EARLY THINNING CAN IMPROVE YOUR STAND OF COPPICE-REGENERATED OAK[1]

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Abstract.--Data from a long-term study established in a coppice-regenerated oak stand in the Missouri Ozarks demonstrated that: 1) superior stump sprouts can be identified as early as age 5, 2) thinning of sprouting clumps will significantly increase the diameter and volume growth of selected sprouts, and 3) the advantages of early thinning of clumps to single dominant sprouts remain evident at age 30. A series of curves are presented that provide a basis for making recommendations concerning the early clump thinning of coppice-regenerated oak stands.

INTRODUCTION

Obtaining adequate oak reproduction in even-aged upland hardwood forests is a widespread problem in the Central Hardwoods Region (Bowersox and Ward 1972, Sander et al. 1984). As a result, advanced regeneration in harvested oak stands is often considered to be the most important component in stand regeneration. Because oaks are prolific sprouters, many trees originate from stumps, and often these large seedling-sprouts grow rapidly (Johnson 1977, 1979, Zahner and Myers 1984).

Unfortunately, despite the importance of these coppice-stems, little is known about the long-term growth and development of coppice-regeneration in oak stands or about the effect(s) of silvicultural treatment(s) on such regeneration. Perhaps the best discussion of these topics are two guides prepared by the USDA Forest Service for advanced oak regeneration (Sander et al. 1976, Sander et al. 1984). However, due to data limitations neither of these guides were able to discuss the long-term development of coppice-regenerated oak stands or the effects of silvicultural treatment on these stands.

This lack of information presents an obvious problem to the forest manager -- if a stand of young (less than 10 years) coppice-regenerated oak is not growing as desired, what should be done? Will a clump thinning on each sprouting stump improve the growth of residual sprouts to the desired level? If so, will the effects remain evident as the stand grows older, or will the improved growth be a short-lived phenomenon? Or, rather than conducting a thinning, is it better to allow the stand to grow until some trees are large enough that a harvest for posts and poles or firewood is possible and then regenerate the stand (naturally or artificially) after harvest?

Long-term studies of the growth and development of coppice-regenerated oak stands are needed to answer these questions. Though such studies are rare, data collected from one study initiated in the Missouri Ozarks in the early 1950s can contribute valuable information to this topic. The purpose of this paper is to present the results of a long-term study of the effects of clump thinning on coppice-regenerated oak stands and to describe a technique for evaluating the probable results of clump thinning on stand development.

MATERIALS AND METHODS

Data were collected from University Forest, a 7200-acre forested tract located in southeastern Missouri and owned by the University of Missouri. The 3-acre study area was

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[1]Paper presented at the Seventh Central Hardwoods Conference, Carbondale, Illinois, March 5-8, 1989.

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of medium quality -- site index 60 to 65 feet base age 50 for red oaks. In 1953, the entire study area was clearcut. Before clearcutting, the age of the stand was approximately 32 years. After clearcutting, the stand regenerated vigorously through stump sprouts. Predominant tree species were scarlet oak (Quercus coccinea Muench.), black oak (Quercus velutina Lam.), southern red oak (Quercus falcata Michx.), white oak (Quercus alba L.), post oak (Quercus stellata Wangenh.), and hickory (Carya spp.) which comprised 34%, 17%, 5%, 23%, 13%, and 8%, respectively, of the regenerated stems.

Three 1.0 acre blocks subsequently were established and each block divided into four 0.25 acre sub-plots. These sub-plots included a 23 foot buffer strip leaving a 0.147 acre measurement plot. In each block, treatments were assigned randomly: one plot was selected for an unthinned control, one for thinning, and two were not used. Five years after clearcutting, a single dominant stem on each sprouting stump was selected and tagged in both the control and thinned plots. In the thinned plots, every multiple-stemmed sprout clump was thinned to a single dominant stem. No single stems were cut, and stumps producing single stems were not included in this study. In the control plots no thinning was done. Thinned plots averaged 600 (selected dominant) stems per acre after thinning and unthinned plots averaged 740 (selected dominant) stems per acre. At age 5, species, diameter of the parent stump at the point of cutting (7 inches above ground), the number of sprouts on the stump, and height of each selected sprout were recorded. At age 30 (25 years after thinning), diameter at breast height (dbh) was measured to the nearest 0.1 inch and mortality of all selected sprouts was inventoried. Dominant sprout heights were also sub-sampled at age 30.

