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TWENTY YEARS GROWTH OF LOBLOLLY AND SHORTLEAF PINE PLANTED AT VARIOUS SPACINGS IN SOUTHERN ILLINOIS

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ABSTRACT - Loblolly pine and shortleaf pine were planted at spacings of 4 x 4, 6 x 6, 8 x 8, and 10 x 10 feet on a medium quality site in southern Illinois. Measurements taken after the eleventh, thirteenth, eighteenth, and twentieth growing seasons showed that growth and yield of loblolly pine are greater than shortleaf pine. Close spacings resulted in reduced heights for both species after the thirteenth growing season. At age 18, mortality was excessive in loblolly pine planted 4 x 4. The 8 x 8 spacing resulted in the greatest loblolly pine volume and the 6 x 6 spacing the greatest shortleaf pine volume by age 20. The 10 x 10 spacing appeared to be too wide to produce optimal quantities of merchantable products of either species at age 20.

Loblolly (Pinus taeda L.) and shortleaf (Pinus echinata Mill.) pine have been widely planted in Illinois. Loblolly is about 150 miles north of its natural range, and shortleaf is at the northern limit of its range, naturally occurring in southwestern Illinois on west-facing Mississippi River bluffs. Because of its silvical characteristics, which indicated a better adaptability to the region, shortleaf pine was originally thought to be the species that would best satisfy the land-management objectives; thus, most of the area planted to pine in southern Illinois has been planted in shortleaf.

The early development of loblolly and shortleaf pine plantations in Illinois has compared favorably with plantations in the southeast (Boggess and Gilmore, 1963). But, as the Illinois plantations grow older, the actual growth rate falls below that expected of these species in their natural ranges. In addition, according to a study of a 29-year-old shortleaf plantation (Burkhart and Gilmore, 1967), the stands appear to display accelerated mortality and declining basal area growth.

Disease is active in older stands. Much of the mortality is attributable to Fomes annosus (Fr.) Karst., an indigenous root rot fungus. The incidence of this fungus in Illinois is increasing and may become great enough to make thinning undesirable silviculturally because of the predisposition of suppressed trees to infection.

One of the most difficult forest management problems to solve is to determine the optimum growing space needed for each age and site so as to attain the desired wood products most rapidly. Crown development of forest trees which can be influenced by regulating tree spacing is closely correlated with rate of tree growth and wood quality. In even-aged stands, the average live crown length is inversely related to the number of trees per acre (Wahlenberg, 1960). For loblolly pine, a crown length less than 30% of tree height generally is not sufficient to maintain normal growth and trees with shorter crowns will not respond to release. On the other hand, crown lengths

of 50% of tree height are excessive because they reduce wood quality; a crown length of 40% produces the maximum volume of clear wood.

When total fiber production is important, close spacings have a definite advantage. Until mortality cancels growth, narrow spacings yield greater cubic foot volumes, but wider spacings allow trees to grow to merchantable sizes sooner. There is, however, a point of diminishing returns for spacing beyond which growing space is wasted for much or all of the life of the stand. Ware and Stahelin (1948) reported that for loblolly, slash, and longleaf pine plantations, close (4 x 4 feet) spacing leads to early overcrowding, retarded growth, and death from suppression before the trees reached merchantable size. Spacings wider than 10 x 10 made insufficient use of the growing space during the early years of the plantations.

The contemporary practice is to plant at the wider spacings for financial advantages. Bennett (1963) pointed out that at age 15 a stocking of 600 slash pine trees per acre (about 8 x 9 spacing) yields over 90% of the volume of 1,000 trees (about 6 x 7 spacing). He viewed densities beyond 800 trees as not profitable at an alternative rate of return of 3 percent.

Site and Stand Description

The plantations described in this paper were established at the Dixon Springs Agricultural Center in Pope County in 1949 to study the effect of spacing on the growth and yield of planted loblolly and shortleaf pine. Boggess and Gilmore (1963) have reported on the early growth through age 13. This paper reports growth of the plantations through age 20.

