Fate of Chinese-fir litter during decomposition as a result of inorganic N additions

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A B S T R A C T

We conducted a controlled experiment to evaluate Chinese-fir litter decomposition and its response to the addition of inorganic N. Litter-derived CO2, microbial biomass carbon (MBC), and dissolved organic carbon (DOC) were monitored during an 87-d incubation of a mixed soil–litter substrate using the 13C tracer technique. Litter C was mostly converted to CO2 (47.4% of original mass), followed by MBC (3.6%), and DOC (1.0%), with 48% remaining unaltered in the soil. The litter decomposition rate significantly increased with the addition of inorganic N, although the effect depended on whether N was added as NH4+ or NO3−. Soil-derived CO2, MBC, and DOC also increased following the combined addition of litter and N. The results showed that only a small percentage of litter C was retained as MBC or DOC and that the conversion rate depended, in part, on the form of inorganic N added to the Chinese-fir plantation soil.

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1. Introduction

In forest ecosystems, plant litter plays an important role in maintaining soil fertility by regulating the nutrient cycle during decomposition (Fioretto et al., 2003; Pandey et al., 2007). Therefore, understanding the decomposition dynamics of plant litter and its controlling factors is critical. Consequently, numerous studies on plant litter decomposition have been conducted using the litterbag technique. These studies confirmed that plant litter decomposition is controlled by initial litter chemistry (Aber and Melillo, 1982; Melillo et al., 1982), external nutrients (Hobbie, 2000; Magill and Aber, 1998), and climate (Berg and McClaugherty, 2008). However, the fate of plant litter during decomposition has not been well evaluated because the decomposition rate is simply expressed as mass loss in the litterbag technique. Most plant litter C is released as CO2 into the atmosphere (Chapin et al., 2002). However, the proportions of the CO2 produced and other fates of plant litter-C (such as MBC and DOC) compared with the total mass loss are unknown (Troyer et al., 2011).

Microorganisms play a critical role in the carbon transformation in forest soil (Nottingham et al., 2009; Hu et al., 2011), and the microbial biomass serves as an important pool for plant litter during decomposition (Garcia and Rice, 1994). In agricultural soils with different histories of maize cropping, John et al. (2003) found that after 40 years, about 23–46% of the microbial biomass carbon (MBC) is derived from maize carbon. The newly formed MBC and the altered microbial community composition in response to plant litter accelerates the decomposition of plant litter and the native soil organic carbon, which potentially influences the transformation of soil carbon and nitrogen in forest ecosystems. Thus, understanding the proportion of plant litter C that is allocated as MBC is important for determining the fate of plant litter and because of its potential effect on soil ecological processes.

Dissolved organic carbon (DOC) is a small fraction of soil organic matter (Troyer et al., 2011); however, its importance in microbial metabolism and ecological processes could not be neglected because of its high bioavailability (Qualls and Haines, 1992). The DOC concentration in soil is controlled by the interaction of its production and degradation (Kalbitz et al., 2000). Different methods, including isotopic techniques (Troyer et al., 2011; Hagedom et al., 2004), have been used to identify the sources of DOC in soil. The DOC in the soil originates from recent plant litter, roots and native soil organic matter (Yano et al., 2005; Fröberg et al., 2003). Thus, determining the proportion of plant litter C allocated into DOC during decomposition is very important.
As a main nutritional limiting factor in most ecosystems (Koerselman and Meuleman, 1996), the effects of nitrogen on ecological process, especially on plant litter decomposition (Magill and Aber, 2000) and soil respiration (Ramirez et al., 2010), were widely studied. A meta-analysis based on 24 individual studies (Knorr et al., 2005) showed that nitrogen positively affects plant litter decomposition during the early stage of decomposition (<24 months), and negatively affects it in the latter stages (>24 months). In addition, the effect of nitrogen is related to plant litter quality, the nitrogen addition rates, and form of the nitrogen (Knorr et al., 2005). Considering the effects of the interaction of the different factors was not calculated in the meta-analysis, predicting the effect of nitrogen and the changes in the proportion of the different intermediates on plant litter decomposition (Liao et al., 2000).