A forest manager is not likely to manage all existing stems in young stands throughout a rotation, but instead is likely to concentrate efforts on those that show the most promise at the time of thinning. Moreover, to gain a thorough understanding of how clump thinning can improve the growth of coppice-regenerated oak stems, it must be known how stems respond throughout the size distribution. Therefore, rather than examine the mean thinning response of all sprouts in this study, the largest 100, 150, 200, and 250 trees per acre were evaluated for each of the control and thinned plots at age 30. "Largest" was determined by dominant sprout height at age 5 and by dominant sprout dbh at age 30. Thus, an identical set of stems was not examined at both ages. However, because it is of interest to know how many of those sprouts originally selected as superior at age 5 maintained dominance at age 30 in each treatment, a "Dominance Index" (DI) was calculated. DI is defined as the percent of sprouts that were among the n largest sprouts (100, 150, 200, or 250) per acre at age 5 as measured by height that were also among the n largest sprouts per acre at age 30 as measured by dbh.

Average dbh and volume at age 30 were also examined on the n largest stems. Gross cubic feet volume was estimated at age 30 using a local volume equation developed for University Forest from detailed measurements of 162 oak trees (Lowell unpubl.).

Lowell et al. (1987) have shown how the data for all sprouts could be used to develop equations to estimate the probability of "success" for a specified sprout diameter at age 30 given the height at age 5 of the sprout and the diameter of the parent stump. The form of the equations and signs of the coefficient estimates are:

$$p = 1/(1+e^{(-(b0-b1*CRIT+b2*HT+b3*TRT*DIAM))}) \quad (1)$$

where p is the probability that, given an initial (age 5) sprout height an individual stem will equal or exceed a given dbh (CRIT) at age 30,
CRIT is the predefined "success" criteria (inches),
HT is the sprout height at age 5 (feet),
TRT is 0 if the stand is not thinned and 1 if the stand is thinned, and
DIAM is the parent stump diameter (inches) measured 7 inches above ground.

The terms in equation (1) are presented in order of descending statistical significance. The most important term is the target diameter -- a larger desired future diameter (CRIT) decreases the probability of "success" (i.e., having a sprout that grows to at least that dbh by age 30). The next most important term is the height of the sprout at age 5 -- a relatively tall sprout has a better chance of achieving "success" than a shorter sprout. Finally, a larger parent-stump diameter provides a competitive advantage to a dominant sprout, but only if a clump thinning is conducted.

Note that because of the way the equations were fitted, a tree is considered "unsuccessful" at age 30 if it does not attain the specified dbh due to either slow growth or mortality. By graphing the probability of success for a sprout of given height against a range of success criteria, Lowell et al. (in prep.) developed a series of curves for use in making silvicultural recommendations for 5-year-old coppice-regenerated oak stands. These curves are reproduced here for red oak and white oaks on thinned and unthinned stands.

RESULTS AND DISCUSSION

Regardless of the portion of the diameter distribution examined, early clump thinning at age 5 benefitted the selected sprouts -- i.e., sprouts that have expressed dominance by age 5 (Table 1). Moreover, the benefit provided by thinning, rather than disappearing, was still prominent at age 30. It is also notable that the magnitude of the response of volume to thinning shows a tendency to increase -- from 2.9 to 4.0 cubic feet for 250 to 100 stems per acre, respectively -- in the larger portion of the diameter distribution. It is also evident that on a percentage basis, cubic foot volume responds more than dbh regardless of the portion of the diameter distribution examined.

The DI values show that, in both thinned and unthinned stands, sprouts identified as superior at age 5 tend to remain dominant at age 30 (Table 1). Thus, superior sprouts can be identified as early as age 5, and most of these sprouts will maintain their dominance, particularly if they are favored by thinning. However, even if sprouts identified as superior at age 5 are not favored by early clump thinning, the DI is still 60 or greater -- i.e., 60% of those sprouts achieving early dominance maintained their dominance to age 30. Apparently, the intra-stump competition present on unthinned stumps is not sufficient to cause a complete suppression of the dominance achieved by superior sprouts at age 5.

To use these findings, it is necessary for forest managers to be able to evaluate the effect of a potential clump thinning on their stands. Figure 1 provides methodology which can be used to develop silvicultural recommendations for these oak stands. The horizontal axis indicates the desired average minimum (not mean) dbh desired in a particular stand at age 30. The five curves on each of the four figures are representative of different average dominant sprout heights at age 5, and the vertical axis, labeled "Probability of Success," provides an estimate of the probability of achieving a desired set of stand conditions at age 30 given the initial (age 5) average dominant sprout height. Another way of viewing this is that p estimates the proportion of sprouts which achieve or exceed the desired dbh.

Table 1.--Average diameter and volume for selected portions of the diameter distribution.