The plantation is growing in soils of the Grantsburg series (Ochreptic Typic Fragiudalfs), which developed under upland forests in 40 to 80 inches of loess deposited on a residuum of sandstone. The Grantsburg soils have a moderately well-developed fragipan at depths of about 30 inches. Both root penetration and movement of moisture are impeded by the fragipan.

The climate is characterized by mild winters, hot summers, and frequent short summer droughts. Rarely are there ice storms or extreme cold. The frost free season averages 195 days annually.

At the time of planting, the area had been abandoned from agriculture approximately 10 years. There was little brush invasion, but a ground cover of broomsedge (Andropogon spp.) had developed on the slightly eroded areas and poverty grass (Aristida dichotoma Michx. and Danthonia spicata (L.) Beauv.) on severely eroded areas. The site was judged to be of medium quality.

One-year-old seedlings used in the study were obtained from the state tree nursery at Jonesboro, Illinois. Loblolly seed came from Maryland and northern Alabama; the shortleaf seed was from an unknown source. Four spacings of 4 x 4, 6 x 6, 8 x 8, and 10 x 10 feet were established in 0.64 acre blocks. A 0.1 acre square sample plot was located in the center of each block for detailed stand measurements. Treatments were replicated four times for loblolly and three times in shortleaf,

except for the shortleaf 4 x 4 spacing, which had two replications. Because of unequal replications, each species was considered as a separate experiment in a randomized, complete-block experimental design.

Field measurements were taken following the eleventh, thirteenth, eighteenth, and twentieth growing seasons. Diameter at breast height (d.b.h.) of each tree on the 0.1 acre sample plots was measured to the nearest tenth-inch, while height of every tenth tree was determined to the nearest foot.

Standard local volume tables were used to compute volumes at ages 11 and 13 but for a number of reasons could not be constructed at ages 18 and 20. Gevorkiantz and Olsen's (1955) composite tables were therefore used for the older ages. They are used by the U. S. Forest Service in southern Illinois without correction and with satisfactory accuracy.

RESULTS AND DISCUSSIONS

Mortality - Survival was nearly uniform over the various spacings for each species, averaging 96 percent for loblolly pine and 90 percent for shortleaf pine at the end of the fourth growing season. However, after 20 growing seasons, mortality was greater at the closer spacings. Table 1 compares stand data for the most recent measurements with those made at the end of the eleventh, thirteenth, and eighteenth growing seasons. Extreme crowding occurred in the 4 x 4 loblolly spacing between the thirteenth and eighteenth years but had not occurred by age 20 in the 4 x 4 shortleaf. The other three spacings of each species had not experienced excessive crowding at age 20 with the possible exception of the 6 x 6 loblolly. Mortality for both species is expected to increase with the passage of time; extreme mortality is expected in the closer spacings of shortleaf pine.

Basal Area - After thirteen growing seasons, the 4 x 4 spacing for loblolly pine had the highest basal area, and total basal area decreased as spacing interval increased. After 20 growing seasons, however, this relationship no longer held true, as the effects of crowding were felt in the 4 x 4 spacing. At the end of the thirteenth growing season, the basal area per acre for 4 x 4 loblolly pine was 170 square feet (Table 1). It increased 6 square feet during the next five years and an additional 6 square feet during the following two years giving a total basal area of 182 square feet per acre at age 20. Mortality had begun to accelerate in the 6 x 6 loblolly spacing, but at age 20 this spacing had the highest basal area. If the mortality continues to advance in the 6 x 6 loblolly spacing, the highest loblolly basal area should be in the 8 x 8 spacing by age 25.

Mortality was not serious at age 20 for any of the shortleaf pine spacings. The highest basal area for this species was found in the 4 x 4 spacing (Table 1).

