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Effects of Seedbed Density and Row Spacing on Growth and Nutrient Concentrations of Nuttall Oak and Green Ash Seedlings

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SUMMARY

Larger size and higher percentages of plantable 1-O and 2-O green ash (*Fraxinus pennsylvanica* Marsh.) and Nuttall oak (*Quercus nuttallii* Palmer) seedlings were produced in the wider spacing-lower density plots. Greater numbers of plantable seedlings were produced in the higher density plots. Spacing significantly affected diameters, heights, and percentages of plantable seedlings, but with few exceptions had no effect on nutrient concentrations of stems and roots.

Additional keywords *Fraxinus pennsylvanica*, *Quercus nuttallii*, seedbed density, seedling, nursery.

INTRODUCTION

Oaks (*Quercus* spp.) have long been the backbone of the southern hardwoods industry. Green ash (*Fraxinus Pennsylanica* Marsh.) is also a prized species because it can be grown on wet sites where other species cannot survive, can be utilized for lumber at smaller sizes, is popular for specialty products, and its price is usually stable.

Thus far, no really reliable method for assuring natural regeneration of oaks has been developed, and many oak stands, when cut, do not have enough oak regeneration to satisfy landowners. Nuttall oak (Q. *nuttallii* Palmer) and green ash may also be used in species conversions, such as replacing overcup oak (*Q. lyrata* Waft.)-water hickory (*Carya aquatica* (Michx.f.) Nutt.) stands on sites that have been upgraded by river overflow and thus are capable of supporting more valuable species.

When hardwood plantations are included in management plans, foresters look for ways to reduce costs. They may also use supplemental or enrichment planting in natural regeneration areas to get adequate regeneration of desirable species, either by pre- or post-harvest planting of fewer, larger seedlings per acre than the normal 1-0 stock used in plantations. Large seedlings could eliminate the need for expensive cultural treatments and at the same time assure regeneration of desired species, particularly the oaks. This paper presents data on seedbed densities and row spacings within nursery beds that can be used to produce larger 1-O and 2-O seedlings that may be in better physiological condition than seedlings grown under conventional nursery practices.

METHODS

The study was conducted in the experimental nursery at the Southern Hardwoods Laboratory, Stoneville, Mississippi. Green ash and Nuttall oak were the species evaluated.

Two spacings between rows were tested, either 6 or 10 inches. Three seedling densities—two, four, or eight seedlings per square foot-were investigated by varying the number of plants within row spacings. Seedlings were then grown for 1 or 2 years. Initially, five nursery beds were used where seedlings were grown for 2 years and another five beds the second year for the l-year-old seedlings. Each bed was considered a replication. Beds were divided into 12 plots, approximately 4 x 15 feet. One seedling density x row spacing x species treatment was randomly assigned to each plot. The central 3 x 10 feet of each plot was planted, with the remainder left open so the seedlings would not compete between plots. Plots with 6-inch spacing between rows had 7 rows each, while plots with 10 inches between rows had 5 rows each.

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In plots with 6 inches between rows, seeds were sown every 12 inches within rows for the two-per-square-foot density, 6 inches for the four-per-square-foot density, and 3 inches for the eight-per-square-foot density. In plots with 10 inches between rows, seeds were sown 7.2, 3.6, and 1.6 inches apart for the two-, four-, and eight-seedling per-square-foot densities, respectively. Two or three acorns and several green ash seeds were sown at each spot to ensure the germination needed for proper density. Seedlings were thinned, to one per spot if necessary, when survival was assured.

One seedling at each seed spot was needed to give proper densities. This situation was not attained in all plots, so thinning was done with the ultimate aim of having the required number of seedlings per plot for the various densities, even though there was not always a seedling at each spot. Thus, plots were thinned to 60, 120, and 240 seedlings per plot for the two-, four, and eight-seedling per-square-foot densities, respectively.

Nursery beds were watered as necessary to assure maximum survival and growth, and they received at least 1 acre-inch per week from rainfall and/or irrigation. Plots were fertilized with 60 pounds per acre of nitrogen in the form of ammonium nitrate in early June, July, and August each year. First planting in the nursery was done in early April 1963 for the 2-O seedlings, and the second planting was done at the same time in 1964 for the 1-O seedlings.

