NURSERY-SEEDED HARDWOODS--INFLUENCED BY DEPTH AND DENSITY OF SOWING

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In the South the problem of determining the proper sowing rate and planting depth for pine seed has been pretty well solved. It is well known, for example, that high rates of pine seeding in nursery beds can result in spindly, top-heavy, or small-diameter stock. On the other hand, sowing rates that are too low may result in excessively large seedlings that fail to utilize the full growing capacity of the beds.[2] However, information on the subject with reference to various hardwoods is rather meager.

This report indicates some of the effects of density and the depth of sowing on the development of several selected hardwood species. As in pine seeding, these two factors were controlled with the aim of producing the maximum number of premium-grade seedlings per unit of seedbed. This means stock that when planted will survive and grow well. Several investigators have shown the importance of high-quality stock to improved survival and early growth of plantations.[3]

The Study.--Oak seed were handpicked in 1958 and 1959 from trees in the piedmont near the Clemson College School Forest. Among the species tested were white oak (Quercus alba L.), southern red oak (Q. falcata Michx.), water oak (Q. ni ra L.), and chestnut oak (Q, prinus L.). In addition, ripened yellow-poplar (Liriodendron tulipifera L.) fruits were collected from a mountainous area near Pickens, S.C. Seed of all these species were sown at the Piedmont Nursery, which is operated in Pickens County by the South Carolina State Commission of Forestry. The sandy loam seedbeds were watered, fertilized, and mulched throughout the growing season according to standard nursery techniques.

The individual experimental plots consisted of beds 10 feet long and 4 feet wide. For a single year's planting, the main test included two replications of the four oak species, three planting depths, and five seedbed densities. The various species of oak were seeded at 1/4-, 1/2-, and 1-inch depths and at densities of 6, 9, 12, 15, and 18 seed per square foot of bed, respectively. Thus, each plot contained a single species sowed at a combined depth and density. The experimental plots were selected at random, and the acorns were placed in them singly by hand.

Four seeding rates were used for the yellow-poplar--15, 30, 85, and 200 grams per square foot. Tests indicated that these rates were equivalent to 394, 848, 2,275, and 5,260 seeds per square foot, respectively. The lowest rate barely covered the ground with seed, and the highest rate covered it with a layer one inch deep; covering at the other rates was intermediate between these two. The seed was covered with a quarter-inch layer of soil and mulched with a thin layer of pine straw.

In each of the test plots, 1- by 2-foot subsample quadrats were established at random. On these quadrats the trend of field germination and height growth were periodically examined. At the end of the test, a final count of surviving seedlings was made. The effects of planting depth and seedbed density on early growth were evaluated by the analysis of variance. A summary of the oak data is given in table 1.

[1] The author acknowledges the valuable assistance of E. W. Cooler, nurseryman, Piedmont Nursery. and the cooperationof the South Carolina State Commission of Forestry in conducting this study. This paper is a condensation of Tech. Contrib. 376, S.C. Agr. Expt. Sta., published by permission of the Director.

[2] Stoeckeler, J. H., and Jones. G. W. Forest nursery practice in the Lake States. U.S. Dept. Agr., Agr. Handb. 110. 124 pp., illus. 1957.

Wakeley, P. E. Planting the southern pines, U.S. Dept. Agr., Agr. Monog, 18. 223 pp., illus. 1954.

[3] Clark, F. B„ and Phares, R. E. Graded stock means greater yields for shortleaf pine. U.S. Dept. Agr. ForestServ, Central States Forest Expt, Sta. Tech. Paper 181, 5 pp.

Shipman. R, D. Survival and growth of graded longleaf pine nursery stock. Jour. Forestry 58: 38-42.

