Comparison of Log Quality from Even-Aged and Uneven-Aged Loblolly Pine Stands in South Arkansas[1]

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*ABSTRACT. Log grade, number of knots, and log volume of the first two logs, as well as form class of the butt log, were compared across three broad sawtimber categories among even-aged plantations, even-aged natural stands, and uneven-aged natural stands of loblolly pine (*Pinus taeda *L.) in Ashley County, AR. Trees from uneven-aged stands had butt logs of better log grade than even-aged plantations, particularly in the large sawtimber component where the average difference was half a log grade. Compared to even-aged natural stands, trees from uneven-aged stands had logs of comparable grade. Trees from even-aged natural stands produced butt logs of slightly better grade, but with greater taper and less volume per log, than trees from even-aged plantations. To produce high-grade loblolly pine sawtimber in the West Gulf region, natural stand management will suffice; plantation management may require supplemental quality intervention such as artificial pruning.*

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The optimal silvicultural system to apply in a given situation depends in large part upon economic benefits that the system can provide for the landowner. Indicators such as growth and yield or economic assessments are easily quantified, are readily accessible to foresters and landowners, and provide a firm basis for silvicultural decision-making. However, stand characteristics that are less obvious, or for which there is no clearly defined price or value established through transaction, are often less firmly established as attributes of a particular system either in the silvicultural literature or through professional observation.

Log quality considerations in pine sawtimber from even-aged and uneven-aged silvicultural systems fall in this category. Stumpage and mill-delivered prices for pine sawtimber are not explicitly subdivided by grade (Timber Mart-South 1986), although in weak markets high quality sawlogs will often be salable whereas low-quality sawlogs will not.[2] Forest industries in south Arkansas that manage for sawtimber practice either even-aged or uneven-aged silviculture, and in some instances both, which indicates that sawlogs of acceptable minimum quality can be economically produced with either approach. Specific observations about log quality and comparisons among different systems more closely resemble silvicultural lore than fact.

The selection system has been reported to produce high quality southern pine timber (Reynolds 1969, Reynolds et al. 1984). In a study in south Arkansas, 41% of the logs harvested during the first 18 years of selection silviculture were grade 1 (according to Crossett Lumber Co. log grading standards), but the proportion decreased to 35% during the subsequent 11 years (Reynolds 1959, 1969). This decline was attributed to a shift in origin of harvested trees from released virgin stock to second growth stock; the proportion of grade 1 logs was expected to increase with increasing duration of management of the second growth stand (Reynolds 1969). In addition, standard marking practice in selection silviculture in south Arkansas is to remove the worst trees and leave the best. Under ideal application, this approach removes trees of poor quality before they become large sawlogs, thereby promoting a stand-level increase in quality of large sawtimber.

Plantations of southern pine are also reported to grow high quality trees. Higher stem quality was reported in plantations subject to early density control and thinning than was reported in stands in the absence of either treatment (Hughes and Kellison 1982). In reporting on the quality of trees removed from plantations during thinning, Sprinz et al. (1979) observed a greater number of high quality trees than nonquality trees. They also noted contradictory observations regarding stem density versus quality of trees removed; in one study, dense stands had more lower grade material removed from them than did less dense stands, but the converse was true in a second study. These authors did not state whether quality of residual trees was consistent with

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[2] Baker, J.B. 1985. Personal communication, Crossett Forestry Field Day, Crossett AR, May 1, 1985.

quality of trees harvested during thinning.

In theory, the key to natural development of a high quality stem under either even-aged or uneven-aged silviculture is early natural pruning to the desired merchantable height, such as 17.3 or 33.6 ft. This early pruning is promoted by stand density, with the simple axiom of the denser the better, up to the point where density causes a reduction in growth and requires treatment to regulate density. Foresters must balance a minimization of growth reduction with the formation of a clear butt log. They must concurrently reduce rotation lengths or perpetuate stand structure, and offset the degree of intervention in early stand development with the expense of stand establishment and the value of expected returns. The significance of log quality in these evaluations was stated by Assmann (1970), who noted that an increased value production by thinning can best be acquired by exerting a positive influence on not only the average timber dimensions but also on timber quality, so that higher prices can be more quickly obtained for timber of given dimensions.