Variables measured at the end of the first and second growing seasons were total height; rootcollar diameter; root/shoot dry weight ratios: percentage of plantable seedlings; and nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) concentrations in the stems and roots. To maintain plot integrity for second-year measurements, five seedlings per plot were selected for sampling nutrient concentrations, starting by lifting the first five seedlings in the southern-most row on the west end of each plot. The five seedlings were composited for one sample per plot for nutrient analysis. Variables other than nutrient concentrations were based on averages of all seedlings in a plot.

All tissue was dried at 70° C and ground before chemical analyses. Nitrogen was determined by the standard Kjeldahl procedure: P by colorimetry with molybdenum blue color development; and K, Ca, and Mg by atomic absorption spectrophotometry after samples had been dry-ashed and taken up in dilute HCl. Root/shoot ratios were obtained by dividing root dry weights by shoot dry weights.

For this study, a plantable 1-O seedling was defined as one with a minimum root-collar diameter of 0.25 inch and 15 inches in height; a plantable 2-O seedling was 0.5 inch in root-collar diameter and 30 inches tall.

STATISTICAL ANALYSES

Non-uniform germination in the nursery prevented using all five beds or replications. Three plots from the five beds that met the density requirements were selected for Sampling and statistical analyses. Therefore, the effects of blocking was lost. Individual analyses for each species and age were don8 by using a completely randomized design. Variables tested were root-collar diameter: height; stem and root N, P, K, Ca, and Mg; root/shoot ratio; percentage of plantable seedlings, and number of seedlings per square foot and per acre.

There were three replications of each treatment combination. All analyses were made at the 0.05 level. Treatments (spacings) were partitioned to test for linear and quadratic effects, and differences between row spacings that provided the same growing space per seedling.

RESULTS AND DISCUSSION

Diameter at Root Collar

Means for each species at each age are shown in tables 1-4. There was a significant linear effect for 1-O. green ash seedlings (fig. 1). Similar trends existed for 2-0 green ash and for Nuttall oak at both ages. Linear contrasts between means accounted for 67 to 97 percent of the sums of squares or variation, depending on Seedling age. Seedling size increased significantly as spacing increased (tables l-4). There were no differences among treatments Of the same seedbed density or growing space, even though spacings between rows and seedlings within rows varied. Quadratic effect for 2-O green ash seedlings was significant but accounted for only 1.6 percent of the sums of squares. This could have been because of more growth in the crown, which could have slowed diameter growth at the widest spacing.

Heights

There was a significant linear effect for 1-O green ash seedlings (fig. 2). Similar trends existed for 2-O green ash and Nuttall seedlings. Linear contrasts between means accounted for 66 to 94 percent of the sums of squares or variation in height growth. Spacing had no effect on the heights of 1-O Nuttall oak seedlings. Seedling heights, except for 1-O Nuttall, increased significantly as growing space increased (tables l-4). As with root-collar diameters, there were no differences among treatments of the same seedbed density or growing space, even though spacings between rows and seedlings within rows varied.

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Table 1.—*Variable means, by spacing, for 1-year-old green ash seedlings*

Variable	Spacing (in)					
	6x3	6x6	6 x 12	10x1.8	10x3.6	10x7.2
Diameter (in)	0.25	0.35	0.44	0.25	0.33	0.46
Height (ft)	1.49	1.81	2.07	1.41	1.69	2.04
Stem N (%)	0.95	0.91	0.85	0.89	0.93	0.89
Stem P (%)	0.13	0.14	0.12	0.13	0.14	0.14
Stem K (%)	0.37	0.41	0.38	0.36	0.37	0.39
Stem Ca (%)	0.54	0.53	0.56	0.83	0.62	0.56
Stem Mg (%)	0.13	0.13	0.13	0.12	0.14	0.13
Root N (%)	1.40	1.21	1.32	1.33	1.38	1.30
Root P (%)	0.20	0.20	0.20	0.21	0.21	0.22
Root K (%)	0.83	0.77	0.80	0.80	0.82	0.82
Root Ca (%)	0.31	0.29	0.31	0.31	0.32	0.29
Root Mg (%)	0.15	0.14	0.15	0.14	0.18	0.15
Root/shoot ratio	0.95	1.01	1.01	1.17	1.22	1.14
Plantable seedlings (%)	44.00	75.30	94.00	39.30	70.70	92.30
Plantable seedlings/ft²	3.5	3.0	1.9	3.1	2.8	1.9
Plantable seedlings (M/ac)	152.4	130.7	82.7	135.1	121.0	82.7

