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The Association Between Western Hemlock Fine Roots and Woody *versus* Non-Woody Forest Floor Substrates in Coastal British Columbia

Introduction

In the wetter climates associated with the coastal forests of the Pacific Northwest, coarse woody debris (CWD) accumulations in the form of snags, downed boles, and large branches can be large in natural forest ecosystems. Although maintaining organic matter for sustainable site productivity is not in dispute, the importance of CWD as a source of soil organic matter is questionable. Forest managers attempting to optimize timber production need to know how CWD affects short-term forest tree growth and productivity. This study addresses the question of the immediate value of CWD for growth of mature (90 year old) western hemlock (Hw). Because of practical difficulty with mature trees growing in different substrates, we utilized fine root distribution or proliferation, as an indicator of important substrates.

Roots in higher plants tend to proliferate in locally rich patches of water or nutrients. Root proliferation can thus be used to test the relative importance of CWD compared to non-woody forest floor substrates and to mineral soil for tree survival and growth. In this study we test the importance of CWD for mature trees in the summer-wet cool mesothermal climate of coastal BC. The objective was to investigate whether the fine roots (<2 mm diameter) of mature Hw proliferate to a different degree in different rooting substrates. Hw was chosen since it is most strongly associated with CWD. If root growth is greater in CWD compared to other substrates, this implies that CWD provides an immediate benefit as a moisture and/or nutrient source.

Study Stands and Methods

We investigated how two humus forms (Mors and Moders) and the adjacent CWD substrates affected root proliferation. The soil moisture regime of sites with Mors were identified as fresh; sites with Moders were fresh to moist. Three areas in the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) variant were sampled: the Capilano watershed north of Vancouver, the Malcolm Knapp Research Forest east of Vancouver, and southeastern Vancouver Island. In order to isolate only Hw roots, the study sites were second-growth, naturally regenerated stands approximately 90 years old, with > 70% Hw cover. The closed canopy shaded out most herbs and all shrubs.

Six sites were sampled within each area: three sites each with Mor and Moder humus forms, for a total of 18 sample sites. Within each stand a sampling site of approximately 100 m² was selected containing only Hw, and having a Hw growing upon a class II downed log (the log is elevated on support points with intact to partly soft wood) in the centre. Sampling locations were selected as follows (Figure 1):

- **i** A Hw tree or sapling growing on class II log was plot centre. Two locations approximately 2-4 m from each side of the tree along the log were sampled;
- **ii** From the centre tree, as close as possible to a 90° angle from the log, another two locations (one on each side) containing a decay class IV or V log (these classes of decayed wood form a mound on the ground with small soft blocky pieces or a soft powdery texture) were sampled. These sampling locations were 2-4 m away from a hemlock tree; and
- **iii** The prevalent non-woody humus form was sampled from two locations as close as possible to location **ii**.

An exact distance and angle was not possible but the closest point criterion prevented observer influence. The substrates sampled were (a) non-woody humus form over mineral soil; (b) the mineral soil under the non-woody humus form; (c) non-woody humus form over the decay class II log; (d) the decay class II log; (e) non-woody humus form over the decay class IV or V wood; and (f) the decay class IV or V wood (Figure 1).

