for seedlings front different planting dates*

	December 15	February 2	March 23
Survival			
1990	90% a	75% b	79% a,b
1991	89% a	71 % a	78% a
Leaf-out date			
1990	March 19 a	March 23 b	March 30 c
1991	March 11 a	March 18 b	March 10 a
1992	March 17 a	March 16 a	March 18 a
Height (cm)			
1990	24.3 a	23.0 a	24.4 a
1991	43.6 a	34.0 a	38.5 a
Caliper (mm)			
1990	4.8 a	4.8 a	4.4 a
1991	7.9 a	6.5 a	7.5 a

In each row, values followed by different letters differ significantly ($P <= .O5$) according to a Fisher's protected LSD test.

plantings. The following year, however, the second planting date had the latest leaf-out, while in 1992, leaf-out dates for the three planting dates were almost identical. In 1990, survival was greatest for the earliest planting, and least for the middle planting date.

The only significant interaction between stocktype and planting date was for leaf-out the first year. In this instance, top pruning greatly delayed leaf-out for the last planting date, although it had little effect on the earlier planting dates.

Discussion

Our initial hypothesis of this study was that reducing the size of a seedling's shoot would create a more favorable shoot-root ratio and improve field performance. This is exactly what we found. Top pruning large 1-year-old container blue oak seedlings dramatically improved field growth compared to unpruned large seedlings or small seed lings. Although this treatment initially created short, bare, branchless seedlings, after 2 years, these seedlings were larger than either unpruned seedlings of the same initial size or small unpruned seedlings. In general, it took 2 years for the benefits of the treatment to be apparent. During the first year after planting, differences in both height and caliper increments were relatively small. By the second year, however, caliper increments of pruned seedlings were more than double those of unpruned seedlings of the same original size, and height increment was more than 10 times greater. Pruned seedlings also had significantly greater height and caliper increments during the second year than small seedlings. This last result suggests that given the choice between planting large and small 1+0 stock, the large stock will likely perform better as long as it is top pruned at or before planting. However, it should be noted that genetic differences between the large and small stock types may have contributed to these differences in growth. While all seedlings were from bulked acorns from a common collection, it is possible that the genotypes that produced the largest seedlings in the nursery were also predisposed to more rapid growth after field planting.

One of the possible reasons that the large pruned seedings grew considerably more during the second growing season was that they leafed out more than a week earlier than small seedlings, and more than 2 weeks earlier than large unpruned seedlings. In the dry Mediterranean climate of California, where soil moisture can become limiting early in the spring, early leaf-out likely confers an advantage because plants can make better use of more favorable growing conditions. However, it is not clear why top pruning the previous year caused this earlier leaf-out. By the third growing season, leaf-out dates of all treatments were similar.

Surprisingly, planting date had relatively little influence on field performance. Although the survival of seedlings planted the earliest was the greatest in 1990, there was little difference between those planted in early February or late March. There were also no significant effects of planting date for any of the four growth variables (height, caliper, height increment, or caliper increment) either year, although the seedlings planted earliest tended to grow more.

Conclusions

This study indicates that top pruning large blue oak seedlings improves field performance. Although they were initially shorter, pruned seedlings grew faster during the next two seasons, were significantly bigger after 2 years than seedlings from the other stocktypes, and generally appeared more vigorous. This treatment is especially recommended for seedlings that have grown tall and "leggy" and appear to have out-of-balance shoot-root ratios. Top pruning could either be done in the nursery or just before or after field planting. Such a treat ment would add little to seedling cost. Based on the results of this study, it is recommended that seedlings be pruned to a 15-cm height.

Although top pruning tended intitially to cause seedlings to develop multiple shoots, most seedlings quickly reestablished dominant leaders arid after 2 ½ years in the field, did not appear bushier than unpruned ones. Planting date did not greatly influence field performance, although those seedlings planted earliest tended to have higher survival and slightly more growth. Other things being equal, it is therefore recommended that seedlings be planted early in the season.

