EFFECT OF HYDROLOGIC REGIME AND SHADE INTENSITY ON GROWTH OF TWO PLANTING TYPES OF ATLANTIC WHITE CEDAR, *CHAMAECYPARIS THYOIDES*, IN THE CAVALIER WILDLIFE MANAGEMENT AREA IN CHESAPEAKE, VIRGINIA

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Abstract: Reestablishment of *Chamaecyparis thyoides*, cedar, is challenging due to the drought and inundation intolerance of young trees, early site conditions, and differences among planting types. The purpose of this study is to compare morphometric parameters of two tree planting types, propagated seedlings and rooted cuttings, at two locations characterized by hydric and mesic hydrologic regimes. In August 2010 and 2011, survivorship and growth (estimated by height, canopy diameter and stem diameter), and shade intensity were quantified. Growth was greater for rooted cuttings than for propagated seedlings. Shade negatively impacted growth in height, canopy diameter, and stem diameter for both planting types. Hydrologic regimes were classified using PIV and growth in all three morphometric parameters for the mesic hydrologic regime (mean PIV = 3.5) was greater than in hydric plots (mean PIV = 2.6). Reestablishment of cedar may be effective in mesic sites; however, mesic sites may not exhibit saturated soils at times of fire and therefore may lack the self-maintenance capacity found in natural cedar ecosystems.

Key words: Atlantic white cedar, restoration, tree morphometry, prevalence index value, wetland indicator status

INTRODUCTION

Atlantic white cedar, *Chamaecyparis thyoides* (L.) B.S.P. (cedar), is an obligate wetland species (NRCS 2012) which occupies peatland swamps from central Maine to south Florida on the Atlantic Coast and west to Mississippi along the Gulf Coast (Korstian 1924). Since the 1700's, cedar has been economically important and was used as shingles, cooperage, shipbuilding, and fencing, perhaps due to the light weight and rot resistance of the wood (Korstian and Brush 1931, Little 1950). Cedar swamps were logged, ditched and drained in order to obtain the wood and were converted to agriculture, which resulted in a decline of ~98% of cedar populations. Some of the largest stands of cedar were in southeastern Virginia and northeastern North Carolina and restoration efforts are ongoing in the region. The Cavalier Wildlife Management Area (CWMA) is located in southeastern Virginia and the Virginia Department of Game and Inland Fisheries (VDGIF) planted 170,000 young cedar there in 2007. Monitoring of these cedar restoration efforts can aid adaptive management and improve future restoration attempts.

Functional parameters such as survival and growth rates are valuable indicators of restoration success and have been used to characterize community dynamics (McCurry et al. 2010, Sharitz et al. 2006, Beckage and Clark 2003). Tree height is relevant at sites in which shade stress from competing vegetation is a consideration (Battaglia et al. 2000). Basal diameter, or root collar, has been measured when evaluating timber production (McCurry et al. 2010, Chaar et al. 2008). Canopy diameter is of interest with regard to availability of forage material for wildlife (Daubenmire 1959) and the microsite effects of canopy may affect soil properties and vegetative patterns (Stolt et al. 2000, Beatty 1984).

Site wetness is an important variable in cedar ecology and optimum cedar growth coincides with limited root zone saturation and cedar is intolerant of inundation (Allison and Ehrenfeld 1999, Harrison et al. 2003, Laderman 1989, Little 1950). To evaluate site wetness, we used Prevalence index value (PIV), a plot-wise calculation derived from species dominance of herbaceous vegetation and wetland indicator status that has been used to indicate hydrologic conditions, including a study in Great Dismal Swamp National Wildlife Refuge (GDSNWR) (Shacochis et al. 2003). Because of the unique responses of wetland plants to variability in water table dynamics (Magee and Kentula 2005), PIV provides a sensitive indicator of the wetness gradient (Carter et al. 1988, Wentworth et al. 1988, and Scott et al. 1989).

