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Comparison of 5th- and 14th-year Douglas-fir and understory vegetation responses to selective vegetation removal

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ABSTRACT

The effects of early vegetation management on the survival and growth of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] were examined 5 and 15 years after planting in the Oregon Coast Range. Our first objective was to document the effects of vegetation species competition upon key ecosystem properties. The second objective was to document the effects of vegetation removal during early Douglas-fir stand establishment upon long-term tree growth and on biomass production by vegetation components. Seven levels of manual vegetation removal were maintained for the first 5 years after planting: 0%, 25%, 50%, 75%, and 100% shrub removal; and 100% shrub removal combined with 50% or 100% herbaceous vegetation removal. Shrub and herb removal did not affect Douglas-fir survival at year five, but treatments providing less than 75% shrub removal significantly reduced Douglas-fir survival by year 15. Removing shrubs and herbs completely (100S + 100H) during the 5 years following tree planting allowed successful tree establishment, with a 366% increase in biomass accumulation per hectare for Douglas-fir in that treatment at the end of 14 years of growth. At 15 years stand age, even with shrub removal alone, a 304% gain in tree biomass per hectare was obtained compared to no vegetation removal (NVR). By stand age 15 years, any increase in the degree of understory removal beyond 75% did not contribute significantly to additional tree survival and growth. The understory vegetation on NVR treatment plots and the herbaceous vegetation on 100% shrub removal (100S) treatment plots, contained >90% and >80% of aboveground biomass N at 5 years, respectively, indicating possible competition for soil N. Soil moisture was not different among treatments at 5 years. Complete vegetation removal (100S + 100H) for 5 years resulted in a significant increase in soil bulk density ($P < 0.05$), a significant decrease in total soil C ($P < 0.05$) and no change in total soil N in the upper 15 cm of the mineral soil. By 14 years, however, only the soil bulk density remained greater ($P < 0.05$) on the 100S + 100H treatment. We conclude that greater tree survival and growth occurred with at least 75% shrub removal. Our results suggest that managers may have substantial flexibility in maintaining a partial understory component suitable for ecosystem productivity, canopy cover and wildlife habitat, while maintaining forests productive for timber resources.

1. Introduction

Management of early successional vegetation is important for the success of Douglas-fir plantations in the Pacific Northwest (Wagner et al., 2004; Tappeiner et al., 2007) and has become a routine silvicultural practice (Wagner et al., 2006). Interspecific competition for light, moisture, and nutrients between planted seedlings and surrounding vegetation is believed to be a principal factor affecting the growth and survival of young Douglas-fir plantations (Shainsky and Radosevich, 1992; Harrington, 2006; Tappeiner et al., 2007; Ares et al., 2007, 2008; Zhang et al., 2008; Dinger and Rose, 2009). Early reductions in stand growth associated with competing vegetation are known to reduce long-term growth and yield (Wagner et al., 2004, 2006; Wagner and Robinson, 2006; Newton and Cole, 2008; Harrington and Tappeiner, 2009; Maguire et al., 2009). Forest ecosystem research also indicates that understory retention can increase soil carbon (C) and nitrogen (N), as well as improve long-term tree growth (Busse et al., 1996.) Studies of different forests in other countries also have shown that controlling competing vegetation is essential for successful establishment of forests being managed for timber and for other resources

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(Sternberg et al., 2001; Picon-Cochard et al., 2006; Yildiz and Eşen, 2006; Yildiz et al., 2007; Pitt et al., 2010).

Salmonberry (*Rubus spectabilis* Pursh) is a dominant shrub in the Oregon Coast Range that can fully occupy newly disturbed sites and inhibit the establishment of other plant species (Tappeiner et al., 1991, 2001). Thus, during stand initiation, treatments are applied to release conifer seedlings from competition with salmonberry and other shrubs until seedlings overtop shrubs during the stem exclusion stage (Tappeiner et al., 2007). Early successional vegetation can affect ecosystem processes in a variety of ways. For example, a dense network of salmonberry rhizomes contributes to soil stability, since these rhizomes can occur at depths of 1–2 m on steep slopes greater than 50% (Tappeiner et al., 1991). Shrub removal from a site may weaken root networks that hold the soil mantle together until a cover of trees occurs. Root networks can make the mantle two to three times stronger than those lacking them (Waring, 1986). Shrub canopies help to provide soil protection, in conjunction with canopy cover, from erosion processes (Keim and Skaugset, 2003; Keim et al., 2006).

Ecosystem productivity and nutrient retention generally increase with interspecific differences in resource requirements (Kimmins, 2004). Cole and Newton (1986) examined the effects of grass and red alder (*Alnus rubra* Bong.) competition with Douglas-fir seedlings in three Oregon Coast Range plantations. Presence of a grass understory was associated with a significant increase in phosphorus (P) concentration in five-year-old Douglas-fir foliage (0.133% P without grass vs. 0.143% P with grass). Thus, a mixture of species (e.g., when shrubs and herbs are part of the ecosystem) may provide better utilization of improved site resources.

