



Tea polyphenols dominate the short-term tea (*Camellia sinensis*) leaf litter decomposition^{*}

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Received Jan. 28, 2016; Revision accepted Apr. 12, 2016; Crosschecked Jan. 5, 2017

Abstract: Polyphenols are one of the most important secondary metabolites, and affect the decomposition of litter and soil organic matter. This study aims to monitor the mass loss rate of tea leaf litter and nutrient release pattern, and investigate the role of tea polyphenols played in this process. High-performance liquid chromatography (HPLC) and classical litter bag method were used to simulate the decomposition process of tea leaf litter and track the changes occurring in major polyphenols over eight months. The release patterns of nitrogen, potassium, calcium, and magnesium were also determined. The decomposition pattern of tea leaf litter could be described by a two-phase decomposition model, and the polyphenol/N ratio effectively regulated the degradation process. Most of the catechins decreased dramatically within two months; gallic acid (GA), catechin gallate (CG), and galocatechin (GC) were faintly detected, while others were outside the detection limits by the end of the experiment. These results demonstrated that tea polyphenols transformed quickly and catechins had an effect on the individual conversion rate. The nutrient release pattern was different from other plants which might be due to the existence of tea polyphenols.

Key words: Tea polyphenol; Catechin; Decomposition; Nutrient release; Polyphenol/N ratio
<http://dx.doi.org/10.1631/jzus.B1600044>

CLC number: S571.1

1 Introduction

In terrestrial ecosystems, apart from fertilization, the decomposition of plant litter is regarded as the main pathway for soil organic matter amendment. Litter decomposition strongly impacts nutrient cycling and the global carbon budget. Many studies have focused on it since the 1960s (Swift *et al.*, 1979; McClaugherty *et al.*, 1985; Aerts, 1997). Climate and litter quality are generally considered as the main factors that regulate the litter decomposition rate

(Meentemeyer, 1978; CouˆTeaux and Bottner, 1995; Trofymow *et al.*, 2002). Although there exists an interaction between climate and litter quality, climate dominates the decomposition process on a large scale, while on a regional level, litter quality is more important (Chadwick *et al.*, 1998; Preston *et al.*, 2000; Berg, 2014).

Parameters such as the ratios of carbon/nitrogen (C/N), lignin/N, lignocellulose/N, or the contents of N and phosphorous (P) are generally used to describe litter qualities (Taylor *et al.*, 1989; Palm and Rowland, 1997; Parton *et al.*, 2007). Commonly a litter with a higher C/N or lignin/N ratio decomposes more slowly (Melillo *et al.*, 1982), because low N content limits the growth of soil microbes leading to a fall in the litter decomposition rate. Much of the literature on the effect of litter quality on its decomposition has focused on lignin, one of the most recalcitrant ingredients,

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^{*} Project supported by the Open Foundation of the State Key Laboratory of Soil and Sustainable Agriculture (No. 0812201215) and the New Cultivation Model for Ecological Tea Plantation Development (No. H20151653), China

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because it only can be utilized by certain unique microbes, and it apparently explains the changes of decomposition rate in a majority of plant species, but it is not suitable in all cases. Some scientists have noticed that polyphenols are strongly correlated with litter decomposition under special conditions (Mesquita *et al.*, 1998; Kurokawa and Nakashizuka, 2008). According to Palm and Sanchez (1990), polyphenol-rich plant litters decompose slowly and the release of nitrogen from their tissues is restricted, even if the degrading materials have a high nitrogen concentration, e.g. poplar trees (Findlay *et al.*, 1996). Moreover, the entrance of a polyphenol, as potential carbon resource or toxicant, may regulate soil microbial activity, and then inversely affects litter decomposition rate. Apart from the close correlation with litter decomposition, polyphenols also play a vital role in nutrient cycling especially of nitrogen, because it can bind with proteins, thereby immobilizing nitrogen (Valus and Jones, 1973; Tharayil *et al.*, 2013). Thus the nutrient release pattern during litter degradation is also worth studying.