Despite the absence of market consideration of tree or log quality in southern pine forestry, schemes for grading logs have been in existence for decades. Using a simple knot-counting approach, Campbell (1962, 1964) produced the first standard guides to grading southern pine logs and trees. He categorized defects on the tree either as degrading features, such as knots, conks, and excess sweep, or as nondegrading features, such as crook, other deductible scaled features, and the many insignificant bumps and swells on a log. In 1968, USDA Forest Service researchers produced specifications for southern pine log grades and tree grades using a much simpler clear-face grading method, the accuracy of which was verified using lumber recovery studies (Schroeder et al. 1968a, 1968b).

The objective of this study is to evaluate and compare log quality of loblolly pine (*Pinus taeda* L.) trees growing in even-aged plantations, and in even-aged and uneven-aged natural stands that contain minor and varying proportions of shortleaf pine (*P. echinata* Mill.), on the upper West Gulf Coastal Plain.

METHODS AND PROCEDURES

Study Areas

Four experimental research demonstration areas, found on similar sites and physiographic settings in Ashley County, AR, and having site indices for loblolly pine of between 85 and 95 ft (base age of 50 years), were used for this study.

The even-aged plantations used were the Cattle Farm Plantation demonstration of the Mid-Continent Division of Georgia-Pacific Corporation. This demonstration area contains pine plantations established on old field sites in 1927 and 1945 by the Crossett Lumber Company. The 1927 plantation was established with 1340 trees per acre, at an approximate spacing of 6 ft × 6 ft. It was initially thinned at age 14 to 1130 trees/ac, and subsequent thinnings have occurred on an average cycle of 4 years. Similar stand establishment and thinning parameters were used for the stands established in 1945. This silvicultural system resulted in the stand having greater density through its life than is typical in contemporary practice.

The absence of hardwoods in these old-field sites may have had an adverse influence on grade; Paul (1932) observed that the highest lumber values were obtained from loblolly pine stands where 20% to 25% of the timber consisted of second-growth hardwoods. Conversely, the high densities under which these stands were established probably serves an analogous purpose in promoting natural pruning. Since contemporary plantation practice is strongly directed at establishment of lower pine densities coupled with keeping hardwoods out of the young stands, these high-density Cattle Farm demonstration areas are likely to produce a level of quality somewhat better than that obtained using contemporary methods. Conversely, the 1927 planting stock was a Georgia seed source with a reputation in south Arkansas for limbiness, a trait known to have a genetically induced basis. Planting stock in 1945 was Arkansas woods-run stock. The degree to which any branchy genotype was modified by an overstocked environment is unquantifiable. Given these assumptions, it is likely that the observations from these stands represent slightly better-than-average conditions for development of tree quality (though poorer than average for stand volume) in even-aged plantation systems.

The even-aged natural stands used were the clearcut and seed-tree stands of the Methods of Cutting study, administered by the USDA Forest Service on the Crossett Experimental Forest. The stands in this study originated from two separate natural regeneration efforts in 1937–38 and 1942–43; growth and yield of the younger stands has been reported (Baker and Murphy 1982). Each system was installed on three 5-ac plots in each of the two periods; thus, trees from twelve 5-ac stands were sampled in this study.

In the clearcut stands, the source of natural regeneration was seedfall from adjacent stands. Site preparation was accomplished by conducting a prescribed burn prior to seedfall, and seedling release was obtained after the third growing season by cutting all hardwoods that were 3.5 in. dbh and larger. In the stands established in 1942–43, there was no thinning in the clearcut stands until age 36, at which time the pine component was thinned; concurrently, all merchantable hardwoods were harvested, and unmerchantable hardwoods were injected with herbicide. Subsequent thinning has been conducted on a 5-year schedule to a residual basal area of 80 ft^2/ac. The clearcut stands established in 1937–38 were not thinned at age 36, but rather were reincorporated into the operational even-aged natural stand management of the Crossett Experimental Forest, which included thinning, injection, and prescribed burning on an irregular schedule.[3]