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Hackberry Seed Sources for Planting in the Southern Great Plains

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Seedlings of 60 families from 24 seed zones of common hackberry (Celtis occidentalis L.) *were planted on a southwest Oklahoma site. Two-year height and survival data suggest that sources from the southwestern part of the hackberry's range are the best sources for use in Oklahoma. For growing hackberry for windbreaks and shelterbelts in western and central Oklahoma, using local seed sources is best.* Tree Planters' Notes 44(2):78-82; 1993.

Common hackberry *(Celtis occidentalis* L.) is receiving increased interest among people planting trees in the Great Plains. This interest is prompted by disease problems that developed in several of the tall-tree species that are commonly planted in the Great Plains. American elm *(Ulmus americana* L.) is in danger of being completely exterminated by Dutch elm disease. Siberian elm *(Ulmus pumila* L.) has suffered high rates of mortality caused by stem canker diseases, insect defoliators, and herbicide drift. Hackberry has the potential to replace or supplement these species in both windbreak and ornamental plantings (Read 1958, Bagley 1979). Also a member of the elm family, hackberry has several desirable traits: a pleasing upright crown with a spreading to rounded head; a straight, clear bole with lower branches occurring 8 to 10 feet from the ground; considerable drought hardiness (Albertson and Weaver 1945); and a lack of any serious diseases (figure 1).

As part of a cooperative regionwide effort in the Great Plains, hackberry seeds were collected from 219 different sites during 1982 to 1988. Provenances were sampled in 9 States: North Dakota, South Dakota, Minnesota, Nebraska, Iowa, Missouri, Kansas, Oklahoma, and Arkansas. Provenance trials were then established in sites across the Great Plains. The objectives of the study were to (1) identify the extent and pattern of genetic variability within hackberry, (2) identify hackberry seed sources best adapted for windbreak and ornamental plantings in the Great Plains and (3) provide a highly variable gene pool that could be utilized for future selection and breeding.

In Oklahoma, Oklahoma State University (OSU) in cooperation with the USDA Soil Conservation Service, established one of the 14 Great Plains trial plantings on the OSU Sandylands Research Station near Mangum, Oklahoma. The objectives of the study at this site were in accord with the region wide objectives but also with the intent to evaluate the best seed sources for central and western Oklahoma and to provide the Oklahoma Department of Agriculture-Forestry Services these data and materials for seed production and breeding purposes.

Materials and Methods

Hackberry seed was collected from native trees on 219 sites from across its natural range (figure 2) in the Great Plains during 1982 to 1988. These collections included samples from 57 seed zones throughout the Great Plains portion of hackberry's range. The seed zones were originally defined by