TABLE 1.--Oak establishment and height growth according to depth and density of sowing

Sowing depth inch	Sowing density per square foot	Established seedlings[1]				Average height of living seedlings			
		White oak	Southern red oak	Water oak	Chestnut oak	White oak	Southern red oak	Water oak	Chestnut oak
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Inches*	*Inches*	*Inches*	*Inches*
	6	87	44	83	79	5.9	6.1	8.9	5.7
	9	86	37	85	78	5.0	4.4	7.9	5.0
1/4....	12	83	36	74	75	4.6	8.4	9.3	6.0
	15	82	51	90	78	5.3	9.0	8.0	6.3
	18	71	37	81	85	5.3	9.5	9.0	6.2
	6	98	67	89	100	6.7	6.9	7.8	5.0
	9	92	65	83	97	4.9	7.0	10.6	5.3
1/2....	12	91	37	94	96	4.8	6.6	8.7	5.1
	15	89	44	84	95	4.4	6.9	9.6	5.4
	18	90	42	82	85	4.2	9.3	9.8	5.0
	6	100	33	97	100	5.2	7.7	10.2	5.5
	9	89	63	99	94	4.8	7.6	11.5	5.5
1.....	12	92	56	79	98	5.0	9.4	8.1	4.8
	15	97	37	78	93	5.2	7.6	9.6	6.7
	18	85	30	80	87	5.3	10.4	9.3	5.2

[1] White and chestnut oak--unstratified seed, fall-sown (mean of 1958 and 1959 plantings); southern red oak--unstratified seed, spring-sown (1959 planting); water oak-stratified seed, spring-sown (mean of 1958 and 1959 plantings).

Oak Establishment.— The average first-year nursery survival varied considerably among the four oaks. Chestnut oak survival was the highest, 89.3 percent. White and water oaks followed with 88.9 and 85.4 percent survival, respectively. Acorns of the latter two species were similar in size while those of the former were nearly twice as large. Survival of southern red oak was the lowest. Its acorns were the same size as those of the white and water oaks. A poor correlation between seed size and survival of the various species is apparent. However, for any given lot within a species, the effect of seeding density and depth was rather striking.

In analyzing the study data for all species, depths and densities of sowing were first combined and the results expressed in terms of their individual contribution to the total variation. Statistically, the differences in both species and depth of seeding were highly significant at the 1 percent level of probability. There were no significant interactions between any two of the above factors. Thus, the survival differences among the species is attributed mainly to differences in depth and density of sowing.

Seeding rates of 6 and 9 acorns per square foot resulted in significantly higher seedling establishment than that obtained from a rate of 18 acorns. Densities of either 6 or 9 acorns per square foot did not lead to survival superior to that resulting from 15 acorns. It may be deducted, therefore, that from the standpoint of seedling establishment and space utilization, a seeding rate of 12 to 15 acorns per square foot is feasible in the Piedmont Nursery. These results are based upon the average seedbed density and depth values for all the oaks.

The results obtained indicate that from a survival standpoint the oaks respond rather critically to variations in depth of sowing. Acorns, with their large endosperms, germinate best in a soil where moisture is readily absorbed and retained during the germination period. The conditions in the soil of the test plots apparently met these requirements at the 1/2- to 1-inch levels. Acorns of all four species planted at the 1/4-inch depth, including the larger seeded chestnut oak, showed significantly poorer survival than those planted at the other depths (fig. 1), but there were no real differences between seedlings sown at 1/2- and 1-inch depths. Therefore, to obtain the highest first-year survival of the four oaks investigated, it is recommended that they be planted not less than 1/2 inch deep and at seedbed densities of 12 to 15 seed per square foot. It has been suggested that the effect of depth may become even more critical for extremely large hardwood seeds such as walnuts.

Yellow-Poplar Establishment.- -Although statistical evaluation of the yellow-poplar trials are not proposed in this study, sufficient evidence indicates that large differences in survival fall within a rather narrow range of seeding rates. To use advantageously the yellow-poplar seeding recommendations derived from these tests, one must recognize that there is no one rate applicable to all nurseries. However, South Carolina nurserymen who are currently using the seeding-rate recommendations presented here report favorable results.

