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Effect of mulch on nitrogen cycling in a hardwood plantation of subtropical Australia

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Abstract We investigated the effect of mulch on N cycling in a hardwood plantation of subtropical Australia by examining monthly in situ net N mineralization for 12 months and natural 15N abundance (δ15N) of soil and plants. Monthly net N mineralization ranged from –23.0 μg g⁻¹ soil (net immobilization) to 52.6 μg g⁻¹ soil across 12 sampling months and across both mulch and non-mulch treatments. There was a significant effect of sampling month on net N mineralization; however, the effect of mulch on net N mineralization was not statistically significant. On average, net N mineralization was higher in soils collected in summer than other seasons. When monthly net N mineralization was partitioned into net ammonification and net nitrification, mulch treatment significantly decreased net nitrification, but did not affect net ammonification. The 0-10, 10-20, 20-30, 30-40, and 40-50 cm soil samples were collected for δ15N analysis 20 months after the mulch treatment was applied. The results showed that soil δ15N increased with depth and mulch treatment significantly decreased soil δ15N (0-10 cm) by 0.8‰. We explored the relationships between the annual averaged in situ net N mineralization rates and natural 15N abundance (δ15N) of 0-10 cm soils. Significant relationship was found between net nitrification and δ15N of 0-10 cm soils (p < 0.05), but no significant relationships were shown between δ15N of 0-10 cm soils and in situ net N mineralization or net ammonification rates. The foliage of 12-month old plantation was sampled from upper and outer canopy position pointing to north and analysed for δ15N. Surprisingly, mulch treatment increased foliar δ15N of trees by 0.7‰ compared to the non-mulch treatment. This may be due to isotopically light, soil NO3⁻ (compared to soil NH4⁺) constituting a more important N source for plants in the non-mulched plots relative in the mulched plots since we did find higher NO3⁻ concentration in the non-mulched soils than in the mulched soils.

Introduction

Quantifying the effects of site preparation on forest soil properties is an important step in assessing the potential for these activities to have long-term effects on forest productivity. Increasing land values have resulted in hardwood plantations being established in more westerly areas of Queensland with below optimal rainfall for seedling survival. One method used to overcome this problem has been to chip or mulch the existing vegetation (mainly Acacia sp. regrowth) using a tractor-drawn mulch machine that leaves a reasonably homogenous covering at the ground through which seedlings are planted. Application of mulch has been used frequently in the establishment of hardwood plantations in southeast Queensland, Australia, and appears to be effective in improving the early growth of trees (Sun et al. 1994). The objectives of this study were to investigate the impacts of mulch on nitrogen (N) cycling by examining in situ soil net N mineralization and 15N natural abundance of soils and plants in a hardwood plantation of subtropical Australia.

Materials and methods

The experiment was established in Pechey, southeast Queensland (27°18’S, 152°3’E), Australia. The site has a freely draining, well-textured Oxisol (Soil Survey Staff 1999). Basic soil properties in 0-10 cm depth are given as follows: soil pH (1:5 H2O)-6.5; TC(%)-11.6; TN(%)-0.4; CEC (cmol kg⁻¹)-34.8; EC (mS m⁻¹)-5.6; Clay (%)-35.0; Silt (%)-31.6; and Sand (%)-33.4.

The experiment was set up in December 2004. Two treatments (mulch and non-mulch) were applied to six 24-m wide by 67.2-m long plots with a randomised block design. For the mulch treatment, a mobile, tractor driven bush chopper was developed, which cut, chipped and spread all the woody weeds at the site as mulch over the plots. On average, the total weight of mulch in these plots was 1.57 kg m⁻² (dry weight), with about 5-cm layer of mulch covering over 80% of the soil area. The C/N ratio of mulch materials was 80.7. For the non-mulch treatment, all the mulch was removed from the plots immediately following site preparation. In situ N mineralisation tubes were installed in the upper, middle and lower slope areas of each block to ensure representative coverage of the block immediately after the treatments was applied. The technique used was that described by Raison et al. (1987) and Blumfield and Xu (2003) for the sequential, in situ exposure of soils for the purpose of studying fluxes of soil mineral N. Sampling took place over 12 consecutive cycles, spanning 1 calendar year, commencing in January 2005. The soil tubes were stored in a cold room at 4 °C until analysis, usually within 2 or 3 days following sampling. Each sample was thoroughly mixed with stones being removed by hand. Mineral N was extracted from the samples by shaking with 2 M KCl at a soil solution ratio of 1:10, and followed by centrifuging at 2000 rpm for 20 min. The supernatant was filtered through Whatman 42 filter papers, and kept frozen if not analysed immediately. KCl extracts were analysed colorimetrically for NH4⁺ and NO3⁻ using a Lachat Autoanalyzer (Quikchem 8000, Zellweger Analytics, Inc., Milwaukee, WI). Mineral-N was estimated as the sum of NH4⁺-N and NO3⁻-N using a Lachat Autoanalyzer (Quikchem 8000, Zellweger Analytics, Inc., Milwaukee, WI). Mineral-N was estimated as the sum of NH4⁺-N and NO3⁻-N from pre-incubation samples. Nitrite N (NO2⁻-N) was not present in significant quantities in these soils and has therefore not been considered for the purposes of this paper. Monthly field net N mineralization was estimated by subtracting pre-incubation soil mineral N from the field post-incubation soil mineral N.

