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Twenty-six-year response of ponderosa pine and Douglas-fir plantations to woody competitor density in treated stands of madrone and whiteleaf manzanita

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ABSTRACT

Ponderosa pine (*Pinus ponderosa* Dougl.) grown in mixture with whiteleaf manzanita (*Arctostaphylos viscida* Parry) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) grown in mixture with Pacific madrone (*Arbutus menziesii* Pursh) in southwestern Oregon showed an increase in growth with removal of competing woody cover. Both conifer species had roughly one-third the volume at plantation ages 26–27 when grown with uncontrolled competition compared to where woody competition was completely controlled at age 2. Intermediate levels of competitors usually led to intermediate levels of growth, but this was more evident with Douglas-fir than pine. When competition was reduced or removed, height/age relationships for Douglas-fir at plantation ages 23 and 27 reflected medium site quality rather than low quality as estimated from adjacent stands, indicating that these sites are potentially more productive than perceived with uncontrolled dense woody cover. These studies support the concept that competition management may allow some poor sites of ponderosa pine or Douglas-fir to be managed on the basis of a higher site potential.

1. Introduction

Southwestern Oregon includes several counties in which hot, dry summers and shallow soils lead to sites of low productivity on a large scale. In 1980, the Forestry Intensified Research (FIR) program was initiated by the College of Forestry at Oregon State University to evaluate reforestation options relevant to ponderosa pine (*Pinus ponderosa* Dougl.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) sites in southwestern Oregon where previous attempts at reforestation had resulted in high rates of plantation failure. At that time, a 110,000-ha area of lands was "withdrawn" from the productive base on federal ownerships because it could not be reforested economically following harvest. The FIR Program pursued a research mission to inquire whether future productive potential in coniferous forests might be realized if suitable regeneration could be obtained and maintained (Hobbs et al., 1992). Vegetation and its competing effects were identified as a key constraint. Tesch et al. (1992) described the general problem of need for control of non-coniferous vegetation in the southwestern Oregon climate and terrain in order to obtain survival of conifers. They also outlined some of the unique adaptations of the sclerophyll shrubs and hardwoods toward their own survival, all of which tend to increase their importance as competitors. Zybach (2007) has recently reviewed evidence that activities of native Americans toward meeting their food and game supplies tended to promote the occurrence of sclerophyll communities which limit conifer invasion.

There is a rich literature describing positive responses of planted conifers when comparing growth in weeded versus unweeded conditions in a wide variety of climates and regions (e.g. McDonald et al., 1999; Miller et al., 2003; Rose et al., 2006; Wagner et al., 2006). Growth responses are often quantitatively linked to degree, duration and structure of competing cover, as in McDonald and Abbott (1997). In many of these, partial contributions of herbs versus woody competitors are defined, with herbs tending to have greater relative importance in early years and lower relative importance in later years. Some of the studies have monitored responses for about a decade, but few have extended beyond 20 years (McDonald and Oliver, 1984; McDonald and Abbott, 1997; Zhang et al., 2006). Most reported substantial growth gains in short terms attributable to control of herbs, but in some (but not all) circumstances longer term effects were observed when woody competitors have been removed, as in Miller et al. (2003) in loblolly pine (*Pinus taeda* L.). The importance of competitor dynamics and length of time over which influence

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persists was germane, along with patterns of divergence versus non-increasing effects in decades following treatment.

Our study examined 26–27 years of data from experiments that evaluated effects of density of whiteleaf manzanita (*Arctostaphylos viscida* Parry) on planted ponderosa pine of the same age, and also density of Pacific madrone (*Arbutus menziesii* Pursh) post-burn sprout clumps on planted Douglas-fir. The studies were on sites that were considered too poor to be managed economically for timber production. Specifically, we asked whether there was a quantitative and generalized influence of density of woody competitors on conifer growth over ≥2 decades when established concurrently. Early results of the studies have been reported previously (Ortiz-Funez, 1989; White and Newton, 1989; Hughes et al., 1990; Pabst et al., 1990; Wang et al., 1995; Hanson, 1997).

2. Methods

2.1. Study sites, design, and measurements

2.1.1. Ponderosa pine/whiteleaf manzanita

The ponderosa pine study was conducted on what was perceived to be three very poor sites (Big Humbug, Little Humbug, and China Gulch, each with 600 mm precipitation) near Ruch, Oregon (42°14′N., 123°02′W.) on USDI Bureau of Land Management (BLM) land in the valley of the Applegate River. The study was located on xeric low-elevation sites with west-southwest facing slopes. Soil is a clay loam 60–90 cm deep underlain by moderately weathered metasedimentary rock. Summer climate is hot and dry; water balance deficits are roughly 427 mm by October (Johnsgard, 1963). Hughes et al. (1987), Ortiz-Funez (1989), White and Newton (1989), and Hanson (1997) have reported results from these installations at intermediate ages.

