Tree Planter's Notes, Volume 40, No. 3 (1989)

Spacing Effects on Seedlings of Northern Red Oak and Yellow-Poplar

T. E. Kolb and K. C. Steiner

Research assistant and professor, The Pennsylvania State University, School of Forest Resources, University Park, PA

*Seedlings of northern red oak (*Quercus rubra *L.) and yellowpoplar (*Liriodendron tulipifera *L.) were grown at spacings of 10.8/m^2 (1 per square foot), 26.9/ m^2 (2.5 per square foot), and 53.8/m^2 (5 per square foot) for 2 years. Spacing had no significant effect on first-year growth of either species, but increasing density significantly reduced second-year growth. Compared to the 53.8/m^2 spacing, 2-year-old seedlings of northern red oak were 3 times larger at 10.8/m^2, and 2-year-old seedlings of yellow-poplar were 4.8 times larger at 10.8/m^2.* Tree Planters' Notes 40(3): 3-4 ; 1989

Large stock size has been recognized as an important factor in increasing the survival and growth rate of planted hardwood seedlings, especially northern red oak (*Quercus rubra* L.) (1-4, 9). Stock size can be increased by genetic selection (5) and by environmental factors such as nursery bed spacing (6-8). We report on the effects of spacing on first-year and second-year growth of northern red oak and yellow-poplar (*Liriodendron tulipifera* L.) seedlings.

Methods

Seedlings of each species were grown in raised outdoor planters at spacings of 10.8/m^2 (1 per square foot), 26 .9/m^2 (2.5 per square foot), and 53.8/m^2 (5 per square foot) for 2 years in central Pennsylvania. Planters consisted of wooden boxes with hardware cloth bottoms containing a local topsoil of high quality. Planters for all spacings were 0.61 m (2 feet) deep, but differed in length and width to accommodate exactly 5 seedlings of a species at the prescribed spacing.

Nutrient analysis on the soil indicated an average pH of 6.2 and the following average nutrient concentrations: 0.118% of nitrogen (percentage of soil dry weight), 84 kg/ha of phosphorus, 0.33 meq/100 g of potassium, 6.7 meq/100 g of calcium, and 0.86 meq/100 g of magnesium.

Seeds of northern red oak (a bulked lot of four open-pollinated seedlots of unknown provenance) and yellow-poplar (also of unknown provenance) were planted in each of six planters for each spacing level on June 1, 1985. Each planter contained either 10 prestratified seeds of northern red oak or 200 of yellow-poplar.

All planters were thinned to 5 evenly spaced seedlings 1 month after epicotyls emerged from the soil. In addition to rainfall, planters were watered to approximately field capacity whenever average soil moisture contents were 15% (dry weight basis) or less.

At the end of each growing season (November 2, 1985, and September 13, 1986), all seedlings from three planters of each species at each spacing were destructively harvested to assess growth. Height, caliper at the root collar, total dry weight, and total leaf area were measured on each harvested seedling. Leaf area was measured with a Li-Cor LI-3000 Leaf Area Meter. Data for each species were analyzed by analysis of variance, and mean separations performed according to Duncan's multiple range test.

Results and Discussion

Spacing had no significant effect on any measure of growth for northern red oak in the first year (table 1). Seedlings averaged 2.1 stem flushes at 10.8/m^2, 2.3 at 26.9/m^2, and 1.8 at 53.8/m^2 the end of the first year. However, spacing had a significant effect on second-year growth of northern red oak seedlings.

Increasing density reduced second-year height, caliper, total dry weight, and total leaf area. Two-year-old seedlings at the widest spacing were 2.5 times taller and 3.0 times heavier than seedlings at the closest spacing. Seedlings averaged 3.1 new stem

---

Research supported by USDA competitive grant 86-FSTY-9-0208.

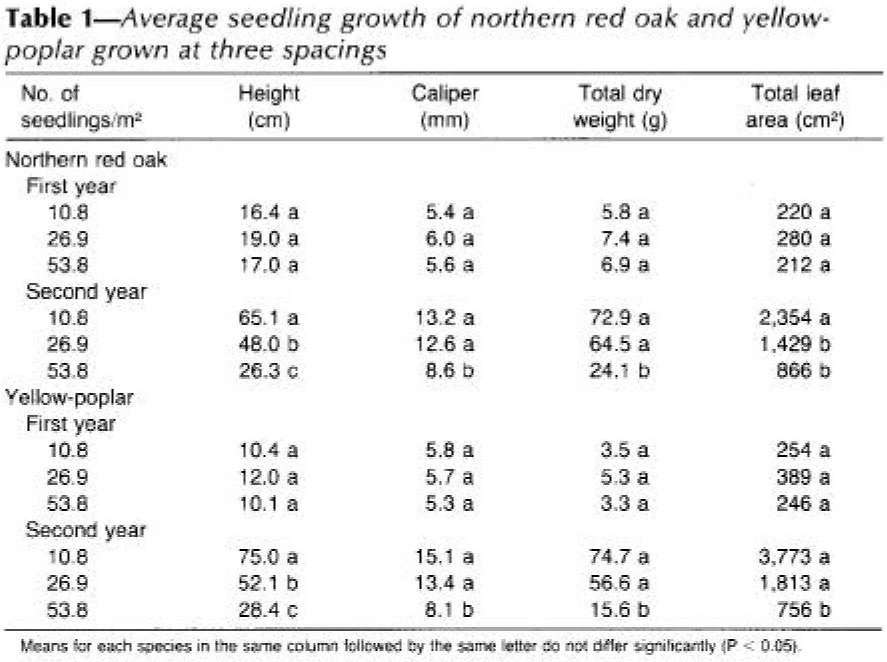

Table 1—*Average seedling growth of northern red oak and yellow-poplar grown at three spacings*

No. of seedlings/m²	Height (cm)	Caliper (mm)	Total dry weight (g)	Total leaf area (cm²)
Northern red oak				
First year				
10.8	16.4 a	5.4 a	5.8 a	220 a
26.9	19.0 a	6.0 a	7.4 a	280 a
53.8	17.0 a	5.6 a	6.9 a	212 a
Second year				
10.8	65.1 a	13.2 a	72.9 a	2,354 a
26.9	48.0 b	12.6 a	64.5 a	1,429 b
53.8	26.3 c	8.6 b	24.1 b	866 b
Yellow-poplar				
First year				
10.8	10.4 a	5.8 a	3.5 a	254 a
26.9	12.0 a	5.7 a	5.3 a	389 a
53.8	10.1 a	5.3 a	3.3 a	246 a
Second year				
10.8	75.0 a	15.1 a	74.7 a	3,773 a
26.9	52.1 b	13.4 a	56.6 a	1,813 a
53.8	28.4 c	8.1 b	15.6 b	756 b

Means for each species in the same column followed by the same letter do not differ significantly ($P < 0.05$).

flushes at 10.8/m^2, 1.7 at 26.9/m^2, and 2.2 at 53.8/m^2 at the end of the second year.

The effect of spacing on yellow-poplar seedlings was similar to that for northern red oak (table 1). Spacing had no significant effect on any measure of growth in the- first year. In the second, increasing density significantly reduced height, caliper, total dry weight, and total leaf area. Two-year-old seedlings at the widest spacing were 2.6 times taller and 4.8 times heavier than seedlings at the closest spacing.

The range of spacings used in this study had little influence on first-year growth of either species. However, densities greater than 53.8/m^2 have been reported to reduce first-year growth of oak seedlings in nursery beds (6, 7). Competition between trees at densities greater than 10.8/m^2 reduced second-year growth of both species.

Reduction of second-year growth by tree-to-tree competition may be an important consideration in nursery production of 2 + 0 seedlings, which have been recommended for successful artificial regeneration of northern red oak (9). Attaining maximum size for 2 + 0 seedlings of both northern red oak and yellow-poplar may require wider spacings than are normally used in nursery production of hardwood seedlings.

Literature Cited

1. Foster, A.A.; Farmer, R.E., Jr. 1970. Juvenile growth of planted northern red oak: effects of fertilization and size of planting stock. Tree Planters' Notes 21:4-6.
2. Johnson, P.S. 1984. Responses of planted northern red oak to three overstory treatments. Canadian Journal of Forest Research 14:536-542.
3. Johnson, P.S.; Dale, C.D.; Davidson, K.R. 1986. Planting northern red oak in the Missouri Ozarks: a prescription. Northern Journal of Applied Forestry 3:66-68.
4. Larson, M.M. 1977. Growth of outplanted northern red oak nursery stock related to shoot characteristics in the seedbed. Tree Planters' Notes 28:21-23.
5. Steiner, K.C. 1986. Integrating tree improvement with hardwood seedling production. Proceedings, Northeastern Area Nurseryman's Conference 39:24-30.
6. Taft, K.A., Jr. 1966. Wider nursery spacing produces larger northern red oak (*Quercus rubra L.*) seedlings. Tree Planters' Notes 79:7-8.
7. Wichman, J.R.; Coggeshall, M.V. 1983. The effects of seedbed density and fertilization of 1-0 white oak nursery stock. Tree Planters' Notes 34:13-16.
8. Wichman, J.R.; Coggeshall, M.V. 1984. Effects of seedbed density and fertilization on root-pruned 2--0 white oak nursery stock. Tree Planters' Notes 35:22-24.
9. Wendel, G.W. 1979. Growth and survival of planted northern red oak seedlings in West Virginia. Southern Journal of Applied Forestry 4:49-54.

Tree Planter's Notes, Volume 40, No. 3 (1989)

Deterioration of Black Spruce Seed During In-Situ Storage and Processing

D. A. Skeates, D. E. Irving, and V. F. Haavisto

Seed specialist (retired) and research assistant, Ontario Ministry of Natural Resources, Ontario Tree Improvement and Forest Biomass Institute, Provincial Seed Research Program, Maple, ON and research scientist, Canadian Forestry Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON

Cones of four age classes were collected from 65 individual black spruce (Picea mariana *(Mill) B. S. P.) trees. After three extraction cycles for each cone lot, germination tests were conducted. Seed from older cones exhibited somewhat lower germinative capacity, but extraction procedures did not reduce total viability. However, reduced germinative energy was exhibited by seed of older cones and by seed recovered from second and third extraction cycles. Implications for subsequent production of different stock products are discussed.* Tree Planters' Notes 40(3):5-8 ; 1989.

Black spruce *(Picea mariana* (Mill) B.S.P.) is a semiserotinous species. Depending on weather conditions throughout the year, cones open partially to release seed and then close during dry weather. After maturation, cones thus periodically release seed over a number of years (5). Though seed yields diminish as the cones age, viable seeds have been recovered from 25-year-old cones. Conceivably, year-round collection of cones of varying ages should therefore be possible.

The periodic release of seed in nature is simulated by extraction techniques currently in use at the Ontario Tree Improvement and Forest Biomass Institute. Studies on multiple-cycle extraction procedures have also been conducted at the Great Lakes Forestry Centre of the Canadian Forest Service (6). At both establishments, seed are subjected to 3 and 5 cycles of soaking, drying, and tumbling to release a higher proportion of the total number of seeds.

This study examines the combined influence of the duration of natural in-situ cone storage and the repeated soaking and drying extraction process on seed quality.

Materials and Methods

As part of a long-term study on black spruce seed yield and quality, samples were collected from 13 stands in the Geraldton Forest District of the Ontario Ministry of Natural Resources. In each stand, five trees were felled and their cone-bearing tops removed. For each tree, cones were picked and separated into one of four age classes, i.e., current (1981), 1-year-old (1980), 2-year-old (1979), and 3- to 5-year-old cones (1976-1978). Seed were extracted from each lot of cones by soaking the cones in warm water overnight, drying them in a kiln at 60 °C (140 °F) for 16 hours and then tumbling them for 15 minutes in a rotary sieve. This extraction process was repeated three times, and the seed from each cycle were kept separate. A total of 780 seed lots were thus obtained.