Table 2.—*Variable means, by spacing, for 1-year-old Nuttall oak seedlings*

Variable	Spacing (in)					
	6x3	6x6	6 x 12	10x1.8	10x3.8	10x7.2
Diameter (in)	0.25	0.30	0.33	0.25	0.31	0.33
Height (ft)	1.56	1.77	1.78	1.79	1.80	1.87
Stem N (%)	1.09	1.02	1.04	0.97	1.01	1.03
Stem P (%)	0.11	0.10	0.10	0.10	0.09	0.10
Stem K (%)	0.29	0.29	0.28	0.29	0.28	0.31
Stem Ca (%)	0.55	0.46	0.51	0.44	0.53	0.47
Stem Mg (%)	0.10	0.11	0.09	0.09	0.11	0.10
Root N (%)	1.39	1.48	1.44	1.44	1.43	1.44
Root P (%)	0.15	0.15	0.13	0.14	0.12	0.14
Root K (%)	0.55	0.54	0.52	0.54	0.62	0.54
Root Ca (%)	0.34	0.27	0.26	0.30	0.31	0.30
Root Mg (%)	0.12	0.13	0.10	0.11	0.12	0.12
Root/shoot ratio	1.53	1.48	1.30	1.15	1.47	1.28
Plantabte seedlings (%)	45.70	59.00	73.30	43.70	68.00	78.70
Plantabte seedlings/ft²	3.66	2.36	1.47	3.50	2.72	1.57
Plantabte seedlings (M/ac)	159.3	102.8	64.0	152.3	118.5	68.8

Table 3.—*Variable means, by spacing, for 2-year-old green ash seedlings*

Variable	Spacing (in)					
	8x3	8x8	8x12	10x1.8	10x3.8	10x7.2
Diameter (In)	0.37	0.52	0.63	0.37	0.50	0.83
Height (ft)	3.07	3.87	4.43	3.06	3.65	4.30
Stem N (%)	0.74	0.78	0.77	0.79	0.79	0.71
Stem P (%)	0.09	0.09	0.10	0.10	0.10	0.09
Stem K (%)	0.32	0.32	0.32	0.34	0.32	0.33
Stem Ca (%)	0.69	0.84	0.66	0.87	0.66	0.81
Stem Mg (%)	0.11	0.11	0.11	0.11	0.11	0.10
Root N (%)	1.44	1.42	1.49	1.45	1.40	1.36
Root P (%)	0.16	0.14	0.16	0.17	0.15	0.15
Root K (%)	0.75	0.74	0.71	0.78	0.67	0.78
Root Ca (%)	0.34	0.33	0.38	0.38	0.37	0.36
Root Mg (%)	0.17	0.16	0.16	0.17	0.15	0.17
Root/shoot ratio	0.82	0.77	0.75	0.79	0.78	0.81
Plantable seedlings (%)	26.00	49.00	69.30	27.30	49.70	72.00
Plantable seedlings/ft²	2.08	1.96	1.39	2.16	1.99	1.44
Plantable seedlings (M/ac)	90.8	85.4	60.4	95.1	66.6	62.7

Table 4.— *Variable means, by spacing, for 2-year-old Nuttall oak seedlings*

Variable	Spacing (in) 6x3	6x6	6x12	1.0x1.8	10x3.6	10x7.2
Diameter (in)	0.36	0.48	0.63	0.39	0.50	0.71
Height (R)	3.52	4.13	4.91	3.74	4.50	5.65
Stem N (%)	0.82	0.80	0.87	0.81	0.86	0.80
Stem P (%)	0.06	0.08	0.09	0.08	0.08	0.08
Stem K (%)	0.21	0.26	0.23	0.23	0.24	0.23
StemCa(%)	0.50	0.58	0.57	0.49	0.56	0.47
Stem Mg (%)	0.07	0.08	0.08	0.08	0.08	0.07
Root N (%)	1.54	1.48	1.59	1.53	1.56	1.59
Root P (%)	0.11	0.13	0.13	0.13	0.13	0.14
Root K (%)	0.41	0.51	0.43	0.46	0.45	0.41
Root Ca (%)	0.40	0.38	0.38	0.40	0.43	0.38
Root Mg (%)	0.11	0.11	0.11	0.11	0.11	0.11
Root/shoot ratio	0.86	0.92	0.98	0.80	0.83	0.85
Plantable seedlings (%)	30.00	48.70	75.00	33.70	53.70	83.30
Plantable seedling&W	2.40	1.95	1.50	2.70	2.15	1.67
Plantable seedlings (M/ac)	104.5	84.9	85.3	117.4	93.6	72.6