Home

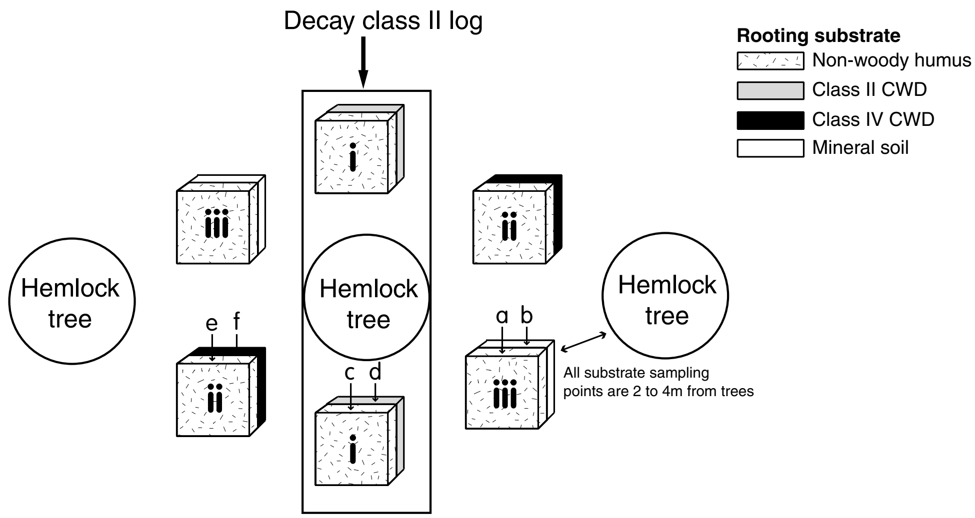

Figure 1. Layout showing the sampling locations (i,ii, iii). Two substrate samples were collected per location (a to f).

Root density was determined by excavating from 750 to 1500 cm^3 of each respective substrate, and collecting the substrate and associated fine roots from the hole. The volume of the hole was determined using 2 mm diameter glass beads. For each substrate, two holes were excavated at each sample point (*i.e.*, two holes for each of the six sampling points). Roots were washed and separated according to size class and then oven dried at 65°C to constant weight. The density of the fine roots was expressed as $mg{\cdot}cm^{-3}$ calculated from the volume of sample cores. The mean density of the four sample cores for each substrate was used for statistical analyses. Chemical analyses for each substrate determined pH, total C, and N-related properties. Statistical analyses for the density of fine roots and chemical properties were done separately for each of the humus forms.

Results

Significant differences ($p < 0.001$) in mean values for root density were detected between the different substrates within both humus forms. Root densities were stratified into six classes: three classes representing the LFH layers, two classes representing the two CWD decay classes and one class representing the mineral soil sampled (Table 1; Figure 2). Root density was approximately two to three times greater in the non-woody LFH substrates compared to the CWD and mineral soil. Significant differences ($p < 0.001$) in mean values for all chemical measures were detected between the different substrates within both humus forms (Table 1). Total N, C:N ratio, and mineralizable-N data were stratified into the same six classes (Figure 3). With some exceptions, two groups were distinguished: a very strong group of the non-woody LFH layers and a weaker group of the CWD and the mineral soil.

Table 1. Means and standard errors (in parentheses) of root density and chemical measures within the Moder and Mor humus forms between the rooting substrates (n=3). LFH = non-woody humus form; log II = decay class II log; log IV = decay class IV/V wood. Values with the same letter in the same row are not significantly different ($p > 0.05$).

Root or substrate characteristic	Rooting substrate					
	LFH on mineral soil	LFH on log II	LFH on log IV	log II	log IV	mineral soil
Moder humus form						
root density (mg cm^{-3})	2.86^{a} (0.56)	3.71^{a} (0.82)	3.87^{a} (0.44)	1.41^{b} (0.31)	1.27^{b} (0.36)	1.40^{b} (0.37)
pH	3.87^{b} (0.13)	3.39^{c} (0.07)	3.41^{c} (0.09)	3.40^{c} (0.10)	3.34^{c} (0.06)	4.43^{a} (0.06)
total-C (%)	44.18^{b} (6.15)	58.68^{a} (2.27)	57.15^{a,b} (2.45)	61.14^{a} (1.23)	59.44^{a} (1.19)	7.78^{c} (1.13)
total-N (%)	1.614^{a} (0.131)	1.660^{a} (0.054)	1.599^{a} (0.105)	0.270^{c} (0.012)	0.442^{b} (0.018)	0.341^{b,c} (0.068)
C:N	27.6^{c,d} (2.3)*	35.5^{c} (2.6)	37.3^{c} (5.0)	247.8^{a} (12.9)	139.2^{b} (2.2)	23.3^{d} (1.9)
mineralizable-N (ppm)	467.64^{a} (51.53)	447.09^{a} (39.40)	459.92^{a} (66.77)	40.37^{c} (6.54)	65.19^{b,c} (8.59)	95.96^{b} (33.39)
Mor humus form						
root density (mg cm^{-3})	5.66^{a} (1.05)	4.44^{a} (0.30)	5.40^{a} (0.82)	1.90^{b} (0.31)	2.09^{b} (0.56)	2.47^{b} (0.64)
pH	3.56^{b} (0.09)	3.44^{b,c} (0.11)	3.35^{b,c} (0.08)	3.23^{c,d} (0.04)	3.06^{d} (0.08)	4.13^{a} (0.18)
total-C (%)	55.73^{a} (0.83)	52.47^{a} (5.07)	56.44^{a} (0.96)	59.59^{a} (2.22)	60.24^{a} (1.91)	3.85^{b} (0.89)
total-N (%)	1.373^{a} (0.067)	1.341^{a} (0.107)	1.391^{a} (0.011)	0.302^{b} (0.057)	0.357^{b} (0.080)	0.110^{c} (0.040)
C:N	41.0^{b} (2.1)	41.2^{b} (7.9)	40.9^{b} (0.9)	220.6^{a} (52.2)	189.0^{a} (34.9)	38.9^{b} (3.1)
mineralizable-N (ppm)	445.91^{a} (22.24)	322.49^{a} (47.07)	380.42^{a} (21.82)	35.01^{b,c} (18.43)	38.72^{b} (10.19)	19.21^{c} (9.98)