Seeds of each lot were dewinged, conditioned in a drying cabinet to reduce moisture content, and cleaned in the Institute's small-scale seed-processing facilities (7). Two 50-seed samples were drawn from each seed lot and placed in sealed petri dishes with a water reservoir. These dishes were placed in a conventional germinator maintained for 16 hours at 25 °C with lights, alternated with 8 hours of darkness at 23 °C. Temperatures were kept within the range recommended by Fraser (4) for Ontario sources, and humidity was maintained between 80 to 85%.

Numbers of germinating seedlings were recorded daily from the fifth to the ninth day. A final germination count was conducted on the twelfth day; no further germination was seen on day 13. A seed was considered germinated when the radicle exceeded twice the length of the seed. Ungerminated seeds were then cut to determine numbers of filled and empty seeds and germination data were adjusted to a percentage of sound seed.

Results

Germination data are summarized by cone age and extraction cycle in table 1 and illustrated in figure 1. Percent germination attained after 12 days (germinative capacity) for the 12 treatments (3 extractions and 4 cone ages) ranged from 80 to 93%. Cumulative germination after 12 days was similar for current (92%) and 1-year-old cones (91%), whereas values for seed from 2-year-old cones were slightly lower (87%). Seed from the 3- to 5-year-old cones exhibited viability (81%) that was about 10% lower than that of seed from the current year's cones. No trends in germinative capacity were apparent between extractions within any cone age class.

On day 5, the percent germination of first-extraction seed far exceeded those of the other two extractions, regardless of the age class of cones (table 1). For all age classes combined, percent germination of seed from the second and third extraction cycles was only about one-quarter that of seeds from the first extraction (table 2). By day 12, mean percentage germination was similar for the three extractions.

Table 1—*Cumulative percentage germination by day related to cone age and extraction cycle*

	Day 5	Day 6	Day 7	Day 8	Day 9	Day 12
1981 (Current) cones						
First extraction	61	85	88	90	91	91
Second extraction	12	58	82	89	90	91
Third extraction	17	43	70	84	90	93
All extractions	30	62	80	88	90	92
1980 (1-year-old) cones						
First extraction	47	80	86	88	89	90
Second extraction	16	49	78	87	90	91
Third extraction	11	33	66	82	89	92
All extractions	25	54	77	86	89	91
1979 (2-year-old) cones						
First extraction	34	73	83	86	88	88
Second extraction	8	40	70	81	84	85
Third extraction	7	27	57	75	83	88
All extractions	16	47	70	81	85	87
1976–78 (3- to 5-year-old) cones						
First extraction	17	59	73	77	79	80
Second extraction	5	27	64	77	81	82
Third extraction	5	19	48	67	76	82
All extractions	9	35	62	74	79	81

Rate of seed germination (germinative energy) was lower for each successive age class of cones (table 1). In the current and 1-year-old cones of the first extraction, cycle, nearly complete germination (within 10% of the total) had occurred by day 6, whereas with the other two age classes, germination was somewhat slower. The germination results from succeeding extractions showed a marked decrease in germinative energy (fig. 1). When the three extractions for each age class of cones were combined, mean germination on day 5 was 30% for seed of current cones, decreasing to 25, 16, and 9% for those of 1-, 2-, and 3-to 5-year-old cones, respectively. Because of the lower germinative capacity of seed from older cones, differences in germination from day to day continued to the end of the test period. However, these diminished from a 21 % difference at day 5 to 11 by day 12 between current and 3- to 5-year-old cones.

Discussion

In operational germination testing, the nursery superintendent or forest manager has been primarily concerned with germinative capacity as a measure of seed quality. This has been based on the assumption that seeds that germinate represent potential seedlings. Rate of germination has not been con-

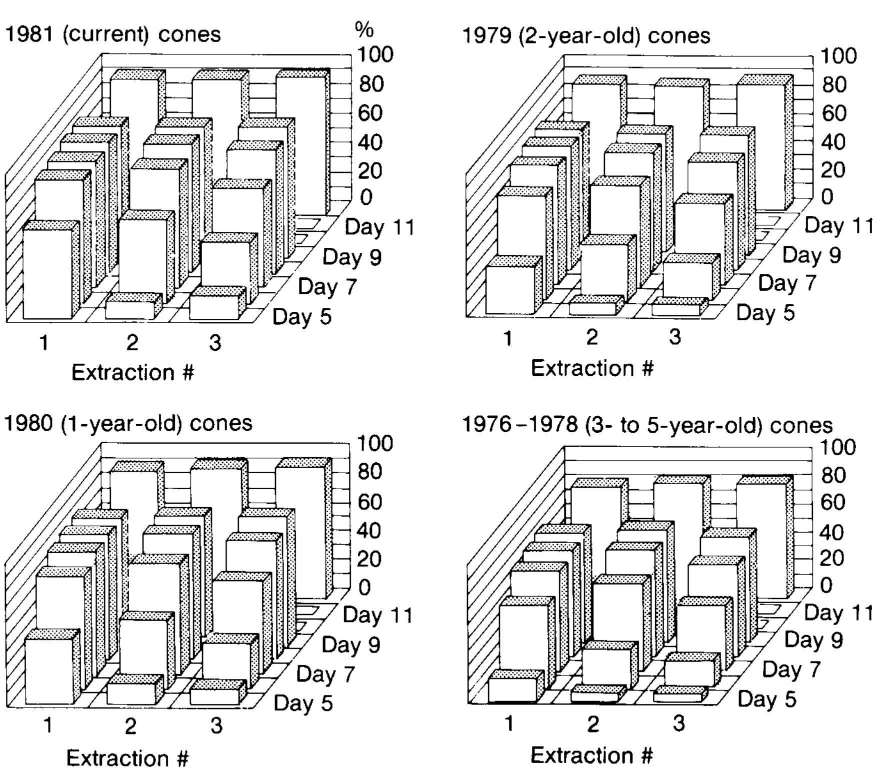

Figure 1—*Germinative energy related to extraction cycle for each of 4 cone age classes.*

sidered as a significant factor in plant performance.

Under optimum germination conditions, differences in germinative energy have had only marginal influence on the duration of germination. Under greenhouse conditions this duration would be expected to increase relative to results from a germination cabinet. On seedbeds under ambient climatic conditions, black spruce germination (emergence) has been observed to take place over a period of weeks. Seed sown onto seedbeds in the forest have even more constraints to normal development.

Time of germination has been shown to have a considerable influence on early stock performance in this species (8). Stresses during the critical germination period can result in slower rates of germination, reducing the season available for growth, and thus resulting in smaller plants at the end of the production cycle. Reduced seed vigor as indicated by lower germinative energy can contribute to decreased germination and losses during the period of emergence and early development. The resultant number of vigorous seedlings could therefore be much lower than might be expected based on germinative capacity under optimum conditions.

In this study, germination was virtually complete by the twelfth day. The percentage of seeds that germinated was only somewhat lower for seeds from older age classes of cones. However, the rate of germination suggested a lower germinative energy for seeds from older cones. Natural in-situ aging seems to have reduced seed quality, a factor the forest manager should consider when determining collection strategies. It is recommended that black spruce seed stocks should not be augmented in poor crop years by collection of cones older than 1 year unless absolutely necessary.

Yields of seed vary with extraction methodology. Fleming and Haavisto (3) have shown that per-cone seed yields can be increased by continuing to extract seed for up to 16 cycles of wetting, drying, and tumbling The potential yields from black spruce cones would appear to

Table 2—*Cumulative mean percentage germination by day related to extraction cycle, combining 4 cone age classes*

	Day 5	Day 6	Day 7	Day 8	Day 9	Day 12
First extraction	40	74	82	85	87	87
Second extraction	10	44	74	84	86	87
Third extraction	10	30	60	77	84	89

be much higher than normally considered (6). Though higher yields should be achievable, the methodology of successive cycling reduced germinative energy in this study. This technique appears to be a form of artificial aging contributing to deterioration in seed quality. There is a need to reexamine and possibly redevelop extraction technologies in order to achieve close to potential yields without unduly affecting germinative energy.

Aging of seeds in the cone and further artificial aging through extraction processes may be more harmful than just loss in germinative energy. Delouche and Baskin (2) have suggested possible deterioration of genetic material in the seed as it ages. Deterioration may proceed even before losses are detectable in germination tests.

The influence of germinative energy on initial plant development as indicated by vigor testing (9) was not assessed in this study. The effect of such influence would be expected to vary for different stock products, i.e., container seedlings, accelerated transplants, bareroot seedlings, and transplants, each of varying age class. However, the negative effects of natural and artificial aging on germinative energy would indicate a need to consider age of cones and extraction technologies as factors influencing seed quality and hence stock quality.

Literature Cited

1. Baker, W.D. 1980. Black spruce cone and seed quality and quantity in relations to geographic location, stand age, and cone age. Internal project proposal, Ontario Ministry of Natural Resources.
2. Delouche, J.C.; Baskin, C.C. 1973. Accelerated aging techniques for predicting the relative storability of seed lots. Seed Science and Technology 1:427-452.
3. Fleming, R.L.; Haavisto, V.F. 1986. A case for improving the efficiency of seed extraction from black spruce (*Picea mariana* (Mill) B.S.P.) cones. Tree Planters' Notes 37(4):7-11.
4. Fraser, J.W. 1970. Cardinal temperatures for germination of six provenances of black spruce seed. Info. Rep. PS-X-23. Petawawa, ON: Canadian Forestry Service. 12 p.
5. Haavisto, V.F. 1975. Peatland black spruce seed production and dispersal in northeastern Ontario. In: Proceedings, Black Spruce Symposium. Publ. O-P-4. Sault Ste. Marie, ON: Canadian Forestry Service Great Lakes Forestry Centre: 250-264.
6. Haavisto, V.F.; Fleming, R.F.; Skeates, D.A. 1988. Theoretical and actual yields of seed from black spruce cones. Forestry Chronicle 64(1):32-34.
7. Irving, D.E.; Gashoka, K.; Skeates, D.A. 1987. Small scale extractory. For. Res. Note 43. Maple, ON: Ontario Ministry of Natural Resources, Ontario Tree Improvement and Forest Biomass Institute. 4 p.
8. Wang, B.S.P. 1973. Laboratory germination criteria for red pine (*Pinus resinosa* Ait.) seed. Proceedings of the Association of Official Seed Analysts 63:94-101.

Tree Planter's Notes, Volume 40, No. 3 (1989)

Optimum Temperatures for Stratification of Several Maple Species

József Tóth and Peter W. Garrett

Professor, Hevesi Ákos Technical School of Agriculture, Szombathely, Hungary, and principal forest geneticist, USDA Forest Service, Northeastern Forest Experiment Station, Durham, NH

Scarification of pericarps in several species of maple (Acer) provided as good, or better, germination than the use of unscarified seed. In years when seed are not abundant, this treatment should result in greater germination. Time of seed collection is critical with some maples, and the inconsistencies in different years are probably due to maturity of seed at collection. Tree Planters' Notes 40(3): 9-12; 1989.

Maple (*Acer* L.) is one of the genera favored by urban planners, landscape architects, and highway engineers in both North America and Europe. Because they are desirable in their own right, and because of increasing problems with air pollution and diseases of some of the native species, both public and private nurseries in the United States have introduced a number of species from Europe and Asia.

These "new" species bring with them unique problems of seed production, seed handling and storage, and seed germination. Dormancy in maple is regulated by the embryo and/or the pericarp and varies by species. This paper addresses only the effects of temperature during the stratification process on germination and does not look at the type of dormancy involved.

Materials

Seed (samaras) of the following species were studied:

1. Hedge maple (*Acer campestre* L.), native to parts of Europe and western Asia; now cultivated throughout climate zone IV. Grows to 15 to 20 m (50 to 65 feet).
2. Amur maple (*A. ginnala* Maxim), native to China and Japan; was introduced into the United States about 1860 and is cultivated in climate zone II. Small, reaches only about 7 m (23 feet).
3. California boxelder (*A. negundo* var. *californicum* (Torr. & Gr.) Wesm.), widely used as an ornamental and for shelterbelts in the United States and Canada. Hardy and drought tolerant.
4. Japanese maple (*A. palmatum* Thunb.), native to Japan and Korea; introduced about 1820 and grows well in climate zone V. Has a very desirable crown shape and reaches about 8 m (26 feet).
5. Norway maple (*A. platanoides* L.), probably introduced from Europe in the 1700's and widely used as a yard and street tree in the United States. May reach 30 m (100 feet).
6. Sycamore or planetree maple (*A. pseudoplatanus* L.), native of Europe and western Asia, brought into the United States very early (1600 to 1700's); grows best in climate zone V. May reach 30 m (100 feet).

