Spatial extent of impact of red alder on soil chemistry of adjacent conifer stands

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We examined patterns in soil N availability and pH along transects extending from mixed stands of conifers (mostly Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)) and red alder (*Alnus rubra* Bong.) to pure conifer stands at two locations. At the relatively infertile Wind River site, increased N availability was apparent for about 8–12 m downslope of the alder–conifer stand, but no effect was apparent upslope. At the fertile Cascade Head site, no trend was apparent in N availability across the stand boundaries, but soil pH in the conifer stand was depressed for about 5 m from the alder–conifer stand. Overall, the effects of alder on soil chemistry appeared limited to a distance of less than half the height of the trees.

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Nous avons examiné à deux endroits différents les variations de la disponibilité en azote (N) dans le sol et du pH le long de transects allant de peuplements mélangés de conifères, surtout du Douglas taxifolié (*Pseudotsuga menziesii* (Mirb.) Franco), et d'aulne de l'Orégon (*Alnus rubra* Bong.) à des peuplements purs de résineux. Dans la station relativement peu fertile de Wind River, l'augmentation de la disponibilité en N était évidente jusqu'à une distance d'environ 8 à 12 m du peuplement mélangé vers le bas, mais pas vers le haut de la pente. Dans la station fertile de Cascade Head, aucune tendance dans la disponibilité en N n'était évidente au-delà des limites du peuplement, mais le pH du sol diminuait jusqu'à une distance d'environ 5 m du peuplement mélangé. Dans l'ensemble, les effets de l'aulne sur la chimie du sol semblaient limités à une distance inférieure à la moitié de la hauteur des arbres.

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Introduction

The influence of N-fixing trees on productivity within mixed-species stands is highly variable across species and sites (Binkley 1991), and little is known of the effect of N-fixing trees on the growth and biogeochemistry of adjacent stands. In a study at the Wind River Experimental Forest in western Washington, R.E. Miller and D. Reukema (to be published) related conifer size to distance from a strip of N-fixing red alder (*Alnus rubra* Bong.) interplanted in a Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) plantation. The diameter, height, and stem volume of Douglas-fir were increased up to 15 m away from the alder–conifer strip. The band of trees showing improved growth was wider and more irregular downhill from the alder–conifer strip than uphill. These authors suggested that flow of subsurface N-rich water from the alders may have been responsible for the slope-related effect. Their study prompted us to examine patterns in soil chemistry in conifer stands in relation to distance