The importance of understory vegetation in forest ecosystems may far exceed the biomass it represents, by increasing soil C and N resources for long-term tree growth (Busse et al., 1996). Management practices that reduce cover of these pioneering plants can lead to increased nutrient losses, may reduce ecological diversity, and possibly may affect sustainability (Radosevich et al., 2007; Perry et al., 2008). The implication for tree growth of retaining or removing the understory is to maintain a balance between the understory's detrimental effect through competition and its beneficial effects on soil fertility and ecosystem biodiversity (Ares et al., 2010). Such issues are relevant to current discussions concerning the need to maintain forest ecosystem productivity (Fisher and Binkley, 2000; Wagner et al., 2004, 2006; Waring and Running, 2007; Campbell et al., 2009), while promoting ecosystem sustainability (Fox, 2000; Kimmins, 2004; Balandier et al., 2006; Radosevich et al., 2007). The objectives were to document: (1) changes in ecosystem properties through manipulation of understory vegetative species composition, and (2) residual effects of vegetation removal during the early years of stand establishment on the long-term growth of trees and understory vegetation components.

We used measurements at stand ages five and 15 years from a competition experiment employing seven vegetation removal treatments in the central Oregon Coast Range (Wagner and Radosevich, 1998) to compare differences in Douglas-fir survival, growth, and biomass productivity. We tested the following hypotheses: (1) Douglas-fir survival, growth, biomass and stem volume would be lower after 14 growing seasons with no control of competing vegetation, and total aboveground ecosystem biomass also would be lower in the absence of understory vegetation control. (2) Greater aboveground N accumulation by competing vegetation would occur during the first 5 years of stand establishment compared to the subsequent 9 years. (3) Tree leaf area and leaf area index would be greater after 14 years on those treatments having greater removal of competing vegetation. (4) Tree height and diameter would be greater after 14 years where competing vegetation was substantially reduced. (5) Specific leaf area for trees would not differ after 14 years. (6) Foliar N concentrations would be greater after 14 years where competing vegetation was reduced. (7) Stable isotope patterns for $\delta^{13}C$ in tree foliage and in understory plants would show evidence for greater vegetation competition for moisture after 14 years. (8) The $\delta^{15}N$ of tree foliage and in competing vegetation would not change after 14 years due to changes in competition for soil N. (9) Soil C, N and soil bulk density would not be affected by differences in vegetation removal treatments.

2. Materials and methods

2.1. Study sites

The study sites were selected based on vegetation zones and topographic aspect. Two vegetation zones were used: a Sitka spruce [*Picea sitchensis* (Bong.) Carr.] zone that stretches along a narrow band parallel to the Pacific Ocean, and a western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] zone situated several kilometers further inland (Franklin and Dyrness, 1973). The two spruce zone sites are situated about 11 km east of the Pacific Ocean near Lincoln City, Oregon (Erickson-Round site: 44°57′N, 123°52′W, south-facing; Minski-Bald site: 44°58′N, 123°50′W, north-facing). South- and north-facing spruce zone sites are located at 230 and 380 m elevation, respectively. The two hemlock zone sites are located ~19 km east of the Pacific Ocean near Waldport, Oregon and at ~400 m elevation (Tidewater site: 44°24′N, 123°50′W, south-facing; Cannibal site: 44°22′N, 123°53′W, north-facing) (Wagner and Radosevich, 1998; Yildiz, 2000).

The spruce zone sites were clear-cut in 1983 (2 years before planting), but not burned. The north-facing site in the hemlock zone was clear-cut and then subjected to a low intensity prescribed burn in 1978. The south-facing site was clear-cut in 1971 and unsuccessfully regenerated until the experiment commenced.

Both vegetation zones have a mild, wet, maritime climate with more than 180 cm average annual precipitation, most of which occurs during November through May. The climate in the spruce zone is characterized by more summer fog and less variation in precipitation and temperature than in the hemlock zone. Both zones have mild, wet winters and relatively warm, dry summers typically extending through July and late September; the growing season is characterized by 15–20 °C daytime average temperature. The coast is influenced by a maritime climate and narrow seasonal temperature fluctuations, and freezing temperatures are rare. Summers are under the influence of the east Pacific Subtropical High, and are cool and relatively dry (Waring and Franklin, 1979). During drier years, the shallow roots of some herbs, shrubs, and tree seedlings, for example, could experience increased moisture stress, with increased competition for soil moisture.

Soils in these two zones are 1–2 m deep, relatively fertile, and well drained. They are derived from Flournoy sandstone, and are high in soil C and N, but may be low in S (Cromack et al., 1999; Perakis et al., 2006). They have a low bulk density (0.5–0.6 g cm^{-3}) and are highly porous (>20 cm h^{-1} permeability), resulting in a highly permeable soil profile that maintains generally aerobic conditions that favor rapid organic matter turnover and nutrient release (Wagner, 1989). The abundant annual rainfall and deep soil developed from sandstone in these zones provide a substantial available soil water resource for these coastal forests (Waring and Franklin, 1979; Wagner, 1989). Soils in the spruce zone are classified as Typic Haplumbrept. Hemlock zone soils are classified as Pachic Haplumbrept.

2.2. Experimental design

This study used a previously established experiment where early successional vegetation was controlled systematically around