Tea is widely cultivated in Southeast Asia as a commercial crop, especially in China (Chen and Lin, 2015), and it uniquely contains a lot of phenolic compounds. Tea polyphenols are distributed in almost every part of the plant, but are particularly prevalent in the leaves accounting for approximately 18%–34% of the dry leaf weight (Wan, 2008). In conventional tea plantations, a large number of trimmed branches return to the soil surface, putting a large amount of polyphenols into the soil, and consequently affect a series of soil processes such as the formation of humus, and nitrogen mineralization. Up to now, there has been little information about the decomposition of tea leaf or pruning branches in situ, and the role of tea polyphenols is unclear. Thus a field experiment was designed to determine the decomposition of tea leaves in terms of mass loss rate, changes in polyphenols, and the nutrient release pattern. We hypothesized that (1) tea polyphenols would stimulate the decomposition rate of tea leaves in the short term; (2) the conversion rate of the tea polyphenol monomers would be different due to their differences in chemical structure; (3) simultaneously the nutrient release pattern might be inconsistent with other plant litters/leaves because of the existence of polyphenols.

2 Materials and methods

2.1 Site description

The research was carried out at the experimental station of the Tea Science Department (30°268' N, 120°199' E), Zhejiang University, located in the north of Hangzhou City, China, which was established for germplasm protection with conventional management in the late 1980s. This area has a subtropical monsoon climate. The mean annual rainfall in this area is 1490 mm, and the mean annual temperature is 18 °C. The soil pH is 5.0, and the soil (0–20 cm depth) comprises 20.22% clay and 44.34% silt.

2.2 Experimental design

The classical litter bag method (Bocock and Gilbert, 1957; Fujii and Takeda, 2010) was used in this study. We found a plot of 12 m×9 m and divided it into three subplots of 12 m×3 m within the area. On the 22nd January, 2013, mature leaves still attached to the trees were collected equally and randomly from the crowns and immediately transported back to the laboratory. In the laboratory, the tea leaves were air-dried at ambient temperature (approximately 20 °C) and stored until determination.

Approximately 4.00 g of air-dried leaves (W_s) were enclosed in 10 cm×20 cm nylon nets (1-mm mesh), all the bags having been weighed (W_1) and labeled previously. In March 2013, after the removal of newly fallen litter, we placed these litter bags on the surface of tea plantation soil immediately beneath the crowns, using metal pins to secure them. Each subsequent month, three replicates from every subplot were sampled until the end of yearly production. From March to November 2013, a total of 27 bags (three replicates×9) were collected and taken back to the laboratory for analysis. We removed soil particles and living plant parts adhering to the bag surface, and the bags were then dried at 40 °C to constant weight. The dry mass of the bags and leaves (W_2) was then determined. The mass loss of each sample was calculated using the following formula: mass remaining (%)=(W_1-W_2)/ W_s ×100%; monthly mass loss was equal to the difference between the two remaining adjacent mass values.

2.3 Chemical analysis

Samples were oven-dried at 70 °C and finely ground through a 20-mesh sieve for analysis. Total

polyphenol content was estimated using the Folin-Ciocalteu method (Heimler *et al.*, 2006) and was calculated by comparison with the standard curve obtained with gallic acid. The results were expressed as gallic acid equivalent (GAE) (mg/100 g of dry weight). To determine the changes in the composition of tea polyphenols (specifically catechins) during the decomposition process, high-performance liquid chromatography (HPLC) analysis was adopted with the modified method proposed by Liang *et al.* (1990). Ground samples (0.20 g) were extracted in a conical flask containing 5 ml 50% (v/v) ethanol in a 70 °C water bath for 10 min, and were stirred in the middle of the process. The extracts were centrifuged at 3500 r/min for 10 min after the flask had cooled to air temperature. The supernatant was transferred to a 10-ml flask and the residues were re-extracted as previously described. The extracts were combined to produce a constant volume, and then filtered through a 0.45- μ m filter. The filtrate (10 μ l) was subjected to HPLC analysis using a C18 column (Agilent Technologies Inc., Santa Clara, CA, USA). The mobile phase A was purified water (MiniQ, Aquapro International Company LLC, USA)/acetonitrile/acetic acid (96.5/3.0/0.5; v/v/v), and the mobile phase B was purified water/acetonitrile/acetic acid (69.5/30.0/0.5; v/v/v). The gradient program was as follows: the mobile phase B was linearly increased from 20% to 65% during the first 35 min, then instantaneously decreased to 20%, and maintained for 5 min. The samples were eluted at 35 °C at a flow rate of 1 ml/min and monitored at 280 nm. The peaks were identified through a comparison of the retention time for the samples with those of the authentic standards.