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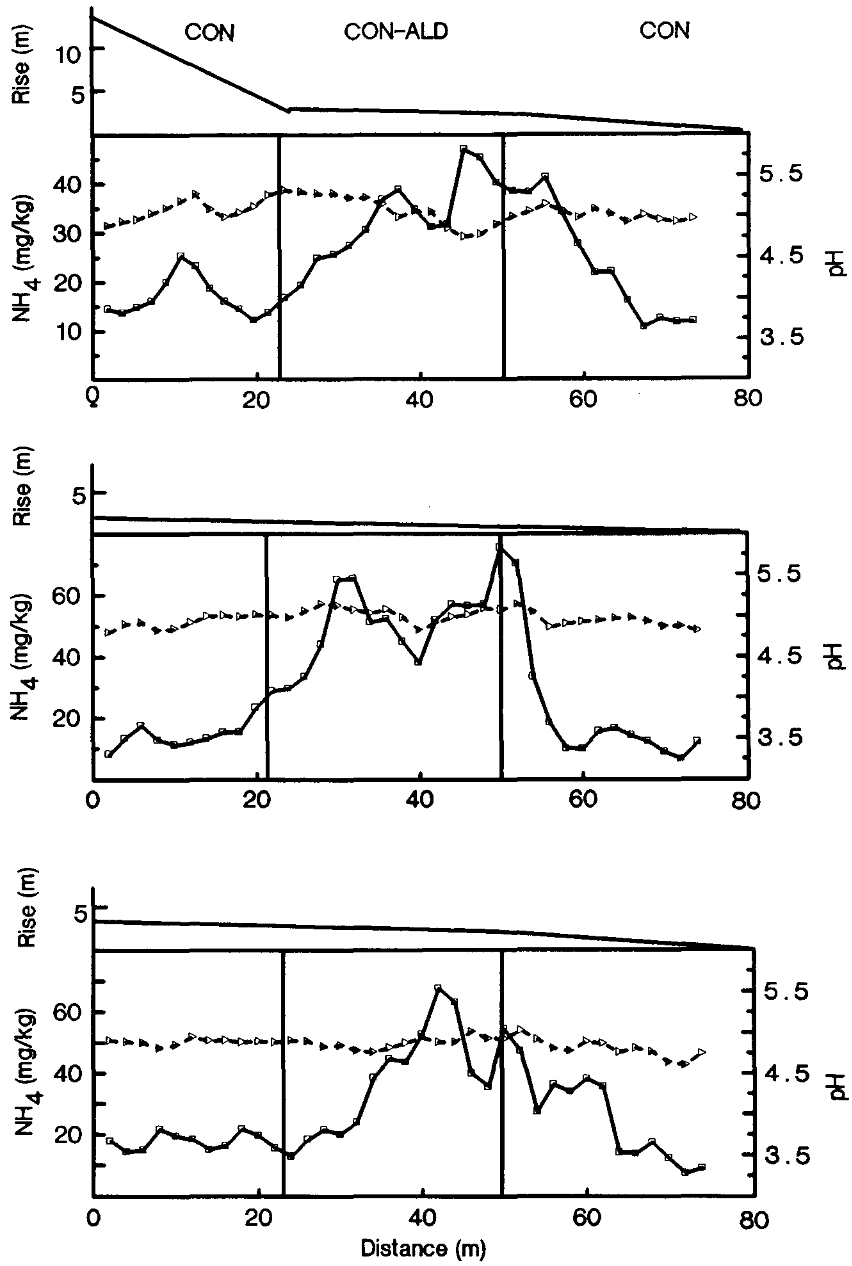

FIG. 1. Pattern of anaerobic-N index (solid line) and pH (broken line) across three transects in the alder–conifer strip at Wind River. Rise is the change in elevation along each transect.

from alder–conifer stands. We mapped soil pH and an index of soil N availability along transects across the alder–conifer strip at Wind River to see how far the influence of N-fixing red alder extended into the adjacent Douglas-fir stand. We also repeated the sampling at the Cascade Head Experimental Forest in western Oregon. We had previously examined differences in averages among these stands (Binkley and Sollins 1990; Binkley *et al.* 1992*a*, 1992*b*), but had not examined the spatial pattern of influences between the stands.

Methods

At Wind River, the species mixture consists of a 20 m wide strip of red alder interplanted in a plantation of Douglas-fir (Tarrant and Miller 1963). Douglas-fir site index is about 25 m at 50 years without alder; the heights of alders ranged between about 20 and 25 m in 1985 (D. Binkley, unpublished data). Aboveground net primary production is about 4.8 $Mg \cdot ha^{-1} \cdot year^{-1}$ in the Douglas-fir stand, compared with 10.3 $Mg \cdot ha^{-1} \cdot year^{-1}$ in the alder–conifer stand (Binkley *et al.* 1992*a*). The soil is an infertile Andic Haplumbrept (Miller and Tarrant 1983). The Cascade Head site is more fertile, with a site index of 40 m at 50 years for Douglas-fir on a Typic Dystrandept soil (Binkley and Sollins 1990). A pure conifer plot (about 40 by 80 m) was established in 1935 by cutting all red alder trees from a naturally regenerated mixed conifer and alder stand (Berntsen 1961). Alder was retained in the mixed species stand surrounding the Douglas-fir plot. The heights of alder trees ranged between about 23 and 28 m (D. Binkley, unpublished data). Aboveground net primary production for the conifer stand is about 19.2 $Mg \cdot ha^{-1} \cdot year^{-1}$, compared with 10.7 $Mg \cdot ha^{-1} \cdot year^{-1}$ in the alder–conifer stand (Binkley *et al.* 1992*a*).