Before crown closure occurred in this study, basal area growth of both species was determined to a large degree by the number of trees per acre. When trees are young and small and not completely occupying the site, most of them grow at approximately the same height and diameter, and yield increases as spacing interval decreases; thus, closer spacings produce higher basal area. As stands grow older, however, individual tree growth rates slow down in relation to their growing space (Reukema, 1966).

Table 1. Growth and stand data per acre of loblolly and shortleaf pine at the end of four selected growing seasons.

	Loblolly pine				Shortleaf pine			
	4'x4'	6'x6'	8'x8'	10'x10'	4'x4'	6'x6'	8'x8'	10'x10'
	Eleventh growing season							
Survival %	92	94	96	94	86	92	95	93
No. of trees	2,497	1,131	654	410	2,321	1,116	645	403
B.A. (sq. ft.)	155	128	106	71	110	93	62	45
Cu. ft. vol.	1,769	1,494	1,205	827	1,032	870	567	406
Av. height (ft.)	27	26	28	27	22	20	20	20
Av. d.b.h. (in.)	3.3	4.4	5.4	5.5	2.8	3.8	4.1	4.4
	Thirteenth growing season							
Survival %	90	93	96	92	82	91	95	93
No. of trees	2,420	1,119	654	397	2,237	1,104	645	403
B.A. (sq. ft.)	170	148	130	92	132	115	85	63
Cu. ft. vol.	2,077	1,869	1,799	1,208	1,403	1,230	951	641
Av. height (ft.)	30	32	34	32	25	25	24	24
Av. d.b.h. (in.)	3.5	4.8	6.0	6.4	3.2	4.3	4.8	5.3
	Eighteenth growing season							
Survival %	66	85	94	89	73	86	91	92
No. of trees	1,792	1,028	638	389	1,987	1,043	620	397
B.A. (sq. ft.)	176	179	166	127	164	151	123	102
Cu. ft. vol.	2,910	3,290	3,195	2,502	2,363	2,353	1,995	1,701
Av. height (ft.)	39	43	46	45	33	38	38	37
Av. d.b.h. (in.)	4.2	5.7	6.9	7.8	3.9	5.1	6.0	6.9
	Twentieth growing season							
Survival %	57	79	87	88	73	86	87	92
No. of trees	1,540	950	590	383	1,987	1,040	590	397
B.A. (sq. ft.)	182	190	172	146	196	173	137	122
Cu. ft. vol.	3,149	4,006	4,108	3,315	2,884	3,206	2,726	2,383
Av. height (ft.)	44	50	53	54	39	45	45	46
Av. d.b.h. (in.)	4.6	6.0	7.2	8.2	4.0	5.3	6.3	7.3

Diameter - The most significant stand parameter measured in the study was d.b.h. During the first 18 growing seasons, average annual diameter increments of loblolly pine increased as spacing interval increased, but the average increments for the last two growing seasons were about the same for all spacings (Table 2). Mortality thinned the 4 x 4 loblolly spacing (Table 1) to the extent that the trees apparently acquired the additional growing space that enabled them to produce more girth. Crowding must be occurring in the other loblolly spacings as evident by increasing mortality (Table 1), resulting in slowing of diameter growth.

Although annual diameter increments of shortleaf pine were greater at the wider spacing for each age period, growth rate decreased after the thirteenth growing season within each spacing. For example, the periodic annual d.b.h. for the first 11 years ranged from 0.25 inch for the 4 x 4 spacing to 0.40 inch for the 10 x 10 spacing. The relative position was the same for the last two years, ranging from 0.05 inch for the 4 x 4 spacing to 0.20 for the 10 x 10 spacing (Table 2). Undoubtedly, crowding occurred for shortleaf at all spacings even though mortality currently is low (Table 1), resulting in a slowing of growth on individual trees.