Total carbon and nitrogen content were determined by dry combustion using a CN LECO-1000 autoanalyzer (LECO Corporation, St. Joseph, MI, USA). Total water-soluble carbohydrate (WSC) was measured by the modified sulphuric-anthrone acid method (Grandy *et al.*, 2000). To the extracted solution derived from the boiling water, 0.5 ml anthrone ethyl acetate solution and 5.0 ml sulphuric acid (H₂SO₄) were added. The optical density of the solutions was then measured at 630 nm using a spectrophotometer and compared with known concentrations of D-glucose as standards. The phosphorus (P), potassium (K), aluminum (Al), calcium (Ca), and magnesium (Mg) contents were analyzed using an

inductive coupled plasma emission (ICP) spectrometer (iCAP 6000 Series, Thermo Scientific, USA) after microwave digestion (ETHOS One, Milestone, Italy) following pretreatment with acid wet oxidation in a mixed solution of HNO₃ (65% (v/v), 6 ml) and H₂O₂ (30% (v/v), 2 ml). The phosphorus content was determined using the molybdate-ascorbic acid method (Olsen *et al.*, 1982). Acid-dissolved fiber and lignin were determined by the sulfuric acid method using a Foss FibreCap (AOAC, 2000).

2.4 Statistical analyses

One-way analysis of variance (ANOVA) followed by Bonferroni multiple comparisons at $P < 0.01$ was performed to test the variance of mass loss and nutrient mass remaining. The Pearson test was used to detect the statistical correlation between the polyphenol/N ratio and mass loss. All data were analyzed using SPSS statistics software (Version 16.0, SPSS Inc., Chicago, IL, USA).

3 Results

3.1 Initial chemical properties and climatic conditions

To determine the influence of litter quality on the decomposition process, initial litter chemical parameters were investigated. The total polyphenol content was 49.20 mg/g, which accounted for approximately 32.5% of the total mass. The initial epigallocatechin gallate (EGCG) concentration was 19.35 mg/g, making it the most abundant catechin monomer among the tea polyphenols. Holocellulose (hemicellulose and cellulose), lignin, and WSC separately shared approximately 19.7%, 3.8%, and 0.1% of the total dry mass; apparently WSC in tea leaves was relatively lower than other organic components. The initial percentages of the main nutrient elements C, N, K, P, Mg, and Ca were 45.6%, 2.6%, 1.3%, 0.2%, 0.3%, and 1.1% of the total mass, respectively. The initial value of the C/N ratio was 17.62 and its dynamic was showed in Fig. 1. Fig. 2 presents the basic climatic conditions for 2013 including the average monthly temperatures and relative humidity levels. The air temperature was higher in July and August than in other months; the relative humidity was less in April, July, and August than in other months.

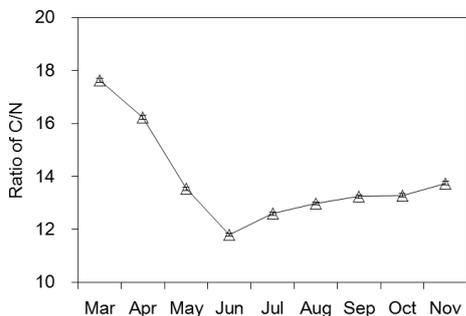


Fig. 1 Variation of C/N ratio of tea leaf litter through the experiment

Error bars represent standard errors

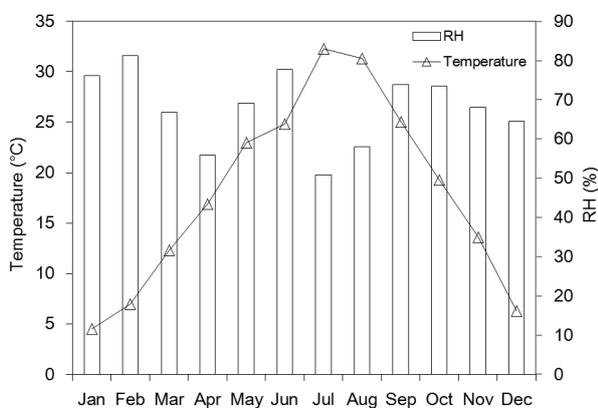


Fig. 2 Average monthly temperature and relative humidity in 2013

Recorded by the Hangzhou Bureau of Meteorology

3.2 Mass loss and monthly mass loss

The mass remaining (%) and the monthly mass loss (%) over the experiment were monitored, and they both changed notably (Fig. 3, $P < 0.01$). From the beginning of the study to July, the mass remaining dropped by approximately 45.0%, whereas only 7.2% mass loss occurred from July to November. After experiment, 56.0% of the total mass disappeared, which was relatively rapid compared with the results of a study on the Japanese cypress (*Chamaecyparis obtusa*) (Fujii and Takeda, 2010). Higher monthly mass loss occurred in July, April, and May (14.6%, 13.4%, and 11.1%, respectively); a lower monthly mass loss was observed in August, September, and October; and negative values were recorded in August and September. At the end of the experiment, all the litter samples had broken down into tiny particles and the leaf structure could barely be recognized, which indicated the comprehensive effects of chemical transformation and physical degradation on the tea leaf litter.