Methods

Half of the seeds of each species had their pericarps scarified and the others were left intact. Seed of each of these treatments, and for each of the six species, were stratified under one of the following temperature regimens:

1. One group of seed was placed outdoors in the soil under ambient conditions. Climatic conditions at the site did not vary from normal during the time of these tests, i.e., temperature and rainfall were near normal.
2. The second group of seed was stratified in moist sand in a growth chamber at temperatures between 1 to 5 °C (34 to 41 °F).

All of this work was carried out in Hungary in cooperation with the Horticultural University in Budapest.

3. The third group of seed was stratified in the chamber at 5 to 10 °C (41 to 50 °F).
4. The final group of seed was stratified at between -5 and -10 °C (14 to 23 °F).

The stratification period started at the beginning of March except for California boxelder, which was started in April. After stratification, four lots of 100 seed from each species and treatment were germinated between sheets of moist filter paper at 23 °C (70 °F) for 21 days in accordance with International Seed Testing Association rules. Germination was scored according to Association guidelines.

Results

In most, but not all, cases scarification of the pericarp as a pretreatment increased germination. Sycamore maple was the notable exception, with germination that was uniformly high except for the coldest stratification treatment (table 1).

Freezing maple seed (treatment 4) of at least these six species during stratification prevented germination completely with both scarified and intact samaras.

Once the pericarp has been opened (scarified), any stratification temperature from 1 °C (34 °F) to ambient field temperatures will produce very high rates of seed germination.

Germination of intact seed (unscarified), which is the way maple seed are usually handled, varies by treatment and by year of seed collection. Some of the seasonal variation is probably due to variation in stage of maturity of seed, which varies from year to year. If seed are collected at the same time each year, and if the maturity of the seed is ignored when collecting, germination can be expected to vary regardless of subsequent treatments.

The variation between the first three treatments in this study is complex and deserves careful attention in nursery operations. Hedge maple and California boxelder had poorer germination with treatment 2 than with treatments 1 or 3. California boxelder produced the best results under ambient conditions, whereas the other species had varying germination responses which, again, could be at least partially explained by condition of seed at time of collection.

For the scarified seed, treatments 1, 2, and 3 are not significantly different except with hedge maple (1982) and Japanese maple (1983, 1984). For intact pericarps there are many differences and no really consistent patterns. For hedge maple (1983, 1984) and all three years for California boxelder, treatments 1 and 3 are better than treatment 2. For Amur maple, treatment 2 looks better. For Japanese maple (1983, 1984) and Norway maple (1981), treatments 1 and 2 look better than treatment 3 but other years do not follow that trend. Treatment 4 yielded little or no germination for any species or year.

Summary

Although we recognized that techniques for mechanical scarification or cracking of pericarps of maple may not be fully developed at this time, the potential of this treatment for improving germination is interesting and may be useful in the future (table 2). Germination of scarified pericarps under field conditions may not equal that obtained under laboratory conditions, but this study did not look at those differences or the reasons for any such dissimilarities.

In every case, scarification of pericarps provided as good, or better, germination than the use of unscarified seed and in many cases these differences were significant. Where seed are not abundant and where percent of germination is important, some seed treatment before attempting germination would be useful.

What this research may show more clearly than anything else is that time of collection may be critical with some species. The inconsistencies observed in different years for both Norway

Table 1—*Percentage germination for 6 species of maples* (Acer) *with scarified and intact pericarps receiving 4 stratification treatments*

Stratification treatment*	% germination† Scarified pericarps	% germination† Intact pericarps
Hedge maple		
1982		
1	100	20
2	75	40
3	0	0
4	0	0
1983		
1	100	100
2	100	30
3	100	100
4	0	0
1984		
1	100	90
2	78	34
3	100	92
4	0	0
Amur maple		
1982		
1	100	70
2	100	90
3	100	60
4	80	6
1983		
1	100	70
2	100	86
3	100	55
4	70	0
1984		
1	100	74
2	100	86
3	100	54
4	65	3
California boxelder		
1981		
1	95	100
2	95	58
3	95	62
4	0	0
1982		
1	100	100
2	100	38
3	100	70
4	0	0
1983		
1	100	96
2	100	38
3	100	65
4	0	0
Japanese maple		
1982		
1	60	35
2	50	0
3	50	0
4	0	0
1983		
1	100	80
2	100	65
3	58	30
4	0	0
1984		
1	76	72
2	70	64
3	48	28
4	0	0
Norway maple		
1981		
1	100	90
2	100	95
3	100	46
4	0	0
1982		
1	85	30
2	95	30
3	100	35
4	0	0
1983		
1	85	30
2	100	100
3	95	20
4	0	0
1984		
1	100	90
2	96	87
3	100	87
4	0	0
Sycamore maple		
1981		
1	100	100
2	100	100
3	100	86
4	0	0
1982		
1	100	25
2	100	20
3	100	66
4	0	0
1983		
1	100	100
2	92	100
3	100	90
4	0	0

*Treatment 1 = outdoors in the soil under ambient conditons; 2 = stratified in moist sand in a growth chamber at 1 to 5 °C (34 to 41 °F); 3 = stratified at 5 to 10 °C (41 to 50 °F); 4 = stratified at −5 to 10 °C (14 to 23 °F).

†Four lots of 100 seeds from each species were germinated between sheets of moist filter paper at 23 °C (70 °F).

Table 2—*Recommended stratification treatments for seeds of 6 maple (Acer) species*

	Recommended stratification treatment*		
Species	Scarified pericarps	Unscarified pericarps	Duration of treatment (days)†
Hedge maple	1	1	90
Amur maple	1	2	60–90
California boxelder	1	1	100–130
Japanese maple	1	1	100–130
Norway maple	2	2	100–300
Sycamore maple	1	2	100–120

*Treatment 1 = outdoors in the soil under ambient conditions; 2 = stratified in moist sand in a growth chamber at 1 to 5 °C (34 to 41 °F).

†*Source:* Schopmeyer, C.S. 1974. Seeds of woody plants of the United States. Agric. Handb. 450. Washington, DC: USDA Forest Service.

maple and sycamore maple may be due to maturity of seed at time of collection. Seed of sycamore maple collected in 1982 obviously were not at the same state of maturity as those collected in 1981 or 1983 and would have wasted time and space in a nursery program.

Some of the results of this study are obvious, whereas others are not so clear. One of the problems with this type of work is that species and individual trees ripen seed at different times. Collecting samaras from several trees on the same date will result in seed at various stages of ripeness, which will effect germination. Because climatic conditions influence seed maturity, collecting from the same tree on the same date over several years may result in the different germination rates observed in this study. Nursery managers must be careful not to adhere too closely to a scheduled date of collection and seed orchard managers should develop information on individual genotypes in the orchard to insure proper seed maturity and maximum germination.

Bibliography

1. Bonner, F.T. 1978. Storage of hardwood seeds. Genetic Resourc. Info. No. 7. Rome: FAO: 10-17.
2. Carl, C.M., Jr.; Snow, A.G., Jr. 1971. Maturation of sugar maple seed. Res. Pap. NF-217. Broomall, PA: USDA Forest Service, Northeastern Forest Research Station. 9 pp.
3. Hess, D. 1979. Növényelettan [plant physiology]. In: Natura. Budapest. 457 p.
4. Krüssmann, G. 1964. Die Baumschule [the tree nursery]. Berlin: Parey Press. 635 p.
5. Probocskai, E. 1965. Faiskola [tree nursery]. Mezögazdasági kiadó Budapest. 689 p.
6. Rehder, A. 1954. Manual of cultivated trees and shrubs, 2d ed. New York: Macmillan. 99 p.
7. Schopmeyer, C.S., tech. coord. 1974. Seeds of woody plants in the United States. Ag. Handb. 450. Washington, DC: USDA Forest Service. 883 p.
8. Toth, J. 1983. Erdészetileg fontosabb juhar fajpk magkezelése [seed treatment of important maple species]. Az Erdo 32(4): 182-183.
9. Tóth, J. 1984. A juharok magcsemete nevelése [rearing of maple seedlings]. Master's thesis. Kertészet Egyetem, Budapest. 139 p.

Tree Planter's Notes, Volume 40, No. 3 (1989)

Effect of Container Type and Watering Regime on Early Growth of Western Larch Seedlings

John H. Bassman, R. Alan Black, and Xui Qi Wang

Associate professor, Washington State University, Department of Natural Resource Sciences, and associate professor, Department of Biology, Pullman, WA, and visiting scientist, Shaanxi Province Forestry Institute, People's Republic of China

*Seedlings of western larch (*Larix occidentalis *Nutt.) were grown in three types of containers (Rootrainer®, Pinecells®, and Styroblocks®) at three different watering regimes (50, 75, or 100% water content). The Rootrainer container combined with a 75% watering regime resulted in the greatest top and root growth. Seedlings grown in Pinecell containers were similar. Styroblock containers resulted in the least growth at all levels of moisture, but the 50% watering regime resulted in the longest roots.* Tree Planters' Notes 40(3):13- 15; 1989.

Western larch (*Larix occidentalis* Nutt.) is a valuable timber species indigenous to moist, well-drained sites of the Pacific Northwest (2). Because of its extremely rapid growth rates (5), western larch is favored for planting on appropriate sites after logging. However, producing vigorous container seedlings for outplanting has been problematic because of the difficulty in controlling growth and phenology. Previous work in our greenhouses (1,4) suggested that different potting containers might result in substantial differences in growth performance, and that there may be interacting effects of containers with moisture regimes. The following study was undertaken to examine early growth performance of western larch seedlings in three commonly used containers and under three differing moisture regimes.

Methods

Stratified western larch seed were sown into one of three types of containers: Ray Leach Pinecells® (Ray Leach "Conetainer" Nursery, Canby, OR); Sixes Rootrainer® (Spencer-Lemaire Industries Ltd., Edmonton, Alberta, Canada); or Beaverfoam Styroblock® 4 (Beaver Plastics Ltd., Edmonton, Alberta, Canada). Cells of each container were of the same size (140 cm^3; 5.5 in^3).

The growth medium was a 1:1 peat-vermiculite mix (Standard Forestry Mix, W.R. Grace & Co., Santa Ana, CA). Seedlings were grown in a greenhouse maintained at 25 °C day and 20 °C night temperatures. Metal halide lamps extended the photoperiod to 14 h with minimum light intensity of 300 to 500 $\mu mol\ m^2 s^{-1}$. Three seeds were sown into each cavity in mid-July 1985; seedlings were thinned to one healthy seedling after about 2 weeks.

The medium of each container is maintained at one of three water contents: 50, 75, or 100% of the weight of the container plus potting medium and water. Weight at field capacity was used as the 100% regime. Weights were determined four times daily throughout the experiment and water contents adjusted accordingly.

Seedlings were irrigated at 15-day intervals alternately with one of two liquid fertilizers:

1. $Ca(N0_3)_2 \times 4\ H_20$ (53 ppm N, 75 ppm Ca) with Sequestrene 330 Fe (Ciba-Geigy, Greensboro, NC) at 2 ppm Fe;
2. Agro 5-25-25 (Pacific Agro Company, Renton, WA) at 20 ppm N with $MgS0_4 \times 7H_20$ at 48 ppm Mg.

This formulation also included 44 ppm P, 83 ppm K, 0.12 ppm S, 0.44 ppm Fe, 0.28 ppm Zn, 0.20 ppm Cu, and 0.08 ppm B.

Each container was represented by 12 blocks, each containing 60 cells. These were subdivided to accommodate the three watering regimes. Thus, 80 cells were available for testing each container x water combination. The heights of 20 randomly selected seedlings from each block were measured on September 3, September 12, and October 15.

