Scientia Silvica Extension Series, Number 45, 2001

Survival and Growth of Planted Seedlings on Woody and Non-Woody Forest Floor Substrates In High and Low Light Environments of Coastal British Columbia

Introduction

In the wetter climates associated with the coastal forests of northwestern North America, coarse woody debris (CWD) accumulations in the form of snags, downed boles, and large branches can be large in natural forest ecosystems. Seedlings often regenerate on stumps and downed logs in the understory of old-growth coastal forests. The question remains though, whether CWD is a necessary component for seedling survival and growth in forests managed for commodity production.

This study addresses one concern of forest managers: is there an immediate nutritional or moisture supply advantage conferred by CWD for the survival and growth of seedlings in the coastal climate of British Columbia? We compared survival and growth of seedlings planted in decaying wood compared to non-woody humus forms and mineral soil under heavy shade and full light conditions. Low light environments are of particular interest since reports of the strong association between CWD and regeneration has primarily referred to understory seedlings and saplings in old-growth forests.

Materials and methods

Three study sites were located north of Vancouver, British Columbia in the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) variant. Each site included a clearcut and an adjacent old-growth stand dominated by Douglas-fir (Df), western hemlock (Hw), Pacific silver fir (Ba), and western redcedar, which were characterized by canopy trees 60 m heigh, 300-750 years old, and 100-200 cm diameter at 1.3m. The understory received only 3% of the sunlight available in the clearcuts. Within each study site, two plots with irregular shapes of about 100 m^2 in area were established: one in the centre of each clearcut and one in each of the adjacent forest understories, located at least 100 m from the edge of the clearcut.

The understory vegetation within each plot was cleared. Three types of soil substrates, CWD of decay class IV and V, non-woody forest floor, and mineral soil (Ahe and Bf or Bhf horizons) were collected nearby each plot and a sample of uniform substrate was put into a 4 L planting pot. One sample of each substrate was taken from each plot to determine its nutrient properties (pH, total C, total N, mineralizable N, extracable P, total SO_4-S, and extractable K, Ca and Mg).

Within each plot, 180 pots were placed together and a berm was constructed around them, with the space between filled in. In the spring, 60 one-year-old container-grown seedlings each of Hw, Ba, and Df were planted in 60 separate pots, with 20 of the pots containing one of the three substrates. A completely randomized layout was used for species and substrates. After two growing seasons, seedling survival surveys were conducted and seedling height, basal diameter and dry weight of leaves, branches, stems, and roots were measured.

Results

Nutrient properties were significantly different among the three substrates ($p < 0.05$), but did not differ between the clearcut and the understory (Table 1). No significant difference in pH was detected between the woody and non-woody substrates, but both were significantly more acid than the mineral soil. The non-woody substrate had significantly greater concentrations of all nutrient measures except extractable Mg. The woody substrate had greater concentrations of total N, mineralizable-N, extractable P, K, Ca, and Mg than the mineral soil. Although, since mineral soil has a bulk density almost six times greater than both woody and non-woody substrates, on a volume basis the differences change. The highest level of nutrients would still be associated with the non-woody substrate (although to a much lesser degree), but the lowest level of nutrients would be associated with the woody substrate.

Table 1. Mean nutrient properties (standard error of the mean in parantheses) of the woody, non-woody, and mineral soil substrates (n = 3). Values with the same letter in the same row are not significantly different ($p < 0.05$).