In the seed-tree stands, the source of natural regeneration was predominantly from the residual seed trees in combination with seedfall from the adjacent stands. These stands were released in the same way as the clearcut stands. The seed trees were removed after the fifteenth growing season, and a salvage operation followed ice damage in the seventeenth growing season. Subsequently, no harvests in the stands established in 1942–43 were conducted until age 36, at which time the same thinning program as described for the clearcut stands was implemented. The seed tree stands established in 1937–38 were not thinned at age 36 but were reincorporated into the even-aged natural stand management of the Crossett Experimental Forest in a similar manner as the older clearcut stands.

The silviculture of these two regimes cannot be viewed as typical of contemporary management of clearcut and seed tree stands, because the absence of a regular thinning program prior to age 36 probably resulted in lower stand volumes than might have been achieved by thinning. However, the overstocked conditions produced by stem density and the lack of thinning implies that these stands probably represent a standard of quality that is higher than average relative to other even-aged natural stands.

The uneven-aged natural stands were those of the Farm Forestry Good Forty and Poor Forty Research Demonstration areas of the Crossett Experimental Forest (Reynolds et al. 1984). These stands originated as the residual stand following a 14 in. stump diameter selective cutting in 1915. The stands have been managed using uneven-aged silvicultural methodology since 1937. For the first 10 years of management, treatments consisted of annual harvest of all competing overstory and midstory hardwoods and annual improvement cutting in the pine component. From 1946 to date, management has consisted of control of understory hardwoods, primarily accomplished using herbicides at approximately ten-year intervals, and harvest in the pine component using volume control methodology; these harvests occurred annually through 1968, then again in 1973, 1980, and 1985. The frequent entries, low sawtimber stocking, and questionable genotypic origin of these stands, when balanced by the harvest of poor quality trees under "cut the worst and leave the best" marking guidelines, suggests that these stands illustrate a program for development of tree quality that is slightly better than average compared with other uneven-aged prescriptions.

Measurements

A total of 216 loblolly pine trees, 72 from each of the three silvicultural systems, were selected for analysis. Eight trees were measured from each of three 1 in. dbh classes within each of three broad sawtimber categories—small sawtimber (10 in., 11 in., and 12 in. dbh classes), medium sawtimber (14 in., 15 in., and 16 in. dbh classes), and large sawtimber (18 in., 19 in., and 20 in. dbh classes)—within each silvicultural system.

Trees were sampled in the following manner. A rectangular grid was imposed on each stand. Grid dimensions depended on the size of the demonstration area; a two-chain grid was used in the even-aged natural stands, and a three-chain grid was used in the even-aged plantations and the uneven-aged stands. At each grid point, the nearest sawtimber-sized tree of qualifying dbh class was located and measured. If the limit for any given dbh class had been sampled, the next nearest sawtimber tree was sampled.

In the plantations and the even-aged natural stands, the oldest stands were sampled first. Observations made after the initiation of sampling were that this strategy resulted in filling the sample quota for large and medium sawtimber classes more rapidly than the small classes. Sampling in the younger stands completed the data collection. Similarly, the Good Forty was sampled before the Poor Forty and resulted in the observation that 51 sample trees were selected from the Good Forty and 21 from the Poor Forty. Observations during the sampling suggested that trees larger than the 20 in. class existed in all stands, but no trees larger than 20 in. were sampled.

On each sample tree, dbh was recorded to the nearest 0.1 in. A 1 ft stump was assumed, and each log was assumed to be 16.3 ft in length. The height to 17.3 ft was measured directly; at that height the diameter outside bark (dob) was taken to the nearest 0.1 in. using a diameter tape, and the average bark thickness was measured to the nearest 0.025 in., as determined by averaging two measurements taken at right angles to the bole using a bark gauge. At a height of 33.6 ft, measured by clinometer, the dob was taken to the nearest 0.1 in. using a Wheeler optical caliper. Sweep and crook in the first and second logs were recorded in 1 in. units using ocular estimate.

