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Fate of particulate and dissolved organic matter in soil N mineralization

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Introduction

The most important pools of organic matter that have been identified as part of the labile fractions are particulate organic matter (POM) and dissolved organic matter (DOM) (Gregorich et al., 1997a; Haynes and Beare, 1996; Janzen et al., 1997). POM is a fleeting pool of organic matter between fresh plant residue and humified organic matter (Gregorich and Janzen, 1996). The DOM consists of various organic compounds, among of these, dissolved organic C (DOC) and dissolve organic N (DON) are important constituents. There is a wide gap in our understanding on the role of two POM fractions i.e. light fraction and heavy fraction in N mineralization pools. In this study, operationally, we define LF as the POM which floated in 1.8 g cm^{-3} sodium Iodide and the occulted POM with soil matrix is considered as heavy fractions. The transformation of insoluble organic N via LF and then DOM may be the bottle neck mechanism of new paradigm of N cycling. Very limited studies were done on POM fractions related on DOM pools, bioavailability, and total N mineralization. Preliminary studies showed initial DON concentration and light fraction POM were correlated well with N mineralization (Bregliani et al. 2005).To understand and quantify the fate of organic matter pools in N mineralization, we conducted an incubation experiment using ^{15}N labeled crop residues. We expect that POM and DOM are interrelated acting as a potential mineralizable N pool. Therefore, we hypothesized a higher enrichment of ^{15}N in POM and DON than the enrichment of ^{15}N in mineral N during mineralization period.

Material and Methods

The incubation experiment was carried out with two main treatments (1) with ^{15}N labeled radish residue amended soil and (2) without residue amended soil (control). Three replications were made for each incubation time. Destructive samples were taken for analysis with specified day's interval (2, 6, 9, 15, 21, 27, 35, 42, 55, 64, 77 and 129). Before filling, the treatment containing crop ^{15}N labeled residue mixed homogenously around 1.88g residue kg^{-1} fresh soil which is equivalent 2.44g residue per kg air dry soil with moisture content 18% w/w. The amount of crop residue added was 4.04 mg ^{15}N/ kg air dried soil. Deionized mineral water was added to adjust the water content to field capacity, estimated as 60% of the water holding capacity in all the treatments. Then these sample bags kept randomly in incubation chamber at 20 ^{o}C and mixed weekly. POM separation was done by modified density fractionation techniques (Sohi et al. 2001). The soil solution was extracted for each sample using a modified centrifugal drainage

technique (Giesler and Lundstrom; 1993). The analyses of DOC, TDN, N-NO_3^-, and N-NH_4^+ were carried out by spectrophotometrically using segment flow analyzer. The DON was calculated from the difference of TDN and mineral N. Bioavailable and recalcitrant fraction of DOM was estimated by using a bioassay. ^{15}N content of soil solution TDN, mineral N, LF and HF well as crop residue were analyzed at the UC Davis Stable Isotope Facility. The ^{15}N isotope signature of inorganic N and TDN was determined using a microdiffusion technique (Stark and Hart; 1996).

Results and Discussion

Dynamics of POM

The amount of LF was significantly ($p < 0.05$) higher at the beginning days of sampling and declined as incubation days increased (Fig. 1a). At the end of the incubation (day 129), the amount of LF obtained was nearly equal for both control and residue amended soil. This indicated that most of the added residue was decomposed. The amount of HF did not significantly ($p > 0.05$) differ over time for soil amended with residue but significantly differed in control soil (Fig. 1b).

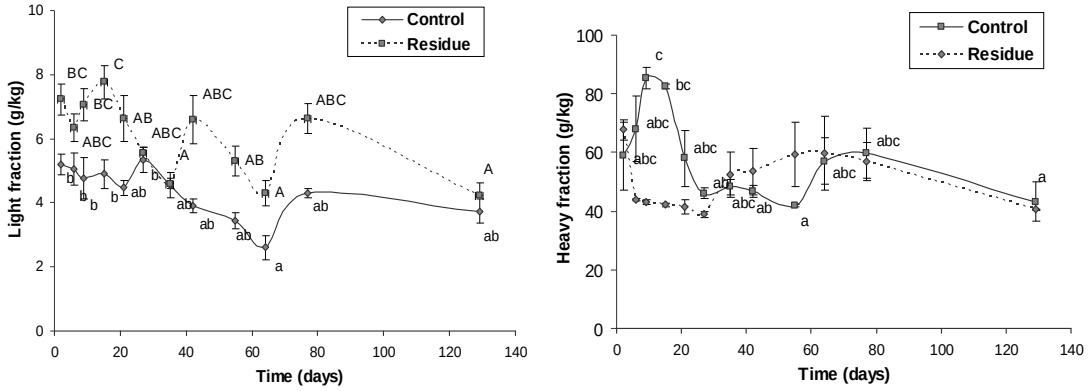


Figure 1. Dynamic of light fraction (a) and heavy fraction (b) particulate organic matter in control soil and soil amended with ^{15}N labeled radish residues during 129 days of incubation. Each point is a mean of three replicates with a standard error. Significance differences ($\alpha = 0.05$) among the sampling times are shown by capital and small letters.