Nutrient properties	Woody substrate		Non-woody substrate		Mineral soil	
	Clearcut	Understory	Clearcut	Understory	Clearcut	Understory
pH	3.5^{b}(0.1)	3.4^{b}(0.1)	3.9^{b}(0.1)	3.6^{b}(0.3)	4.6^{a}(0.1)	4.9^{a}(0.2)
total C (%)	50.3^{a}(0.9)	50.1^{a}(0.9)	43.5^{a}(2.5)	46.4^{a}(1.7)	4.4^{b}(1.1)	8.1^{b}(5.6)
total N (%)	0.22^{b}(0.04)	0.20^{b}(0.02)	1.09^{a}(0.05)	0.94^{a}(0.22)	0.15^{c}(0.01)	0.09^{c}(0.02)
C:N	239^{ab}(32)	251^{ab} (22)	40^{bc}(1)	57^{bc}(17)	29^{bc}(7)	124^{b}(100)
min-N (ppm)	55^{b}(10)	48^{b}(8)	344^{a}(103)	309^{a}(119)	24^{c}(5)	11^{c}(2)
extractable P (ppm)	24.2^{b}(8.3)	14.1^{b}(6.4)	48.7^{a}(10.5)	60.3^{a}(25.2)	5.7^{c}(4.7)	2.4^{c}(2.1)
total SO_4-S (ppm)	0.30^{b}(0.07)	0.42^{b} 0.03)	2.20^{a}(0.35)	1.62^{a}(0.28)	0.23^{b}(0.05)	0.75^{ab}(0.3)
extractable K (ppm)	21.3^{b}(0.3)	30.3^{b}(2.8)	74.3^{a}(12.1)	133.3^{a}(32)	11.7^{c}(2.2)	5.7^{c}(0.3)
extractable Ca (ppm)	633 (44)	368^{b}(71)	1867^{a}(349)	1023^{a}(328)	70^{c}(15)	37^{c}(2)
extractable Mg (ppm)	133.3 (7.3)	161.7^{a}(29)	203.3^{a}(16)	211.7^{a}(21)	8.7^{b}(0.7)	5.3^{b}(1.5)

The effect of light conditions and rooting substrate on survival varied significantly among the three species ($p < 0.05$; Figure 1). Df survival was significantly higher in clearcuts than in the understories, but was not affected by substrate. Survival of Hw was also not affected by substrates but was significantly higher in the understories. Survival of Ba was significantly lower on woody substrates in the clearcuts than in the understories but not different among other variables.

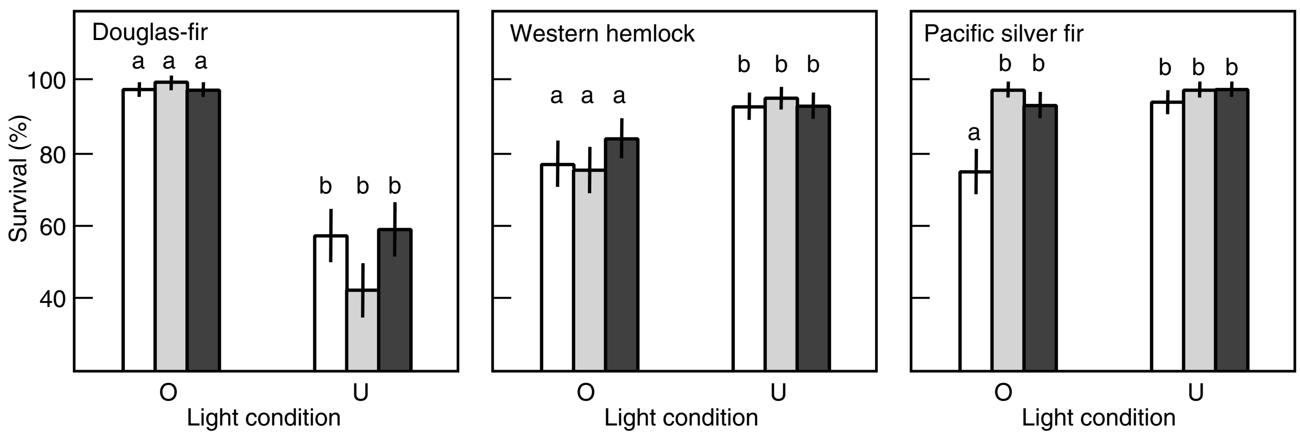

Figure 1. The effect of light condition (U - understory and O - clearcut) and substrate on survival at the end of the second growing season. Within each set the bars from lighter to darker represent woody substrate, non-woody substrate, and mineral soil. Error bars represent 1 standard error of the mean. Values with the same letter are not significantly different ($p > 0.05$).