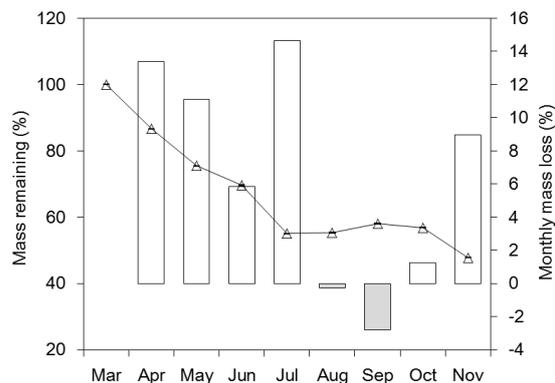


Fig. 3 Mass remaining and monthly mass loss during the experimental period

Line with hollow triangles represents the mass remaining (percentage of initial), and error bars indicate standard errors; columns stand for the monthly mass loss, columns in white and light gray represent positive and negative values, respectively

3.3 Variation of organic components

The total polyphenols decreased dramatically in the first two months, and less than 10% remained; the monomer catechins also fell sharply during the same period. From May to November, the total polyphenol content remained at 2.0%–3.0%, and only gallic acid (GA), catechin gallate (CG), and galocatechin (GC) were detected at very low levels (Fig. 4a, Table 1). The mass remaining of WSC reduced greatly in the first two months from 100.0% to 18.2% (Fig. 4e). Hemicellulose barely changed during the experiment; however, cellulose and lignin decreased steadily, and were eventually reduced to 13.2% and 16.2%, respectively (Figs. 4b–4d).

3.4 Nutrient release

Potassium was released most rapidly from 100% in March to 17.9% in June, and remained constant thereafter (Fig. 5b). Phosphorous remaining (%) was enhanced in the first month (117.0%), and thereafter stayed in the range of 97.8%–109.0%, which means that the phosphorous content barely changed during decomposition (Fig. 5a). For nitrogen, there was a steady accumulation period from March to September, the mass remaining even increased to 130.0% in June and July, followed by a tiny decrease in the later stage (Fig. 5a). Magnesium gradually declined after a short period of increase from March to April, while a modest increase occurred in September (Fig. 5b). The mass remaining of calcium fluctuated through the decomposition process but was always higher than the original value (Fig. 5b).