In addition, the first log of each tree was divided into north, east, south, and west quarter-circumferences or faces. Defects in the first log were mapped vertically by 1 ft height increments and circumferentially by 1 in. dbh increments on a tally sheet. The second log was visually inspected by faces of one-eighth bole circumference for the presence or absence of a clear face. The presence of red heart disease (*Phellinus pini* [Fr.] Pilat) or other fungal activity, or of holes in the bark with a diameter greater than 0.5 in., was also recorded.

[3] Baker, J.B. 1990. Personal communication, Monticello AR, June 11, 1990.

Logs were graded by applying the log grading specifications developed by Schroeder et al. (1968a) instead of the tree grading specifications (Schroeder et al. 1968b); the visual limitations in applying log grades to the upper stem (lack of visibility and lack of proper height estimation) were overcome using binoculars and careful mensurational technique. Knots were defined as visible branch stubs more than 0.5 in. in diameter at the bole, visible overgrown knots of any size, and holes more than 0.25 in. in diameter at the bole surface (Schroeder et al. 1968a). Grade of the first log was evaluated for two cardinal face configurations—the north, south, east, and west faces, and the northeast, southeast, southwest, and northwest faces. The log grade assigned was that resulting from the maximum number of clear faces obtained, as modified by the presence of sweep or rot. Grade of the second log was similarly evaluated.

The form class of the tree was determined in the standard manner (Avery 1975). Doyle and International ¼ in. log rules were used to calculate log volumes for the first log based on the direct application of the formula rule (Avery 1975), using the measured dib at 17.3 ft. Doyle and International ¼ in. volumes for the second log were similarly obtained by direct computation, using a dib at 33.6 ft calculated by assuming that the bark thickness at 33.6 ft was the same as that at 17.3 ft.

There were no differences in mean diameter within a sawtimber category among different silvicultural systems (tested using analysis of variance, with mean comparisons made with Scheffe's test at the 0.001 level). The Lillefors nonparametric test ($P < 0.05$) was used to determine whether the distribution of data deviated from normality. Data which did not differ from normality were analyzed using analysis of variance, with differences between means tested using the Student-Newman-Kuels test at $P < 0.05$ (Norusis 1988). Data which were not normally distributed were analyzed using the Kruskal-Wallis test at $P < 0.05$; if mean differences were detected with this test, paired mean differences were tested using the Mann-Whitney test at $P < 0.05$ (Neave and Worthington 1988, Norusis 1988).

Table 1. Number (percentage) of standing logs by silvicultural system, sawtimber category, and indicated log grade. EA PLT = even-aged plantations, EA NAT = even-aged natural stands, UEA = uneven-aged natural stands.

Sawtimber category	Log grade 1	Log grade 2	Log grade 3
I. First 16 ft log			
A. EA PLT			
10"–12"	1 (4.2%)	10 (41.7%)	13 (54.2%)
14"–16"	4 (16.7%)	8 (33.3%)	12 (50.0%)
18"–20"	9 (37.5%)	9 (37.5%)	6 (25.0%)
All trees	14 (19.4%)	27 (37.5%)	31 (43.1%)
B. EA NAT			
10"–12"	9 (37.5%)	5 (20.8%)	10 (41.7%)
14"–16"	13 (54.2%)	8 (33.3%)	3 (12.5%)
18"–20"	10 (41.7%)	14 (58.3%)	0 (0.0%)
All trees	32 (44.4%)	27 (37.5%)	13 (18.1%)
C. UEA			
10"–12"	9 (37.5%)	11 (45.8%)	4 (16.7%)
14"–16"	13 (54.2%)	8 (33.3%)	3 (12.5%)
18"–20"	16 (66.7%)	7 (29.2%)	1 (4.2%)
All trees	38 (52.8%)	26 (36.1%)	8 (11.1%)
II. Second 16 ft log			
A. EA PLT			
10"–12"	0 (0.0%)	0 (0.0%)	24 (100.0%)
14"–16"	0 (0.0%)	0 (0.0%)	24 (100.0%)
18"–20"	0 (0.0%)	4 (16.7%)	20 (83.3%)
All trees	0 (0.0%)	4 (5.6%)	68 (94.4%)
B. EA NAT			
10"–12"	0 (0.0%)	1 (4.2%)	23 (95.8%)
14"–16"	0 (0.0%)	0 (0.0%)	24 (100.0%)
18"–20"	0 (0.0%)	0 (0.0%)	24 (100.0%)
All trees	0 (0.0%)	1 (1.4%)	71 (98.6%)
C. UEA			
10"–12"	0 (0.0%)	1 (4.2%)	23 (95.8%)
14"–16"	0 (0.0%)	3 (12.5%)	21 (87.5%)
18"–20"	3 (12.5%)	7 (29.2%)	14 (58.3%)
All trees	3 (4.2%)	11 (15.3%)	58 (80.6%)

