Forest Fuel Chipping Effects on Soil Microbial Communities

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Background

Over 100 years of fire suppression and over grazing by cattle have shifted the ponderosa pine forest stand structure from a wide open savanna-like structure to one with very high tree densities, which in turn has contributed to destructive forest fires such as the Hayman fire of 2002. The current restoration program for the ponderosa pine ecosystem in the Colorado Rocky Mountains involves thinning and reintroduction of fire through prescribed burns to bring back the historical forest structure and function (Dahms and Geils, 1997).

As an alternative to slashpile burning, thinned forest fuel can be lopped and scattered on the forest floor, or masticated into chips which are then spread on the forest floor and left to decompose naturally. Biomass removal and creation of layers of wood residues will likely alter physical, chemical and biological conditions of the forest floor and upper mineral soil layers, yet the magnitude, duration and implications of such changes are largely unknown.

Objective

Our objective is to determine the effects of chipped or lopped-and-scattered slash material on soil fungal biomass and microbial C and N mineralization activities in the Manitou Experimental Forest, a ponderosa pine forest located in the Colorado Front Range, 24 km north of Woodland Park, CO.

Methods

Small Plot Studies

Chip plot study: In 2004, ponderosa pine chips were added to depths of 0, 5, or 10 cm to the surface of the forest floor in ~ 50-m long plots that were replicated twice in a randomized complete block design (Fig. 1). In June, 2007, composite soil samples were collected (0-10 cm) from each plot for microbial analyses.

Fig. 1. 10-cm deep chip plot in June, 2007.

Lop and scatter plot study: In 2004, slash material was lopped and scattered on the forest floor (~ 47 Mt ha^{-1} loading rate) on duplicate plots arranged as a randomized complete block design. Each block contained a nontreated plot, and composite soil samples (0-10 cm depth) were collected in June, 2007, from the control plots and under the woody debris and in open spaces between the woody debris in the lopped-and-scattered plots (Fig. 2).

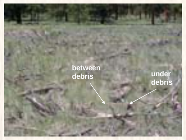

Fig. 2. A lop-and-scatter plot in June, 2007, showing examples of soil sampling locations.

Fig. 3. Mastication study area located in the Manitou Experimental Forest.

Larger Scale Study

A study was initiated in 2004 on a ~12 ha area which included three treatments: nontreated control, whole-tree harvesting with all chipped biomass retained on site (thinned + chips treatment) and whole-tree harvesting with all thinned material removed (thinned treatment) (Fig. 3). Thinning operations reduced basal area from 25.5 m^2 ha^{-1} to ~ 11.5 m^2 ha^{-1}. The average depth of chips on the forest floor was 2 cm.

In July 2007, soil samples (0-10 cm depth) were collected every 50 m along a 500-m transect in each treated and nontreated (control) area, for a total of ten samples per treatment.

Analyses

Fungal biomass was measured by direct microscopy with conversion of fungal hyphal biovolume to biomass C (Jiménez Esquilín et al., 2007).

C mineralization activity was determined by quantifying the amount of CO_2-C evolved during a 28-d incubation at 25 ºC and 75% soil water holding capacity.

N mineralization activity was calculated as the net NH_4-N and NO_3-N produced during the 28-d incubation.

ANOVA (SAS Institute Inc., Cary, NC) were performed on data from the small plot experiments using a randomized complete block design and α = 0.05. Multiple response permutation procedures (MRPP) were performed on data from the larger scale study, using 100,000 permutations for treatment difference comparisons and α = 0.05.

Results from Small Plot Studies

Chip Plots

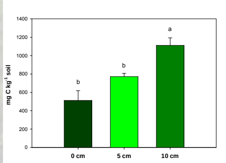

Fig. 4. Fungal biomass in soil under 0, 5 or 10 cm of chips. Bars are ± 1 standard error.

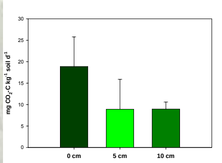

Fig. 5. C mineralization activity in soil under 0, 5 or 10 cm chips. Bars are ± 1 standard error.