One site factor that is closely related to diameter growth is available soil moisture. In southern Illinois, soil moisture frequently limits diameter growth because of the character of the soil and because of the loss of moisture via evapotranspiration (Boggess, 1957). It has also been shown that stand density also influences the rate of water absorption (Bay, 1963). Trees at wider spacings usually grow for a longer period during a growing season than trees in dense stands (Boggess, 1957). When moisture is a limiting factor in a stand of trees, that limit may not have been reached in a less dense stand, thus, annual diameter increment will, in all probability, be larger in trees spaced at wider intervals.

Diameter of young trees in this study compared well with those in plantations of similar age in other regions. For example, d.b.h. of trees planted 6 x 6 in this study average 5.7 and 5.1 inches for loblolly and shortleaf pines, respectively, at age 18 (Table 1), whereas d.b.h. of trees spaced the same in the Virginia Piedmont was 5.7 inches for 16-year-old loblolly pine (Kormanik and Hoekstra, 1963).

Height - Average height for both species spaced 4 x 4 was less (significant at the .05 level) at age 18 than heights in the other three spacings. Average height of loblolly pine planted at 6 x 6 also was less (significant at 0.5 level) than those for the two wider spacings (Table 1). The differences are attributed to competition between trees.

The effect of stand density on height growth becomes more pronounced as trees age (Table 1). At age 20, height difference between trees planted at 4 x 4 and those planted at 6 x 6 has increased to 6 feet (significant at .01 level). More than likely, this height difference between the two narrow spacir will continue to increase and greater differences will become evident between the 6 x 6 and the wider spacings.

Cubic-foot Volume - The number of trees per acre has a large influenc on the total cubic feet produced on that acre before the site is completely occupied by the stand.

At age 20, loblolly pine had produced more wood in the 6 x 6 and 8 x 8 spacings (about 4,000 cubic feet) than in the 4 x 4 and 10 x 10 spacings (about 3,200 cubic feet). It is interesting to note that at this age 590 trees on an acre are producing as much volume as 950 trees and 383 trees are producing as much volume as 1,540 trees.

Shortleaf pine is not occupying the site at age 20 as completely as loblolly pine is. The greatest volume for shortleaf pine was about 3,200 cubic feet in the 6 x 6 spacing, followed by the 4 x 4, 8 x 8, and 10 x 10 spacings.

Despite the relatively faster rates of basal area growth shown in the shortleaf pine stands during the past seven years (Table 2), superior height growth largely explains the greater volume obtained in the loblolly pine stands. These findings are consistent with those found by Jackson (1958) in a similar study in Georgia.

Based on cubic feet per tree, the fastest growing trees for both species were those with the widest spacing interval (Table 1). Future measurements are needed, however, to indicate whether the faster rates will eventually narrow the differences in total net volume between the 10 x 10 and 8 x 8 spacings. The 10 x 10 spacing may prove to be too wide because stands that are appreciably understocked cannot be expected to reach normal stocking during a short rotation (Wellwood, 1943). On the other hand, a stocking of 400 trees per acre produced almost as much volume as 600 trees per acre (Bennett, 1963), and a 10 x 10 spacing may eventually become the optimum spacing.

Cord Volume - Our study supports what others have found; namely, at 20 years of age, the yield of wood that meets the minimum specifications for pulpsticks, as measured in standard cords, is influenced by spacing. Our results show that the yield of loblolly pine pulpwood was about the same in the 6 x 6 and 8 x 8 spacings (Table 2), but more than likely the 8 x 8 spacing will yield the greater pulpwood volume within the next three years.

While loblolly pine's growth and yield in southern Illinois are quite encouraging, they are somewhat less than those reported in its natural range. For example, in Louisiana, 18-year-old loblolly pine planted at 8 x 8 spacing averaged 1.9 cords per acre per year (Hansbrough, 1968). In Illinois the growth at this spacing has been 1.7 cords per acre per year (Table 3). The best yield in the Louisiana plantation was 40 cords per acre in 18 years planted at 10 x 10 feet, whereas in our study loblolly produced only 26 cords per acre at 10 x 10 feet in 18 years.