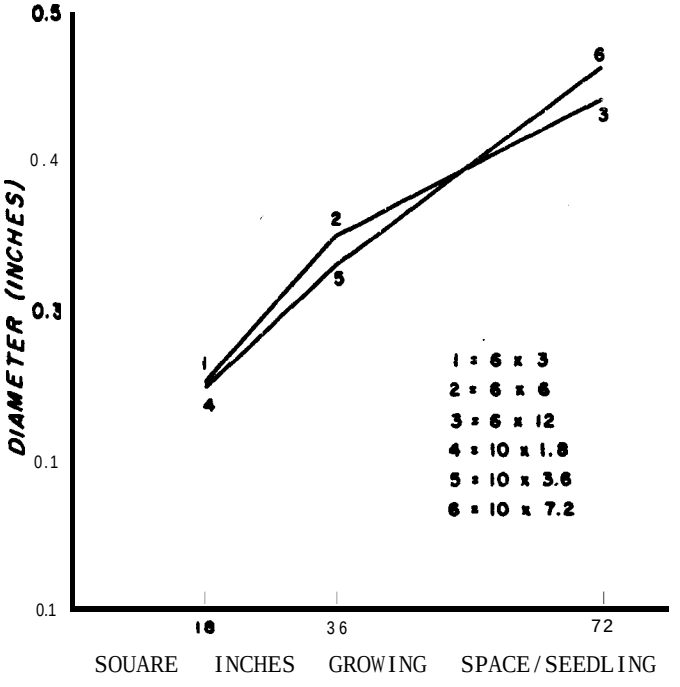

Figure 1.—*Root-collar diameter, by spacing, for 1-0 green ash seedlings in nursery.*

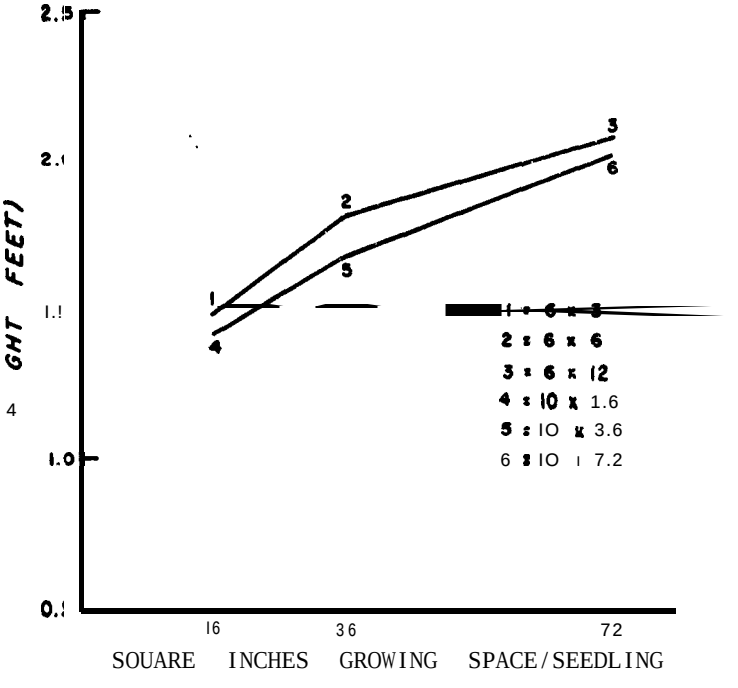

Figure 2.—*Total heights, by spacing, for 1-0 green ash seedlings in nursery.*

Nutrient Concentrations

Individual analyses by species and age showed that spacing treatments had no effect on the nutrient concentrations of stems and roots (tables l-4). One-year-old seedlings, with only a few exceptions, had higher nutrient concentrations in the stem and roots than P-year-old seedlings. Although concentrations were generally higher in 1-O seedlings, total amounts of a given nutrient would have been larger in the 2-O seedlings because of their larger sizes.

Root/Shoot Dry Weight Ratios

Root/shoot ratios for a given species and age were not affected by spacing (tables l-4). Although they were not statistically compared, 1-O green ash seedlings apparently had a larger root/shoot ratio than. 1-O Nuttall. These differences had disappeared in 2-O seedlings, and root/shoot ratios were about the same in both species.