RESULTS

Distribution of Log Grade

The even-aged plantations had the lowest proportion of grade 1 logs and the highest proportion of grade 3 logs in the first log in all the sawtimber classes of the study (Table 1). Half of the small and medium sawtimber butt logs and 25% of the large sawtimber butt logs in the plantations were grade 3. Conversely, 44% of the butt logs from the even-aged natural stands and 53% from the uneven-aged stands were of log grade 1 (Table 1). Two-thirds of the butt logs of the large sawtimber category in the uneven-aged stands were grade 1.

Over 90% of the second logs in this study were grade 3 (Table 1). The proportion of grade 3 logs by sawtimber category and silvicultural system exceeded 80% in all but the large sawtimber category from the uneven-aged stands. These results reinforce the perception that the greatest quality is in the first log of the stand, regardless of size class or silvicultural system.

Log Volume

There were no differences in either the Doyle or International ¼ in. volumes of the first log by silvicultural system in the small and medium sawtimber categories (Table 2), nor in either measure of volume in any sawtimber category in the second log. However, trees from both the even-aged plantations and the uneven-aged stands had greater volume in the first log

Table 2. Log volume (Doyle and International ¼") in the first and second logs, and form class of the first log, by size category and silvicultural system. EA PLT = even-aged plantations, EA NAT = even-aged natural stands, UEA = uneven-aged natural stands.

Size category	First 16 ft log volume, fbm		Second 16 ft log volume, fbm		Girard form class
	Doyle	Intl. ¼"	Doyle	Intl. ¼"	
Small sawtimber					
EA PLT	26.4 a[1]	52.4 a	8.8 a	26.5 a	81.7 b
EA NAT	21.8 a	46.5 a	7.6 a	24.6 a	77.8 a
UEA	25.3 a	50.9 a	8.6 a	26.5 a	80.4 b
Medium sawtimber					
EA PLT	75.0 a	108.9 a	45.0 a	75.1 a	83.8 b
EA NAT	68.6 a	99.8 a	38.9 a	67.9 a	80.4 a
UEA	66.8 a	101.8 a	38.3 a	67.0 a	81.3 a
Large sawtimber					
EA PLT	144.3 b	180.7 b	88.9 a	123.6 a	83.8 b
EA NAT	127.5 a	163.8 a	87.2 a	121.8 a	79.7 a
UEA	147.5 b	183.8 b	91.4 a	126.1 a	84.0 b
All sawtimber					
EA PLT	81.9 a	114.0 a	47.6 a	75.1 a	83.1 c
EA NAT	72.1 a	103.4 a	44.9 a	72.2 a	79.3 a
UEA	80.5 a	112.2 a	45.8 a	72.6 a	81.9 b

[1] Differences among means within a column by category that are followed by similar letters are not significantly different; significance of differences among means tested at $P < 0.05$ using Student-Newman-Keuls mean comparison test (Norusis 1988).

than those of the even-aged natural stands in the large sawtimber category, under either log rule. When considering all trees, log volume differences by silvicultural system were not significant.