Three seedlings per block were destructively harvested on the same dates for determination of total root length and root dry weight. Root lengths were measured using a semiautomated X-Y-plotter-based method (6). Harvested material was dried to constant mass at 50 °C and weighed. Data were analyzed using analysis of variance procedures and treatment means compared using Duncan's multiple range test (2). Differences were declared significant at probability level of $P=0.05$.

Results and Discussion

Seedlings in the Rootrainer container displayed the greatest height growth. Seedlings grown in the Pinecell and Rootrainer containers both showed greater height growth than seedlings grown in Styroblocks (table 1). The 75% watering regime resulted in the greatest overall height growth. Seedling heights with the other two regimes were similar 90 days after planting; however, the 50% watering regime limited height growth during early establishment (table 1). Root growth, both length and weight, followed a similar pattern (table 2).

There was a significant interaction between container type and water regime. In both the Pinecell and Rootrainer containers, the 75% water regime resulted in the greatest height growth throughout the experiment, but the influence of the other two water regimes changed over time (fig. 1). Within the Styroblocks, the greatest and least height growth resulted from the 100 and 50% watering regimes, respectively, during early establishment. However, these differences were minimal by 90 days after sowing (fig. 1).

Root length and weight behaved similar to height growth in both the Pinecell and Rootrainer containers, but the magnitude of difference caused by the 75% water regime in the Rootrainer was considerably greater (fig. 2). In the Styroblock containers, the 50% water regime resulted in the greatest root length; the 100% watering regime, the least. The 50 and 75% watering regimes had equal effect on root dry weight (fig. 2).

Why the different containers should contribute to such differences in growth performance is not clear, but it may be related to the thermal characteristics of the fabrication material. The Rootrainer is made from a thin polystryrene sheet plastic that provides little insulation and allows rapid heat transfer. By contrast, the Styroblock containers are formed from expanded bead polystyrene and provide good insulation and much slower heat transfer characteristics. The polyethylene material used in Pinecells would probably fall somewhere in between. Thus, potting medium in the Rootrainers may heat more rapidly

Table 1—*Effects of container type (over all watering regimes) and water regime (over all container types) on height of western larch seeds sown July 13*

	Seedling height (cm)	
Category	Sept. 3	Oct. 15
Container type		
Pinecell	1.69 ± 0.03 b	2.14 ± 0.03 b
Rootrainer	1.77 ± 0.02 a	2.25 ± 0.04 a
Styroblock	1.45 ± 0.02 c	1.91 ± 0.03 c
Water regime		
50%	1.39 ± 0.02 c	1.98 ± 0.03 b
75%	1.83 ± 0.03 a	2.38 ± 0.04 a
100%	1.69 ± 0.02 b	1.93 ± 0.03 b

Values shown are means (± standard error) of 240 samples. Those values followed by the same letter within a category are not significantly different ($P \leq 0.05$) for that date. Duncan's multiple range test.

Table 2—*Effects of container type (over all watering regimes) and water regime (over all container types) on root length and dry weight of western larch*

Category	Root length (cm)	Root weight (g)
Container type		
Pinecell	153.5 ± 10.7 b	0.05 ± 0.003 a
Rootrainer	171.5 ± 14.7 a	0.05 ± 0.007 a
Styroblock	104.6 ± 5.4 c	0.03 ± 0.001 b
Water regime		
50%	150.0 ± 8.49 b	0.04 ± 0.002 b
75%	186.1 ± 14.0 a	0.06 ± 0.007 a
100%	93.5 ± 6.0 c	0.03 ± 0.002 c

Values shown are means (± standard error) of 36 samples. Those values followed by the same letter within a category are not significantly different ($P \leq 0.05$), Duncan's multiple range test.

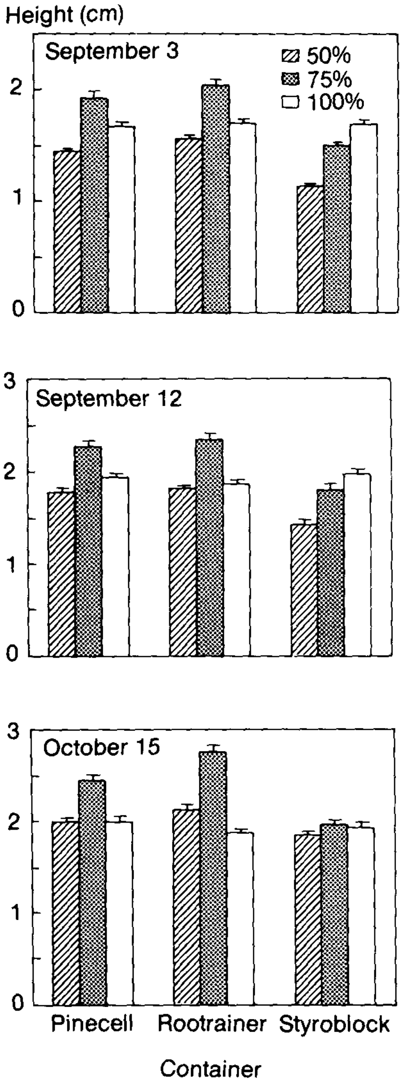

Figure 1—*Height growth of western larch seedlings in relation to combinations of container type and watering regime. Seeds were sown July 13 and measurements made September 3, September 12, and October 15. Each vertical bar is the mean of 80 samples. Error bars represent one standard error of the mean.*

during the day and stay warmer for more of the day than medium in Styroblocks. This, in turn, would contribute to greater root development, consistent with our observations.

In summary, of the three containers and three moisture regimes tested, the Rootrainer container combined with a 75% watering regime resulted in the best top and root growth in young western larch seedlings. Seedlings grown in Pinecell containers were similar. Styroblock containers resulted in the least growth at all levels of moisture. The 50% watering regime resulted in the greatest root length.

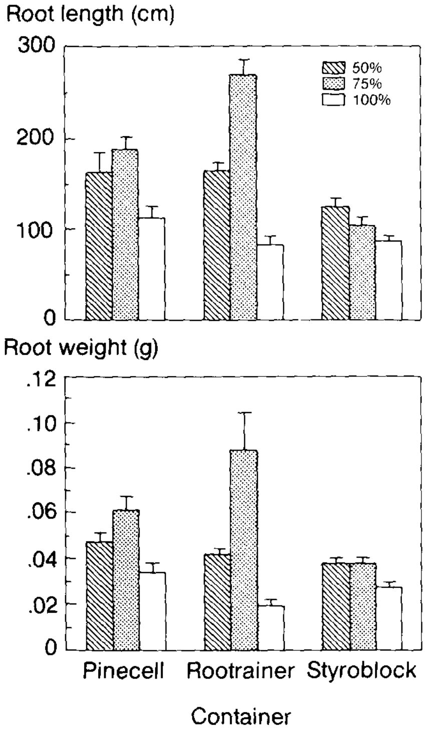

Figure 2—*Root growth of western larch seedlings in relation to combinations of container type and watering regime. Seeds were sown July 13 and measurements made October 15. Each vertical bar is the mean of 36 samples. Error bars represent one standard error of the mean.*

Literature Cited

1. Higgins, S.S.; Black, R.A.; Rademaker, G.K.; Bidlake, W.R. 1987. Gas exchange characteristics and water relations of *Larix occidentalis.* Canadian Journal of Forest Research 17:1364-1370.
2. SAS Institute, Inc. 1985. SAS user's guide: statistics, 5th ed. Cary, NC. 956 p.
3. Schmidt, W.C.; Shearer, R.C.; Roe, R.L. 1976. Ecology and silviculture of western larch forests. Tech. Bull. 1520. Washington, DC: USDA Forest Service.
4. Shaw, J. 1984. Density-dependent effects on water relations of western larch *(Larix occidentalis* Nutt.). Master's thesis. Washington State University, Pullman, WA.
5. Shearer, R.C. 1982. Establishment and growth of natural and planted conifers 10 years after clear-cutting and burning in a Montana larch forest. In: Baumgartner, D.M., ed. Site preparation and fuels management on steep terrain. Pullman, WA: Washington State University Cooperative Extension: 149-157.
6. Wilhelm, W.W.; Norman, J.M.; Newell, R.L. 1983. Semiautomated X-Y-plotter-based method for measuring root lengths. Agronomy Journal 75:149-152.

Tree Planter's Notes, Volume 40, No. 3 (1989)

Causes of Mortality in Outplanted Ponderosa Pine Container Seedlings in the Southwest

L. J. Heidmann and Sally M. Haase

Research plant physiologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Forestry Sciences Laboratory, Flagstaff, AZ and research forester, USDA Forest Service, Riverside Forest Fire Laboratory Pacific Southwest Forest and Range Experiment Station, Berkeley, CA

*Rocky Mountain ponderosa pine (*Pinus ponderosa *var.* scopulorum *Engelm.) seedlings, raised in containers under a low N regime, were planted on a 1-year-old burn in central Arizona and were protected from wildlife. Survival after 1 year was 90%. There were no differences in survival between naturally shaded and unshaded plots. Mortality was caused primarily by frost heaving and drought.* Tree Planters' Notes 40(3):16 19; 1989.

Regenerating Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm.) in the Southwest (Arizona, New Mexico, and southwestern Colorado) is difficult because of drought conditions at critical times during the year, competing vegetation (primarily perennial grasses), browsing mammals, and slow juvenile growth.

Difficulty in obtaining regeneration is also closely related to soil types. Forest soils in the Southwest are volcanic (derived from basalt rocks) or sedimentary in origin. Natural regeneration on volcanic soils is almost nonexistent because of frost heaving and drought (5,7). It is easier to get natural regeneration on sedimentary soils when correct procedures are followed (8), although these soils will also heave, especially if they are compacted (3). Larger bareroot and container seedlings do not heave readily on either soil (3,10). Therefore, planting seedlings on both soils is successful when established guidelines are followed (7,11). Correct procedure, however, is not always observed.

Often, essential steps, such as site preparation or protection from grazing animals, are omitted. When this happens, low survival is inevitable. An additional factor, recently observed with bareroot stock, is that survival may be inversely related to size of planting stock. Larger seedlings survive at lower rates, especially during dry years, than smaller trees (4). Poorer survival of larger trees presumably occurs because of a greater transpiring surface, which would be detrimental during droughts.

Results from container plantings have been quite varied. Reasons for failure can be attributed, to a great extent, to small container size and faulty practice in raising the seedlings. Often, because of poor planning, crops are sown at the wrong time and delivered to the planting site while still in succulent condition. If this occurs while temperatures are still well below freezing, mortality with be high.

This note reports the results of planting of a 16-ha burn on the Fort Valley Experimental Forest.

Methods

Site. The planting site is approximately 26 km northwest of Flagstaff, AZ, and is in the ponderosa pine/Arizona fescue (*Pinus ponderosa/Festuca arizonica*) habitat type, Arizona fescue phase (2). The elevation is 2,195 m, and the site is mostly level. The soil is well developed and classified as a Mollic eutroboralf; soil texture is a silt loam (6). Outcroppings of basalt rocks occur throughout the site. A few small areas could not be planted because of rocks.

The prefire stand was composed, primarily, of an old-growth ponderosa pine overstory with an understory of poles that originated in the bumper seed crop year of 1919. In June 1982, a fire that started just outside the Experimental Forest crossed the boundary and burned approximately 16 ha. Most of the stand trees were killed by the fire. Dead trees were left standing after the fire.

Seedlings. Seedlings were raised in the Bureau of Indian Affairs (BIA) greenhouse at McNary, AZ. Seeds collected earlier, just north of the Experimental Forest, were shipped to the greenhouse in August 1982. Seeds were sown in Tinus Rootrainers® (492 cm^3), manufactured by Spencer-LeMaire, Ltd., Canada. Substrate consisted of a 50:50 (v/v) mixture of peat moss and vermiculite. Totes (a tote contains 40 cavities) of seedlings were watered regularly with plain water until after germination. At that time, Peter's 15-30-15 water-soluble fertilizer was applied regularly in the irrigation water to provide 40 parts per million (ppm) N. Peter's S.T.E.M. fertilizer containing micronutrients also was added to the irrigation water, as was Sequestrene 330, an iron supplement. Each 100 liters of fertilizer solution contained 4.26 kg NPK (15-30-15), 32 g S.T.E.M., and 900 g Sequestrene 300 (1).

