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Survival and competitiveness of *Quercus rubra* regeneration associated with planting stocktype and harvest opening intensity

Robert C. Morrissey · Douglass F. Jacobs · Anthony S. Davis · Ron A. Rathfon

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Abstract Successful regeneration of northern red oak (*Quercus rubra* L.) on productive sites is problematic in eastern North American forests. Natural and artificial regeneration often cannot compete with fast-growing, shade intolerant species such as yellow-poplar (*Liriodendron tulipifera* L.). This study examines 5-year survival, growth, and competitive ability of planted northern red oak seedlings in various group selection harvest sizes in south-central Indiana, USA. Seedling stocktypes consisted of high (BHD; 75 seedlings m^{-2}) and low (BLD; 21 seedlings m^{-2}) nursery-bed-density bareroot seedlings, and small (CS; 11.4 L) and large (CL; 18.9 L) container seedlings. Group selection openings included large (0.400 ha), medium (0.100 ha), and small (0.024 ha) circular gaps in four stands. Larger stocktypes and gap sizes improved seedling height, diameter, and growth; ANOVA indicated only gap size was significant for seedling survival. Logistic regression showed survival was positively correlated to diameter at year 1, and aspect, gap size, and stocktype were significant predictors of survival. Our data indicated no differences in density of natural regeneration among gap sizes, although trends suggest greater numbers of bigger competitors in larger gaps sizes. Yellow-poplar regeneration was the tallest competitor of more than 50% of all northern red oak seedlings. Competitive status of seedlings after 5 years differed only by stocktype, with large container stock in a better competitive position than bareroot stock. However, less than 20% of seedlings in all stocktypes in each gap treatment were considered competitive (i.e., ≥80% of the height of tallest competitor) against their tallest competitor. The use of larger planting stock may offer greater

R. C. Morrissey · D. F. Jacobs (✉)
Department of Forestry and Natural Resources, Hardwood Tree Improvement and Regeneration Center, Purdue University, 715 West State Street, West Lafayette, IN 47907, USA
e-mail: djacobs@purdue.edu

A. S. Davis
Department of Forest Resources, Center for Forest Nursery and Seedling Research, University of Idaho, P.O. Box 441133, Moscow, ID 83844, USA

R. A. Rathfon
Extension Forester, Department of Forestry and Natural Resources, Purdue University, 12000 Purdue Farm Road, Dubois, IN 47527, USA

opportunities for successfully regenerating northern red oak seedlings on productive sites but likely would have to be accompanied by treatments to reduce woody competition.

Keywords Group selection harvest · Northern red oak · Competitive capacity · Yellow-poplar · Container seedlings

Introduction

Successful natural regeneration of oak (*Quercus* spp.) on productive sites has been a consistent challenge in eastern North American forests for more than 60 years (Clark 1993; Johnson et al. 2002). Oaks are vital to local economies and cultures providing wood products, wildlife habitat, recreation, and aesthetic values. Even-aged management techniques, such as clearcutting and shelterwood, designed to favor natural oak regeneration have proven unreliable (Loftis 1983, 1990; Sander and Graney 1993; Groninger and Long 2008; Morrissey et al. 2008). Other methods designed to improve competitive status of natural and artificial regeneration have been more successful. These include competition control, stocktype selection, and altering stand structure to favor oaks (Spetich et al. 2002; Dey et al. 2003; Povak et al. 2008).

In forests of the Central Hardwood Region, present-day natural and anthropogenic disturbances tend to be minor, often affecting only individual trees or small groups of neighboring trees. Historically, understory disturbances such as fire or grazing would have allowed for oak advance regeneration to take advantage of those small canopy disturbances (Sander and Graney 1993). However, fire suppression efforts during the last century have resulted in closed canopy forests and forest fragmentation has contributed to increased deer populations, both conditions that do not encourage the growth and survival of advanced oak regeneration. Group selection methods attempt to replicate the structure that results from small-scale, low intensity disturbances. Opening size greatly influences growing conditions within gaps, which, in turn, influences species composition and growth of seedling regeneration (Johnson et al. 2002). Understanding the interplay between gap size and regeneration response can result in improved growth and survival of oak seedlings. Generally, large gaps favor shade intolerant species, and small gaps favor shade tolerant species. Northern red oak is intermediate in shade tolerance (Sander 1990) and can grow well in group selection openings that are at least as wide as the height of the adjacent forest (Minckler 1961; Marquis 1965). However, if openings are too large, seedlings may quickly become suppressed by fast growing, shade-intolerant species (Smith 1981; Weigel and Parker 1997; Jenkins and Parker 1998).

Although several silvicultural treatments designed to promote oak regeneration in reforestation settings have demonstrated good potential for success, few forest owners use these silvicultural treatments (Kittredge et al. 2003; Jacobs et al. 2004). Many treatments are perceived to be too labor intensive and costly, but they are critical on mesic sites where oaks must compete with advanced regeneration of shade-tolerant species and fast-growing competitors such as yellow-poplar (*Liriodendron tulipifera* L.; Beck and Hooper 1986; Groninger and Long 2008). Plantation establishment success of oaks has been inconsistent because of competing vegetation, animal browse, and poor seedling quality (Johnson et al. 2002; Jacobs et al. 2004; Dey et al. 2008). Treatments that effectively maintain an oak presence on reforestation sites need to be designed to reduce financial and labor inputs to make them more feasible for forest owners, or at least prove to have very high rates of success for these significant investments.