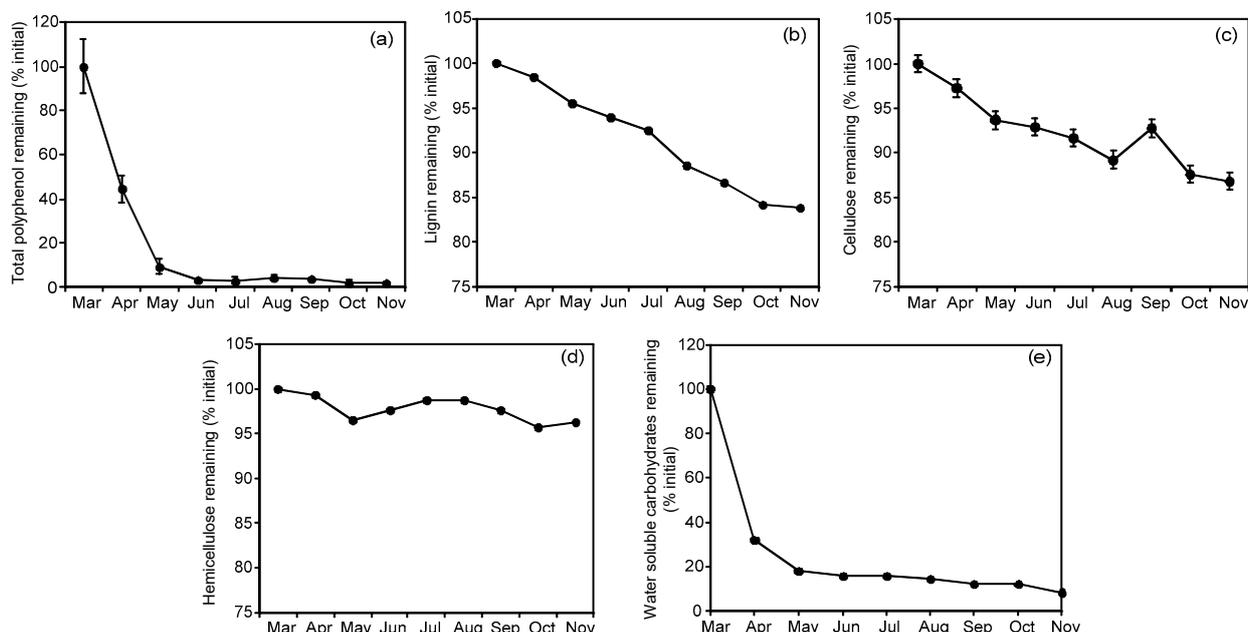


Fig. 4 Mass remaining of chemical components in tea leaf litters through the experimental period (a) Polyphenol; (b) Lignin; (c) Cellulose; (d) Hemicellulose; (e) Water soluble carbohydrates. Error bars indicate standard errors

Table 1 Mean concentration of catechins determined by HPLC at different sampling time

Sampling time	Catechins (mg/g)									
	GA	GC	EGC	C	EC	EGCG	GCG	ECG	CG	
Mar.	0.50±0.00 ^a	3.75±0.01 ^a	12.34±0.01 ^a	0.54±0.05 ^a	4.85±0.03 ^a	19.35±0.01 ^a	0.56±0.01 ^a	0.92±0.10 ^a	0.74±0.02 ^a	
Apr.	0.07±0.01 ^b	2.57±0.01 ^b	0.67±0.01 ^b	0.01±0.00 ^b	0.04±0.00 ^b	0.03±0.00 ^b	0.15±0.00 ^b	0.46±0.05 ^b	0.58±0.01 ^b	
May	0.05±0.01 ^c	0.51±0.01 ^d	0	0	0	0	0.09±0.00 ^c	0.01±0.00 ^c	0.09±0.03 ^d	
Jun.	0.03±0.00 ^d	0.04±0.01 ^f	0	0	0	0	0.02±0.00 ^d	0.01±0.00 ^c	0.03±0.04 ^d	
Jul.	0.03±0.01 ^{cd}	0.15±0.01 ^e	0	0	0	0	0	0	0.04±0.00 ^d	
Aug.	0.03±0.01 ^d	0.70±0.01 ^c	0	0	0	0	0	0	0.26±0.01 ^c	
Sep.	0.03±0.02 ^d	0.67±0.01 ^c	0	0	0	0	0	0	0.25±0.12 ^c	
Oct.	0.03±0.01 ^d	0	0	0	0	0	0	0	0	
Nov.	0	0	0	0	0	0	0	0	0	

“0” means “not found” or values less than 0.01. Data are expressed as mean±SD (n=3). Values with lowercases were significantly different ($P<0.01$). GA: gallic acid; GC: gallic catechin; EGC: epigallocatechin; C: catechin; EC: epicatechin; EGCG: epigallocatechin gallate; GCG: gallic catechin gallate; ECG: epicatechin gallate; CG: catechin gallate

