OAK REGENERATION USING THE TWO-AGE SYSTEM

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Abstract—The two studies presented in this paper were completed in southeastern Kentucky and were designed to evaluate acorn production and development of advanced white oak reproduction from fully released white oak (*Quercus alba*) trees typical of reserve trees in the two age system. Twelve 2 acre 60- to 90-year-old white oak dominated stands were randomly assigned 1 of 3 treatments including an uncut treatment, and two cut treatments of 20 fully released canopy trees per acre, and 34 trees per acre. Acorn production from 11 to 15 years and regeneration accumulation, canopy cover and light regimes were monitored 15 years after treatment. Released trees produced significantly ($p < 0.01$) more acorns (1,424 grams per tree per year) compared to unreleased trees (689 grams per tree per year). Highly significant differences ($p < 0.001$) were found among treatments for cumulative white oak advanced regeneration density, height and densitometer readings. Strong relationships between densitometer readings and: PPFD; regeneration density; and regeneration height were found (R^2=ranging 0.743 to 0.974). The results of this study indicate that reserve white oak trees can provide for the recruitment of advanced oak regeneration and maintenance of light levels using easily applied crown densitometer readings can enhance the development of advanced regeneration required for the long-term maintenance of this species after future regenerative treatments.

INTRODUCTION

By definition the two age system maintains two distinct age classes throughout the majority of the rotation and is initiated by treatments which retain a limited number of canopy trees (reserve trees) along with a cohort of younger regenerating stems (Nyland 1996). Typically the two age stand is produced using a deferment cut where a limited number of reserve trees, occupying 10-30 ft^2 of basal area per acre, are selected from the overstory and retained for a second rotation while the remaining stems are removed (Stringer 1998). The number and distribution of the reserve trees must be such that as they produce little short- or long-term effect on regeneration and the development of the younger age class (Miller and Schuler 1995). Often times the stand, with the exception of the reserve trees, is subject to site preparation operations similar to clear cutting. This results in two distinct age classes, the older reserve trees and the younger regenerating cohort. While this system has been often termed shelterwood with reserves or irregular shelterwood the term shelterwood is misleading because the reserve trees are not intended to provide any sheltering effect to the regeneration.

This method has been used as an aesthetic alternative to clearcutting and as a means of potentially developing a limited number of large diameter high value sawtimber trees in a stand (Sims 1992; Smith and others 1989). The system also has structural and habitat advantages compared to clear cutting (Beck 1986; Miller and others 1995). Regardless of the objective, reserve trees in deferment cuts must be of proper vigor, landscape position, species, age, and potential tree grade so that they will survive and provide a viable product after two rotations. Not all stands and species can be managed using the two age system. Species which are relatively long lived and are commercially important make good candidates for reserve trees.

Besides the aesthetic and habitat values that two-aged stands have compared to clear cut stands they can be used to "life boat" species which do not have viable reproductive life forms at the time of cutting. A traditional clearcut essentially stops sexual reproduction in the stand for a substantial portion of the rotation and can limit the potential for the development of viable advanced regeneration. The reserve trees in the two age system provides for the potential for continued sexual reproduction in the stand and the ability to develop advanced regeneration which can be manipulated prior to the second regeneration cut. The maintenance of sexual reproduction throughout a rotation or a significant portion of it may be important for sporadic producers such as oak species. This paper presents the results of two studies conducted on the same study area. The first study was designed to determine acorn production from fully released small sawtimber white oak (*Quercus alba*) trees. The second study was designed to determine whether stands containing only a limited number of released white oak canopy trees could initiate the development of advanced regeneration.

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Citation for proceedings: Outcalt, Kenneth W., ed. 2002. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 622 p.

METHODS

This paper reports both the acorn production between 12 and 15 years of fully released white oak trees and the 15 year cumulative development of new seedlings and advanced regeneration in stands retaining a limited number per acre of fully released canopy white oaks. The study site was located at Robinson Forest, the University of Kentucky research and demonstration forest located in Cumberland Plateau Physiographic Province in southeastern Kentucky. While this study was initiated as a growth and yield study for crop tree management of small sawtimber white oak stands (Stringer and others 1988) the full crown touching release and the relative numbers of crop trees in these stands (within the range recommended for two age reserve trees) provided an excellent opportunity for the determination of some of the regeneration dynamics associated with stands managed under a two age system. In 1983 twelve 2 acre 60- to 90-year-old white oak dominated stands were selected for study. In 1983 each stand was randomly assigned one of 3 treatments including an uncut treatment, a treatment leaving only 20 canopy trees per acre, and one leaving only 35 canopy trees per acre. The treatments were imposed by full crown touching release of selected canopy trees. These trees were of average dbh for co-dominant and dominant trees in these stands. One-half acre growth and yield plots were established in the middle of each treated stand. Trees > 2.54 cm dbh were tagged and survival and growth monitored and ten 1/100th acre regeneration plots were also randomly established in each growth and yield plot. In 1994, three reserve canopy trees were randomly selected in each growth and yield plot and 3 one meter square acorn traps (David and others 1998) were randomly placed under the crown of each tree. Acorns were collected from traps at two week intervals during the fall of 1994 through 1997. Total acorn mass was determined for each tree and pooled by treatment for analysis.