After two growing seasons, surviving seedlings had significantly different growth rates (Figures 2 and 3). The diameter, height, and total biomass of Df and Hw seedlings were significantly smaller in the understories than in the clearcuts. The effect of light on diameter and height growth in Ba was less pronounced than that for Df and Hw, but total seedling biomass was smaller. In the understory, no significant differences were detected for any measure between the substrates for the three species. The clearcut was completely different: Df seedling diameter, height, and total biomass were significantly greater in the non-woody substrate compared to the woody substrate; but significant differences were not detected for substrate with respect to diameter. Hw seedling diameter, height, and total biomass were greatest in the non-woody substrate, but there were no differences in the woody substrate *versus* mineral soil. Ba seedling diameter and height were significantly greater in the non-woody, but significant differences were not detected between woody substrate *versus* mineral soil. However, there were significant differences in total biomass between the three substrates.

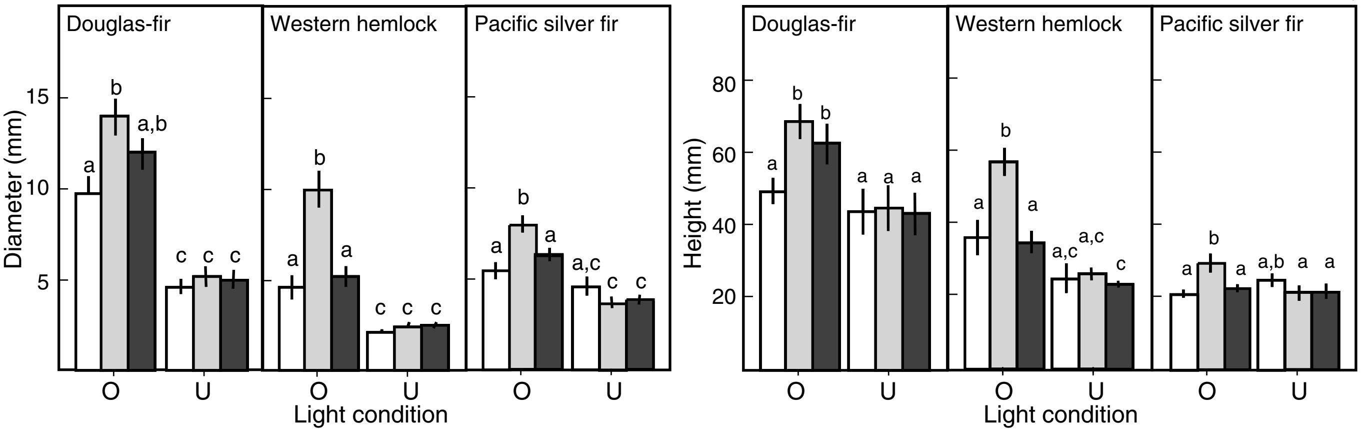

Figure 2. Root collar diameter and total height of planted seedlings in relation to light condition (U - understory and O - clearcut) and substrate at the end of the second growing season. Within each set the bars from lighter to darker represent woody substrate, non-woody substrate, and mineral soil. Error bars represent 1 standard error of the mean. Values with the same letter are not significantly different ($p > 0.05$).

