

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

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Seedlings of northern red oak (Quercus rubra L.) and yellowpoplar (Liriodendron tulipifera L.) were grown at spacings of 10.8/m² (1 per square foot), 26.9/m² (2.5 per square foot), and 53.8/m² (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/m² spacing, 2-year-old seedlings of northern red oak were 3 times larger at 10.8/m², and 2-year-old seedlings of yellow-poplar were 4.8 times larger at 10.8/m². 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/m² (1 per square foot), 26.9/m² (2.5 per square foot), and 53.8/m² (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, plant-

ers 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/m², 2.3 at 26.9/m², and 1.8 at 53.8/m² 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

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

| No. of seedlings/m ² | Height (cm) | Caliper (mm) | Total dry weight (g) | Total leaf area (cm ²) |
|---------------------------------|-------------|--------------|----------------------|------------------------------------|
| 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/m², 1.7 at 26.9/m², and 2.2 at 53.8/m² 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/m² 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/m² 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.

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