Unlike the oaks, germination and establishment of yellow-poplar under most nursery conditions is notoriously low. A large amount of seed is required per square foot of bed, because the average laboratory germinative energy of stratified seed is only about 5 percent. The sowing of quantities of yellow-poplar seed that have been determined by weight appears to be a reasonably accurate method of obtaining a desired stand. Table 2 summarizes the effects of different yellow-poplar seeding rates on first-year establishment and seedling size.

Our findings indicate that fall-sowing unstratified yellow-poplar seed at a rate of no more than 15 grams per square foot of bed will give the highest survival (2.3 percent). At this rate, approximately 43 seed were required to produce a single living seedling. The next highest survival (1.3 percent) was obtained at the same rate of seeding from springs own seed. It is interested to note that by doubling the rate to 30 grams, survival of the

TABLE 2.--Nursery survival and height growth of yellow-poplar, according to seeding rate and season of sowing

Season of sowing	Seed per square foot of bed		Seedling survival per square foot of seedbed		Seed required to produce one seedling	Weight of seed required to produce one seedling	Average height of living seedling
	Number	*Grams*	*Number*	*Percent*	*Number*	*Grams*	*Inches*
Fall[1].....	403	15	9.4	2.3	43	1.6	15.2
Spring[2].....	385	15	5.1	1.3	75	2.9	17.6
Fall.....	925	34	6.4	.7	144	5.3	13.4
Spring.....	771	30	6.7	.9	115	4.5	19.2
Fall.....	2,236	85	9.0	.4	248	9.4	15.2
Spring.....	2,313	89	2.1	.09	1,101	42.3	12.0
Fall.....	5,122	195	15.1	.3	339	12.9	14.9
Spring.....	5,397	208	.2	.0004	26,985	1,040.0	5.6

[1] Unstratified seed (mean of 3 replications).
[2] Stratified seed (mean of 2 replications).

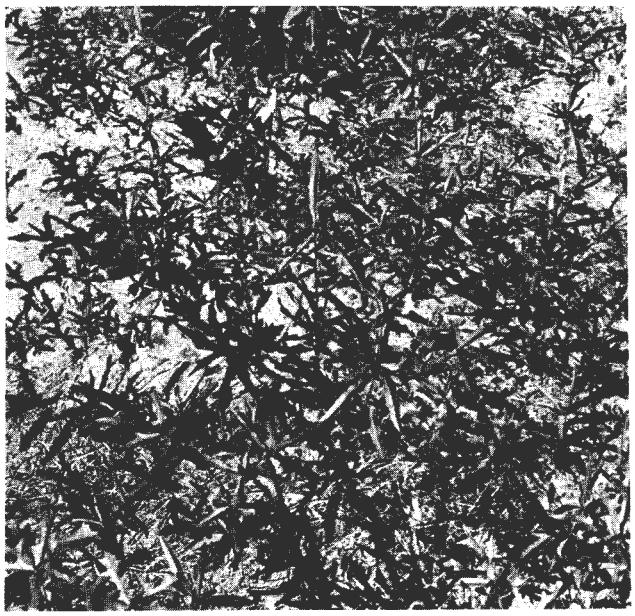

Figure 1.--The effect of seeding depth on seedling survival and height growth of water oak (seeding density 9 per square foot): Above - seeding depth 1 inch; survival 99 percent; seedling height 11.5 inches. Below - seeding depth ¼ inch; survival 85 percent; seedling height 7.9 inches.

Figure 2.--Survival of yellow-poplar as affected by rate of sowing: Above -15 grams of seed per square foot; fall-sown, unstratified; survival 2.3 percent. Below - 85 grams of seed per square foot; fall-sown, unstratified; survival 0.4 per cent.

fall-sown seed was reduced to 0.7 percent. Of the remaining densities, up to a maximum of 200 grams, first-year survival was extremely low. One can conclude, under conditions of this test, that the lowest rate gave the highest survival. It does not follow, however, that a density of less than 15 grams per square foot will result in proportionally higher survival; seeding rates below this amount were not investigated. The effect of different rates of sowing by weight for unstratified yellow-poplar seed is illustrated in figure 2.