Final white oak regeneration measurements were taken during July 1997 and included the number and height of each white oak stem established after treatment. To provide a relative gauge of canopy light interception and the light environment at each regeneration plot a concave spherical crown densitometer™ (Forestry Suppliers, Inc. 24 quarter inch cross hairs) reading was taken at plot center. Data was recorded and is expressed in this paper as the

Table 1—Density and height of *Quercus alba* advanced regeneration in two age stands[a]

	density (no./ha)	height (cm)	densitometer reading
uncut	227b	19.8b	5.72c
20 per acre	930a	35.0a	7.16a
35 per acre	450b	29.9a	6.47b

[a] Values with different letters are significantly different ($p < 0.01$) using ANOVA and LSD(t).

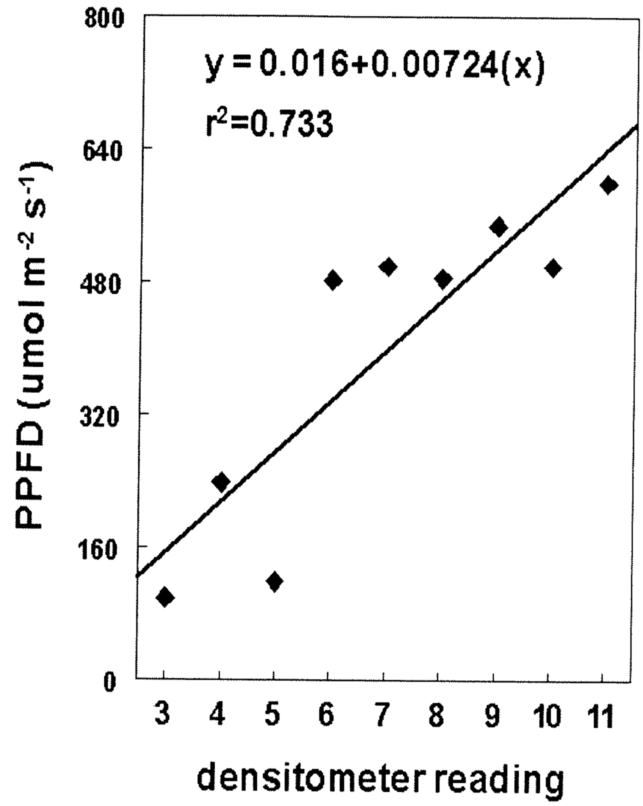

Figure 1—Data points represent average PPFD for each densitometer reading. The line represents a positive linear relationship ($y = 0.016 + 0.00724(x)$, R^2=0.733) between densitometer reading and PPFD.

number of cross-hairs where open sky was observed. At the same time a series of five photosynthetic photon flux density (PPFD) measures (μmol/meter²s PAR) were taken at a height above ground equal to the average height of the advanced regeneration (30 centimeter) at every other plot center using a quantum sensor (LI-COR, Inc.) and the values averaged by plot. All PPFD and densitometer readings were taken under clear sky conditions. White oak advanced regeneration data were pooled by treatment and subjected to statistical analysis using ANOVA and LSD(t) to determine treatment effects. Simple linear regression was used to establish the relationship between PPFD (dependent variable) and densitometer reading (independent variable) and advanced regeneration height (dependent variable) and densitometer reading (independent variable) pooled over all treatments. The Levenberg-Marquardt algorithm was used to establish best-fit coefficients of nonlinear functions for regeneration density (dependent) and densitometer reading (independent) pooled over all treatments.

RESULTS AND DISCUSSION

There was no significant difference ($p > 0.05$) among annual acorn yields of the 20 and 35 tree per acre treatments and data were pooled for comparison with the uncut treatment. Analysis of released treatments vs. uncut (unreleased) treatment showed a highly significant difference ($p = 0.008$) in acorn yield (as expressed on a per