Figure 1—*Outplanted hackberry seedlings.*

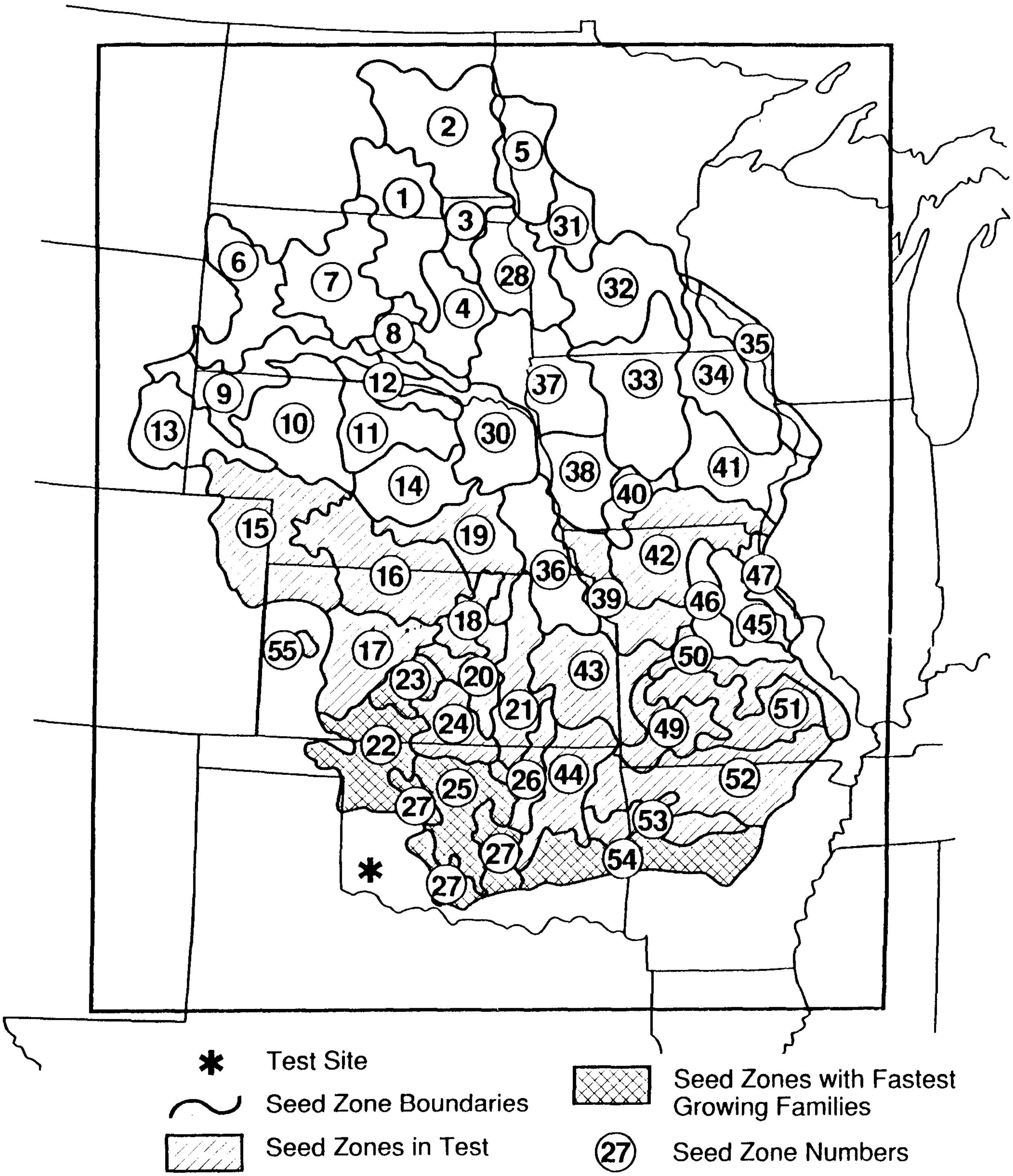

Figure 2—*A regional map of the hackberry seed zones sampled in the Great Plains study, the seed zones represented in this test, and the seed zones with the fastest growing families at age 2.*

Cunningham (1975) and were based on climatic and soil data. Additions and modifications to these seed zones have been made by Cunningham (1982) and Cunningham and Jacobson (1981), resulting in the zones shown in figure 2.

Planting stock was grown by the North Dakota Association of Soil Conservation Districts at their Lincoln-Oakes Nursery in southeastern North Dakota. Seeds were sown in October of 1988 and they germinated in May 1989. Seedlings were lifted in October 1989 as 1+0 stock and held in cold storage at 28 /F (-2 /C) until shipping. Planting stock was shipped in March 1990 to Oklahoma State University where it was put back in cold storage until outplanting in April 1990. Total cold storage time following shipping was about 2 weeks. Seedlings were stored in 5-gallon (18.9-liter) buckets with water and peat moss during the planting operation.