Chinese-fir (Cunninghamia lanceolata) is an important coniferous timber species that has been extensively grown in Southern China for more than 1000 years (Chen and Wang, 2004). Chinese-fir litter is characterized by high C:N ratio and lignin concentration (Yang et al., 2004), thus its decomposition may be limited by a lack of inorganic N (Liao et al., 2000). Unsustainable forest management practices, such as successive planting, short rotation times, whole-tree harvesting, and poor site preparation, had significantly decreased soil fertility, e.g. soil nitrogen availability (Chen et al., 1990). Therefore, the high C:N ratio of Chinese-fir litter was supposed to interact with low nitrogen availability in soil to hinder the carbon cycling, such as litter decomposition and SOC mineralization, in Chinese-fir plantations (Liao et al., 2000).

To understand better the litter and SOC decomposition in Chinese-fir plantations, we conducted a controlled experiment under laboratory conditions using 13C-labeled Chinese-fir litter and the addition of inorganic N. The specific objectives of the study are as follows: (1) to quantify the different fates (CO2 production, MBC and DOC) of Chinese-fir litter during decomposition; and (2) to examine the effects of NH4+-N and NO3−-N addition on the fate of Chinese-fir litter during decomposition. Given that microbes preferentially take up inorganic nitrogen as NH4+ N (Lavelle and Spain, 2003) and cost more energy to uptakes NO3−-N, we hypothesize that the addition of NH4+ N accelerates Chinese-fir litter decomposition compared with the addition of NO3−-N.

2. Materials and methods

2.1. Soil and labeled litter

The soil used was collected from a 0 cm to 10 cm layer in a second-generation Chinese-fir plantation located at the Huizhou Experimental Station of Forest Ecology, Chinese Academy of Sciences (109°36'E, 26°51'N), Hunan Province, China. The soil was classified as clay loam (25.12% sand, 45.53% silt, 29.35% clay) with a pH of 4.3. The soil bulk density was 1.4 g cm−3. The soil C and N concentrations were 12.61 g kg−1 and 1.18 g kg−1, respectively, which corresponds to a C:N ratio of 10.7. The δ13C of soil organic carbon was −27.8%.

Uniformly 13C-labeled Chinese-fir leaves were obtained using 13C-labeled carbon dioxide (13CO2)-C in a growth chamber for 3 months. The total C, N, P and dissolved organic C concentration of the Chinese-fir leaves were 465.1 g kg−1, 8.11 g kg−1, 0.99 g kg−1 and 93 g kg−1. The δ13C of the Chinese-fir leaf was 243%.

2.2. Experimental design

The soil samples were taken to the laboratory and treated as follows. Approximately 12 kg of soil from the second-generation Chinese-fir plantation was passed through a 2 mm sieve and adjusted to water-holding capacity (WHC) of 40%. The soil was pre-incubated for 15 d in a bucket containing a beaker with 100 mL of distilled H2O to avoid desiccation, and a beaker with 100 mL of 0.1 mol L−1 sodium hydroxide (NaOH) solution to trap evolved CO2. The experiment included 2 litter additions ( CK: no fIr addition, FR = 1.5 mg litter-C g−1 soil) and 3 nitrogen additions (CKN = no N addition, +NH4 = 100 mg NH4−N kg−1 soil, +NO3 = 100 mg NO3−-N kg−1 soil) arranged in a 2 × 3 factorial design.