Shade is another important variable in cedar survival and growth. Young cedar may be overwhelmed by competing vegetation such as a closed tree canopy (Laderman 1989), vines such as Greenbriar (*Smilax laurifolia*)(Buell and Cain 1943), and/or several shrub species (Brown and Atkinson 1999).

The purpose of this study was to evaluate survivorship, height, canopy diameter, and basal diameter of two planting types of cedar and determine if one type is superior. Additionally, we also evaluated the effect of hydrologic regime and shade intensity of surrounding vegetation on cedar survival and growth. A concurrent study by Foster et al. (This Volume) in GDSNWR, which lies 5 km west of CWMA, employed a very similar experimental design to the present study, though that study did not test PIV and shade intensity effect on cedar survival and growth.

METHODS

Site Description

The CWMA, located in Chesapeake, Virginia, is a 1,538-ha tract adjacent to the North Carolina state boundary that is maintained by the VDGIF. The property is predominately cutover forest land, with extensive stands of planted Loblolly Pine (*Pinus taeda*). This site is historically part of the Great Dismal Swamp and was ditched and drained more than 200 years ago (Ruffin 1836). According to forestry records, cedar was present at this location (David Norris, pers. comm.). Cedar restoration efforts at CWMA began in 2007 and approximately 265,000 cedar had been planted as of 2009.

Study Design

In May 2010, 180 rooted cuttings from ArborGen® (Arborgen Inc., Bellville, GA) and 180 propagated seedlings from the North Carolina Forestry Service were planted following the study design of Foster et al. (this volume) in ten 10-m^2 plots. Each plot contained 6 rows of 6 trees per row, alternating between rooted cuttings and propagated seedlings, within two portions of cutover forest land that encompassed 1,841 ha (VDGIF 2012). Morphometric data were collected August through December 2010 and August through December 2011.

Morphometric parameters included standard techniques for height, canopy diameter, and basal diameter. Height was measured with a meter stick from ground surface to terminus of the tallest tree branch. Canopy diameter was measured on 3 sides per tree with a meter stick at the widest portion of each tree. Basal diameter was measured at stem base of each tree with Mantax Precision Calipers (Haglof, Inc., Madison, MS).

Percent aerial cover of all plants less than 1 m in height was estimated in three 1-m^2 subplots that were established within a 5-m radius of each 10-m^2 plot. A cover class system adopted from Mueller-Dombois and Ellenberg (1974) was used to determine dominance. Plant identification, taxonomy, and wetland indicator status of plant species followed the NRCS Plants Database (NRCS 2012, table 1) to determine PIV from dominance of herbaceous vegetation. The PIV was used to characterize the hydrologic regime of the study sites.

Table 1. Wetland indicator categories and wetland indicator index used in PIV (prevalence index value) calculations (Environmental Laboratory 2012, NRCS 2012).

Category	Probability of Occurrence in Wetlands	Indicator Status	Wetland indicator index
Obligate wetland	>99%	OBL	1.0
Facultative wetland	67% to 99%	FACW+	1.75
		FACW	2.0
		FACW-	2.25
Facultative	33% to 67%	FAC+	2.75
		FAC	3.0
		FAC-	3.25
Facultative upland	1% to 33%	FACU+	3.75
		FACU	4.0
		FACU-	4.25
Upland	<1%	UPL	5

The PIV was calculated as a form of weighted averaging:

$$\textit{PIV} \text{ for Plot A} = \frac{\text{Species Dominance in Plot A} * \text{Species Indicator Status}}{\text{Total Dominance of All Species in Plot A}}$$

Vegetative shade intensity within a 0.25-m radius circle centered on each tree was estimated via subjective visual inspection and shade scores were assigned using a range of 0 to 3 in which 0 = no shade, 1 = low, 2 = moderate, and 3 = high shade.

Data Analysis

Statistical analyses were performed using SigmaPlot 3.1 (2012). The effect of shade on morphometric growth was determined using a linear regression. Student t-tests ($p = 0.05$) were used to test for differences in height, canopy diameter, and basal diameter of nursery planting types and among hydrologic regimes. Normality was evaluated using the Kolmogorov-Smirnov test.