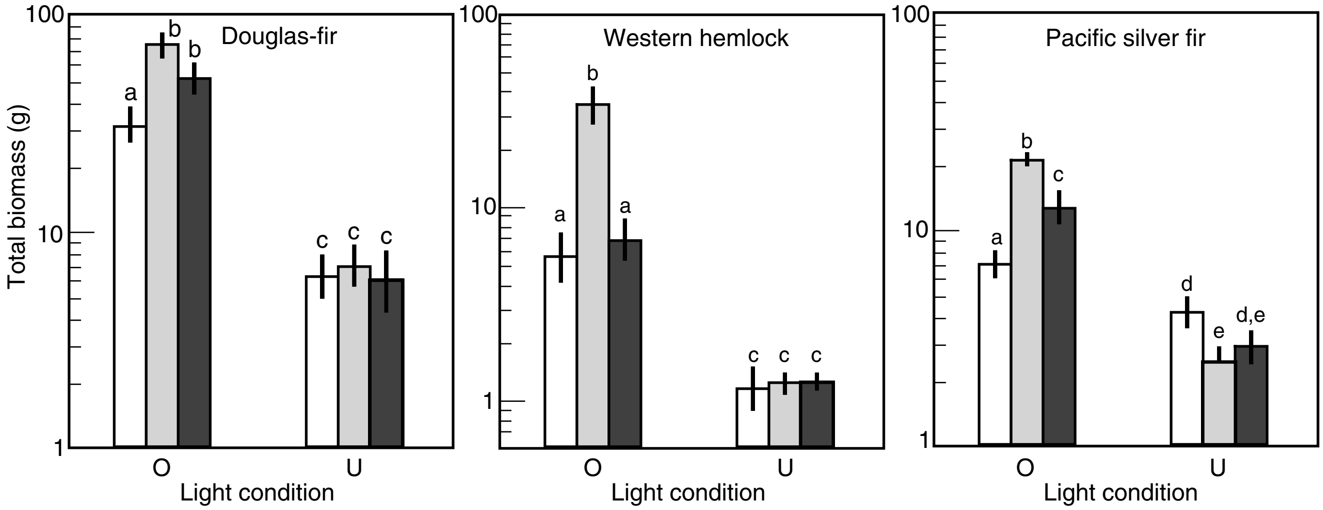

Figure 3. Total biomass of planted seedlings in relation to light condition (U - understory and O - clearcut) and substrate at the end of the second growing season. Within each set the bars from lighter to darker represent woody substrate, non-woody substrate, and mineral soil. Error bars represent 1 standard error of the mean. Values with the same letter are not significantly different ($p > 0.05$).

Discussion

The location in the summer wet climate of the CWHvm1 variant presumably eliminates moisture as a factor in substrate advantage to seedling survival and growth. There was no indication that the summer weather during the trial period was unusual. However, the small volume planting pots may have influenced moisture availability associated with the three different substrates.

Except for Ba, substrate did not appear to influence seedling survival after two growing seasons. Seedling growth was substrate-dependent in the clearcut but not under shade. In the open, Hw and Ba grew best in the non-woody organic substrate. This relationship was positively correlated with the nutrient measures of the substrates on a mass basis. When expressed on a volume basis, the mineral soil has greater nutrient availability compared to the woody substrate. Thus the growth of all three species does not strictly follow the nutrient availability of the three substrates. There was no growth trend between open-grown seedlings in the non-woody organic substrate compared to the mineral soil. Comparing open grown seedlings in the woody and non-woody organic substrates, growth was related to nutrient availability of the substrates.

Nutrient measures for woody and non-woody substates on a mass basis are comparable since the bulk densities of decay class IV and V wood are similar to non-woody humus substrates.

CWD may not be important to tree growth in the short term compared to non-woody humus substrates on sites with sufficient moisture in coastal BC. However, this does not rule out other indirect values. CWD may be important for tree survival and growth in one or more or the following indirect roles:

1. CWD may sequester nutrients through fungi and wood-inhabiting invertebrates, and return the nutrients to the forest floor through spores and waste.
2. Decayed wood may provide habitat and refugia during periods of drought for mycorrhizae and invertebrates, which may be necessary for nutrient cycling.
3. CWD may provide a better seedbed than non-woody organic forest floor substrates due to the lack of herb and moss competition, or lack of seed pathogens on CWD.
4. If small mammals are necessary to disseminate some mycorrhizal spores, then maintaining the structural habitat component for small mammals becomes critical.

Conclusions

CWD does not provide any advantage for seedling growth in the wetter climates of south coastal BC, on sites without a water deficit or excess. The non-woody humus substrate provides greater availability of nutrients and increased growth. The non-woody humus layer is by far the most important organic material to maintain after any logging practice. On the other hand, CWD is not as poor a substrate for seedling growth as implied by its high C:N ratio, lower nutrient content, and recalcitrant lignin composition. Decay class IV and V wood is as good as mineral soil for the growth of Hw and Ba seedlings. Df, however, does not grow as well in woody substrates compared to non-woody organic substrates and mineral soil. When seedlings are established under shaded conditions, rooting substrate appears to have no effect on growth.

Reference

Kayahara, G.J. 2000. The effect of coarse woody debris on site productivity of some forest sites in southwestern British Columbia. Ph.D. Thesis, University of British Columbia, Vancouver, BC. 123 pp.

Scientia Silvica is published by the Forest Sciences Department,
The University of British Columbia, ISSN 1209-952X

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