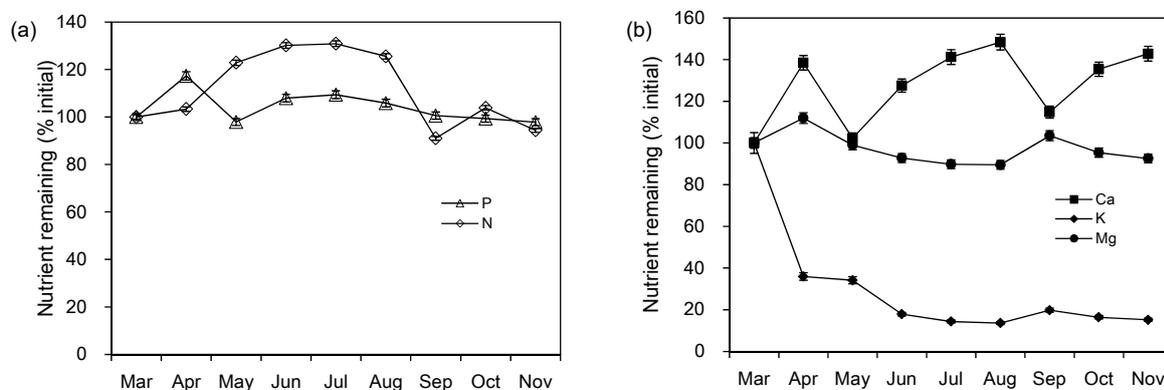


Fig. 5 Dynamics of nutrient remaining during the experiment

(a) Hollow triangles and diamonds represent the dynamics of phosphorus (P) and nitrogen (N), respectively; (b) Solid squares, diamonds, and circles represent the dynamics of calcium (Ca), potassium (K), and magnesium (Mg), respectively. Error bars indicate standard errors

4 Discussion

4.1 Mass loss pattern and organic matter dynamics

Based on the above results, the short-term decomposition of tea leaves can be described as a two-part process: an initial stage of rapid and constant mass loss and a stagnant stage of very slow mass loss. This pattern is similar to the two-phase decomposition model reported by Melillo *et al.* (1989) for red pine litter decomposition. The reason for the fast degradation during the early stage is generally attributed to the swift leaching of soluble components and the rapid decomposition of carbohydrates (Mesquita *et al.*, 1998; Trofymow *et al.*, 2002; Peng *et al.*, 2014). As the decomposition continues, the proportion of recalcitrant constituents such as lignin, polyphenolics, and cellulose gradually increases, resulting in a slow decomposition stage.

Phenolic compounds and lignin have been reported to influence decomposition rates (Melillo *et al.*, 1982; Northup *et al.*, 1998; Hättenschwiler and Vitousek, 2000). In this study, the proportion of lignin was relatively small compared with polyphenols and its mass loss rate was comparatively stable; thus it could not explain the rapid mass loss. In contrast, the rapid decomposition of polyphenols exactly matched the mass loss pattern. From March to May, polyphenols notably decreased by 67.5%, indicating the highest decomposition rate compared to other organic components (Fig. 4a). The reduction of tea polyphenols is largely due to their water solubility and strong oxidizing capacity; polyphenols have multiple reactive groups and active sites facilitating their involvement in a variety of chemical reactions (Wan, 2008). However, the transition of tea polyphenols was too rapid to be detected, as suggested by Mesquita *et al.* (1998), mainly owing to the extremely high concentration of polyphenols in tea leaves and their chemical properties.

The stagnation stage from June to November mostly related to holocellulose rather than lignin in this study (Figs. 4c and 4d). The lignin degradation rate is about twice that of cellulose, according to previous reports that lignin can physically inhibit microbial attacks on the holocellulose fraction or compound the recalcitrant matrix by the encrustation of cellulose (Sinsabaugh and Linkins, 1989; Berg and McClaugherty, 2003; Adair *et al.*, 2008). Addition-

ally, the degradation of both lignin and cellulose is mainly dominated by microorganisms. Given the rich polyphenols in tea plantations' ecosystems, we speculated that the diversity and community structure of decomposers in tea plantations might be affected by phenolic compounds, then consequently changing the decomposition rate of lignocellulose. Instead of the decreasing mass loss rate, monthly mass loss was relatively high in July (Fig. 4b). At the same time, we observed the highest average temperature of 32.3 °C and the lowest relative humidity in July, so the biggest monthly mass loss might result from the increasing photo-thermal effect during that period as suggested by Wang *et al.* (2015) where ultraviolet (UV) exposure could increase litter biodegradability by increasing the microbial accessibility of lignin, as well as the labile carbon supply to microbes.

4.2 Role of polyphenol in the short-term decomposition of tea leaf litter

To verify the hypothesis of the role of polyphenols in tea leaf litter decomposition, we examined a few common indicators according to prior studies. The C/N ratio is a classical predictor of litter decomposition rate: a higher value represents a higher proportion of organic components in the litter, ultimately resulting in slower decomposition. In the present study, the initial C/N ratio was 17.62 in tea leaf litter samples. It declined sharply in the first three months, and then rose gradually in the latter five months (Fig. 1). The loss of total polyphenol explained the reduction in the C/N ratio during the first two months, with the constant disappearance of these easily decomposed substances in the first stage. Lignocellulose components finally took control of the rest of the process, leading to an increasing C/N ratio. The changes in the C/N ratio perfectly reflected the monthly mass loss from March to June (Fig. 3), but with the slight augmentation of the C/N ratio after June, and the monthly mass loss did not decrease as predicted. Apparently, the C/N ratio can explain a part of the decomposition rate of tea leaf litter but not the whole process.