RESULTS

Survivorship

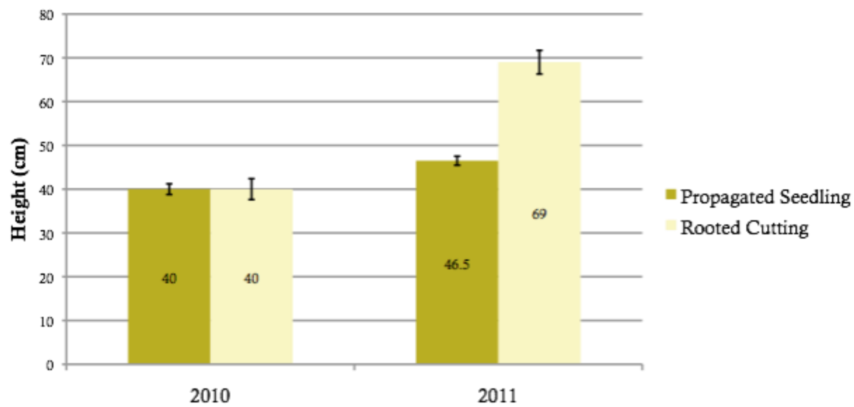
From 2010 to 2011, survivorship of rooted cuttings (78.3%) was similar to propagated seedlings (81.1%). To compare hydrological regimes, planting types were combined and survivorship in the hydric regime (82%) was similar to the mesic regime (78%).

Growth of Planting Types

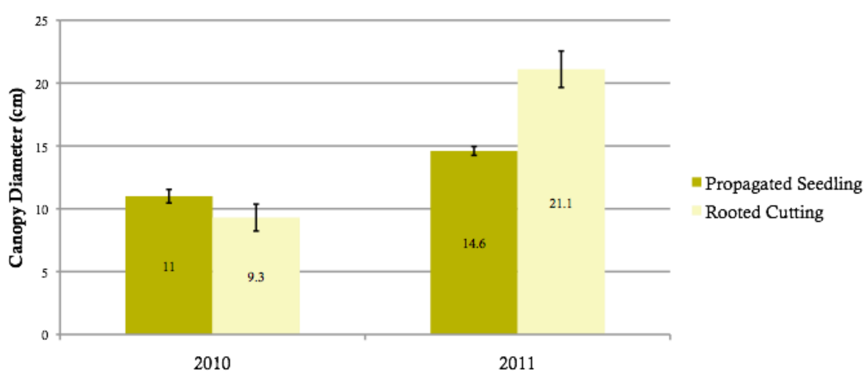
Growth for all three morphometric parameters during 2010 and 2011 was greater for rooted cuttings than for propagated seedlings (figure 1). Height of rooted cuttings (69 cm ± 1.02 cm) was greater than that of propagated seedlings (46.5 ± 2.7 cm, p = 0.001). Rooted cutting canopy diameter (21.1 ±1.45 cm) was greater than that of propagated seedlings (14.6 ± 0.35 cm, p = 0.001); and, basal diameter of rooted cuttings (7.52 ± 0.31 mm) exceeded that for propagated seedlings (6.5 mm ± 0.06 mm, p = 0.001).

Figure 1. Morphometry of planting types in 2010 and 2011 including height (A), canopy diameter (B), and basal diameter (C) with hydrologic regimes combined (± 1 SE).