Shortleaf pine in this experiment has produced the greatest volume of pulpwood at the three widest spacings at age 20 (Table 3). It is likely that shortleaf pine growing at either 6 x 6 or 8 x 8 will yield the greatest pulpwood volume within the next five years.

In terms of cord volume, the growth rates found in this 20-year-old Illinois plantation indicate that both species are more valuable if kept on the stump and allowed to grow, presumably increasing in value at almost similar rates. Based on these results, age 20 is not a rational rotation age for most of the spacings.

Table 2. Periodic annual per acre growth for loblolly and shortleaf pine.

	Loblolly pine				Shortleaf pine			
	0-11 years	12-13 years	14-18 years	19-20 years	0-11 years	12-13 years	14-18 years	19-20 years
	Basal area (square feet)							
4 x 4	14	7	1	3	10	11	6	16
6 x 6	12	10	6	5	8	11	7	11
8 x 8	10	12	7	3	6	11	8	7
10 x 10	6	10	7	10	4	9	8	10
	d.b.h. (inches)							
4 x 4	0.30	0.10	0.14	0.20	0.25	0.30	0.14	0.05
6 x 6	0.40	0.20	0.18	0.15	0.35	0.25	0.16	0.10
8 x 8	0.49	0.30	0.18	0.15	0.37	0.35	0.24	0.15
10 x 10	0.50	0.45	0.28	0.20	0.40	0.45	0.32	0.20
	Volume (cubic feet)							
4 x 4	161	154	167	120	94	185	192	260
6 x 6	136	187	287	358	80	180	225	427
8 x 8	109	297	279	456	52	192	209	365
10 x 10	75	190	259	406	34	117	212	341

Table 3. Cord volume per acre for loblolly and shortleaf pines at the end of 18 and 20 growing seasons.

	Loblolly pine		Shortleaf pine	
	18 years	20 years	18 years	20 years
4 x 4	20a	25a	14c	21a
6 x 6	29b	36b	20b	29b
8 x 8	31b	39b	18b	27b
10 x 10	26c	34c	16c	29b

Within an age group for each species, a is significantly different from b and c at the .01 level and b is significantly different from c at the .05 level.

SUMMARY

The following conclusions may be drawn from results of the measurements taken at the end of 20 growing seasons.

(1) This study revealed no reason why loblolly pine and shortleaf pine plantations cannot continue to be used to reforest old fields in southern Illinois. Both species showed satisfactory growth during the first 20 years, even though shortleaf is at the limit and loblolly is beyond the natural range of the species.

(2) Management plans can be designed to use tree spacing as the principle silvicultural tool for eliminating or postponing the need for thinning and to control stand density. Tree growth and development in southern Illinois pine plantations can also be influenced from establishment by carefully planting trees of high genetic quality from appropriate seed sources.

(3) Growth and yield of loblolly pine is superior to shortleaf pine at age 20.

(4) Shortleaf pine yields its greatest volumes at a planting spacing of at least 6 x 6 but probably not wider than 8 x 8 feet at age 20.

(5) Although for pathological reasons, the maximum practical rotation for these southern pines in Illinois may be shorter than those customarily used in the South, the growth rate of trees in the experimental plantation indicates that a rotation of 20 years is too short. Our data show that this a very vigorous stage of development, adding volume at very high rates.

(6) A spacing interval as close as 4 x 4 for loblolly pine is not to be recommended, as excessive mortality will occur at an early age. Competition and overcrowding are so acute after 20 growing seasons that average height is significantly shorter at this spacing. Low vigor and extremely high mortality predisposes a stand to possible insect and disease epidemics. Yield is low at this spacing, and any thinning would be precommercial, thus adding materially to the cost of producing the forest crop.

(7) The 10 x 10 spacing appears to be too wide to produce optimal quantities of merchantable products at age 20. These stands have apparently not fully utilized the potential productive capacity of the site up to this time. With continuing faster growth rates, it appears that this spacing may still develop stands that are near optimum as final rotation age is approached.

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