The site, a Meno loamy-sand soil, was previously growing wheat. Several fertilizer applications were made to the study site in anticipation of planting no-till alfalfa, which never was planted. These fertilizer applications included 1 ton per acre (2.24 metric tons/ha) of 50% effective calcium carbonate equivalent lime (September 9, 1989), 209 pounds per acre (516 kg/ha) of 17-0-38 N-P-K (October 4, 1989), and 120 pounds per acre (134.5 kg/ha) of 34-0-0 (December 18, 1989). Site preparation included application of 1 pound active ingrediem per acre (1.12 kg/ha) of glyphosate (Roundup®) before planting, followed by 2 pounds per acre (2.24 kg/ha) active ingredient oryzalin (Surflan®) broadcast immediately after planting.

The study at the Sandylands Research Station contains five blocks, each having 60 families from the 24 seed zones representing the southern half of the Great Plains collection (figure 2). The planting is in a randomized complete block design with each family represented by one 4-tree family row-plot per block in 5 blocks. The 4-tree family row-plots were planted on a 10- x 15-foot spacing with 15 feet (4.6 m) between rows and 10 feet (3.0 m) within rows. A border row of Oklahoma origin (1+0 seedlings) hackberry was planted around the entire plantation.

Weed control during the growing season ineluded mowing, light disking, and hand weeding as needed. Following several weeks of severe drought, the trees were irrigated once in July 1990. In September 1990, winter wheat was interplanted in the plantation for erosion control. The wheat was shredded in April 1991. In May 1991, all weeds were removed around the tree bases. Weed control in July 1991 included bush hogging and blade plowing between rows.

A survival count was made in late August 1990. In May 1991, replacement seedlings were planted for those accessions for which seedlings were still available. Blocks 1, 2, 3, 4, and 5 had 36, 26, 10, 13, and 9 seedlings replaced, respectively. Replacement seedlings were 1+1 stock, which had been transplanted their second growing season at the USDA Forest Service's Bessey Nursery at Halsey, Nebraska.

Survival and height measurements were taken after the second growing season. Trees were considered alive if they exhibited any green foliage. Height measurements were taken from ground level to the tallest point on the tree without moving the tree. Data were analyzed on a plot-mean basis using the SAS GLM procedure. Family and seed zone means were compared using Duncan's multiple range test. The format of the analysis of variance is given in table 1.

Results and Discussion

First-year plantation survival was 89%, with 132 dead trees among the original 1,200 planted. In the spring of the second year, 94 of these trees were replanted. At the end of the second growing season, survival based on total number of trees planted (now 1,294) was 86`%>. Ninety-four trees, or 8%of the planting positions, were empty after the second growing season, and 52 of the replacement trees were alive. The height data analysis includes these trees, as their removal did not significantly change the results.

Variation in survival among families and among seed zones was significant (table 1). Family survival, including replacement, ranged from 35%, (seed zone 52, table 2) for a north central Arkansas family to 100//, for 13 families from across the seed zones represented. Six of these families were found to be in collections from the three seed zones (22, 23, and 54) with the fastest growing trees. Survival by seed zone (table 2) ranged from 68 to 100% with the poorest survivors from seed zone 52 located in northern Arkansas. Sources and families from this seed zone showed the greatest variation in survival and extreme variation in growth. Survival in seed zones 21, 22, and 55 was 100% and survival exceeded 90% in 5 additional zones (table 2). Individual families in 20 of the 24 seed zones sampled exceeded 90%> survival. There was

Table *1-Analysis of variance to test for seed zone and family differences for second-year height and survival of an Oklahoma planting of hackberry.*

		Survival		Height	
Source	df	Mean squares	Pr>F	Mean square	Pr>F
Block	4	0.0424		0.8189	
Zone	23	0.0558	0.025	0.5958	0.005
Block x zone	92	0.0241		0.0845	
Family (zone)	59	0.0521	0.025	0.1637	0.005
Error	143 (140)*	0.0296		0.0746	

*'There were 140 df for the height analysis. These df are corrected for missing cells.