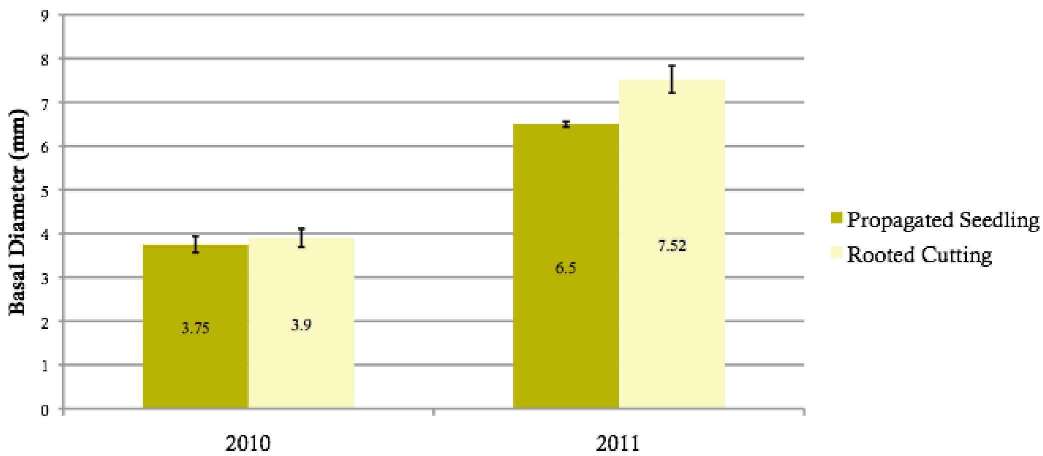
A.



B.



C.