In addition to the C/N ratio, many studies have also treated the recalcitrant components such as lignin and holocellulose (cellulose and hemicellulose) as important factors for stimulating the litter decomposition rate, especially in the latter stages of the process.

Commonly, the higher these recalcitrant components, the slower the decomposition (Cooke and Whipps, 1993; Moore *et al.*, 1999; Silver and Miya, 2001). The initial value of lignin/N was 1.46 in the present study, with little change throughout the experiment. Using the Pearson correlation test, we did not find significant correlations either between the lignin/N ratio and mass loss, or between the lignin/N ratio and monthly loss. Similarly, no correlation existed between cellulose/holocellulose and mass loss/monthly mass loss. Thus, lignin and cellulose cannot explain the short-term tea leaf litter decomposition rate. This is mainly because of the relatively small proportion of lignin in tea leaf litter.

Therefore, we turned to tea polyphenols, which accounted for about 32.5% of the total dry mass in this study. The variation of tea polyphenol content is presented in Fig. 4a. The initial polyphenol/N ratio of tea leaf litter was 12.9. In the first three months of decomposition, the polyphenol/N ratio significantly and rapidly decreased, and remained in the range of 0.2–0.5 thereafter. A significantly negative correlation ($r=-0.88$, $P<0.01$) between the polyphenol/N ratio and mass loss was recognized, indicating the significant depression of polyphenols on tea leaf decomposition. A similar inhibition effect of polyphenols on litter decomposition has been found in pigmy forests (Northup *et al.*, 1998).

The reason why polyphenols affect litter decomposition is still unclear, although a great many hypotheses have attempted to explain the phenomenon. Polyphenols regulate the mobility of nutrients by a series of mechanisms. Adsorption to clay minerals and/or complexation with sesquioxides protects them from microbial attack, reduces the toxic effects of aluminum in acid soils, and competes effectively with other negatively charged compounds for sorption sites. Polyphenols binding to sesquioxides can not only depress phosphate sorption, but also desorb immobile phosphate; thus, high polyphenol concentrations might contribute to the maintenance of phosphorus availability in highly weathered and acidic soils with high levels of iron and aluminum sesquioxides. The property of accumulating iron and aluminum in tea and tea plantation soils (Ruan *et al.*, 2003), and the higher concentration of phosphorus in tea leaf litter (2.04–2.09 mg/g) than in forest leaf litter, indirectly confirmed the combination of polyphenols

and phosphorus. In addition, the stimulation of polyphenols on microbial activity is not well known (Schmidt *et al.*, 2013; Winder *et al.*, 2013). Further investigation is required to determine the genuine function of polyphenols in tea leaf decomposition and the interaction between them and other factors.

4.3 Nutrient release pattern

The release of nutrients during litter decomposition is a dynamic rather than a direct process. It is associated with the litter quality and the decomposition period, and is also associated with the characteristics of the nutrient itself. Generally, there are three release patterns for nutrients during litter decomposition: (1) the leaching-release pattern; (2) the leaching-enrichment-release pattern; and (3) the enrichment-release pattern.

Nitrogen and phosphorus are important for decomposer growth (Melillo *et al.*, 1982; Dziadowiec, 1987) and are not mobilized nor fixed by microorganisms to any great extent. In the present study, both nitrogen and phosphorus accumulated in the early stage then decreased slowly, representing an enrichment-release pattern. The short period of phosphorus increase from March to May might be related to the polyphenol dynamics mentioned above. The accumulation of nitrogen mainly appeared in May to August, during which time the average nitrogen remaining was about 127.3% (Fig. 5a). This enhancement of nitrogen was consistent with previous studies (Johansson, 1993; Berg and Cortina, 1995; Fujii and Takeda, 2010). Low-quality litter with limited nutrients often needs to adsorb nutrients from the environment at the beginning of the decomposition, and it always takes a long time to reach the threshold for release. With a relatively low nitrogen concentration in tea leaf litter, nitrogen accumulated for five months before release, and even the final nitrogen remaining was still as high as 94.5%. The periodical accumulation and release of nitrogen during decomposition are usually attributed to a higher initial C/N ratio or a higher lignin concentration, which could retain nitrogen in the substrate (Osono and Takeda, 2004a; 2004b). Berg *et al.* (1993) assumed that nitrogen fixation occurred when litter had approximately 0.3%–1.4% nitrogen, while nitrogen release appeared when the nitrogen content was in the range 0.6%–2.8%. Obviously this hypothesis cannot explain

nitrogen accumulation during the decomposition for tea leaf litter with initial nitrogen content of 2.63%. However, some other studies have found that the impact of litter polyphenol concentration or the polyphenol/N ratio on the nitrogen release rate is stronger than that of the C/N or lignin/N ratio (Fox *et al.*, 1990; Palm and Sanchez, 1991; Oglesby and Fownes, 1992), especially in acidic and infertile soils. This observation agrees well with the results from this experiment.