Immediately after incorporation of ^{15}N labeled radish residue resulted in an increased ^{15}N content in both LF and HF ($p < 0.05$). The amount of ^{15}N in both LF and HF was significantly ($p < 0.05$) higher at day 2 in comparison to other days (Fig. 2a). The ^{15}N content in LF was sharply declined at day 6 and remained constant onward. The ^{15}N enrichment was significantly ($p < 0.05$) higher at day 2 for LF and in HF was constant over the incubation time (Fig. 2b). The ^{15}N enrichment was higher in LF in comparison to HF throughout the incubation period.The decrease in LF with increased incubation time showed that LF was more rapidly decomposed then the HF because LF mainly consists of plant residue and microbial biomass which have a rapid turnover rate (Janzen et al., 1992). Hassink (1995a) also explained that decay rates of individual fractions decreased with increasing density and decreasing size.

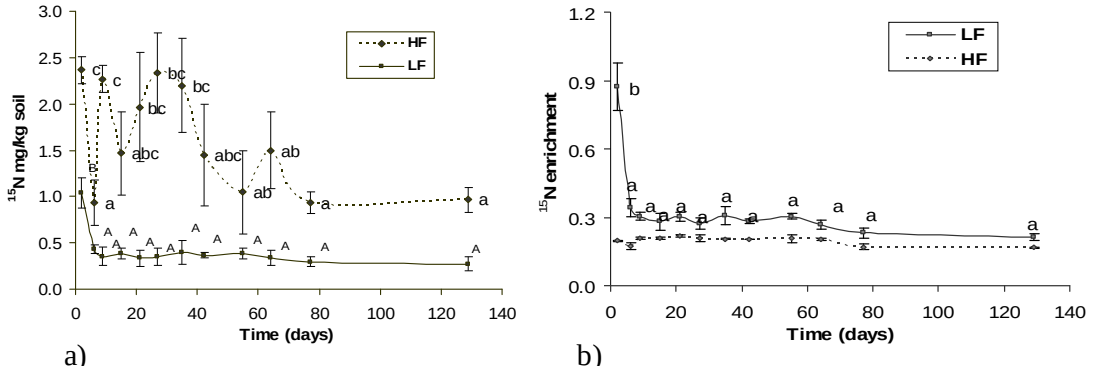


Figure 2. ^{15}N content (a) and ^{15}N enrichment (b) in light and heavy fraction with ^{15}N labeled radish residue amended soil during 77 days of incubation. Each point is a mean of three replicates with a standard error. Significance differences ($\alpha = 0.05$) among the sampling times are shown by letters.

Dynamics of DON and DOC

The bioavailable fraction of DOC was on average 15% of total DOC in both control and residue amended soil (Fig. 3a). The DOC concentration significantly ($p < 0.05$) increased immediately after incorporation of radish residue. One day after residue incorporation, the DOC concentration of residue amended soil was 136 % higher than the initial DOC concentration of control soil. During day 1 to day 15, DOC concentration was significantly ($p < 0.05$) higher compared to DOC after day 15 in both control and residue amended soil. After day 15, both recalcitrant and bioavailable fraction of DOC remained constant. The addition of ^{15}N labelled residue significantly ($p < 0.05$) increased DON concentration in soil. The bioavailable fraction of DON in residue amended soil (Fig. 3b) showed similar trend as bioavailable fraction DOC (Fig. 3a).