Seedlings were raised for 12 weeks in the greenhouse under constant light and an environment enriched with CO_2 then were gradually hardened off in the greenhouse by turning off supplemental lighting and the CO_2 generator. Temperatures were dropped 5.6 °C every 2 weeks, and watering was greatly curtailed. Fertilization also was stopped.

In mid-December, seedlings were moved outside to a lathhouse, where they were not watered until spring. After a heavy watering, seedlings again were stressed. Fertilizer was not applied until after tops had begun to grow.

Site Preparation. Many open areas of the burn contained heavy stands of perennial grasses, primarily Arizona fescue and mountain muhly (*Muhlenbergia montana*). In the shade of dead poles, various annual grasses and forbs began to invade in the spring of 1983.

During the spring of 1983, all areas with live vegetation were sprayed with glyphosate (Roundup®) at a rate of 3.36 kg active ingredient/ha using Herbimicron sprayers.

Planting. Seedlings were transported to the Experimental Forest in June and stored in an outdoor lathhouse, where they were watered and fertilized regularly. Seedlings were held in the lathhouse until August 8 when planting began. On the afternoon of August 8, a heavy rain drenched the site.

Trees were planted under contract on a 2.44- by 2.44-m spacing. The contractor was given the option of using KBC bars, hoedads, or augers in planting trees. Trees were planted by all three methods, but augers were not used extensively because of rocky conditions.

Elk (*Cervus elaphus*) have been a particular problem in the area. Therefore, after trees were planted, Vexar® seedling protectors, 7.6 by 45.7 cm, were placed around each seedling, held in place with two number-9 wire pins.

Sampling. In October 1983, five open areas and five areas under standing dead poles (natural shade) were chosen for sampling. The 10 sampling areas were well distributed throughout the planting site. It was not possible, however, to pair shaded and unshaded plots. In each area, 50 trees were selected for survival checks and were marked with wire flags. Survival was checked in October 1983 and three times in 1984. Survival rates were determined using the following grading system.

1. Trees alive and growing.
2. Trees alive, but not growing.
3. Trees dead.

A t-test for unpaired plots was used to determine differences in survival and mortality between shaded and unshaded plots.

Results and Discussion

Overall, survival 14 months after planting was 90%. Although survival under natural shade was 4% greater than in the open, the differences were not significant (P = 0.20). In the open, 50% of the mortality was from frost heaving (16 trees), compared to 30% (6 trees) under natural shade. Percentage of trees planted that heaved, however, was 6.4 in the open and 2.4 under natural shade (table 1). On this same site, Larson (9) found heaving of first-year ponderosa pine seedlings established from seed to be exceptionally heavy. Almost all of nearly 1,000 seedlings heaved out of the ground between October 1957 and April 1958. The fact that seedling transplants in this study heaved at a low rate confirms findings by Schramm (10) that larger conifer seedlings heave less than smaller, newly germinated seedlings.

Drought ranks as the second greatest cause of mortality (table 1). Throughout the planting period, heavy rains fell on the area. From July 26 to October 13, 20.3 cm of precipitation was recorded. Approximately 15.2 cm fell in September. After the fall wet period, however, conditions became very dry. During the winter of 1983-84, only 63.5 cm of snow fell, approximately 25% of expected snowfall. In addition, the spring of 1984 was one of the driest on record. Beginning with the summer rains in July 1984, precipitation has been well distributed and soil moisture has been excellent.

Despite the fact that seedlings were protected by Vexar tubes, several trees were browsed, primarily by elk, because protectors either were knocked over by animals or the pin holding them heaved from the ground. About the same number of trees were browsed in the open and in the shade (tables 1 and 2).

Although there are no controls with which to make comparisons, observations over many years indicate that this plantation was successful because all factors necessary to ensure success were present. Seedlings were grown from seed collected locally, raised to a proper size, and conditioned to withstand moisture stress. Competing vegetation was eliminated, and seedlings were protected from browsing mammals. All of these factors should be considered when initiating planting projects in the southwestern United States.

Table 1—*Mortality of ponderosa pine container seedlings planted in the open and under natural shade on a recent burn in central Arizona*

Cause of mortality	Open			Natural shade		
	Mortality			Mortality		
	No.	Percent	P	No.	Percent	P
Frost heaving	15	50.0 a	0.05	6	30.0 a	0.05
Mammals	1	3.33		2	10.0	
Drought	8	26.67 a	0.03	4	20.0 a	0.03
Misc.	6	20.0 a	0.50	8	40.0 a	0.50
Total	30	100.0 a	0.20	20	100.0 a	0.20

Treatments with the same letter in common do not differ significantly at the level indicated. Comparisons were only made where large numbers of seedlings were involved or where there appeared to be differences.

Table 2—*Damage to ponderosa pine container seedlings planted in the open and under natural shade on a recent burn in central Arizona*

Cause of damage	Open			Natural shade		
	No. trees	Percent planted	P	No. trees	Percent planted	P
Frost heaving	1	0.04		2	0.08	
Mammals	52	20.8 a	>0.50	55	22.0 a	>0.50
Total	53	21.2 a	>0.50	57	22.8 a	>0.50

Treatments with the same letter in common do not differ significantly at the level indicated. Comparisons were only made where large numbers of seedlings were involved or where there appeared to be differences.

Literature Cited

1. Cornett, Z.J. 1982. Nutrient and mycorrhizal effects on the rootshoot ratio of containerized ponderosa pine seedlings. Ph.D. dissertation, University of Arizona, Tucson. 90 p.

2. Hanks, J.; Fitzhugh, E.L.; Hanks, S.R. 1983. A habitat type classification system for ponderosa pine forests of northern Arizona. Gen. Tech. Rep. RM-97. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 22 p.
3. Heidmann, L.J.; Thorud, D.B. 1975. Effect of bulk density on frost heaving of six soils in Arizona. Res. Note RM-293. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.
4. Heidmann, L.J. 1989. Unpublished data. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Flagstaff, AZ.
5. Heidmann, L.J. 1976. Frost heaving of tree seedlings: a literature review of causes and possible control. Gen. Tech. Rep. RM-21. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p.
6. Heidmann, L.J.; Thorud, D.B. 1976. Controlling frost heaving of ponderosa pine seedlings in Arizona. Res. Pap. RM-172. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p.
7. Heidmann, L.J.; Larson, F.R.; Rietveld, W.J. 1977. Evaluation of ponderosa pine reforestation techniques in central Arizona. Res. Pap. RM-190. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p.
8. Heidmann, L.J.; Johnsen, T.N., Jr.; Cole, Q.; Cullum, G. 1982. Establishing natural regeneration of ponderosa pine in central Arizona. Journal of Forestry 80(2):77-79.
9. Larson, M.M. 1961. Seed size, germination dates, and survival relationships of ponderosa pine in the Southwest. Res. Note 66. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.
10. Schramm, J.R. 1958. The mechanism of frost heaving of tree seedlings. Proceedings of the American Philosophical Society 102(4):333-350.
11. Schubert, G.H.; Heidmann, L.J.; Larson, M.M. 1970. Artificial reforestation practices for the Southwest. Agric. Handb. 370. Washington, DC: USDA Forest Service. 25p.

Tree Planter's Notes, Volume 40, No. 3 (1989)

Fall-Lifted Douglas-Fir Outperforming Spring-Lifted Stock 13 Years After Planting

John P. Sloan

Forester, Intermountain Research Station, USDA Forest Service, Boise, ID

*A 1972 study showed that Douglas-fir (*Pseudotsuga menziesii *var*. glauca*) seedlings lifted in mid-November outgrew those lifted in early March. When the plots were remeasured in 1985, after 13 growing seasons on a south-facing granitic slope in central Idaho, the fall-lifted trees continue to grow faster than the spring-lifted seedlings.* Tree Planters' Notes 40(3):20-24; 1989.

In 1972, a study was undertaken at Lucky Peak Nursery by Morby and Ryker (10) to determine the feasibility of late-fall lifting, cold storage, and spring planting of several conifers in southwestern Idaho. They found that ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), Engelmann spruce (*Picea engelmannii* Parry ex Englem.), and western larch (*Larix occidentalis* Nutt.) seedlings lifted in late fall and stored through the winter survived and grew as well as spring-lifted stock. Surprisingly, however, the fall-lifted Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) seedlings not only survived as well but also grew almost twice as much as did the spring-lifted seedlings (11).

Although the timeframe of the original study was only three growing seasons, we visited and remeasured the Douglas-fir plots in September 1985 to see if the growth differential continued for the 13 years since planting.

Original Study and Followup

Seedlings grown at Lucky Peak Nursery near Boise, ID, were lifted in mid-November after oscilloscope traces indicated dormancy. Half of the trees were packed in polyethylene-lined paper bags and the other half in open-ended wooden crates. Half of the seedlings in each type of package were held in cold storage at 28 °F (-2.2 °C) from November 13 until April 2, when they were placed in storage at 33 °F (0.6 °C) and held until they were shipped to the planting site on May 3. The other half were stored at 33 °F the entire time between lifting and shipping.

For comparison, seedlings of the same age, from the same seedlot, grown in an adjacent seedbed were lifted and packed in early March. Again, seedlings were stored in bags and crates but at only one temperature, 33 °F (0.6 °C), from March 7 until May 3. Nursery soil, site characteristics, cultural treatments, and seedling size were essentially the same for fall- and spring-lifted stock.

The planting site is located in the Wetfoot Creek drainage on the Emmett District of the Boise National Forest. The Douglas-fir seedlings were planted in granitic soils on a south aspect at an elevation of about 5,000 feet (1,524 m).

In early May, trees were planted in three blocks; each block contained six plots, one for each treatment. The 24- by 14-foot (7.3- by 4.3-m) plots were completely cleared to mineral soil using hand tools. Fifty trees were planted on each plot, and the trees were spaced 2 feet (0.6 m) apart both within and between rows. Seedlings were planted in 1973; their growth and survival were measured after the first (1974) and third (1976) growing seasons. Thirteen years after planting (1986) we took follow-up measurements, which had not been planned for in the original study.

Seedling Survival and Growth

First-year records show that significantly fewer of the trees packaged in crates and stored over winter at 28 °F (-2.2 °C) survived than trees subjected to the other treatments ($a = 0.05$) (10). Because the humidity in the freezer storage varied between 52 and 69% the lower survival was attributed to the drying of exposed tops. In the 33 °F (0.6 °C) cooler the average humidities were in a more favorable range: 85 to 92%. Third-year survival showed the same difference between treatments (11). But after 13 growing seasons, the survival of fall-lifted seedlings stored in crates at 28 °F differed only from the spring-lifted seedlings (table 1).

Mean seedling height differences between treatments, observed after the first growing season, continued through the third year. Crated trees stored at 28 °F did not grow as much as the other fall-lifted seedlings and were similar in height to springlifted trees (11). Mean seedling height differences between spring- and fall-lifted treatments increased from the third to the thirteenth year, but at the 95% confidence level the only significant difference is between the fall-crated seedlings stored at 33 °F and the spring-lifted seedlings stored in bags (table 1).

The 1985 height figures may be somewhat misleading, because the results were seriously confounded by the close tree spacing and die-back of tops. Seedlings were planted with 2-foot spacing to reduce space requirements, costs, and and site variability within the plots. Because the original objectives did not call for long-term monitoring of tree growth, interpretation of follow-up measurements is difficult.

Most of the die-back occurred in the plots of fall-lifted stock (fig. 1). The die-back is due, at least in part, to competition-related stress in the trees and is compounded by the harsh south-facing site where moisture is probably the limiting factor for growth. For each treatment, as the mean height has increased, the number of cases of top dieback has also increased. In other words, the fall-lifted trees are larger and have reached a point of more intense competition for space than the spring-lifted trees. Therefore, the mean height differences between treatments have actually been reduced.

More meaningful than the mean height and survival after 13 years is the percentage of trees more than 10 ft (3 m) tall (fig. 2). Twenty percent of all fall-lifted trees alive after 13 years were more than 10 feet in height, whereas only 0.5% of the spring-lifted trees were more than 10 feet. Figure 3 illustrates the height differences between spring-lifted crated seedlings on the left and fall-lifted crated seedlings on the right by the measuring pole. The seedlings in both plots were stored at 33 °F.