However, the Girard form class showed significant differences among trees from different silvicultural systems in each sawtimber category (Table 2). Medium sawtimber trees in the even-aged plantations had significantly less taper than those from the other stands. In both the small and large sawtimber components, there was no difference in taper between trees from even-aged plantations and uneven-aged natural stands, but both had significantly less taper than trees from the even-aged natural stands. When considering all size classes, the even-aged plantations had significantly less taper than the uneven-aged stands, which had significantly less taper than trees from the even-aged natural stands.

Knot-based Comparisons

As expected, the mean number of knots per face in the first log increased as increasingly poorer faces were included in the average (Table 3). Similarly, the difference among mean knots per face of the first log by sawtimber category and system became more prominent with the inclusion of increasingly poorer faces in the analysis. To illustrate the trends in these data, comparison of the average number of knots per face based on the three best faces approximates the number of knots that affect the manufacture of lumber. In each sawtimber category, the first log of trees from the uneven-aged stands had significantly fewer knots per face than those from the even-aged plantations. In the medium sawtimber category, trees from even-aged natural stands also had a butt log with significantly fewer knots per face than trees from the plantations; in the large sawtimber component, there was no difference in knot number per face in the first log between trees from even-aged plantations and even-aged natural stands. When combining all sawtimber classes, there were significant differences in the average number of knots per butt log among each system, with the fewest knots in butt logs from uneven-aged stands and the most knots in butt logs from the even-aged plantations. Similar trends were observed when evaluating knots based on an average of all four faces.

When knots are assessed using the log grading approach, trees from uneven-aged stands had significantly better grade in the first log than even-aged plantations within each sawtimber category and across all categories (Table 4). There was no difference in grade of the first log between trees from uneven-aged stands and trees from even-aged natural stands; trees from even-aged natural

Table 3. Knots per face in the first log, based on the best face, worst face, and on averages of the best 2, 3, and 4 faces, by size category and silvicultural system. EA PLT = even-aged plantations, EA NAT = even-aged natural stands, UEA = uneven-aged natural stands.

Size category	Mean, knots per face				
	Best face	Best two faces	Best three faces	All four faces	Worst face
Small sawtimber					
EA PLT	1.25 b[1]	1.67 b	2.01 b	2.53 b	4.08 b
EA NAT	0.75 ab	1.17 ab	1.44 ab	1.94 ab	3.42 ab
UEA	0.58 a	0.81 a	1.03 a	1.32 a	2.20 a
Medium sawtimber					
EA PLT	0.75 a	1.02 b	1.39 b	1.88 b	3.33 b
EA NAT	0.25 a	0.42 a	0.62 a	0.91 a	1.75 a
UEA	0.75 a	0.56 a	0.69 a	0.94 a	1.67 a
Large sawtimber					
EA PLT	0.42 a	0.65 b	0.86 b	1.18 b	2.12 b
EA NAT	0.17 a	0.46 b	0.71 b	0.99 b	1.83 b
UEA	0.08 a	0.10 a	0.19 a	0.34 a	0.79 a
All sawtimber					
EA PLT	0.81 b	1.11 b	1.42 c	1.86 c	3.18 c
EA NAT	0.39 a	0.68 a	0.93 b	1.28 b	2.33 b
UEA	0.36 a	0.49 a	0.64 a	0.87 a	1.56 a

[1] Differences among means within a column by category that are followed by similar letters are not significantly different. Significance of differences among means tested at $P < 0.05$ using Kruskal-Wallis test; if among-means test was significant, differences between means was tested using Mann-Whitney test (Norusis 1988).

Table 4. Log grade of the first and second logs. EA PLT = even-aged plantations, EA NAT = even-aged natural stands, UEA = uneven-aged natural stands.