For the incubation, 15 replicates of 145 g of dry soil (conversion according to water content) were placed in 1000 mL incubation vessels for each treatment. Then, 465 mg of 13C-labeled Chinese-fir litter, 7.5 mL of 0.24 mol L−1 ammonium sulfate solution, and 15 mL of 0.24 mol L−1 potassium nitrate solution were added to the soil. Lastly, the water content of each treatment was adjusted by adding distilled water to maintain a WHC of 60%, and the soil was thoroughly mixed. The 15 replicates of each treatment were divided into 3 groups. The first group included three replicates, and was used to measure the CO2 released from soil. The jars were incubated in the dark for 87 d at 16.5°C (the average annual temperature). Three additional jars with a beaker containing 10 mL of distilled H2O and a beaker containing 10 mL of 0.1 mol L−1 NaOH solution were sealed served as the controls to account the CO2 trapped in the air. To collect CO2 from respiration, a glass vial containing 10 mL of 0.1 mol L−1 NaOH solution was placed in the incubation jars and the jars were sealed. The NaOH traps were replaced periodically before saturation. The CO2 released from the soil was measured daily for the first 15 d. The second group contained three replicates and it was used to analyze 13C abundance. Soils were placed in 1000 mL glass jars containing a vessel with 10 mL of distilled H2O and stored in the dark. After 15, 47, and 87 d, the gas in each treatment was sampled with syringe for 13C abundance analysis. After sampling, all flasks were opened, aired for 10 min to avoid completely anaerobic conditions, sealed, and then stored in the dark. The third group contained six replicates. Those jars also contained a vessel with 10 mL of distilled H2O to keep soils moist, then opened and aired periodically to avoid anaerobic conditions. After 15, and 87 d, three jars were randomly selected from each treatment and were opened. The soil samples were then used to analyze inorganic N, soil microbial biomass carbon, and dissolved organic carbon.

2.3. Soil chemical analysis

The CO2 trapped in NaOH was titrated with 0.05 mol L−1 HCl (Hu et al., 2006). Inorganic N was determined from 2 mol L−1 KCl extractions (1:5 soil solution ratio). NH4+ -N was colorimetrically determined using a spectrophotometer, and NO3− -N was determined by ion chromatography (Liu et al., 1996).

Soil microbial biomass C was determined in duplicate using the chloroform fumigation – K2SO4 extraction method, as described by Vance et al. (1987). Briefly, 25 g of soil was fumigated 24 h at 25°C with 10 mL ethanol-free chloroform and extracted with 100 mL of 0.5 mol L−1 K2SO4 for 1 h. The organic carbon in the extracting agent was measured via dichromate oxidation (Vance et al., 1987). The microbial biomass C was calculated using the following formula: CMB = EC/Kc, where EC is the difference in organic C concentration of the fumigated and unfumigated extracting agent and Kc = 0.38 (Lu, 1999). The organic C concentration in unfumigated extracting agent was used to express the DOC concentration (Dijkstra et al., 2006).

The remaining parallel extracts were combined and dried at 60°C in a ventilated oven, and the dried K2SO4 was ground and used to determine the 13C abundance using stable isotope-ratio mass spectrometers (DELTAPLus XP). The analytical precision of the δ13C measurements was 0.15%.

The δ13C value in unfumigated extracting agent was used to express the 13C abundance of the DOC, whereas the 13C abundance of the MBC was estimated using the following equation:
\[ \delta^{13}C_{\text{MBC}} = (\delta^{13}C_{\text{FUM}} \times C_{\text{FUM}} - \delta^{13}C_{\text{CON}} \times C_{\text{CON}})/(C_{\text{FUM}} - C_{\text{CON}}), \]

where \( C_{\text{CON}} \) and \( C_{\text{FUM}} \) are the organic C concentration extracted from the unfumigated control and the fumigated samples, respectively; and \( \delta^{13}C_{\text{CON}} \) and \( \delta^{13}C_{\text{FUM}} \) are the \( \delta^{13}C \) of the control and fumigated samples, respectively. Calculation

When Chinese-fir litter was added to the soil, the CO2, MBC, and DOC derived from Chinese-fir litter (\( \delta^{13}C = 243\% \)) and native soil organic carbon (\( \delta^{13}C = -27.8\% \)) would have different \( \delta^{13}C \) values.