Spring-lifting appears to have suppressed height growth of the Douglas-fir seedlings in this study. Morby and Ryker (11) also reported slow initial height growth in operational planting in southern Idaho and foresters continue to make similar observations. Typically, even when survival is good, Douglas-fir go through a bushy stage lasting 3 to 5 years. This phenomenon is probably related to the physio-

Table 1—*Mean field survival and heights of fall- and spring-lifted Douglas-fir from Lucky Peak Nursery 1, 3, and 13 growing seasons after planting*

Month lifted	Storage temperature (°F)	Type Package	Survival (%) 1973	Survival (%) 1975*	Survival (%) 1985	Height (cm) First-yr growth 1973	Height (cm) Total 1975	Height (cm) Total 1985	No. of 10-ft trees/ 100 planted (1985)
Nov.	28	Bag	75 a	67 a	57 ab	6.3 a	39 a	220 ab	8.6
Nov.	28	Crate	57 b	41 b	36 b	4.3 b	25 b	178 ab	4.0
Nov.	33	Bag	90 a	87 a	46 ab	7.5 a	44 a	204 ab	7.4
Nov.	33	Crate	76 a	65 a	61 ab	7.4 a	41 a	243 a	24.6
March	33	Bag	96 a	87 a	81 a	3.7 b	22 b	130 b	0.0
March	33	Crate	93 a	75 a	73 a	3.2 b	22 b	162 ab	0.7

Means in columns followed by the same letter do not differ significantly at the 95% confidence level.

*Some of these survival figures are different than those appearing in Morby and Ryker (11) because of typographical errors in that publication.

logical condition of the planting stock. Slow initial growth is especially undesirable on sites where intense brush competition will overtop young Douglas-fir plantations. In this case, the harsh dry site may have contributed to the difference in growth rates.

Several other studies have also shown that Douglas-fir can be lifted late in the fall and held in storage anywhere from 1 to 6 months without a decrease in survival in the field (1,4,7,12,13,17). Depending on the seed source and location of the nursery, lifting windows for Douglas-fir may open as early as the first part of November (4,5,17) or may not open until mid-December (16). Hermann and others (3) reported that effects of long-term storage are generally negative. Ritchie (15) showed that root regeneration potential increased for the first 6 months of storage, then dropped sharply.

Dick (2) found that cold storage in excess of 5 weeks reduced the height growth of spring-lifted Douglas-fir. Likewise, the storage period of the spring-lifted stock—exceeding 7 weeks—could have reduced height growth of the Douglas-fir seedlings in this study. Lavender (8) showed that, in mild climates, cold storage benefits seedlings lifted in late fall or winter by more efficiently satisfying chilling requirements.

In addition to fulfilling chilling requirements of seedlings, cold storage can have other effects. According to Jenkinson and Nelson (6), Douglas-fir seedings stored in mid-winter doubled their resistance to dehydration and those stored in late winter maintained their high resistance.

Nyland (14) found budburst of spring-lifted Douglas-fir to be as much as 25 days ahead of those coming from cold storage. Depending on the site and weather, seedlings that are so physiologically active might not withstand the stress from transport, temporary storage, planting, spring frosts, or numerous other handling practices and environmental components.

The discrepancy in growth between fall- and spring-lifted stock seems to be due to physiological differences because the

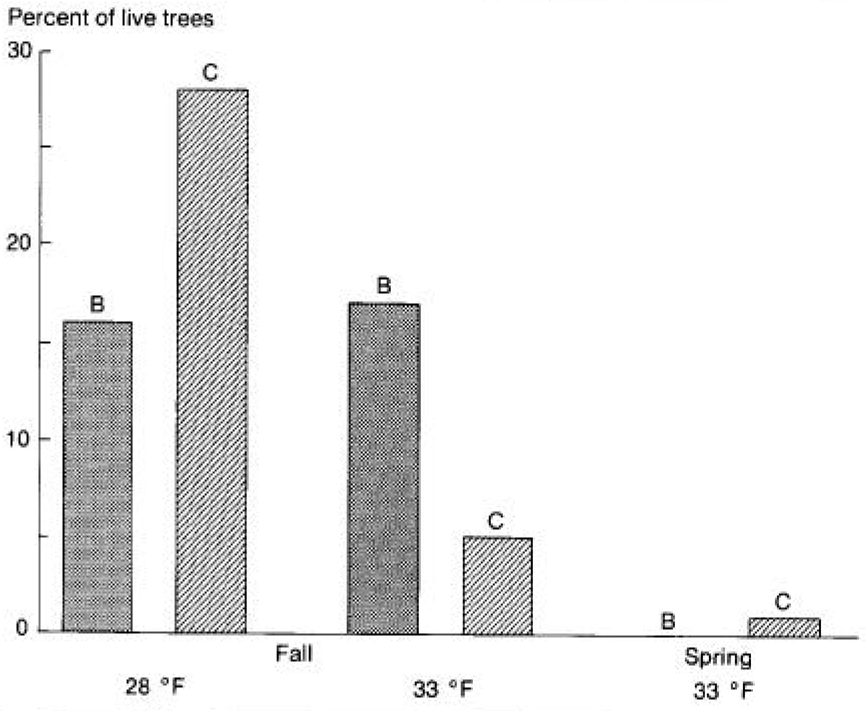

Figure 1—*Mean die-back of Douglas-fir in percentage of live trees after 13 growing seasons. The six treatments are* (**1**) *fall-lifted, stored in bags (B) at 28 °F,* (**2**) *fall-lifted, stored in crates (C) at 28 °F,* (**3**) *fall-lifted, stored in bags at 33 °F,* (**4**) *fall-lifted, stored in crates at 33 °F,* (**5**) *spring-lifted, stored in bags at 33 °F, and* (**6**) *spring-lifted, stored at 33 °F.*

seedlings appeared to be physically and morphologically identical. Douglas-fir lifting windows have been closely studied in the milder coastal zone of the western United States (3-5,8, 9,16), but more study is needed in the continental climate of Lucky Peak Nursery. We do know that the dormancy cycle is very complicated and that it may differ for each seed source and year, depending on weather and cultural practices.

The growth of the spring-lifted stock might have been improved if the winter conditions had allowed an earlier lift date or if the storage time could have been shortened.

Conclusions

The type of package and the storage temperature did not have great or lasting effects on the growth and survival of the Douglas-fir seedling except when the crated trees were exposed to the low humidity of freezing temperatures. Storing trees in crates at 28 °F (-2.2 °C) caused higher initial mortality. In years that followed, survival has not changed much relative to the other treatments.

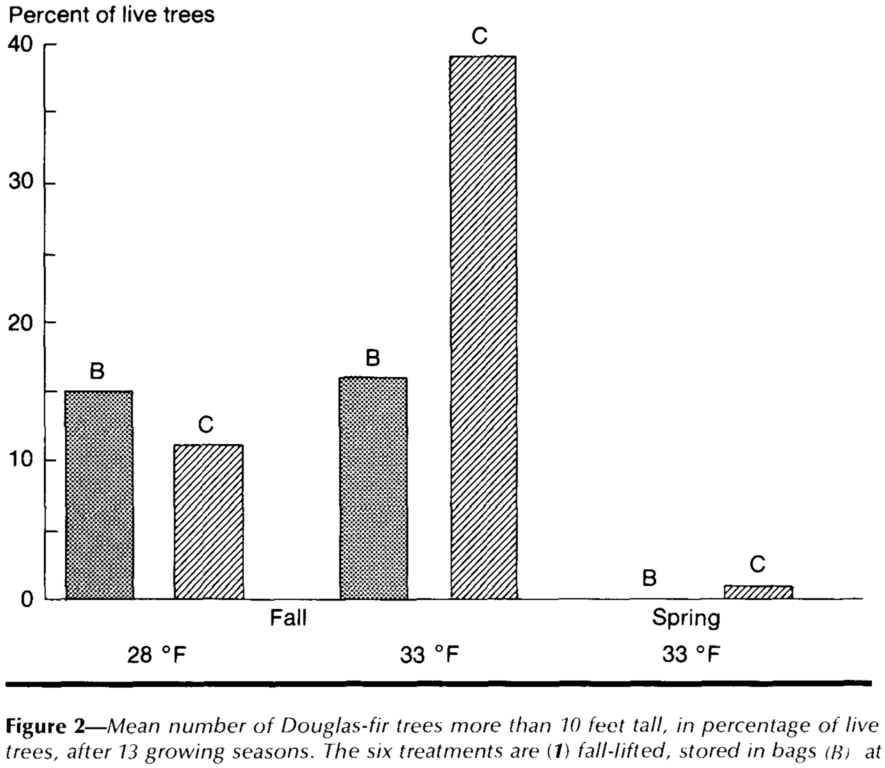

Figure 2—*Mean number of Douglas-fir trees more than 10 feet tall, in percentage of live trees, after 13 growing seasons. The six treatments are* (**1**) *fall-lifted, stored in bags (B) at 28 °F,* (**2**) *fall-lifted, stored in crates (C) at 28 °F,* (**3**) *fall-lifted, stored in bags at 28 °F,* (**4**) *fall- lifted, stored in crates at 33 °F,* (**5**) *spring-lifted, stored in bags at 33 °F, and* (**6**) *spring- lifted, stored in crates at 33 °F.*

Two major conclusions can be drawn from the remeasurement of this study. First, fall-lifted Douglas-fir has outgrown spring-lifted stock for 13 years on a harsh site in southwest Idaho. Second, when Douglas-fir seedlings get a good start after planting, the increased height is still noticeable 13 years later. Conversely, after a poor start the spring-lifted trees continue to lag behind in height. We must strive to plant the most vigorous trees possible and plant them properly. If seedling initial height growth is surpressed for any reason, the trees may never catch up.

References

1. Deffenbacher, F.W.; Wright, E. 1954. Refrigerated storage of conifer seedlings in the Pacific northwest. Journal of Forestry 52(12):936-938.
2. Dick, J. 1963. First-season survival and growth of stored Douglas-fir, noble fir, and ponderosa pine planting stock. For. Res. Note 51. Centralia, WA: Weyerhaeuser Company, Forestry Research Center. 5 p.
3. Hermann, R.K.; Lavender, D.P.; Zaerr, LB. 1972. Lifting and storing western conifer seedlings. Res. Pap. 17. Corvallis, OR: Oregon State University, School of Forestry. 8 p.