Size category	Log grade First log	Second log
Small sawtimber		
EA PLT	2.50 b	3.00 a
EA NAT	2.04 ab	2.96 a
UEA	1.79 a	2.96 a
Medium sawtimber		
EA PLT	2.33 b	3.00 a
EA NAT	1.58 a	3.00 a
UEA	1.58 a	2.88 a
Large sawtimber		
EA PLT	1.88 b	2.83 b
EA NAT	1.58 ab	3.00 c
UEA	1.38 a	2.46 a
All sawtimber		
EA PLT	2.24 b	2.94 b
EA NAT	1.73 a	2.98 b
UEA	1.58 a	2.76 a

[1] Differences among means within a column by category that are followed by similar letters are not significantly different. Significance of differences among means tested at $P < 0.05$ using Kruskal-Wallis test; if among-means test was significant, differences between means was tested using Mann-Whitney test (Norusis 1988).

stands had better butt-log grade than trees of plantations in the medium sawtimber component and when considering all sawtimber categories. In the second log, uneven-aged stands had significantly better average log grade than either even-aged natural stands or even-aged plantations only in the large sawtimber component and in the overall comparison, but these differences are of little practical significance.

DISCUSSION

Concern that uneven-aged silviculture produces logs of inferior quality appears to be unfounded for loblolly pine stands in the upper West Gulf Coastal Plain. The data presented here indicate that trees from uneven-aged stands produce sawlogs of better log grade, with fewer surface knots, than trees from even-aged plantations. Compared to even-aged natural stands, uneven-aged stands produce trees having an equivalent number of surface knots and comparable grade.

Natural pruning of saplings is promoted in the overstocked conditions that characterize natural regeneration of loblolly pine in an even-aged block or an uneven-aged gap. Some trees in an uneven-aged stand may undergo a period of growth suppression during some part of their early development. This suppression promotes natural pruning due to the shaded conditions required for the tree to become suppressed. If suppressed trees retain crowns of sufficient size, they will respond to release (Reynolds et al. 1984), a process that results in new wood being added to a relatively knot-free bole.

The fact that trees of a given size are older in uneven-aged stands than in even-aged stands undoubtedly contributes to the observed differences in grade. The age of the sampled trees in the uneven-aged stands in this study were not obtained. However, a diameter-age relationship from an uneven-aged stand in Bradley County, AR, on a similar site, under uneven-aged management for 40 years, and of similar stand structure was obtained[4]; 20 in. trees in this stand were 70 years old, roughly ten years older than the 20 in. trees in the plantations in this study.

However, for purposes of management, there is a singular lack of importance in knowing the precise age of an individual tree in an uneven-aged stand. The sustainable periodic yields that characterize a well-regulated uneven-aged stand depend less on age structure than on stand structure inferred through the diameter distribution. The fact that the age of a tree in an uneven-aged stand is likely to be greater than that of a tree of similar size in an even-aged stand implies that some age-dependent wood product parameters, such as log quality, will be concomitantly affected. Depending on the parameters of interest, forest managers or forest landowners may consider this an advantage.

The regular cutting-cycle entry in an uneven-aged stand promotes a winnowing effect that ultimately may be the major determinant of improved quality in uneven-aged stands. The standard marking rule of "cut the worst and leave the best" on these demonstration research sites has promoted high quality residual trees, particularly in the large sawtimber component.

Conversely, the plantation environment is intended to promote early height growth and rapid stand-level volume production. Thinnings in plantations are probably less selective by size class, which leads to a reduced opportunity to improve quality of the bole. Compared to the plantations in this study, contemporary plantations are typically established at lower densities with wider spacings, and are thinned at an earlier age for optimal development. These cultural treatments will tend to reduce natural pruning, probably at the expense of clear boles. The use of improved planting stock selected for favorable branch characteristics related to pruning might have improved the log quality in plantations under a similar overstocked density regime; whether these attributes improve grade under the lower densities typical of contemporary plantation management is subject to debate.

It is perhaps surprising that trees from the even-aged natural stands in this study had significantly greater taper than trees from either even-aged plantations or uneven-aged natural stands. Young even-aged natural stands of loblolly pine in south Arkansas are generally excessively dense, a condition that usually favors natural pruning and confers a desirable lack of taper to individual trees. However, the even-aged natural stands in this study underwent their first thinning at a relatively advanced age (Baker and Murphy, 1982). Stands managed with a delayed thinning strategy commonly exhibit a retrogression of stem form over time (Larson 1963) in accordance with hypotheses that the cross-sectional increment of the stems of residual trees is concentrated in the lower and

[4] Age = $-8.18 + 3.948 * DBH$; $9.6'' < DBH < 31.5''$, $R^2 = 73.3\%$, df = 28.

upper bole, thereby serving to increase the degree of taper in the first log. One would expect that even-aged natural stands that are thinned in a more timely fashion would contain trees of higher form class values than those reported in this study.