Chinese-fir litter and the soil organic carbon derived (CO2-C, MBC, or DOC) were estimated using the following equations:

\[ Q_{\text{Litter}} = Q_L \times (\delta_L - \delta_S)/(|\delta_L - \delta_S|) \]

\[ Q_{\text{Soil}} = Q_L \times (\delta_L - \delta_I)/(|\delta_L - \delta_I|) \]

In the equation, \( Q_L \) is the total CO2 production, MBC, or DOC concentration of the amended soil; \( Q_{\text{Litter}} \) is the amount of CO2 production, MBC, or DOC concentration derived from Chinese-fir litter; \( Q_{\text{Soil}} \) is the amount of CO2 production, MBC, or DOC concentration derived from native soil organic carbon; \( \delta_L \) is the \( \delta^{13}C \) of CO2 production, MBC, or DOC; \( \delta_I \) is the \( \delta^{13}C \) of the added Chinese-fir litter; and \( \delta_S \) is the \( \delta^{13}C \) value of native soil organic carbon.

The proportion of initial Chinese fir litter-C released as CO2 per day was used to estimate the decomposition rate of litter during decomposition. The proportion of native SOC released as CO2 at the end of incubation was used to estimate the decomposition of SOC.

### 2.4. Statistical analysis

All data were expressed as the mean of three replicates ± SD. One-way ANOVA was used to test the effect of inorganic N addition on Chinese-fir litter decomposition. Two-way ANOVA was used to test the effects of Chinese-fir litter and inorganic N addition on native SOC decomposition. Three-way ANOVAs were used to test the effects of litter and/or inorganic N additions on the NH4+\textsuperscript{−}-N and NO3\textsuperscript{−}-N concentration, MBC, and DOC. The significant differences among treatments were analyzed using Least Significant Differences’ (LSDs) multiple comparison post hoc tests (\( P < 0.05 \)). All statistical analyses were conducted with SPSS version 13.0 (SPSS, Chicago, IL, USA).

### 3. Results

#### 3.1. NH4\textsuperscript{+}-N and NO3\textsuperscript{−}-N concentrations in soil

Both the Chinese-fir litter and the addition of inorganic N significantly changed the availability of soil inorganic N (\( P < 0.05 \); Table 1; Fig. 1). During the incubation, Chinese-fir addition significantly decreased soil NH4\textsuperscript{+}-N and NO3\textsuperscript{−}-N concentration. The sampling date interacted with the addition of Chinese-fir litter and affected the soil inorganic N concentration (Table 1) such that the decrease in both NH4\textsuperscript{+}-N and NO3\textsuperscript{−}-N concentrations caused by Chinese-fir litter in early stage (15 d) was larger than that in the later stage (87 d). The soil NH4\textsuperscript{+}-N and NO3\textsuperscript{−}-N concentrations were significantly enhanced by the addition of NH4\textsuperscript{+}-N and NO3\textsuperscript{−}-N addition, respectively. Moreover, the interaction of Chinese-fir litter and inorganic N on NH4\textsuperscript{+}-N and NO3\textsuperscript{−}-N was significant.

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* \( P < 0.05 \)

** \( P < 0.01 \), NS: not significant.

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Fig. 1. Effects of additions of Chinese fir litter alone or with addition of inorganic nitrogen on NH4\textsuperscript{+}-N and NO3\textsuperscript{−}-N concentration in the soil during incubation at 16.5°C. Vertical bars are standard errors (n = 3). CK\textsubscript{F} = no fir addition; CK\textsubscript{K} = no N addition.
3.2. Decomposition dynamics of Chinese-fir litter

The form of the inorganic N significantly affected the decomposition rate dynamics of the added Chinese-fir litter during incubation (Fig. 2). During the early stage (0–15 d), the decomposition rate of Chinese-fir litter was 1.56% per day and was significantly enhanced to 1.88% and 2.21% per day (P < 0.01) because of the addition of NH4\(^+\)-N and NO3\(^-\)-N, respectively. After 47 d of incubation, the Chinese-fir litter decomposition was hindered by the addition of both NH4\(^+\)-N and NO3\(^-\)-N. At the end of incubation (87 d), about 47.3% of Chinese-fir litter was decomposed. The percentage significantly increased to 57.9% and 64.2% (P < 0.01) when NH4\(^+\)-N and NO3\(^-\)-N were added to the soil, respectively.