The fast release of potassium was similar to many previous studies of leaf decomposition (Fahey *et al.*, 1988; Laskowski *et al.*, 1995b; Osono and Takeda, 2004b), mostly due to its mobility. Potassium is hard to incorporate into organic structures (Marschner and Rimmington, 1988). Magnesium was also highly mobile, but it decreased quite slowly (Fig. 5b), unlike in other studies (Fahey *et al.*, 1988; Laskowski *et al.*, 1995a). This phenomenon might contribute to the ability of polyphenols to absorb exchangeable inorganic cations (Ca, Mg, and K) by providing sorption sites (Wan, 2008). Calcium fluctuated dramatically and ultimately increased to 127.0% (Fig. 5b), which was similar to the result from an experiment carried out by Fujii and Takeda (2010), in which the calcium in Japanese cypress leaves was released slowly, and might be due to the incorporation into structural organic compounds; thus it is mostly released by microbial activity (Dziadowiec, 1987).

5 Conclusions and prospects

During the short-term decomposition of tea leaves, the conversion of tea polyphenols was rapid. Simultaneously it regulated the mass loss rate as well as affected the process of nutrient release indirectly. Our study highlighted that a large number of polyphenols in tea plantation ecosystems had a very close relationship with nutrient cycling, but their long-term effects need further investigation. Management in conventional tea plantation is quite intensive, and a large number of pruned branches and leaves can enter the soil by tillage, so the decomposition process of tea plant litter below ground is worth future study.

When a large quantity of polyphenols enter tea plantation soils, soil microbes could use them as a carbon resource for growth, but it is possible that they

might sometimes inhibit the growth of microorganisms. Microorganisms are involved in a series of metabolic processes such as soil respiration and nutrient cycling. Therefore, it is very important to study the soil microbial activity and community structure after polyphenol amendment in tea plantations because this could provide information on the huge potential for carbon sequestration in tea plantation soils.

Acknowledgements

The authors would like to thank Prof. Yao-ping LUO and Hai-rong XU (both from the Institute of Tea Science, Zhejiang University, Hangzhou, China) for assistance with the experimental design and other members in the Xiao-chang WANG's lab.

Compliance with ethics guidelines

Dong-mei FAN, Kai FAN, Cui-ping YU, Ya-ting LU, and Xiao-chang WANG declare that they have no conflict of interest.

This article does not contain any studies with human or animal subjects performed by any of the authors.

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中文概要

题目: 多酚控制茶树叶片短期分解过程的研究

目的: 通过测定茶树叶片的分解速率及养分释放规律, 研究茶多酚在茶树叶片分解过程中的作用。

创新点: 测定了茶树叶片在茶园地表的分解速率和养分释放规律, 并确定了茶多酚/氮素比值在茶树叶片短期分解过程中的主导作用。首次利用高效液相色谱法监测了分解过程中儿茶素的变化规律。

方法: 采集成熟的茶树叶片, 在室内风干后利用分解袋法测定其分解速率。分解袋放置于茶园地表用于模拟田间条件, 逐月收集分解样品。实验结束后, 测定各月份叶片的干重残留量、月均干重损失率、多酚等有机组分含量以及各元素含量。

结论: 茶树叶片的干物质损失规律可以“两相分解模型”进行描述, 茶多酚/氮素比值是调控分解速率的主要因素。分解过程中, 茶多酚的转换十分迅速, 同时儿茶素单体的结构影响其分解速率: 大部分的儿茶素单体在分解初始两个月内迅速消失, 没食子酸(GA)、儿茶素没食子酸酯(CG)、儿茶素(GC)在分解后期少量检出, 而其他儿茶素已不在检测限内。茶树叶片中大量多酚的存在及其特有性质可能影响着叶片中的养分释放过程。

关键词: 茶多酚; 儿茶素; 分解; 养分释放; 多酚/氮素比值