The desirable form class values for trees from the plantations in this study reflect the favorability of the plantation environment for early growth and development, though not necessarily for good natural pruning. Larson (1963) observed that repeated light and moderate thinnings minimize the increased taper that follows heavy thinning. The repeated light thinnings imposed on the plantations in this study proved to be an excellent silvicultural treatment for the promotion of stems with a minimum of taper.

Given these observations regarding stem form, the greater log volume in trees from the large sawtimber category in even-aged plantations versus that from even-aged natural stands is not unexpected. Trees of a given dbh with less taper have larger scaling diameters than those with greater taper, and thus the log volume based on dbh will undoubtedly be greater. Significant differences in form class between trees from the even-aged systems were evident even in the small sawtimber component, whereas differences in butt log volume were only significant in the large sawtimber component. These log volume comparisons are intended to illustrate per-log differences attributed to form class; productivity comparisons among systems should not be inferred from these comparisons.

The high form class value of trees from the uneven-aged stands is previously unmentioned in the literature. For example, Assmann (1970) noted that trees from selection stands have greater taper and are shorter than trees of similar diameter from even-aged stands; if equal-height trees are compared, the trees from the selection stand are older and have a larger dbh. Assmann also stated that timber produced under the selection method is more tapered and knotty, particularly when density is moderate or low. However, these studies were based on the tolerant European silver fir (*Abies alba* Mill.) and the mid-tolerant Norway spruce (*Picea abies* [L.] Karst.). These observations may not be valid for loblolly pine, which is intolerant, prunes well naturally, and responds to release at advanced ages.

The trees in the large sawtimber component of the Good and Poor Forties existed before the stands were placed under uneven-aged regulation. However, the trees in the medium and small sawtimber component probably initiated their development following the inception of regulation, and there is only a slight decrease in average form class in those diameter classes. The development of regeneration in uneven-aged stands is poorly understood, but appears to be in part related to the occurrence of gaps in the overstory beneath which a clump of congenerational reproduction develops somewhat according to even-aged stand dynamics (Guldin 1987). This hypothetical developmental pattern would confer a desirable lack of taper to individual trees within the gap, especially for a relatively intolerant species such as loblolly pine, and is consistent with observations by Assmann (1970) that timber quality in the selection forest improves with greater density of the growing crop.

One might argue that plantations have an advantage in achieving desired size at an earlier age, thus compensating for a lower average log grade. This is undoubtedly true of plantations established using genetically improved stock and intensive site preparation. In this study, however, the oldest age class in the even-aged natural stands was younger than the oldest age class of plantation trees as judged from establishment records. One might also argue that the advantages of enhanced stand-level volume production from even-aged plantations outweigh the disadvantages of grade. The implications of such considerations are beyond the scope of this paper, but the yields from these stands have been reported elsewhere (Guldin and Baker 1988).

If high grade sawtimber is to be produced using even-aged plantation silviculture, artificial pruning may be required. This is especially true if plantations are managed at wider spacings through the submerchantable and the subsawtimber component in order to maximize early stand-level volume increment; it will also be true if the target tree size is relatively small, and if rotation lengths are relatively short. In order to execute such treatments in a cost-effective manner, the development and application of inexpensive artificial pruning methods merit consideration as an alternative to even-aged or uneven-aged natural stand management.

The extrapolation of these results to species and regions beyond those reported here is inappropriate. For example, it is doubtful that uneven-aged silviculture in shortleaf pine in the Ouachita Mountains region would result in better grade than that available from even-aged plantation silviculture. The long rotation ages required for managing shortleaf pine in plantations will favor a more complete natural pruning of the bole, and may therefore result in production of stems of similar quality under either system. The reported results should be considered indicative, rather than conclusive, for loblolly pine in the upper Coastal Plain in the West Gulf region. □

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