3.3. Native soil organic carbon decomposition after 87 d of incubation

The results of the ANOVA indicated the significant effects of the addition of Chinese-fir litter and of inorganic N on native soil organic carbon decomposition (Fig. 3). After 87 d of incubation, the Chinese-fir litter significantly increased the CO2 production of the native soil by 20% (Fig. 3). The addition of NH4\(^+\)-N significantly decreased CO2 production from native soil by 19.5%, where the addition of NO3\(^-\)-N increased it by 9.8%. The interaction of Chinese-fir litter and inorganic N on CO2 production was not significant (P = 0.149).

3.4. Microbial biomass carbon

The addition of Chinese-fir litter and inorganic N significantly affected the total MBC in soil; the effects of the addition of Chinese-fir litter on MBC depended on sampling time (P < 0.01). The addition of Chinese-fir litter stimulated a significant increase in the MBC at the 15 d; however, this effect was not significant in the 87 d sampling. The MBC in the soil decreased to a certain extent because of the addition of inorganic N.

In this study, the sources of microbial biomass carbon were determined by \(^13\)C labeling, which provided more information on the effects of the addition of Chinese-fir and inorganic N. After the addition of the Chinese-fir litter, the MBC was still mainly derived from native soil. The percentages depended on the addition of inorganic N, and ranged from 62.1% to 80%. The two-way ANOVA results indicated that the significant effects of the addition of Chinese-fir litter and of inorganic N on the MBC derived from native soil (Table 1). The MBC derived from the native soil was significantly enhanced by the addition of Chinese-fir litter in the 15 d sampling, and the effects were not significant in the 87 d sampling. Fig. 4 shows that the effects of inorganic N on the MBC derived from the Chinese-fir litter were significant in the 15 d sampling, and not significant in the 87 d sampling.

3.5. Dissolved organic carbon

The results of the ANOVA indicated the significant effects of Chinese-fir litter and inorganic N on the DOC concentration (Table 1). The addition of Chinese-fir litter significantly enhanced the DOC except for the +NH4 treatment in the 87 d sampling. The effects of inorganic N addition on the DOC concentration were dependent on the form of inorganic N. In the 15 d sampling, the DOC concentration decreased in the following order: CK\(_N\) = +NH4 > +NO3.

After determining the sources of DOC, we found that the increase in DOC after the addition of Chinese-fir was mainly due to added organic matter. The effects of inorganic N on the DOC from the native soil was significant (P < 0.01). The DOC concentration was significantly enhanced by the addition of NO3\(^-\)-N in both samplings, and was only enhanced by the addition of NH4\(^+\)-N in the
first sampling. The interaction of the addition of Chinese-fir and of inorganic N addition with the DOC was significant in the 87 d sampling.

3.6. Fate of Chinese-fir litter after 87 d of decomposition

Table 2 shows the effects of the addition of inorganic N on the fate of the Chinese-fir litter after 87 d of decomposition in the soil. In the control treatment, 47.3% of the Chinese-fir litter was released into atmosphere as CO$_2$, and the percentage increased to 59.7% and 64.2% with the addition of NH$_4^+$-N and of NO$_3^-$-N, respectively. Approximate 3.3% and 1.1% of the Chinese-fir litter were allocated to MBC and to DOC, respectively. The effect of the addition of inorganic N on the allocation of Chinese-fir litter into MBC and DOC was also significant (Table 2).