Figure 3—*Comparison of fall- and spring-lifted seedling plots after 13 years. The Douglas-fir trees on the right side of the photo were lifted in the fall. Those on the left were lifted in the spring. Both plots shown were crated seedlings stored at 33 °F.*

4. Jenkinson, J.L. 1983. Seed source lifting windows improve plantation establishment of Pacific slope Douglas-fir. In: Duryea, M.L.; Brown, G.N., eds. Seedling physiology and reforestation success. The Hague: Martinus Nijhoff/Dr W. Junk. 27 p.
5. Jenkinson, J.L.; Nelson, J.A. 1978. Seed source lifting windows for Douglas-fir in the Humboldt Nursery. In: Western Forest Nursery Council and Intermountain Nursery man's Association, combined nurseryman's conference and seed processing workshop: Proceedings; 1978 August 7-11; Eureka, CA. San Francisco, CA: USDA Forest Service, Pacific Southwest Region, State and Private Forestry: 77-95.
6. Jenkinson, J.L.; Nelson, J.A. 1985. Cold storage increases resistance to dehydration stress in Pacific Douglas-fir. In: Proceedings: Western Forest Nursery Council Intermountain Nurseryman's Association combined meeting; 1984 August 14-16; Coeur d'Alene, ID. Gen. Tech. Rep. INT-185. Ogden, UT: USDA Forest Service, Intermountain Research Station: 38-44.
7. Lanquist, K.B.; Doll, J.H. 1960. The effect of polythene and regular packing methods on ponderosa pine and Douglas-fir seedlings stored over winter. Tree Planters' Notes 42: 29-30.
8. Lavender, D. 1964. Date of lifting for survival of Douglas-fir seedlings. Res. Note 49. Corvallis, OR: Oregon State University, Forest Research Laboratory. 21 p.
9. Lavender, D.P.; Wright, E. 1960. Don't lift Douglas-fir too early because late lifting increases survival and vigor, studies show. The Timberman 61(8):54-55.
10. Morby, F.E.; Ryker, R.A. 1975. Winter storage and packaging effects on Lucky Peak seedlings. Res. Note INT-195. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 10 p.
11. Morby, F.E.; Ryker, R.A. 1979. Falllifted conifers successfully spring planted in southwest Idaho. Tree Planters' Notes 30(3):27-29.
12. Novotny, V. 1966. [Results of storing conifer seedlings in polyethylene in the winter of 1965 66] Lesnaya Promyshlennost 45 (11) :487-489.
13. Nyland, R.D. 1974. Fall lifting for over-winter cold storage of conifers. AFRI Res. Rep. 22. Syracuse, NY: State University of New York, College of Environmental Science and Forestry. 5 p.
14. Nyland, R.D. 1974. Cold storage delays flushing of conifers. AFRI Res. Note 10. Syracuse, NY: **State** University of **New York, College of Environmental Science and Forestry.** 2 p.
15. Ritchie, G.A. 1982. Carbohydrate reserves and root growth potential in Douglas-fir seedlings before and after cold storage. Canadian Journal of Forest Research 12:905-912.
16. Todd, G. 1964. Douglas-fir seedlings have roots? Journal of Forestry 62:561-563.
17. Winjum, J.K. 1963. Effects of lifting date and storage on 2+0 Douglas-fir and noble fir. Journal of Forestry 61(9):648-654.

Tree Planter's Notes, Volume 40, No. 3 (1989)

Field Grafting of Sweet Pecan to Bitter Pecan Rootstock in Seasonally Flooded Bottomlands

James M. Dyer and B. G. Cantrell

Associate professor, Louisiana Tech University, School of Forestry, and research scientist, Mycogen Co., Ruston, LA

*Four grafting techniques were used to join sweet pecan (*Carya illinoensis *Wang) K. Koch) scions to bitter pecan (*C. aquatica *(Michaux) Nuttall) rootstock in seasonally flooded bottomlands of northern Louisiana. Dormant season grafts resulted in negligible survival; however, inlay bark grafting, a non-dormant-season technique, resulted in a 76% survival rate. Differences in origins of scion material had a significant effect on survivability, whereas degree of crown closure above the grafted trees and origin of scion material were related to scion growth rates.* Tree Planters' Notes 40(3):25-28; 1989.

Bottomland forests in the southeastern United States are being cleared at an alarming rate. Turner (14) estimated that between 1960 and 1975 approximately 3 million hectares of bottomland forests in the southeastern United States were cleared for agricultural purposes. Lands that have poor drainage, and thus little agricultural potential, represent the majority of bottomland forests remaining in many areas of the southeast today. On many of these poorly drained sites, overflow typically begins in November and persists into May (15), so that standing water usually remains on these sites well into the growing season.

Only a few tree species are suited to withstand this duration of flooding, and of these, a limited number have any commercial or wildlife value (2). Conventional management techniques for improving hardwood species composition, such as planting seedlings or direct seeding, are not effective options in areas prone to growing season inundation (1).

Interspecific grafting, however, might provide an alternative to allow some degree of timber stand improvement, particularly for wildlife management. Grafting scion material capable of producing fruit with high wildlife value or upper stem wood of commercial value to rootstock material already acclimated to growing-season inundation could be a method for improving some of these marginal sites.

We report on efforts to graft scions of sweet pecan (*Carya illinoensis* (Wang) K. Koch), a species with high commercial and wildlife food value, to rootstock of bitter pecan (*C. aquatica* (Michaux) Nuttall), a wet-site species with negligible commercial value and marginal wildlife value (9). The objectives of this study were to determine if grafting these two species was feasible under field conditions, and to identify a grafting technique that would require little time, effort, or cost, while achieving a high survival rate.

Methods and Materials

Three suitable sites were found in northcentral Louisiana. These sites were typical of the many poorly drained areas found in the southeast United States with fine-textured soils, level topography, and water depths between 2 and 75 cm during the growing season. The primary overstory type consisted of bitter pecan and overcup oak (*Quercus lyrata* Walt.), some baldcypress (*Taxodium distichum* (L.) Rich.) on the permanently flooded areas, and limited amounts of water oak (*Q. nigra* L.) and willow oak (*Q. phellos* L.) on slightly higher elevations. Many of the bitter pecan stands were almost pure, with very few other species interspersed, a typical situation in that few other species can survive or reproduce on such sites (12).

Four grafting techniques commonly used in sweet pecan orchards were used to join the sweet pecan scions to bitter pecan rootstock. These included three dormant season grafting techniques (side, saddle, and cleft grafts), and one non-dormant-season technique (the inlay bark graft). Dormant season grafting was done prior to bark slippage (February and March) and non-dormant-season grafting was accomplished within a 5-day period after initiation of rootstock bark slippage (typically the first or second week of May).

Ninety saddle grafts, 190 side grafts, 200 cleft grafts, and 160 inlay bark grafts were made over a 2-year period on the three study sites. The grafts were made according to techniques described by Hartmann and Kester (5). The inlay bark grafts were protected with a wrapping of aluminum foil, covered with a plastic bag, and wrapped with grafting tape. After healing, the wound was covered with pruning paint. This is similar to the "Texas" (fig. 1) method of graft protection as described by Hancock (4). Time per graft was recorded for each grafting technique. Sweet pecan scion diameters ranged from .95 to 1.3 cm. Grafts were made 1.4 m above the groundline on rootstock that ranged from 2.5 to 10.2 cm in diameter.

Figure 1—*Inlay bark grafting (Texas method) using sweet pecan scions on bitter pecan rootstock on a typical site in northcentral Louisiana.*

Sweet pecan scion material was collected from two sources: a wet-site donor tree growing on a site subjected to dormant season flooding and a dry-site donor tree growing on a site not flooded at any time. The distinction between sites was made because of evidence that the timing of spring growth initiation may be related to moisture characteristics of a site (6,13). Scion material was collected in January and immediately placed in cold storage (2.2 °C). Half of all grafts for each of the four grafting techniques were made using the wet-site scion material and half were made using the dry-site material.

The degree of crown closure above each grafted tree was estimated and tallied according to percentage covered. Crown closures were listed by 10% increments and ranged from 0 to 50% coverage.

One-year survival rates were compared between grafting techniques, by degrees of crown closure, and according to site origin of scion material using Chi-square (10). Scion growth variables measured were height and incremental growth (difference in diameter at the scion base from the beginning to end of the growing season). The influences of the amount of crown closure and site origin of scion material on these variables were analyzed by analysis of variance (10).

Results

Survival. The only dormant season grafting technique with any appreciable survival was the cleft graft, with a first-year survival of 5%. This low sample size precluded any analysis of what effects crown closure or scion source may have had on survival. Average time per graft was slightly more than 10 minutes per specimen.

Of the 160 inlay bark (non-dormant-season) grafts made, 142 (93%) exhibited leaf initiation and 122 (76%) survived the first year. Of the 38 that died, 44% died because of insect damage during leaf initation, 15% died because of mechanical damage (falling trees or limbs), and 41% from undiscernible causes.

No significant correlation between degree of crown closure and survival was detected. There was, however, a positive correlation between source of scion material and survivability, with scions collected from the dry-site tree surviving better than those from the wet-site tree (table 1). Each inlay bark graft required slightly less than 6 minutes to accomplish.

Growth. Surviving cleft graft scions grew an average of 88 cm in height and 0.64 cm in diameter in 1 year, with an average of 38 cm of height growth for every 0.04 cm of diameter growth. Due to the low survival with this type graft, no comparisons were possible relative to site source of scion material or degree of crown closure.

Significantly greater height and diameter growth rates for surviving inlay bark graft scions were associated with wet-site scion material (table 1). Additionally, the degree of crown closure above grafted specimens had a significant effect on growth rates with greater degrees of closure associated with increased height and diameter growth (table 2).

Conclusions

For a field grafting of sweet pecan scions to bitter pecan rootstock, non-dormant-season grafting seems best. By using the inlay bark graft and protecting it according to the Texas method, we achieved a 1-year survival rate of 76%, which compares favorably to 74% survival rates reported for sweet pecan to sweet pecan grafts (3). This technique was considerably quicker than dormant season grafting techniques used in this study and can be quickly taught to someone with no previous experience.

The source of scion material apparently affected growth and survival in that scions from the dry-site tree had significantly greater survival but significantly lower height and diameter growth. Because only one tree was used as a dry-site donor and only one as a wet-site donor, differences in survivability may be attributable to individual tree variation rather than to differences exclusively due to site variation. There does, however, appear to be a correlation between slower growth rates and better survival rates.

Another factor affecting growth rates was the degree of crown closure above the grafted specimen. Faster growth rates were associated with increased amounts of crown closure. Other workers (8,11) have documented greater stem elongation associated with shaded conditions. Etiolation is associated with higher rates of auxin production that occur under such conditions (7). If excessive scion elongation occurs without commensurate diameter growth, the possibility of mechanical damage by wind will increase. The relationship between height growth and diameter growth should be closely monitored in future years.

This study demonstrated that field grafting of sweet pecan to

Table 1—*Survival and growth of wet-site and dry-site sweet pecan scions grafted to bitter pecan rootstock in northcentral Louisiana*

	No. trees grafted	No. with leaf initiation	No. surviving*	Ht. growth** (cm)	Diameter growth** (cm)
Wet site	80	74 (92%)	55 (69%)	93	.49
Dry site	80	76 (95%)	67 (84%)	73	.34

* Significantly different at .05 level (Chi-square).
** Significantly different at .05 level (ANOVA).

Table 2—*First-year sweet pecan scion growth rates according to degree of crown closure above the grafted specimen*

% Crown closure	No. grafted that survived	Height growth (cm)	Diameter growth (cm)
50	6	117*	.71**
40	33	86	.46
30	21	84	.36
20	33	86	.43
10	24	66	.28
0	5	51	.32

* Height growth at 50% crown closure significantly different ($P < .05$) from height growth at 10% and 0% crown closure (ANOVA).
** Diameter growth at 50% crown closure significantly different ($P < .05$) from diameter growth at 10% crown closure (ANOVA).

bitter pecan can be successfully accomplished with a minimum of time and effort. However, because this report is based on survival and growth rates for only 1 year, more research is needed on long-term survival and growth, fruit production, and development of upper stem wood.

Literature Cited

1. Barrett, J.W. 1980. Regional silviculture of the United States, 3d. ed. New York: John Wiley and Sons. 551 p.
2. Broadfoot, W.M.; Williston, H.L. 1973. Flooding effects on southern forests. Journal of Forestry 71:584 587.
3. Gammon, N., Jr.; Sherman, W.B. 1983. Comparison of the Texas method with yellow cap grafting seal in topworking pecan trees. Pecan South 10:18-19.
4. Hancock, B.G. 1981. Texas method inlay grafting pecans. Texas A & M Univ. Publ. L-818. College Station, TX: Texas Agricultural Extension Service.
5. Hartmann, H.T.; Kester, D.E. 1983. Plant propagation: principles and practices. Englewood Cliffs, NJ: Prentice-Hall.
6. Kramer, P.J.; Kozlowski, T.T. 1979. Physiology of wood plants. New York: Academic Press. 811 p.
7. Leopold, A.C.; Kreidmann, P.E. 1975. Plant growth and development. New York: McGraw-Hill Book Co. 473 p.
8. Maximov, N.A. 1938. Plant physiology. New York: McGraw-Hill Book Co. 473 p.
9. Putnam, J.A.; Furnival, G.M.; McKnight, J.S. 1960. Management and inventory of southern hardwoods. Agric. Handb. 181. Washington, DC: USDA Forest Service. 102 p.
10. SAS Institute, Inc. 1982. SAS user's guide: basics. Cary, NC. 923 p.
11. Shirley, H.L. 1929. Light requirements and silvicultural practices. Journal of Forestry 27:535-538.
12. Sternitzke, H.S.; Putnam, J.A. 1956. Forests of the Mississippi delta. For. Survey Rel. 78. Asheville, NC: USDA Forest Service, Southeast Forest Experiment Station. 42 p.
13. Treshow, M. 1970. Environment and plant response. New York: McGraw-Hill Book Co. 422 p.
14. Turner, R.E.; Forsythe, S.W.; Craig, N.J. 1981. Bottomland hardwood forest land resources of the southeastern United States. In: Wetlands of bottomland forests. New York: Elsevier: 13-28.
15. USDA Soil Conservation Service. 1971. General soils map of Union Parish, Louisiana. Fort Worth, TX.

