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Does the shelterwood method to regenerate oak forests affect acorn production and predation?

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Abstract

The shelterwood system is one of the primary methods currently used to encourage regeneration of oak forests; yet, little is known about its influence on acorn production and predation. We compared acorn production, and predation by insects and mammals in stands of red oak (*Quercus rubra* L.) that were regenerated by the shelterwood method (50% canopy removal) to that of uncut (control) stands in the first year of production after the harvest treatment. In each plot, we measured stand and tree characteristics and estimated acorn production by using both acorn traps and a visual crown survey to place trees into productivity classes. Acorns collected in traps were examined to record the external and internal conditions, percentage of cotyledon damaged and the presence of insects. Exclusion cages were used to quantify acorn predation by mammals in harvested and control plots. Oaks in the shelterwood plots produced more acorns than oaks in uncut stands if the acorn crop was rated by the crown survey method, but not when production was measured with acorn traps. We found no evidence that the shelterwood method influenced acorn predation by insects or mammals. Visual examination of the exterior of the pericarp indicated that insects attacked 44% and 47% of the acorns in harvested and control plots, respectively. Most of the damage produced by insects was attributed to pip galls (cynipid wasps) and acorn weevils (*Curculio* sp.), which in most cases damaged more than 75% of the cotyledon. Squirrels and chipmunks were the primary mammals responsible for removing 50% of the acorns in the fall-spring whereas mice took 33% of the acorns. Use of the shelterwood method in conjunction with leaving the best acorn producers can be used to create the desired stand structure while maintaining or increasing acorn production and oak regeneration potential in the stand.

Keywords: *Quercus rubra*; Regeneration by shelterwood system; Seed production; Pre-dispersal seed predation; Post-dispersal seed predation

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1. Introduction

In Canada, red oak (*Quercus rubra* L.) occurs in the southeastern mixed coniferous–deciduous and deciduous forests, from east of Lake Superior to Nova Scotia. Although red oak can be a common main canopy species in these northern forests, it is hard to regenerate and sustain its current level of stocking in the overstory.

Many factors contribute to the difficulty of maintaining oak by natural regeneration in these forests. Typically, natural regeneration of red oak forests occurs after disturbances (e.g., fire) that open the forest canopy and understory, thus favoring oak seedling growth and recruitment into the overstory by providing more light in the forest understory (Crow, 1988; Dey, 2002). Fire suppression, however, has resulted in the displacement of oaks by more shade-tolerant species (Abrams, 1992), and historical trends suggest the replacement will continue (Nowacki et al., 1990). The natural regeneration of oaks is further complicated because acorn production by red oak is highly variable among individuals and fluctuates from year-to-year (2–7 years interval between large crops) for individual trees (Healy, 2002; Johnson et al., 2002). This natural variability in acorn production makes it hard to time silvicultural practices with a good seed crop to favor oak regeneration. Variability in seed production is due, in part, to the (1) inherent periodicity of good to bumper acorn crops, (2) differences in individual tree characteristics such as age, size of crown and crown dominance, (3) stochastic environmental factors that affect flowering, pollination and seed development, and (4) predation of oak flowers and acorns by insects and vertebrates (Christisen and Kearby, 1984; Sork et al., 1993; Dey, 1995). In addition, some red oaks are consistently good acorn producers, whereas others are not, although they may be dominant trees in the site (Healy et al., 1999; Healy, 2002; Johnson et al., 2002).

Crown size, health and vigor are major determinants of acorn production of oaks (Downs and McQuilken, 1944; Christisen, 1955; Sharp and Sprague, 1967; Goodrum et al., 1971; Sork et al., 1993). The potential to produce acorns is partially related to stand density and the degree crowns are exposed to direct sunlight (Johnson et al., 2002). Compared to forest-grown trees, open-grown oaks have (1) larger, wider crowns with greater surface area and volume, (2) more leaf area and foliage biomass, (3) higher densities of live, healthy branches, (4) greater live crown ratios, and (5) greater crown exposure to direct sunlight; all of which are correlated with acorn production.

Oak seedling establishment occurs mainly in years when production of sound acorns exceeds predation (Downs and McQuilken, 1944; Gysel, 1957; Christisen and Kearby, 1984). Predation by insects, mammals and birds may result in low acorn survival, especially in years of low to moderate acorn production (Marquis et al., 1976). It has been hypothesized that in years of mast production seed predators become satiated, leaving a greater number of seeds available for dispersal and germination (Murphy, 1968; Janzen, 1971). Insects can destroy the entire crop in low seed years, and a large proportion of the acorns in highly productive years (Galford et al., 1988). Many insects, such as weevils (e.g., *Curculio* spp., *Conotrachelus* spp.), moths (e.g., *Melissopus* spp.) and cynipid wasps, attack acorns causing damage that prevents germination (Kearby et al., 1986; Weckerly et al., 1989; Johnson et al., 2002). Mammals such as deer (Harlow et al., 1975), squirrels (Short, 1976), chipmunks (Pyare et al., 1993) and mice (Gómez et al., 2003) are known predators of acorns and can consume high proportions of the acorn crop in years of poor to moderate production (Sork, 1984). However, mammals and birds also play a beneficial role in oak seed dispersal, and their caching of acorns promotes germination (Darley-Hill and Johnson, 1981; Jensen and Nielsen, 1986).

Currently, the shelterwood system is one of the primary methods used to encourage the regeneration of oak forests (Hannah, 1987; Dey and Parker, 1996). To create the shelterwood for oak regeneration, trees are harvested from below (i.e., from the lower diameter classes first) until the desired overstory stocking is achieved. Non-oaks are preferentially removed, leaving co-dominate and dominate oaks in the overstory to produce acorns. Reductions in stand stocking may promote acorn production by providing more growing space for oak crown expansion and development, and by modifying environmental conditions that influence acorn production and predation. Few studies have scientifically evaluated the effects of thinning or shelterwood harvesting on acorn produc-