4. Discussion

4.1. The fate of Chinese-fir litter and its effect on native soil carbon

Stable $^{13}$C isotope has been widely used to identify the CO$_2$ derived from added organic materials and native soil organic carbon (Conde et al., 2005; Zimmerman et al., 2011; Blagodatskaya et al., 2011). This technique allows the study of the dynamics of Chinese-fir litter during decomposition and its effect on native soil organic carbon decomposition at the same time. The results of this study show that 47% of the C in Chinese-fir litter is converted into CO$_2$ after 87 d of incubation at 16.5 °C. Furthermore, the addition of Chinese-fir litter significantly enhanced the CO$_2$ production derived from native SOC after 87 d of incubation, and caused a significant positive priming effect in both the control treatment and the inorganic N treatments. This phenomenon was expected because it has been observed in previous studies with the addition of plant residues (Fontaine et al., 2004, 2007), simple sugars (Hamer and Marschner, 2005), and root extracts (Mary et al., 1992). Given that the MBC derived from native soil was significantly increased with the addition of Chinese-fir litter during the initial stage of incubation (Fig. 4), we attribute the positive priming effect to enhanced microbial growth and the accompanying increased in enzyme production (Kuzyanov et al., 2000). We were unable to find a significant correlation between the addition of Chinese-fir litter and of inorganic N and the CO$_2$ production derived from the native soil ($P = 0.149$). This finding suggests that Chinese-fir litter induced a priming effect in both its own (FIR) and the N additions (+NH$_4^+$ and +NO$_3^-$) treatments.

Soil microorganisms are the drivers of litter decomposition and nutrient release (Garcia and Rice, 1994; Saffigna et al., 1989), and are an important sink for added organic materials (Troyer et al., 2011). In this study, the addition of Chinese-fir litter had a significant positive effect on microbial biomass C in the 15 d sampling, but it had a neutral effect in the 87 d sampling. This is consistent with the findings of Jin et al. (2010), who found that the effect of plant litter on soil MBC is related to the addition rate and sampling time in semiarid grassland ecosystems. After the source of MBC was determined using the $^{13}$C stable isotope technique, we obtained more information on the effects of the addition of Chinese-fir litter. Our results show that the change in MBC after the addition of Chinese-fir litter could not be completely accounted for by the MBC derived from Chinese-fir litter because the MBC derived from native soil was changed significantly in both the 15 d and the 87 d samplings (Fig. 4). We attribute this significant change in the MBC from the native soil to the activation of microorganisms by the enhanced nutrients and substrate (Kuzyanov, 2010). However, this activation effect does not last for a long time probably due to the rapid exhaustion of added Chinese-fir litter.

Soil dissolved organic carbon was significantly increased by the addition of Chinese-fir litter (Table 1). We attribute this increase mainly to Chinese-fir litter-derived DOC because the variation of native soil-derived DOC explained by addition of Chinese-fir litter was quite small. The DOC-C derived from Chinese-fir litter generally accounts for 1.0–1.2% of the initial total C in the Chinese-fir litter, and this percentage was relatively constant during incubation (Fig. 5). We did not observe a significant decrease in the Chinese-fir litter-derived DOC with time because of the following reasons: First, the initial DOC flush from the Chinese-fir litter was easily degraded (Kramer et al., 2010). In this study, added DOC accounted for 20% of total litter-C. However, litter-derived DOC at first sampling (15 d) was only 1.0% of the C from added litter. Therefore, the significant decrease trend may have been missed. In accordance with our study, Troyer (2011) found that the maize-derived DOC is 3.3% of the C from the added maize after 0.2 d, which decreased to 0.31% after 14 d. These results indicate a very short half-life. Second, on day 15 and onwards, the DOC was mainly from the decomposition of the Chinese-fir litter instead of the initial DOC in the Chinese-fir litter. Considering the new DOC was also easily degraded, we concluded that the dynamics of new DOC is dependent on the decomposition of the Chinese-fir litter. For example, after 87 d of incubation, the changes in the DOC and the CO$_2$ production...
from the Chinese-fir litter followed a similar pattern, which indicates that the two ecological processes are closely related.