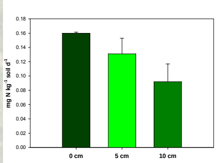

Fig. 6. N mineralization activity in soil under 0, 5 or 10 cm of chips. Bars are ± 1 standard error.

Three years post application, fungal biomass C was significantly greater in plots which received 10 cm of chips to the forest floor, with over twice as much fungal biomass under the 10-cm chip depth treatment compared to the control (nontreated) soil (Fig. 4).

Although differences were not statistically significant, C mineralization activity was lower in chipped plots (Fig. 5.), and N mineralization activity was lowest in the 10-cm chip depth treatment (Fig. 6).

Lop and Scatter Plots

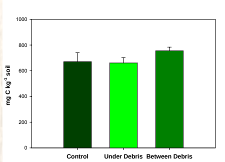

Fig. 7. Fungal biomass in nontreated (control) soil and soil directly under or between lopped and scattered slash. Bars are ± 1 standard error.

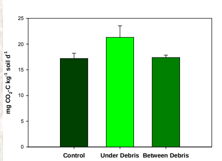

Fig. 8. C mineralization activity in nontreated (control) soil and soil directly under or between lopped and scattered slash. Bars are ± 1 standard error.

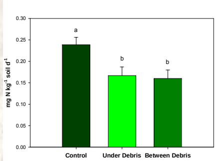

Fig. 9. N mineralization activity in nontreated (control) soil and soil directly under or between lopped and scattered slash. Bars are ± 1 standard error.

There were no significant differences in fungal biomass C (Fig. 7) or C mineralization activity (Fig. 8) between the nontreated control and lopped-and-scattered plots, nor were there differences between soil samples collected directly under debris or in open spaces between debris in the lopped-and-scattered plots.

N mineralization activity was significantly lower in lopped-and-scattered plot soils, with activity being reduced by ~ 30% compared to soil from the nontreated control plots (Fig. 9).

Results from Larger Scale Study

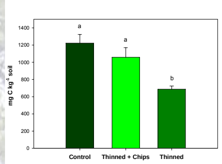

Fig. 10. Fungal biomass in soil from nontreated forest (control), thinned forest with chipped slash added to soil surface (thinned + chips), and thinned forest with no chip addition (thinned). Bars are ± 1 standard error.

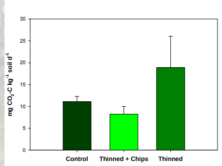

Fig. 11. C mineralization activity in soil from nontreated forest (control), thinned forest with chipped slash added to soil surface (thinned + chips), and thinned forest with no chip addition (thinned). Bars are ± 1 standard error.

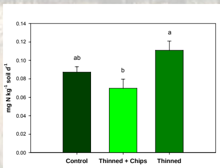

Fig. 12. N mineralization activity in soil from nontreated forest (control), thinned forest with chipped slash added to soil surface (thinned + chips), and thinned forest with no chip addition (thinned). Bars are ± 1 standard error.

Differences in regards to fungal biomass C and microbial mineralization activities were generally due to the effects of tree thinning and not chip additions to the forest floor. Fungal biomass was significantly lower in thinned-only soils (Fig. 10).

C mineralization activity tended to be greater in thinned-only soils (Fig. 11), and N mineralization activity was significantly greater in soils from the thinned-only treatment compared to soils from the thinned + chips treatment (Fig. 12).

Conclusions

Chip additions to the forest floor have the potential to increase fungal biomass C relative to nontreated soil, although an excess of 5 cm of chips may be required.

Chip additions may prevent losses of fungal biomass following whole-tree harvesting.

C and N mineralization activities responded to chipping and thinning in opposite directions as fungal biomass C trends. Chipping treatments which increased fungal biomass tended to decrease mineralization activities, whereas thinning-only treatment reduced fungal biomass C and increased mineralization activities.

References

Dahms, C.W., Geils, B.W., 1997. An assessment of forest ecosystem health in the Southwest. Gen. Tech. Rep. RMRS-GTR-295, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, 97 p.

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