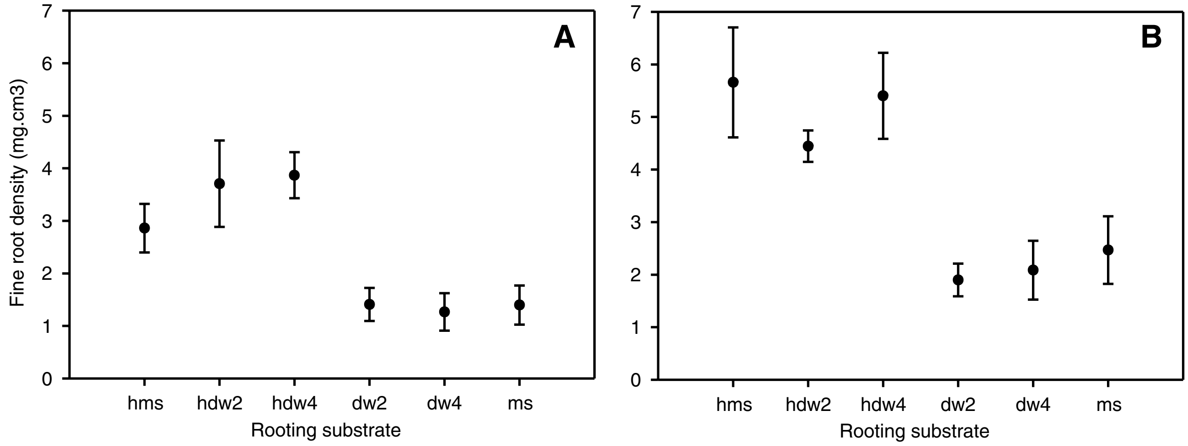

Figure 2. Plot of the mean and standard error of the fine root density associated with each rooting substrate. (A) is the Moder humus form, and (B) is the Mor humus form. For the rooting substrate: hms = LFH over the mineral soil, hdw2 = LFH over the decay class II log, hdw4 = LFH over the decay class IV log, dw2 = decay class II log, dw4 = decay class IV log, and ms = upper 10 cm of the mineral soil under the LFH substrate.