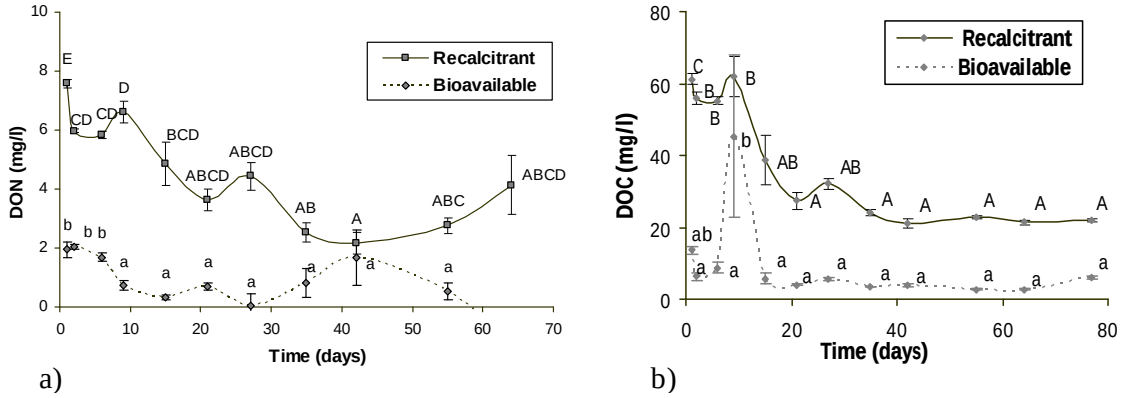
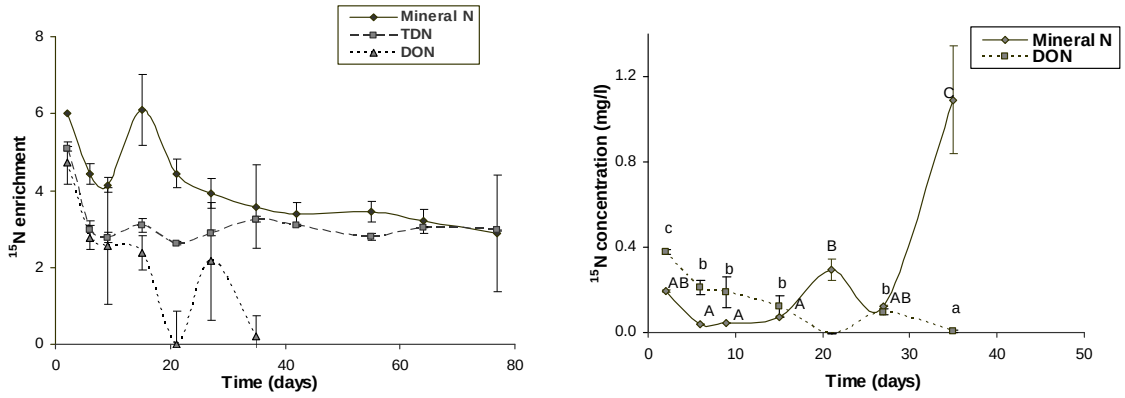


Figure 3. Two fractions recalcitrant and bioavailable, in DON (a) and DOC (b) in ^{15}N radish residue amended soil. Each point is a mean of three replicates with a standard error. Significance differences ($\alpha = 0.05$) among the sampling times are shown by letters. The significance differences were obtained by using log transformed data.

The ^{15}N enrichment was higher in mineral N than TDN and DON.Immediately after incorporation of ^{15}N lablled residue, the ^{15}N enrichment increased in mineral N, TDN and also in DON (Fig. 4a). Initially (day 2), the ^{15}N enrichment values were 6.0, 5.0 and 4.7 in mineral N, TDN and DON respectively.The ^{15}N enrichment of mineral N was higher but unstable during first three weeks, declined afterwards and remained constant from weeks 5. The ^{15}N enrichment of TDN showed more stable trend than mineral N. During first 35 days the difference in ^{15}N enrichment in mineral N and TDN was slightly higher than after day 35. After day 35, both mineral N and TDN showed stable trend and nearly equal ^{15}N enrichment. The ^{15}N enrichment in DON was unstable over the incubation period of 77 days. After day 35, the ^{15}N enrichment in

DON was much lower and negatives which are not shown here. During these days, we were unable to calculate ^{15}N enrichment accurately since TDN and inorganic N was alomost equal. The concentration of ^{15}N in mineral N differed significantly ($p < 0.05$) with incubation time (Fig. 4b). During day 2 to day 21, ^{15}N concentration sharply declined in mineral N as well in DON. ^{15}N concentration exponentially increased after day 27 in mineral N but in DON declined (Fig. 4b).



a) b)

Figure 4. ^{15}N enrichment in mineral, TDN and DON (a) and ^{15}N concentration in mineral N and DON (b) with ^{15}N labeled radish residue amended soil. Each point is a mean of three replicates with a standard error.

In our study, all three fractions (LF, DON and mineral N) showed that the ^{15}N enrichment increased immediately after incorporation of ^{15}N labelled residue (Fig. 2b and Fig. 4a). We hypothesized that LF act as a source of DON and inorganic N, and that the DON pool plays an intermediate role in N mineralization. However, the observed ^{15}N enrichment in these fractions did not support these hypotheses, since we did not see the higher ^{15}N enrichment in LF than the $^{!5}N$ enrichment of DON and inorganic N. Likewise, the ^{15}N enrichment of DON was not higher than inorganic N (Fig. 4a). In addition, the mineralization rate of crop residue increased with incubation time but the enrichment of DON showed gradual decrease in time. The gradual decrease of ^{15}N enrichment in DON indicates that there was no strong change in its inputs. Hence these results suggested that a change in the turnover rate of DON is not associated with the N mineralization rate of crop residue. These results revealed that the main flow of decomposed N from residue did not pass or may not necessary pass via DON pool.

Conclusions and Outlook

This study showed that neither DON nor POM function as a distinct N source fraction in soil. The collected DOM was predominantly recalcitrant (~80%), suggesting that the bioavailable DOM fraction cannot be measured with current sampling techniques. The concentration of DOM strongly increases upon incorporation of crop residues, but diminish sharply within a few days. Our results also suggest that the DOM fraction is heterogeneous in composition; the most bioavailable part is consumed within a few days whereas the remaining part is fairly constant. Further research should focus on bioavailable fraction analysis.

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