Growth and Seedling Size.--It was not the intent of this study to obtain detailed measurements of shoot and root development. However, some information on the relative differences in size of stock was obtained by measuring the height growth of the various test species. A sufficient number of seedlings was taken at random from each of the various depth-density combinations to obtain average heights. Relative differences in seedling size of three of the oaks, including root and shoot lengths, are presented in figure 3.

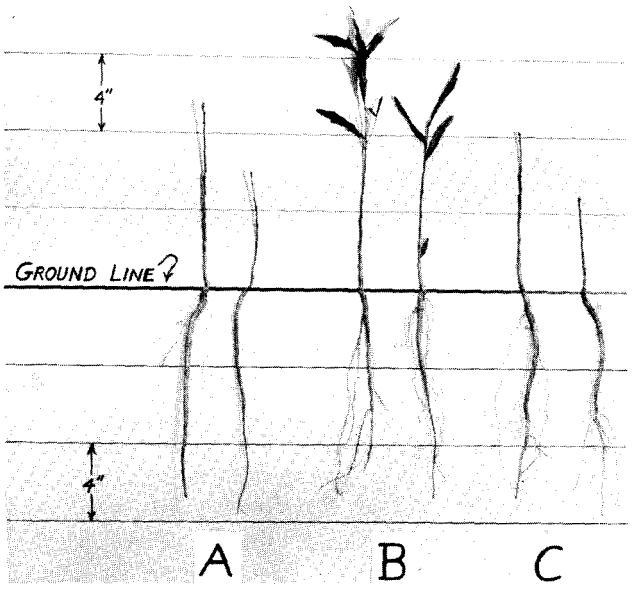

Figure 3.--Hardwood shoot and root development after one year in the nursery: Tallest and shortest seedlings of A, southern red oak; B, water oak; C, white oak.

A rather wide range in seedling size occurred in the hardwoods tested. The largest planting stock was yellow-poplar with a maximum top growth averaging 14.1 inches for a single year. Of the oaks, water oak was the tallest with an average top growth of 9.2 inches, while southern red oak averaged 7.8 inches. The smallest seedlings were chestnut and white oaks with average tops of 5.5 and 5.1 inches, respectively. Although chestnut oak had the highest survival of the oaks, its average first-year growth was quite low. It is apparent that for the hardwoods included in this study, seed size is a poor indicator of early height growth. Possibly during the germination period, reserve storage materials are used up at rate that are inherent for each species. This may partly explain why seed size is more closely related to the early germination process below ground than to growth above ground. Once the seedlings have emerged from the ground, the young shoots appear to be more dependent upon photosynthesis for their growth than upon the seed reserves.

An analysis of the mean height growth of the oaks tested indicates that neither bed density nor depth of planting exerts any significant influence upon seedling height growth. The data in table 3 shows little variation in height growth with varying seedbed density for the white, water, and chestnut oaks, but considerable variation for southern red oak. For southern red oak, the results indicated better height growth at the highest density. This correlation of growth with density, in contrast to the small variation of the remaining oaks, was difficult to explain. One might surmise that a proportionately larger number of acorns was required for that species per square foot of bed, in compensation for its inherently low survival.

TABLE 3.--Average first-year height growth of 4 upland oak species planted at various seedbed densities (all depths)

Sowing density per square foot (number)	White oak	Southern red oak	Water oak	Chestnut oak
	Inches	*Inches*	*Inches*	*Inches*
6.....	5.9	6.9	9.0	5.4
9.....	4.9	6.3	10.0	5.3
12.....	4.8	8.1	8.7	5.3
15.....	5.0	7.8	9.1	6.1
18.....	4.9	9.7	9.4	5.5

The results of the foregoing tests suggest that additional investigations are needed to establish nursery seeding recommendations for other promising hardwood species.