Table *2-Mean height and survival by seed zone for hrrckHerrtl fnrvilies in nn Oklnlrorrro seed source test*

Seed zone	No. of families	X ht (m)	% Survival with replacement	X ht (m)	Family range % survival
54	2	1.48 a	98	1.45-1.50	95-100
22	3	1.18 b	100	0.95-1.43	100
23	4	1.10 bc	93	0.63-1.47	78-100
27	1	1.09 bcd	87	1.09	87
25	1	0.97 bcde	82	0.97	82
52	5	0.94 bcdef	68	0.60-1.15	35-95
26	2	0.94 bcdef	87	0.85-1.01	78-95
44	2	0.93 bcdef	83	0.68-1.17	76-90
24	3	0.90 bcdefg	88	0.78-0.99	78-95
43	2	0.85 cdefgh	88	0.71-0.98	50-100
17	2	0.84 cdefgh	88	0.64-1.03	82-95
49	2	0.82 cdefgh	84	0.70-0.94	71-100
51	2	0.80 defgh	98	0.79-0.81	95-100
50	2	0.79 efgh	86	0.78-0.80	82-90
53	1	0.78 efgh	95	0.78	95
18	2	0.72 efgh	84	0.71-0.72	82-86
39	4	0.72 efgh	92	0.60-0.80	77-100
21	1	0.71 efgh	100	0.71	100
42	2	0.69 efgh	84	0.58-0.81	79-90
55	1	0.66 fgh	100	0.66	100
16	3	0.64 fgh	87	0.44-0.95	81-95
20	4	0.61 gh	78	0.53-0.69	74-86
19	5	0.59 h	89	0.50-0.71	79-95
15	4	0.56 h	74	0.53-0.60	63-90

*Mean heights with the same letter in common are not significantly different.

no apparent geographic trend in survival. It is also worth noting that the three seed zones with the fastest growing seedlings also all exceeded 90% survival.

Average tree height for the plantation for surviving trees was 0.83 m. Average family heights varied from 0.44 to 1.50 m (table 2), and an analysis of variance showed the family contribution to height variance to be statistically significant (table 1). After 2 years in the field, the fastest growing families also generally showed high survival, with eight of the ten fastest growing families exceeding 95% survival. Thus, preliminary 2-year results sug-Best selection of the fastest growing families for windbreak and conservation planting should also insure high survivability. Survival and early growth are the most important traits for initial selection of genotypes for such plantings.

Analysis of variance showed the seed zone contribution to total variance for height to be significant (table 1). Examination of average height by seed zone showed that the trees in the four high est ranked seed zones exceeded a meter in height by the end of the second growing season (table 2). This can be considered an excellent growth rate for any hardwood species planted in the relatively harsh environment of the southern Great Plains. The families from seed zone 54 grew significantly

aster than all other families averaged by seed
one (table 2), based on a Duncan's multiple range
est. On a family basis (family analysis not presented), the two families in seed zone 54, plus one amily from seed zone 23 and one from seed zone :2, were significantly faster growing than all other amilies, except for one additional family in seed one 23.

The five best seed zones, based on average tree ıeight, were zones 54, 22, 23, 27, and 25 (table 2). Vhen plotted on the seed zone collection map figure 2), it becomes apparent that the best seed

ones to collect from for windbreak plantings in outhwest Oklahoma are the extreme southern and outhwestern sources of hackberry. The recommenlation to use local or near-local seed sources of

3agley (1979), who found local or near-local Kansas ıackberry sources best for Kansas. In the absence ıf further tests or data, it is reasonable to recomnend the use of local or near-local sources of ıackberry for plantings in the southern Great 'lains.

data are the best available at this time. Fifth-year data from all 14 Great Plains plantings will be available in late 1994. However, this particular planting test was the southernmost of the 14, and located just southwest of the contiguous natural range of hackberry (about 20 miles west and 50 miles south of the range).

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