	Largest n stems per acre			
	100	150	200	250
Dbh (inches) [1/]				
Control	7.6a	6.9a	6.0a	5.6a
Thinned	9.2b	8.5b	7.8b	7.2b
Increase(%)	21	23	28	29
Volume (cubic feet)				
Control	9.5a	7.8a	6.2a	5.3a
Thinned	13.5b	11.6b	9.8b	8.2b
Increase(%)	53	49	58	55
Dominance Index (%) [2/]				
Control	60	62	63	67
Thinned	69	74	79	78

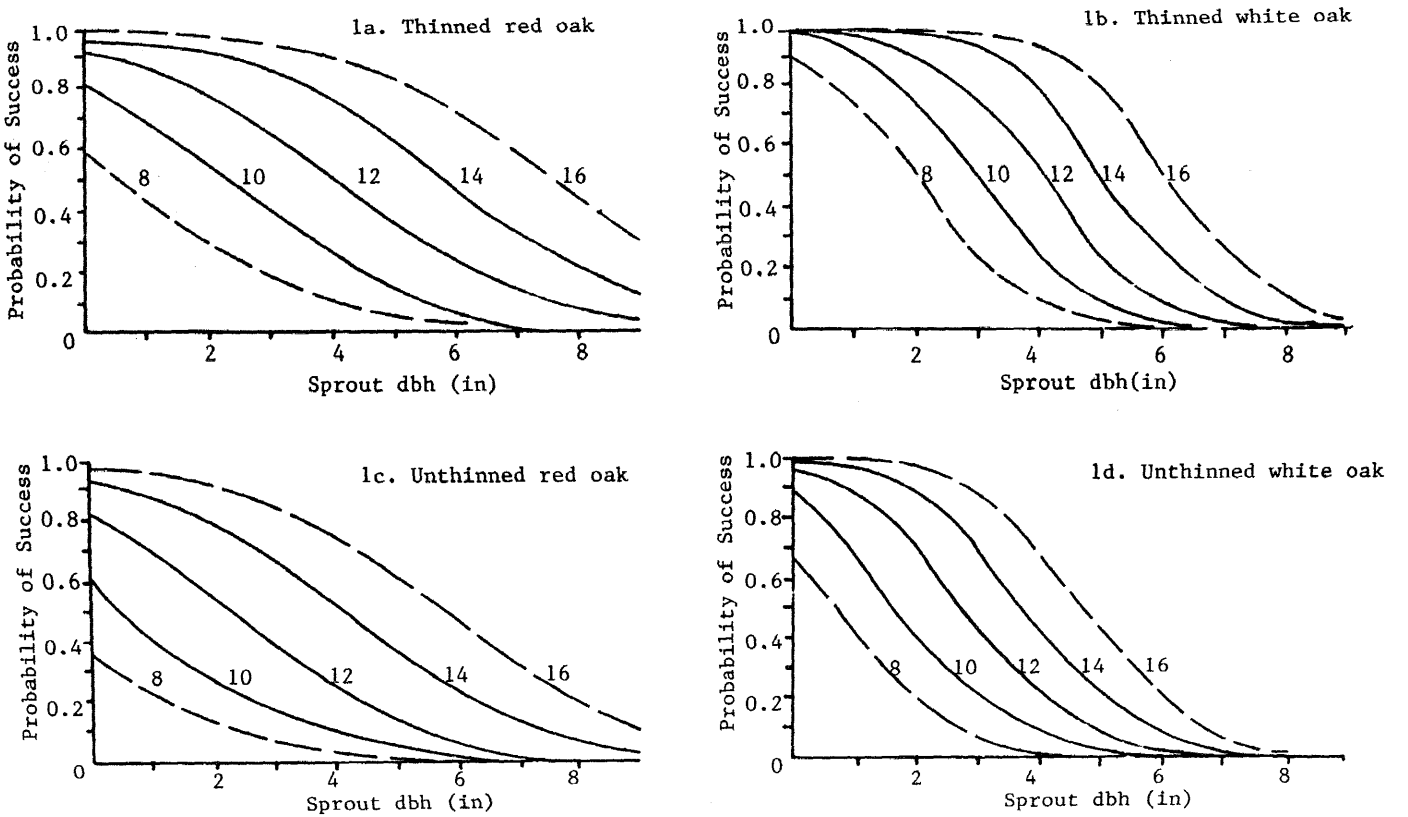
[1/] Within a parameter, measurements followed by the same letter are not significantly different at the 99% confidence level. Dominance Index was not tested for significant difference.

[2/] Dominance Index is the percent of stems among the largest n trees at age 5 by sprout height, and also among the largest n trees by dbh at age 30.

To utilize the curves in Figure 1, an inventory of coppice-regeneration must be conducted. A sample of sprouting stumps must be selected and the height of the dominant sprout on each stump recorded. The number of sprouting clumps per acre must also be estimated from this inventory. While no specific sample intensity is recommended here, the sample size must be large enough to provide a sample which the forest manager is confident is representative of the stand conditions. After this inventory is completed, the curves are used as illustrated in the following example.