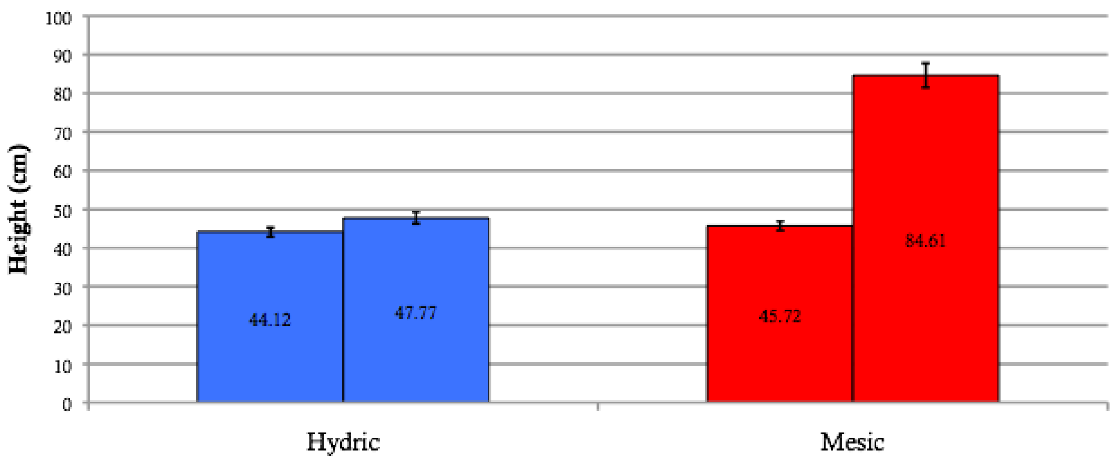


Growth of Planting Types in each Hydrologic Regime

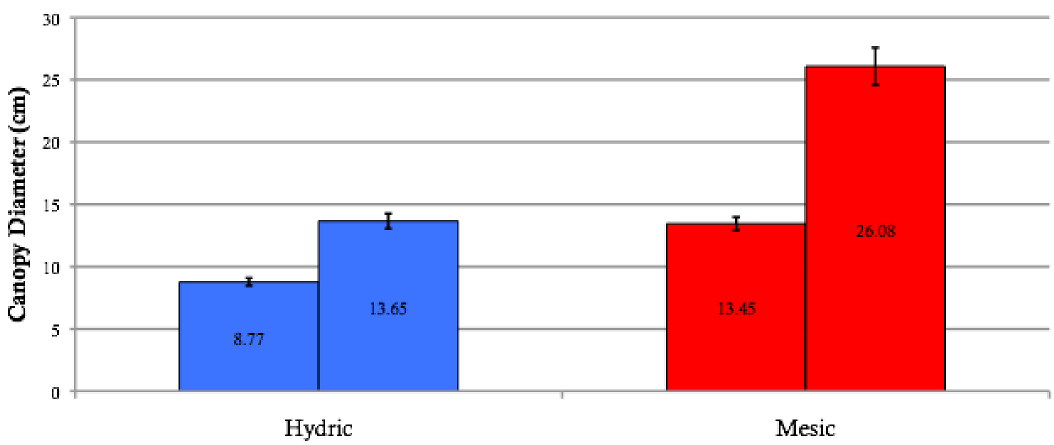
Mean PIV of plots in the hydric hydrologic regime (2.6 ± 0.23) was less than that of plots in the mesic hydrologic regime (3.5 ± 0.24, p = 0.019). With both planting types combined, growth was greater in mesic plots in 2010 and 2011(figure 2). Height in mesic plots (84.61 ± 3.14 cm) was greater than in the hydric plots (47.7 ± 1.52 cm, p = 0.401). Canopy diameter in mesic plots (26.08 ± 1.5 cm) was greater than in the hydric plots (13.65 ± 0.61 cm, p = 0.001); and, basal diameter in mesic plots (9.97 ± 0.29 mm) was greater than in the hydric plots (5.5 ± 0.16 mm, p = 0.001).

Figure 2. Growth (change in morphometric parameter) from 2010 (left bar in pairs) to 2011 (right bar in pairs) with planting type (rooted cuttings and propagated seedlings) combined. Hydric and mesic hydrologic regimes are represented and three morphometric indicators of growth included height (A), canopy diameter (B) and basal diameter (C) of trees.

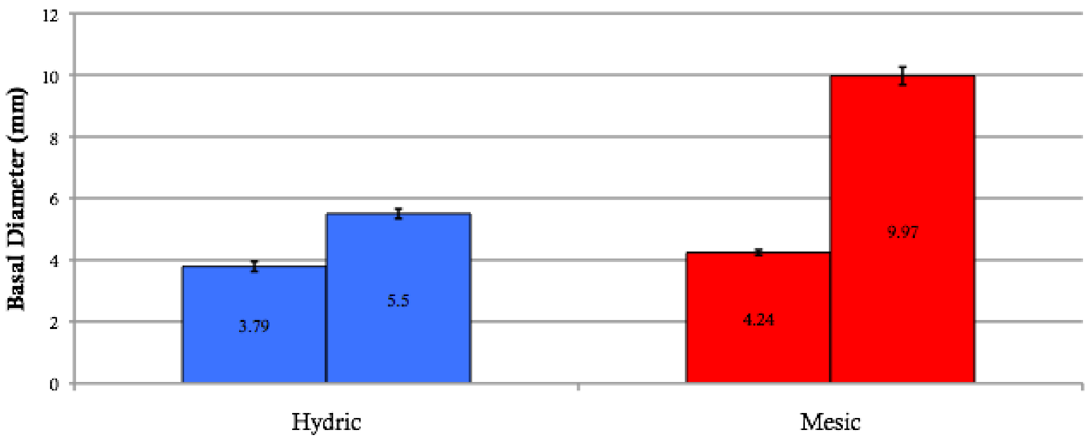
A.



B.



C.



Shade Intensity

Growth was negatively impacted by shade intensity of rooted cuttings for height, canopy, and basal diameter in hydric plots (p = 0.001) and mesic plots (p = 0.001). For propagated seedlings, growth was negatively impacted by shade intensity for height, canopy, and basal diameter in hydric plots ($p \leq 0.001$ for all) and mesic plots (p = 0.065, 0.001, and 0.017, respectively). With planting types combined, average shade score in hydric plots (2.0) was greater than in mesic plots (1.0, p = 0.01).

DISCUSSION

Survival of Cedar

Survival rates were similar among planting types, but differed among hydrologic regimes. When both planting types were combined for analysis, survival was slightly greater in the hydric plots. As an obligate wetland species (Reed 1988), cedar may succumb to desiccation (Akerman 1923, Little 1950) in GDSNWR sites where PIV was above 3 (Foster 2012, Shacochis et al. 2003).