δ15N was determined for soil collected from five random cores (4 cm-diameter) within each plot in June 2006. We collected 0-10, 10-20, 20-30, 30-40, 40-50 cm soil at each plot. The soil cores from same plots and same depth were pooled. For plant sampling, the leaf samples were collected in June 2006. One north-facing branch in the upper canopy was randomly selected from four average trees per plot. Five fully expanded mature leaves from as close to the tip of the selected branch as possible as possible were targeted, and collected. The leaves from the same plot were pooled together, placed in paper bags and dried in an oven at 60 °C. δ15N of soil and plant samples was determined with Mass Spectrometer (GV Isoprim, Manchester UK) at Griffith University, Brisbane, Australia using the following equation:

δ15N (‰) = \left( \frac{R_{sample}}{R_{standard}} - 1 \right) \times 1000
where R_{sample} \text{ is } ^{15}\text{N}/^{14}\text{N} \text{ ratio of a sample and } R_{standard} \text{ is } ^{15}\text{N}/^{14}\text{N} \text{ ratio of the atmospheric standard.}

**Results and discussions**

Monthly net N mineralization ranged from -23.0 \text{ mg g}^{-1} \text{ soil} \text{ (net immobilization)} to 52.6 \text{ mg g}^{-1} \text{ soil} \text{ across both treatments (Fig. 1A). There was a significant effect of sampling month on net N mineralization (P < 0.05); however, the effect of mulch on net N mineralization was not statistically significant (P > 0.05). On average, net N mineralization was higher in soils collected in summer months than other seasons. When monthly net N mineralization was partitioned into net ammonification and net nitrification, mulch treatment significantly decreased net nitrification rate (P < 0.05, Fig. 1B), but did not significantly affect net ammonification (P > 0.05, Fig. 1C).

The foliage of 12-month old plantation was sampled and analysed for \( \delta^15\text{N} \). It was a surprise that the mulch treatment increased foliar \( \delta^15\text{N} \) of trees by 0.7 ‰ compared to the non-mulch treatment, given that it had the opposite effect on soil natural \( ^{15}\text{N} \) abundance. We believe there are two potential explanations for this response. First, the mulch treatment increased the rooting depth of trees and consequently, the \( ^{15}\text{N} \) abundance of N available for plant assimilation. However, according to root biomass measurements in this plantation (Data not shown) and the study by Watson (1988), the mulch treatment had no effect on the absolute or proportional rooting depths of plants. Therefore, differences in rooting depth cannot explain mulch effect on foliage \( ^{15}\text{N} \) abundance in the plantation. The second potential mechanism responsible for the mulch-induced increase in foliage \( ^{15}\text{N} \) of trees is that trees exploit different N pools in the mulched plots vs. the non-mulched plots. Lower rates of net nitrification caused by the mulch treatment may decrease the availability of \( \text{NO}_3^- \). Because nitrification discriminates against \( ^{15}\text{N} \), \( \text{NO}_3^- \) should be isotopically lighter than \( \text{NH}_4^+ \) (Feigin et al. 1974). Consequently, if trees in mulched plots assimilate proportionally less \( \text{NO}_3^- \) than \( \text{NH}_4^+ \), foliage of trees in the mulched plots will be isotopically heavier than those in the non-mulched plots. This is how we believe the mulch treatment enriched foliage \( ^{15}\text{N} \) of trees in this plantation since we had shown the lower net nitrification rates in the mulched plots than in the non-mulched plots.

**Fig. 2 Soil \( ^{15}\text{N} \) in a hardwood plantation of subtropical Australia subject to the mulch and non-mulch treatment.**

**Reference**