Percentage and Numbsr of Plantable Seedlings

The number of seedlings per square foot and per acre were calculated by using the percentage of plantable seedlings and inital density (tables l-4). For 1-O green ash, analyses of variance showed a significant negative linear effect for number of seedlings per acre (fig. 3). Because this was a calculated value, percentage of plantable seedlings and number of seedlings per square foot would follow- the same trend. Similar trends also existed for 2-O green ash and Nuttall oak at both ages. Linear contrasts between means accounted for 91 to 97 percent of the sums of squares or variation, depending on seedling age. The number of plantable seedlings per acre decreased significantly as spacing increased (tables l-4). There were no differences among treatments of the same seedbed density or growing space, even though spacings between rows and seedlings within rows varied.

Although lower percentages of plantable seedlings were produced in the higher density-closer spacing treatments, the largest number of plantable seedlings per square foot and per acre were produced at the higher densities, simply because there were more seedlings per plot.

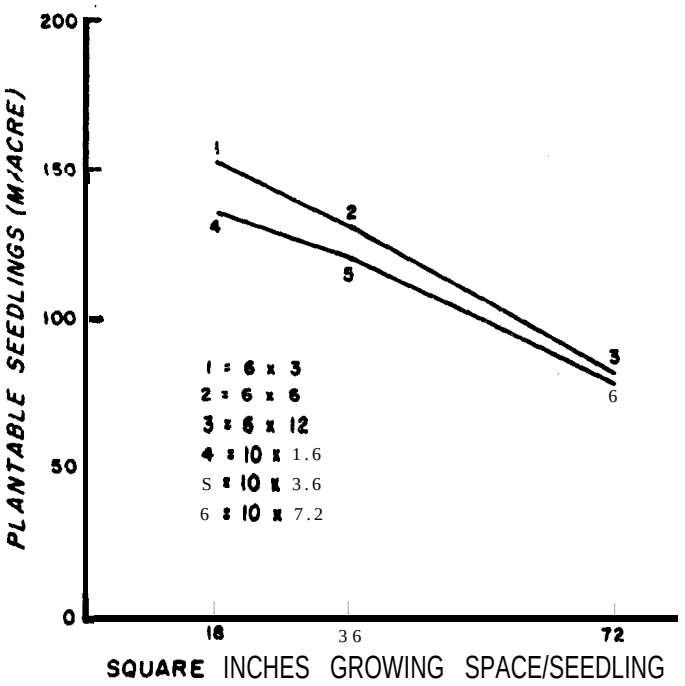

Figure 3.—*Number of plantable seedlings per acre for 1-0 green ash seedlings in nursery.*

SUMMARY AND CONCLUSIONS

In this study, larger seedlings and higher percentages of plantable seedlings were produced in the wider spacing, lower density plots. The greater numbers of plantable seedlings were grown at the higher densities because there were more seedlings per plot from the beginning. Spacing affected root-collar diameters, heights, and percentages of plantable seedlings. Results of this study indicate that nurserymen could use densities of 8-10 seedlings per square foot and produce good 1-O hardwood seedlings. Densities apparently have more effect on growth during the second year. When growing larger seedlings for supplemental or enrichment planting, four plants per square foot would produce a high number of plantable seedlings per acre of more desirable size.

Spacing generally did not affect the nutrient concentrations of roots or stems. If nutrients were available, seedlings were able to take up enough to meet their demands for satisfactory growth.

For good survival and early growth, the root system of seedlings should be in balance with the top, otherwise the seedlings will not grow much until the root system becomes stablished. About a 1:1 root/shoot. ratio is generally accepted as standard. Apparently, 1-year-old green ash had a larger root/shoot ratio than 1-O Nuttall oak; however, the differences were not apparent in the 2-O seedlings of either species. Therefore, any of the spacings used should not adversely affect root/shoot ratios.

The larger 2-O seedlings would have to be planted in holes made with a gasoline-powered or tractor-mounted auger. These augers produce a 6- to O-inch-diameter hole, which would mean some root pruning would be necessary for the root system to fit the hole. Our experience at the Southern Hardwoods Laboratory indicates that pruning can be done without harming the seedlings. This planting method would be expensive on a per-tree basis. However, when one considers planting fewer (80-75) trees per acre in supplemental planting, without expensive site preparation and cultural treatments, costs should be comparable to conventional planting of 1-O seedlings along with cultivation. Potential benefits of the large seedlings are rapid early growth and reduction in wildlife damage (Johnson 1988).

LITERATURE CITED

Johnson, Robert L. 1988. Studies show steps to more success planting oak forests. Forest Farmer 46(1): 20-21.

* U. S. GOVERNMENT PRINTING OFFICE: 1988 • 566019 / 85012