PIV of plots in the hydric water regime (2.6 ± 0.23) was less than the reported values for the three sites in the GDSNWR (PIV = ~3.0) but higher than found in two sites within Alligator River National Wildlife Refuge (PIV = ~2.2, ARNWR) in North Carolina. Correspondence of PIV to water tables is difficult to discern, but the effects of water table on survivorship have frequently been reported. Harrison et al. (2003) summarized survival results for both their study and for a similar study by Mylecraine et al. (2003) stating that lowest mortality can be expected when depth to water table ranges from -5 to -40 cm; and similarly, Cook (2012) reported optimum survival of our two planting types in GDSNWR at a mean depth to water table of -6 cm. Thus, survival results in the current study suggest that our hydric plots may exhibit similar water table depths to those found in cedar stands in GDSNWR and that our mesic plots are drier than GDSNWR stands.

Growth of Cedar

Growth was greater in mesic plots for both planting types. In studies reported by Harrison et al. (2003) and Mylecraine et al. (2003), greater growth was observed in driest conditions (soil surface was as much as 40 cm above the mean water table in those studies). Similarly, Cook (2012) reported that increased growth in height coincided with deeper water tables (drier conditions favored growth). When water tables are deeper (drier), cedar roots may become dry and root stress has been reported for mature cedar in GDSNWR (Rodgers et al. 2003), a condition which might be tolerated if trees possess large root biomass. Foster (this volume) noted that the initial size (including roots) of our rooted cuttings was greater than that for propagated seedlings, and Cook (2012) asserted that the initially greater size of rooted cuttings may have enhanced cedar growth in drier plots.

Among planting types, we found that rooted cuttings generally grew faster than propagated seedlings; however, absolute differences in growth were relatively minor and Seidel (This Volume) found no differences in growth when adjusted for herbivory.

Shade Effects

Shade had a negative effect on growth of rooted cuttings and propagated seedlings. Several authors have reported that shade in young cedar stands can impede and prevent early growth (Brown and Atkinson 1999, Buell and Cain 1943, Laderman 2003). In a study that manipulated light intensity, Belcher et al. (2003) reported that heavy shading was lethal and that full sun increased cedar growth except during June through August, when growth was greatest for trees that received the next highest treatment, 45% full sun. That study also reported a significant increase in root biomass among trees exposed to full sun, which may confer a competitive advantage in relation to water table conditions as discussed previously.

Conclusion and Management Implications

The current study was of relatively short duration and continued investigation would be required to determine if rooted cutting performance continues to exceed that of propagated seedlings; however, this study addresses survival and growth at a critical period in cedar establishment (Korstian 1924, Little 1950). Only minor differences in performance among planting types were detected in this study; therefore, selection of planting materials could be determined by price.

In this study, PIV of non-cedar vegetation was used as a surrogate for hydrologic regime of plots in the CWMA, a restored cedar swamp in Chesapeake, Virginia. While differences in survival were minimal, mesic plots exhibited greater growth; and both responses suggest that the site may be drier than most natural cedar swamps.

Findings from several lines of research in a 4-year study of cedar swamps in southeastern Virginia and northeastern North Carolina characterized risks associated with low water tables (dry conditions) and specified risks of Red Maple (*Acer rubrum*) invasion or peat-consuming fire (Atkinson 2001, Atkinson et al. 2003). PIV was calculated at all sites in that study, and high PIV, similar to values reported here, were reported for GDSNWR (Shacochis et al. 2003). All of the GDSNWR mature cedar stands have been eliminated by subsequent fires and the risk of fire should be a concern at the CWMA. However, the currently low water tables at CWMA may be facilitating cedar establishment in the near term. Gradual increases in water table should be considered in order to reduce the risk of fire and to create conditions characteristic of self-maintaining cedar swamps.

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