Soils were sampled every 2 m along transects passing through the alder–conifer strip at Wind River and through the pure conifer plot at Cascade Head in November of 1990. Each transect stretched 20 m

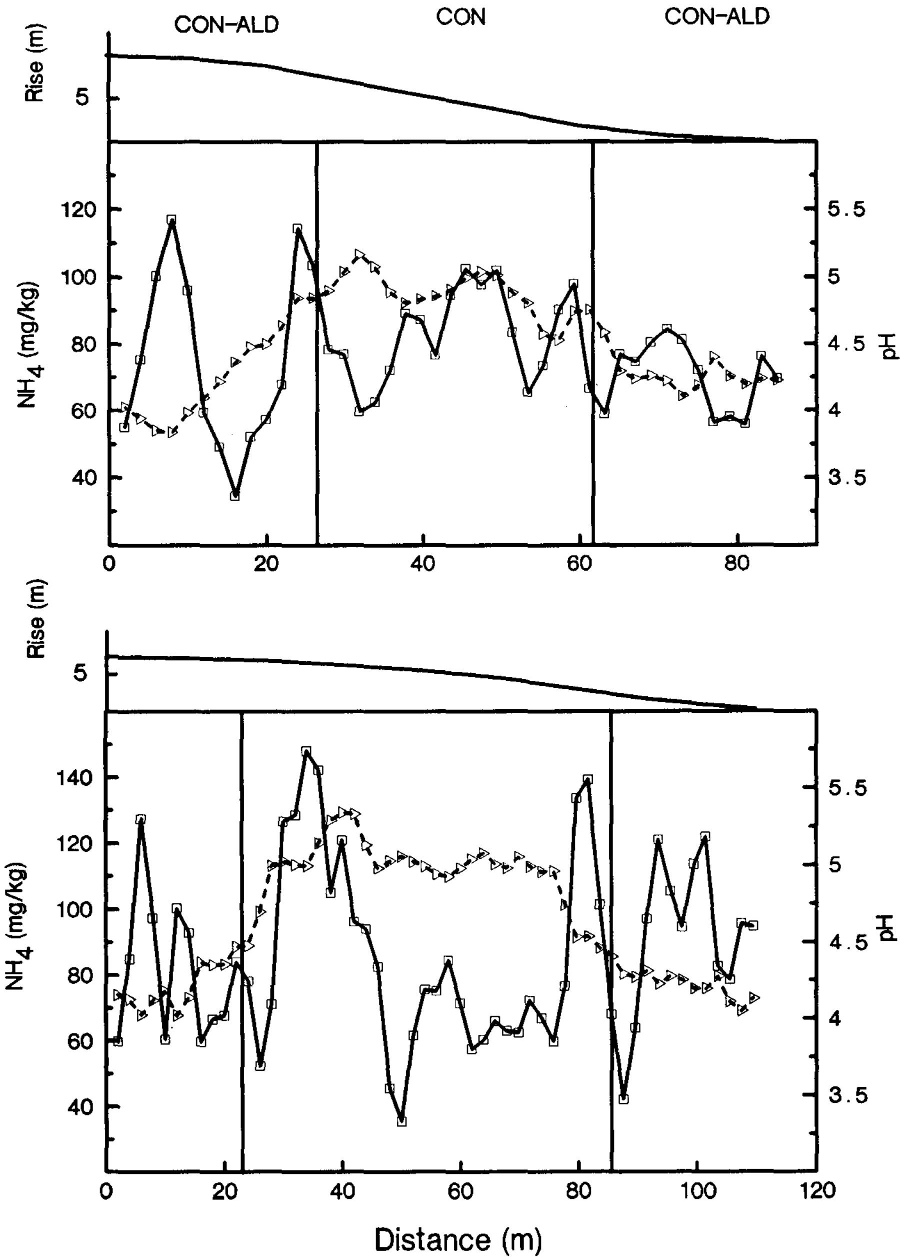

FIG. 2. Pattern of anaerobic-N index (solid line) and pH (broken line) across two transects in the conifer plot at Cascade Head. Rise is the change in elevation along each transect.

