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Twenty-five year response of non-crop trees to partial release during precommercial crop tree management

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ABSTRACT

An underappreciated component of precommerical crop tree release (PCTR) is the inevitable partial release of non-crop trees. While the response of fully released crop trees is increasingly understood, few studies have examined the response of non-crop trees. The effects of precommercial crop tree release at canopy closure on upper canopy persistence, mortality, and diameter growth over 25-years were examined on seven study areas established in Connecticut in 1988. Each area had nine 8 m × 8 m plots for each of two treatments: PCTR and unmanaged controls. The equivalent of 156 crop trees per hectare were completely released by cutting all stems with adjacent crowns. This resulted in the inadvertent partial release on two or more sides of 480 upper canopy, non-crop trees per hectare. Diameters and crown classes of all stems (DBH > 2 cm) were measured annually. For those stems in the upper canopy at when treated, partial release increased the proportion of oaks, but not maples or birches, which persisted in the upper canopy. Partial release increased the proportion of intermediate oaks that ascended into the upper canopy and reduced mortality. Partial release increased 25-year diameter growth of oaks. However, releasing upper canopy, sapling oaks on only one side did not increase upper canopy persistence or diameter growth. PCTR increased the proportion of oaks among the largest 300 trees per hectare twenty-five years after treatment. Where predicted oak densities are below management goals, precommercial crop tree release should be considered as a tool to increase survival and growth of quality oak saplings.

1. Introduction

A critical stage in stand development is the period immediately following canopy closure. This stem exclusion stage (Oliver, 1981) or the aggradation phase (Bormann and Likens, 1979) begins with thousands of upper canopy stems per hectare. During the subsequent decades of intense competition for growing space, upper canopy density will rapidly decrease, especially in the first few decades, to several hundred in poletimber stands and then to only a couple of hundred per hectare in mature sawtimber. Forest managers could let this process continue unabated without control of stand composition until commercial cutting is feasible in the large poletimber stage if there is a fuelwood/fiber market or else wait until the stand has reached the sawtimber size class. Delaying active management precludes the possibility of manipulating stand composition, which can be especially important when there is a wide differential of value among tree species (Miller, 1986).

Alternatively, managers could invest in precommerical crop tree release of valuable species that otherwise would likely be subordinated and lost (Zenner et al., 2012). In this paper, precommercial crop tree release (PCTR) will refer to complete crown release in sapling stands and is synonymous with cleaning (Helms, 1998) and an older definition of weeding (Downs, 1946). A subtle, but important difference, between terms is the emphasis of crop tree management is on selecting individual stems for release, while the emphasis of cleaning is on improving stand characteristics. The earliest bulletins based on practical experience recommended weeding to remove stems interfering with potentially more valuable stems (Tillotson, 1916), including as early as six years after overstory removal (Cline, 1929). The goal was to promote growth of selected species with little consideration of non-crop tree stems; perhaps because suggested spacing was 2–5 m between crop trees (400–2500 per hectare) and a second (or third) operation at 3–4 year intervals was recommended if needed (Cline, 1929; Hawley and Hawes, 1925).

Later experimental work generally confirmed that PCTR increased survival/upper canopy persistence (Trimble, 1974), diameter growth (Allen and Marquis, 1970; Della-Bianca, 1983b; Miller, 2000; Robinson et al., 2004), or both (Downs, 1946; Lamson and Smith, 1978) of upland oaks that otherwise were subordinated by less valuable species. However, crop tree release did not increase 5-year diameter growth of 7–9 year-old, upper canopy

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northern red oaks (*Quercus rubra* L.) and had minimal effect on upper canopy persistence in West Virginia (Smith, 1977). Another study found 5-year, but not 10-year, diameter growth of northern red oak was increased by PCTR (Lamson, 1988).

Similarly, PCTR increased diameter growth and/or survival of red maple (*Acer rubrum* L.) (Della-Bianca, 1983b; Lamson, 1988; Smith, 1977; Sonderman, 1985; Trimble, 1974), black birch (*Betula lenta* L.) (Smith and Lamson, 1983), black cherry (*Prunus serotina* Ehrh.) (Church, 1955; Smith and Lamson, 1983), and yellow-poplar (*Liriodendron tulipifera* L.) (Allen and Marquis, 1970; Miller, 2000; Sonderman, 1985).

The focus of crop tree research has been on the response of the crop trees with minimal attention paid to the surrounding forest matrix. This matrix is comprised of both unreleased trees and of non-crop trees that are partially released when the competitors of crop trees are removed (Fig. 1). While non-crop trees constitute the large majority of trees, few studies have examined either their response to partial release or how their response affects stand dynamics.

Every tree in a fully stocked stand is surrounded by several neighboring competitors. Cutting the trees neighboring a selected crop tree will inevitably cause the inadvertent partial release on two or more sides of several non-crop trees in the upper canopy; i.e., the some of the neighbors of the competitive neighbors are released. Thus, the number of partially released non-crop trees is greater than fully released crop trees and any examination of stand level effects must include non-crop trees.