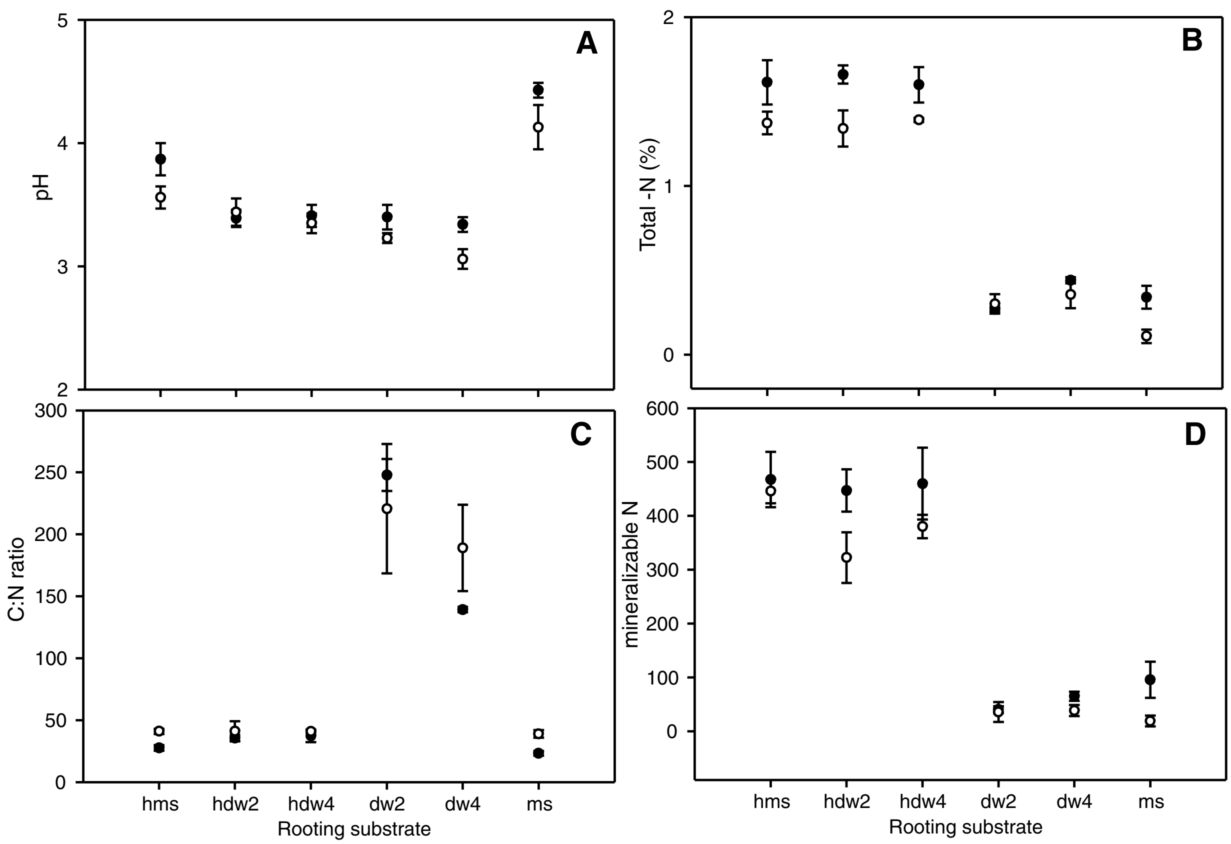

Figure 3. Plot of the mean and standard error of (A) pH, (B) total-N, (C) C:N ratio, and (D) mineralizable-N associated with each rooting substrate. The Moder humus form is represented with solid circles and the Mor humus form with hollow circles. The acronyms for the rooting substrates are: hms = non-woody humus form over the mineral soil, hdw2 = non-woody humus form over the decay class II log, hdw4 = non-woody humus form over the decay class IV log, dw2 = decay class II log, dw4 = decay class IV log, and ms = upper 10 cm of the mineral soil under the non-woody humus form.

Considering the three nitrogen measures (total-N, C:N ratio, and mineralizable-N), there was a general pattern for both humus forms. Mean values for the non-woody LFH layer were consistently significantly different from the two decay classes but with no significant differences detected among the three non-woody LFH layers. For both humus forms, the two CWD decay classes and the mineral soil showed different groupings for nitrogen measures.

Home

Discussion

According to the root proliferation hypothesis, CWD appears to provide little immediate benefit to tree growth in the presence of non-woody humus forms on sites without a water deficit. Since the climate of the areas used in this study does not typically have a long dry growing season, and the study sites did not have a soil water deficit, the moisture value of CWD can be disregarded for this study. Root proliferation generally follows the nutrient content of the substrates.

Conclusions

If root proliferation is accepted as a good indicator of substrates that benefit tree survival and growth, then CWD has less short-term value to trees compared to non-woody humus substrates on sites without a water deficit in the summer-wet climates of coastal BC. Despite the strong association of seedlings and saplings with CWD, there appears to be no relationship between CWD and tree productivity.

Reference

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

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