These plantations occurred in three units previously dominated by 40- to 50-year-old whiteleaf manzanita, and not recently occupied by conifers except near roadsides and isolated clumps upslope. In late 1980, the sites were cleared with a brushrake; the brush was piled in windrows and burned in an operational pilot program. In spring 1981, the soil was ripped with a crawler tractor to a depth of 45 cm along planting rows. In those rows, Douglas-fir and ponderosa pine bare-root stock were planted in a 50:50 mixture at a spacing of 3-m × 3-m or slightly closer. To encourage survival, herbaceous competition was controlled for the first 2 years by either spraying with glyphosate (first year) or hexazinone (second year) herbicide while protecting the manzanita (China Gulch) or applying paper mulch mats (Big Humbug and Little Humbug).

Evaluation of shrub density effects was conducted in 0.04-ha plots containing over 30 conifer seedlings per plot and many thousands of manzanita seedlings. Shrubs were thinned to densities of 27,000, 13,500, 6720, 3360, 1700, and 0 (Trees only) shrubs per hectare (sph). Gaps in the shrub distribution were filled by interplanting nearby wildlings. The 13,500 sph density was installed in two plots in each of the three replications for a total of 7 plots per site (replication). Associated woody species, i.e. wedgeleaf ceanothus (*Ceanothus cuneatus* Nutt.), poisonoak (*Toxicodendron diversilobum* (Torr. and Gray) Greene) and sprouting Oregon white oak (*Quercus garryana* Dougl. ex Hook.), were completely removed by herbicide applications for the first 3 years (see White and Newton, 1989). Herbaceous species were also removed for the first 5 years, except for the additional 13,500 plot. This treatment was referred to as 13500HERBS, and herbaceous species were allowed to develop after the first 2 years. The statistical design was a randomized complete block with seven treatments consisting of six levels of manzanita density, one of which included herbs, and three replications.

Trees were thinned to 20 stems per plot (494 tph) at age 6, with the intention of having as close as possible to an even mixture of pine and Douglas-fir. However, heavier mortality in Douglas-fir resulted in some plots having only pine trees. In year 21, one of the replication units (China Gulch) was subjected inadvertently to a mechanical fire hazard reduction treatment to eliminate continuity of fuel. This operation removed all the manzanita in all plots in that replication, and removed some of the remaining conifers. There is therefore an unknown influence of the fire hazard reduction treatment on mean tree size although all remaining individual trees were identified and measured. At age 26, number of pines per plot ranged from 12–20 for the Humbug units and 4–9 for China Gulch.

2.1.2. Douglas-fir/madrone

The study of Pacific madrone, a hardy sclerophyllous hardwood, with Douglas-fir was on BLM land currently classified as Douglas-fir site V (site index$_{50}$ 17 m, King, 1966) within a slash-and-burn administrative study toward the rehabilitation of madrone-dominated sites. The site (Shoestring) was at 650-m elevation with very shallow soil but with 1080 mm precipitation, near Canyonville, OR (42°N., 123°12′W.). Following the burn, the site was planted in December 1979 with 2-year-old (2 + 0) bare-root Douglas-fir on a 2.4-m × 2.4-m or closer spacing. Very little herbaceous cover appeared in the first year, and cover was sparse the second year. The second year after planting, when madrone sprouts were the dominant vegetation and about 2 m tall, we installed a study of competitive influence of density of sprout clumps on planted Douglas-fir of the same age. This study has been reported previously by Hughes et al. (1990), Pabst et al. (1990), and Hanson (1997).

Four madrone densities were replicated with and without retention of associated shrubs and herbs in a 4 × 2 randomized block factorial design on 0.04-ha square plots with three blocks. The densest sprout clump treatment (HIGH) relied on natural spacing in which clump spacing was about 2.7 m × 2.7 m (1372 clumps per hectare (cph)) with no removals. Two other densities were achieved by chemical removal of all other sprout clumps with 2,4-D directed sprays to leave clumps at spacings of 5.5-m × 5.5-m (331 cph; MED) and 7.9 m × 7.9 m (160 cph; LOW). For the fourth treatment (No madrone), all madrone clumps were removed, making four levels of madrone competition ranging from none to unrestricted.

For each level of madrone, there was a factorially combined treatment applied in year 3 in which understory herbs and shrubs were treated (or not) with a directed spray of glyphosate herbicide. The herb treatment did not control evergreen shrubs such as canyon liveoak (*Quercus chrysolepis* Liebm.) effectively, but did give temporary control of herbs and longer term control of poisonoak, deerbrush ceanothus (*Ceanothus integerrimus* Hook. and Arn.), and a few other deciduous species.

Initially, fifteen Douglas-fir seedlings were selected at random in each plot for repeated measurements of growth. At age 13, we thinned the population at that time to a planned level of 20 trees per plot (494 trees per hectare (tph) or 4.5 m × 4.5 m spacing), in all but unthinned-madrone (HIGH) plots, and tagged all trees; the originally tagged trees were retained unless suppressed by other Douglas-firs. We postponed thinning in the densest madrone plots to ensure that we would have a measurable population of conifers in the longer term; there was no obvious indication at that time of imminent intraspecific competition among the conifers in this understory situation, and that condition persisted as of time of last measurement.

2.2. Measurements

Diameters at 15 and 137 cm above ground (where present) of all trees of record were measured in fall each of the first 5 years,