Whether PCTR was considered beneficial in earlier papers depended on whether the growth and upper canopy persistence of the non-crop trees had been included in an analysis. Unfortunately, there has been a paucity of research that examined the effect of precommercial release on changes at the stand level; and stand level changes necessarily include non-crop trees along with crop trees. Previous research reported thinning 8-yr-old stands to 30% stocking, and repeating the treatment at ages 10, 17 and 22 years, had no lasting impact on composition and mean diameter of the largest 300 stems per hectare in Ohio (Hilt and Dale, 1982). Ten years after treatment, upper canopy composition did not differ between untreated control and precommercial crop tree plots of 12–16-year-old stands in the mid-Atlantic region (Miller, 2000). In a slightly older, 25-yr-old northern hardwood stand, PCTR had no significant effect on species and structural characteristics thirty-one years later (Leak and Smith, 1997).

Despite the aforementioned studies reporting that precommercial manipulation had minimal effect on future stand composition and structure, there has been a resurgence of interest in precommercial crop tree release fostered by the recognition that nearly all of a mature stand's economic value is concentrated in 150 trees per hectare (Miller et al., 2007). Thus, precommercial crop tree management provides a prescriptive tool to enhance the proportion of high quality trees by removing similar-sized trees with defects (e.g., low forks, poor form, cavities) that limit economic value, but do not limit competitive status.

The objective of this study was to examine: (1) how partial release at canopy closure, i.e., at the beginning of the stem exclusion stage, affected subsequent growth and upper canopy persistence of non-crop trees; and (2) examine how precommercial crop tree management affected stand composition and structure. The twenty-five years covered by this study included the critical period of rapid canopy sorting and vertical stratification during the transition from sapling to poletimber stands. Because the trajectory of stand development in upland hardwood forests is largely set by the poletimber stage (Rentch et al., 2009), it is hoped the results of this study will assist forest managers to make informed decisions of whether or not to implement precommercial crop tree management in a given sapling stand.

2. Methods

2.1. Study areas

In 1988, seven study areas were established in western and central Connecticut in sapling stands where canopy closure was complete. Stands were on forests managed by the Division of Forestry, Connecticut Department of Energy and Environmental Protection (Table 1). Three study areas originated after red pine (*Pinus resinosa* Ait.) salvage harvests combined with cutting all residual stems with diameters greater than 5 cm. Remaining areas were initiated using a shelterwood cut followed by a final overstory removal. Greater detail on pretreatment stand structure is described in Ward (2013).

Soils were mesic Typic Dystrudepts; stony to extremely stony; fine sandy loams derived from gneiss, schist, and granite glacial melt-out tills that were acidic to strongly acidic (pH 3.5–6.0) (NRCS, 2016). Elevations ranged from 180 to 320 m above mean sea level. Thirty-year (1981–2010) climatic data were from Hartford, Connecticut centrally located among the plots (NOAA, 2016). The area is in the northern temperate climate zone. Mean monthly temperature ranged from −3 °C in January to 23 °C in July. There were an average of 176 frost free days per year. Average annual precipitation was 116 cm per year, evenly distributed over all months.

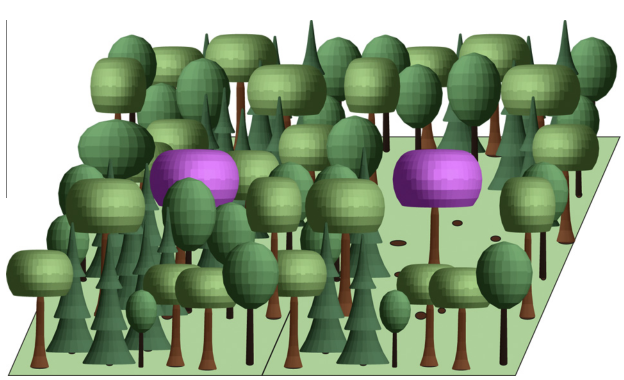

Fig. 1. Crop tree release in sapling stands provides an opportunity to release potentially valuable trees from competition. Crop tree to left was not released.

Table 1
Description of study areas used in precommercial thinning study in Connecticut and median initial size of northern red/black/scarlet oaks in dominant and codominant crown classes.

	Initial stand values					
	Stand age (years)	DBH (cm)	Height (m)	Stocking (%)[a]	Height in 2011 (m)	Site index (m)[b]
Tunxis	7	4.4	6.3	117	17.4	24
Hunter's Mountain	11	4.8	6.9	89	16.3	21
Overlook	12	4.1	5.9	84	15.3	20
Blueberry	12	3.9	5.4	70	16.4	22
Woodchopper	15	6.0	7.5	96	13.8	18
Mott Hill	19	6.8	8.6	100	17.2	20
Rockytop	22	6.7	7.1	102	16.1	18

[a] From Ward (2013).
[b] Site index estimated using stand ages and heights in 2011 with Table 3 in Lamson (1980).

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