Tree Planter's Notes, Volume 40, No. 3 (1989)

Growth Differences Among Patented Grafts, Seed Orchard Seedlings, and Nursery-Run Seedlings of Black Walnut

William E. Hammitt

*Professor of forestry, University of Tennessee,
Department of Forestry, Wildlife, and Fisheries,
Knoxville, TN*

*A major consideration in short-rotation management of black walnut (*Juglans nigra *L.) is the planting of genetically improved stock. Two sources of improved planting stock were compared with nursery-run (i.e., average seedlings obtained from the nursery) seedlings to evaluate differences in diameter, height, and stem form quality. Purdue #1 patented grafts, seedlings developed from direct-seeded nuts (TVA seed orchard), and nursery-run seedlings were compared after 4 years of intensive management. No significant differences were found between patented grafts and the seed orchard material, but both outperformed nursery-run material by 20 to 30% growth increases.* Tree Planters' Notes 40(3):29-32; 1989.

Black walnut, perhaps more than any other hardwood species, is intensively managed in plantations for short-rotation veneer logs. Successful plantation establishment is now fairly common, with growers recognizing the importance of intensive cultural practices such as weed control, pruning, thinning, and in some situations, fertilization *(3-5, 9)*.

Also important for the production of veneer-quality logs in short-rotation management is the planting of genetically improved stock. Possible diameter and height gains of from 15 to 30% above nursery-run stock (average nursery seedlings) have been projected (8), whereas Wright (11) states that "25-year veneer log rotations are entirely possible if we start with a fast-growing variety and care for it intensively."

Although improved seedlings from seed orchard sources have been recommended for more than 20 years, Beineke (1) has advocated the merits of grafted stock from superior trees. Growth and form comparisons between 9-year-old patented Purdue #1 (USDA patent granted Purdue University) grafts and nursery-run seedlings showed net increases for the grafts of 31% in height, 29% in dbh, and 61% in form. In addition, comparisons between seedlings from Purdue #1 grafts and nursery-run seedlings showed increases for the Purdue seedlings of 11% (height), 19% (dbh), and 18% (form), over the nursery-run material.

The purpose of this paper is to report diameter, height, and form differences for a 4-year-old plantation of Purdue #1 grafts, seed orchard nut-seedlings from Tennessee, and nursery-run seedlings from Missouri.

Materials and Methods

The test plantation is located at Harrison, OH, about 20 miles NW of Cincinnati. Soils consist of a Martinsville silt loam (surface layer typically 9 inches thick, subsoil about 35 inches thick), and an Eldean loam (surface layer typically 7 inches thick, subsoil about 29 inches thick). Site index for a 20-year-old, 1-acre intensively managed planting directly adjacent to the study plantation suggests a value of 80+ for black walnut (10).

In spring of 1984, grafts, nuts, and seedlings of the three sources of black walnut were planted in a fescue field. The 1-year-old Purdue #1 grafts (2-year rootstock) were bareroot material, about 10 to 15 inches tall, from West Lafayette, IN; the field-planted nuts were from a Tennessee Valley Authority (TVA) clonal seed orchard (seed sources from Tennessee and northern Alabama) at Norris, TN; and the 1 +0 nursery-run seedlings were barerooted, about 20 to 30 inches tall, from the Missouri State Department of Conservation nursery at Licking, MO. A systematic planting design at 10 by 10-foot spacing was used, with the grafts planted at 40-foot intervals, the seed orchard nuts at 20-foot intervals, and the nursery-run seedlings as "spacer" trees where needed (fig. 1). All sources received similar cultural treatment: sod was removed from the spot (2 by 2 feet) at planting; the spot was sprayed twice annually for weed control with glyphosphate/sim-

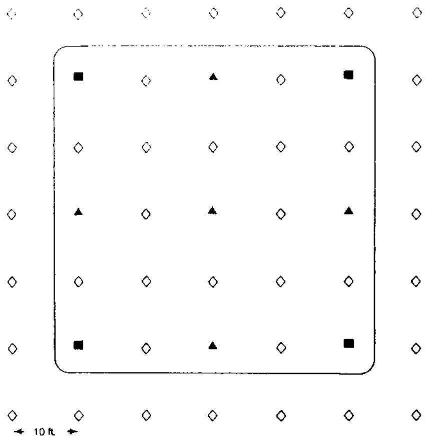

Figure 1—*Plantation design for the patented Purdue #1 grafts* (solid squares), *TVA seed orchard seedlings* (solid triangles), *and Missouri nursery-run seedlings* (open diamonds).

azine, mowed three times annually between rows, and fertilized annually with a 15-15-15 NPK formulation (100 pounds/ acre) beginning in 1985.

Growth and form measurements were taken in fall 1987. Twenty-five Purdue grafts existed in the plantation and all were measured. To keep sample size among the sources approximately equal, 40 seed orchard and 40 nursery-run seedlings were sampled systematically throughout the plantation. Stem diameter was measured at 0.5 and 4.5 feet (dbh) above the ground. Six inches was selected rather than ground level because of the lower stem swelling at the graft unions. Total height was measured to the nearest half foot. Stem form was determined by counting the number of terminal shoots. We used this procedure instead of the 5-point stem rating system employed by Beineke (1) because it seemed less subjective to researchers' rating abilities.

Growth and form measurements for the three sources were analyzed by analysis of variance (P = 0.05). The general linear model procedure and Duncan's multiple range test were used to test variable means.

Results

No significant differences were found between the patented Purdue #1 grafts and the TVA seed orchard seedlings for diameter growth (both ground level and dbh), total tree height, and number of terminal shoots (table 1). Mean values for all but total tree height were very similar for the two genetically improved sources.

Both Purdue #1 grafts and seed orchard seedlings outperformed nursery-run material for growth but not stem form (P= 0.05). Percentage growth differential of the grafts over the nursery-run seedlings were 8.9 for ground level diameter, 28.3 for dbh, 30.7 for total height, and 10.1 for form (table 1). Similar increases were found for seed orchard material versus nursery stock, except that Patented grafts were 9.4% taller than seed orchard material. The

Table 1—*Average diameter, height growth, and stem form for a 4-year-old black walnut plantation comparing patented graft, seed orchard, and nursery-run planting stock*

		Diameter (in)			
Planting stock	N	at 0.5 ft	at breast height	Height (ft)	Form (no. of shoots)
Purdue #1 grafts	25	2.57 ab	1.36 a	10.82 a	1.48 a
Seed orchard seedlings	40	2.61 a	1.37 a	10.04 a	1.48 a
Nursery-run seedlings	40	2.37 b	1.06 b	8.28 b	1.63 a
Percent differential between Purdue #1 grafts and nursery-run seedlings		8.9	28.3	30.7	10.1
Percent differential between seed-orchard seedlings and nursery-run seedlings		10.1	29.2	21.3	10.1

Means within a column followed by the same letter do not significantly differ at the 0.05 level, based on the Duncan's multiple range test.

average gain of 30.7% (2.54 feet difference) in total tree height of grafted stock over the nursery-run seedlings is visually obvious within rows of the plantation (fig. 2).

Discussion

The 28.3% increase in dbh and 30.7% increase in height growth of the Purdue #1 grafts over the nursery-run stock are within the 15 to 30% growth differentials projected for genetically improved material by Rink and Stelzer (8). The two figures are also strikingly close to the 29% dbh and 31% height increases obtained by Beineke (1) for Purdue #1 grafts versus nursery-run material. If these juvenile growth differences can be maintained or improved, perhaps a 30- to 40-year rotation can be reality for black walnut.

Kung (6) and McKeand (7) have both shown through comparison studies of seedlings and mature trees that the height growth and cubic foot volume correlations for black walnut tend to stabilize around ages 3 to 4. For example, Kung (7) found the correlation between juvenile height and cubic foot volume at 30 years reached a plateau at age three. However, form tends to show much more long-term variation.

Figure 2—*Growth differences can be clearly seen between the genetically improved stock and nursery-run seedlings. The shorter trees in the center row are nursery-run stock. Trees are 2½ years old at the time of the photograph.*

Although Purdue #1 grafted material showed a significant growth increase over nursery-run stock, it was no better than the seed orchard improved stock from Tennessee, except for a slight difference in total height. This is somewhat unexpected, since the grafts were 2-year-old root stock and therefore, had an initial growth advantage of 2 years over the nuts of the TVA stock. Part of the growth increase in Tennessee seed orchard stock is probably due to the fact that it is planted approximately 200 miles north of the originating sources in Tennessee and Northern Alabama, and the Purdue grafts are planted approximately 60 miles south of their source. Bey (2) recommends planting sources about 150 miles north of their geographic origins.

One of the major attributes of the Purdue #1 grafted stock has been terminal dominance, leading to excellent stem form (1). Beineke obtained a 61% improvement in stem form for grafts versus nursery stock in Indiana. However, his data and those reported in this paper cannot be compared, due to the different methods used to evaluate stem form in the two studies. Beineke used a 5-point subjective rating system that evaluated the entire stem, whereas in this study only the number of terminal shoots were reported.

Counting the number of terminal shoots revealed no difference between grafts and seed orchard material, and general observation shows both improved sources to have good overall stem form. Even though form is of great importance in black walnut management, 4 years is too early to assess long-term differences. When re-evaluating the three black walnut sources in another 4 years, the Beineke rating system will be used to better detect long-term differences in growth form.

Literature Cited

1. Beineke, W.F. 1982. New directions in genetic improvement: grafted black walnut plantations. In: Black walnut for the future. Gen. Tech. Rep. NC-74. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station: 64-68.
2. Bey, C.F. 1980. Growth gains from moving black walnut provenances northward. Journal of Forestry 78(10):640-641, 645.
3. Braun, J.M.; Byrnes, W.R. 1982. Growth of black walnut in a fertilized plantation. In: Black walnut for the future. Gen. Tech. Rep. NC-74. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station: 97-104.
4. Burke, R.D.; Williams, R.D. 1973. Establishment and early culture of plantations. In: Black walnut as a crop. Gen. Tech. Rep. NC-4. St. Paul, MN: USDA Forest Service, North Central Forest and Range Experiment Station: 36-41.
5. Byrnes, W.R.; Krajicek, J.E.; Wichman, J.R. 1973. Weed control Gen. Tech. Rep. NC-4. In: Black walnut as a crop. Gen. Tech. Rep. NC-4. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station: 42-48.
6. Kung, F.H. 1973. Development and use of juvenile-mature correlations in a black walnut tree improvement program. In: Proceedings, 12th Southern Forest Tree Improvement Conference, 1973 June 12-13; Baton Rouge, LA. Baton Rouge, LA: Louisiana State University: 243-249.
7. McKeand, S.E. 1978. Analysis of half-sib progeny tests of black walnut. Master's thesis. Purdue University, West Lafayette, IN
8. Rink, G.; Stelzer, H.E. 1982. The status of black walnut tree improvement programs in the north central region. In: Black walnut for the future. Gen. Tech. Rep. NC-74. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station: 57-60.
9. Schlesinger, R.C. 1982. Pruning for quality. In: Black walnut for the future. Gen. Tech. Rep. NC-74. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station: 87-91.
10. Schlesinger, R.C.; Funk, D.T. 1977. Manager's handbook for black walnut. Gen. Tech. Rep. NC-38. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station. 22 p.
11. Wright, J.W. 1966. Breeding better timber varieties. In: Black walnut culture. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station: 53-57.