Suppose that a stand of 5-year-old red oak stump sprouts is found to have an average dominant height of 10 feet and an estimated 500 sprouting stumps per acre. (In this study there were an average of 670 sprouting stumps per acre.) From Figure 1a the forest manager can determine that a clump thinning will produce a stand where the probability at age 30 of a 1)2.0 inch average minimum diameter is 0.53, 2)3.0 inch average minimum diameter is 0.38, and 3)4.0 inch average minimum diameter is 0.25. Viewed a different and perhaps more meaningful way, a clump thinning will produce a stand at age 30 in which 53% of the 500 dominant sprouts (265 per acre) will be at least 2 inches dbh, 30% (190 sprouts per acre) will be at least 3 inches dbh, and 25% (125 sprouts per

Figure 1. Curves used to evaluate the effectiveness of early clump thinning. (Values on curves are mean stand height (feet) at age 5.)



acre) will be at least 4 inches dbh. The intersection at 0.81 of the curve for 10 feet with the Y-axis also indicates that 81% of the original 500 dominant sprouts (405 per acre) will survive to age 30. These relationships, of course, are limited only to realistic stand densities.

The effectiveness of this clump thinning can be assessed by examining the projected future stand if no thinning occurs. Using the previous example for comparison, Fig. 1c shows that if a clump thinning is not conducted a stand will develop at age 30 in which 28% of the 500 dominant sprouts (140 per acre) will be at least 2.0 inches dbh, 17% (85 sprouts per acre) will be at least 3.0 inches dbh, and 10% (50 sprouts per acre) will be at least 4.0 inches dbh. Thus a clump thinning will produce a stand with 89% more stems -- 265 rather than 140 per acre -- which are at least 2.0 inches dbh compared to an unthinned stand, 124% more stems at least 3.0 inches dbh, and 150% more stems at least 4.0 inches dbh. Moreover, on the unthinned stand only 58% of the sprouts (290 stems per acre) can be expected to survive to age 30. Thus, in addition to the greater number of larger stems produced by the thinning, a forest manager will also have more stems to manage at age 30 thereby producing a greater number of management options than for an unthinned stand.

The different shapes of the curves in Figure 1 make it apparent that there are also species differences in growth potential. As the specified "success criteria" increases, the Probability of Success shows a tendency to be less for white oak than red oak implying that the growth of a given red oak sprout will exceed that of white oak. For example, in a thinned stand a 12 foot white oak sprout (age 5) has virtually no chance of reaching 7 inches dbh by age 30 whereas a similar red oak sprout has a 0.16 chance of achieving this dbh. Conversely, white oak sprouts have a better chance of survival than red oak sprouts. For example, in a thinned stand a 12 foot white oak sprout has almost a 100% chance of survival (dbh=0) compared to the 92% chance for a similar red oak sprout. Considering that the red oak and white oak species groups are composed primarily of scarlet oak, and white and post oak, respectively, these differences agree with the assessment that white and post oak tends to grow slowly and have intermediate shade tolerance, whereas scarlet oak grows rapidly and is relatively shade intolerant (Harlow and Harrar 1969).

In using these guides, there are two factors of which a user must be aware. First, not only is height at age 5 indicative of future "success", but also the diameter of the parent stump is significantly and positively correlated with "success", but in thinned stands only (see equation (1) and Lowell et al. 1987). Hence after a thinning operation, sprouts with relatively large parent stump diameters can be expected to outperform sprouts with smaller parent stump diameters. (Figures 1a and 1b were produced using the average parent stump diameter of 4.9 inches.) If a stand is not thinned, no competitive advantage results for a sprout with a relatively large parent stump diameter. This may be a consideration for managers who decide, for economics reasons, to thin only selected clumps in a coppice-regenerated stand. In such an operation, efforts should be concentrated on those clumps with relatively large parent stump diameters, provided that stump spacing will not cause excessive inter-stump competition in the future. Second, the limits of the original study must be kept in mind. The results presented apply to an average site wherein the treatment is a clump thinning and not a thinning to control the stand density. Estimates will vary with a better or poorer site and also if subsequent thinnings are used to control overall stand density.

CONCLUSIONS

It is possible to identify superior sprouts as early as age 5 in stands of coppice-regenerated oak. Furthermore, if these superior sprouts are released at age 5 by a clump thinning, significant increases in dbh and volume will result. These increases (compared to dominant sprouts in unthinned clumps) will remain conspicuous 25 years after thinning. By using success probabilities, a forest manager can determine if, given the size and number of stems at age 5, a future stand with a desired minimum diameter can be obtained. Moreover, if stands are not thinned early, by the time they reach age 30 -- a point at which some researchers have recommended a first thinning -- existing growing stock will be inferior to that which would have existed if an early thinning had been conducted.

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