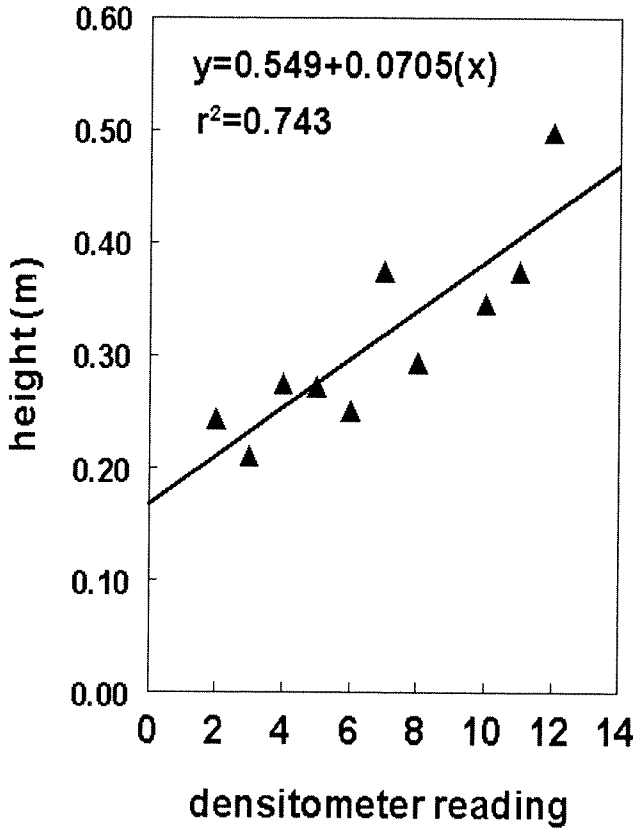

Figure 2—Data points represent average *Quercus alba* advanced regeneration stem density for each densitometer reading. The line represents an exponential relationship between densitometer reading and regeneration density (y = 43.615 + 22.373*exp(-x/-2.489), R^2=0.974).

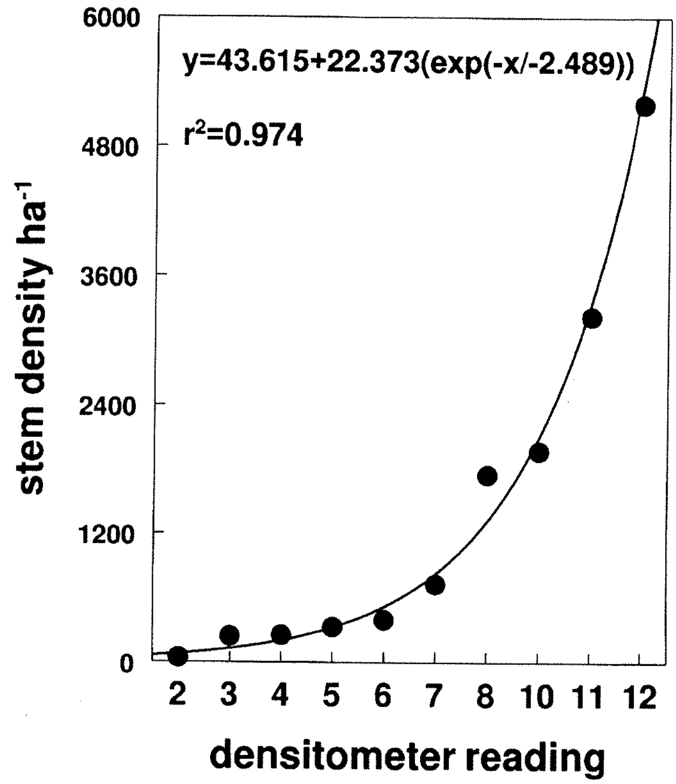

Figure 3—Data points represent average *Quercus alba* advanced regeneration height for each densitometer reading. The line represents a linear relationship between densitometer reading and regeneration height (y=0.549+0.0705(x), R^2=0.743).

tree basis). Released trees annually averaged 1,424 grams of acorns per tree compared to 689 grams per tree for unreleased trees. This indicates that fully released trees, typical of those that would be retained as reserve trees in deferment cuts in white oak dominated stands, have the capability of not only maintaining but improving acorn yield, a prerequisite for the development of advanced regeneration in two aged stands.

Highly significant differences ($p < 0.001$) were found among treatments for white oak advanced regeneration density, advanced regeneration height, and densitometer readings (table 1). The 20 reserve tree per acre treatment developed twice the number of regenerating white oak trees as the other treatments over the 15 year measurement period. The height of the white oak regeneration established after the treatment was greater for both cut treatments compared to the uncut treatment. The average height of the regeneration is relatively small at this point in time and would not be expected to be competitive if the stands were regenerated with the advanced regeneration in this condition. It is probable that some form of manipulation will be necessary to develop high vigor advanced regeneration prior to a future regeneration harvest. However, the advanced regeneration that developed after treatment indicates that the reserve trees are providing viable propagules which are developing advanced regeneration for future manipulation and stand regeneration.

Densitometer readings were also higher for the cut stands compared to the uncut stands. A positive linear relationship (y = 0.016 + 0.00724(densitometer reading), R^2 = 0.733) was found between densitometer reading and PPFD indicating a relationship between measurable canopy density and light levels at advanced regeneration height (figure 1). A positive relationship was also found between densitometer reading and advanced regeneration height (figure 2) and densitometer reading and advanced regeneration density (figure 3). An exponential relationship was found between densitometer reading and regeneration density (y = 43.615 + 22.373*exp(-densitometer reading/-2.489), R^2 = 0.974) while a linear relationship existed between densitometer reading and regeneration height (y = 0.549+0.0705(densitometer reading), R^2 = 0.743).

The results of this study indicate that small sawtimber sized co-dominant reserve white oak trees are capable of maintaing acorn production and resulting in the production of advanced regeneration that will potentially aid in the long-term maintenance of this species after future regenerative treatments. A positive correlation between canopy density and regeneration height along with the positive correlation between canopy density and light level indicates that light levels developed from the treatments encouraged regeneration development. This data indicates dramatic increases in advanced regeneration density can be obtained when the combined understory, midstory, and overstory exhibit a densitometer reading greater than 6.

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