beyond the border of the strip or plot to enable us to map gradations across stand edges. At Wind River, three transects were sampled 50–80 m apart, each perpendicular to the alder–conifer strip. Two transects at Cascade Head started in the mixed stand and passed through the pure Douglas-fir plot; one parallel to the slope and the other perpendicular to the slope. At each location on the transects, three soil cores of the 0.0–0.15 m mineral soil (Ah horizon) were composited and mixed, and coarse roots were removed. Samples were kept in a cooler at about 4°C for several days and then air dried prior to analysis.

Anaerobic incubations used 10 g of air-dried soil and 50 mL of deionized water, incubated at 40°C for 7 days (Keeney 1982). We chose anaerobic incubations for simplicity and because previous comparisons among methods in these stands showed close correspondence between anaerobic incubations and other methods (Binkley *et al.* 1992*b*). After incubation, 50 mL of 4 M KCl were added, and samples were shaken, filtered, and analyzed for ammonium N using a Lachat flow injection spectrometer (Latchat Instruments 1988). Soil pH was measured with a glass electrode in a well-mixed slurry with 5 g of air-dried soil and 10 mL of deionized water.

Results

At Wind River, anaerobic-N levels ranged from less than 10 mg/kg of dry soil to nearly 80 mg/kg. A sharp increase in anaerobic-N levels corresponded to the alder–conifer strip (Fig. 1). Within the strip, anaerobic N averaged 33 mg/kg across all three transects, compared with 17 and 24 mg/kg on each side of the strip. Slope strongly influenced the extent of increased N availability into the adjacent stands. Alder had no effect on N levels uphill from the strip, but increased N availability for about 8–12 m downslope. At Cascade Head, available N levels exhibited no clear pattern along the transects (Fig. 2). The longer transect showed some decline in N availability near the middle of the conifer stand, but no clear extent of alder influence was discernible.

No pattern emerged for soil pH along the Wind River transects (Fig. 1); pH in water was relatively constant across each transect, though the pH differed among transects (from 4.8 to 5.2). At Cascade Head, soil pH was higher in the conifer stand (Fig. 2), averaging about 5.0 compared with 4.3 for the alder–conifer stand. The pH effect of adjacent stands extended about 5 m beyond the stand edges at Cascade Head. The extent of the alder effect on pH appeared unrelated to topography.

Conclusions

Alder increased available soil N for 0–12 m into adjacent conifer stands, depending strongly on slope. The maximum distance is less than half the height of the alder trees. The extent of increased N availability downhill from the alder–conifer strip at Wind River was somewhat shorter than the distance of increased stem size reported by R.E. Miller and D. Reukema (to be published). Their sampling occurred at intervals of 15 m from the edge of the strip, giving low resolution for effects that extend only a few meters. The relationship between slope and extent of increased availability of N are consistent with two mechanisms: subsurface flow of N in solution and downhill transport of N-rich alder litter. The lack of an alder effect on soil N uphill from the alder–conifer strip also agrees with the thin, abrupt transition in Douglas-fir size (R.E. Miller and D. Reukema, to be published). At Cascade Head, where available soil N was 3 times greater than at Wind River, any increase in N availability associated with the alder was swamped out by variation around high average soil N levels along the transects. Soil pH varied with species only at the fertile Cascade Head site, and the pattern appeared unrelated to topography.

Our findings emphasize the importance of both the magnitude and spatial extent of alder-induced differences in soil chemistry. The extent of alder influence appeared quite limited, extending less than half of the height of the trees; this generalization needs more extensive testing.

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