4.2. Effect of the addition of inorganic N

As expected, the fate of the Chinese-fir litter during decomposition and the native SOC dynamics were modified by the addition of inorganic N. Our results show that the CO2 produced from the Chinese-fir litter significantly increased from 47.4% to 59.7% and 64.2% with the addition of NH4+-N and NO3−-N, respectively, after 87 d of incubation. This result is consistent with those of previous studies (Liao et al., 2000; Taylor et al., 1989; Fog, 1988). However, the effects of inorganic N (+NH4 and +NO3) on the decomposition of native soil organic carbon did not follow the same pattern. Native SOC decomposition decreased by 19.8% with the addition of NH4+-N, and increased by 9.7% with the addition of NO3−-N. In addition, the MBC and DOC derived from the Chinese-fir litter and the native soil were also changed because of the addition of inorganic N. For example, the DOC from Chinese-fir litter increased because of the addition of inorganic N in both the 15d and the 87 d sampling, whereas the MBC from Chinese-fir litter decreased, except for the Fir + NH4 treatment in 15d the sampling. Although the effect of inorganic N was significant (P < 0.01), general conclusion was not easily drawn because of the following reasons. Microorganisms preferentially take up inorganic nitrogen as NH4+-N because the uptake of NO3−-N costs more energy (Lavelle and Spain, 2003; Merrick and Edwards, 1995; Marzluf, 1997). This was also validated by the greater NH4+-N immobilization in the Chinese-fir litter during incubation and the higher MBC concentration in the Fir + NH4 treatment in the 15d sampling. However, significantly higher inhibitory effect on MBC was observed with +NH4 than +NO3 treatment in most cases, especially in the 87 d sampling. This may be explained by the following mechanisms. Firstly, since uptake of NO3−-N has a higher energetic demand than that of NH4+-N, more C substrate is needed to produce the same amount of MBC, thus caused higher decomposition rate of added Chinese-fir litter and native SOC. Secondly, the different effects of +NH4 and +NO3 may be related to soil acidity caused by nitrification. Although not measured, nitrification is known to lower the pH, which can harm microorganisms, especially when the substrate of nitrification is enhanced (Wallensten et al., 2006). Based on the response of CO2 production, MBC, and DOC concentration in this study, the addition of inorganic N positively affected the soil carbon dynamics, thereby affecting the fate of Chinese-fir litter by enhancing nutrient availability. The positive effect of +NH4 was weakened due to its microbial preference and soil acidity during nitrification. Nevertheless, predicting which effect was dominant is difficult under different conditions. Further studies are needed to determine the possible relationship of inorganic N and soil microorganisms with different soil type, nutrients status, and added materials.

Stable 13C isotope is a powerful technique that allows the study of turnover of substrate and its effect on soil ecological process. However, soil processes are driven by environmental variables (such as soil moisture, temperature and soil animals) except for added substrate, and this kind of studies are currently conducted in simulation experiment in laboratory. Thus, the contributions of those environmental variables are seldom considered. Therefore, a combination of isotopic tracer studies and environmental manipulation was needed to elucidate soil processes and specific mechanisms.

5. Conclusions

This study investigated the fate of Chinese-fir litter after 87 d of decomposition at 16.5 °C, as well as its response to inorganic N addition. Similar to previous studies, most of C from the Chinese-fir litter (47.4%) was released into the atmosphere as CO2, and this proportion increased to 59.7% and 64.2% with the addition of NH4+-N and NO3−-N, respectively. The proportion of Chinese-fir litter-C allocated for DOC followed the same pattern as that of CO2, which indicated a close relationship between these two ecological processes. The effects of inorganic N on soil C process depended on the form of added inorganic N. These findings would improve our understanding of the decomposition of Chinese-fir litter and mineralization of native soil organic carbon in response to the enhanced inorganic N in Chinese-fir plantations in subtropical China.

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