

Effects of tea genotype and slope position on soil soluble organic nitrogen pools

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Abstract

Soil soluble organic N (SON) pools, microbial biomass, and protease and asparaginase activities at the 0-15 cm and 15-30 cm layers in ten year old tea plantations of two genotypes - Oolong tea (*Camellia sinensis* (L.) O. Kuntze cv. huangjingui) (designated as 'OT') and Green tea (*C. sinensis* (L.) O. Kuntze cv. Fuyun 6) (designated as 'GT'), established at different slope positions. Concentrations of soil SON measured by 2 M KCl extractions under the OT plantation were generally greater than under the GT plantation, while concentrations of soil SON were greater in the middle position (MS) and lower position (LS) positions than in the upper position (US) position. Trends in soil microbial biomass C and N between the two genotypes and across the slope positions were similar to the SON pools. Soil protease and asparaginase activities were generally higher in the MS and LS positions than in the US position, while soil protease activities were higher under the OT plantation than under the GT plantation. Results from this study support that the genotype and the slope position are key factors controlling the availability of soil SON in tea plantations.

Key Words

Soil soluble organic nitrogen (SON), *Camellia sinensis* (L.) O. Kuntze, genotype, slope position, protease, asparaginase

Introduction

Soluble organic nitrogen (SON) is considered to play a vital role in ecosystem processes (e.g. Cookson *et al.*, 2007). However, information on soil SON availability and associated microbial processes in tea orchards is scant. Tea (*Camellia sinensis* L. O. Kuntze) is one of the most important beverage crops in the world. Green, Oolong and black teas are the most common types, but differ genetically. Slope position is a key topographic factor influencing microclimate, species composition and ecosystem functions in many terrestrial ecosystems (McNab, 1993; Sariyildiz *et al.*, 2005). It has been suggested that slope position affects soil particle distribution, soil temperature and moisture, and C and nutrient cycling processes in grasslands (e.g. Turner *et al.*, 1997) and forestlands (e.g. Sariyildiz *et al.*, 2005). Different genotypes of tea cultivars vary with physiological processes and nutrient uptake and stocks (e.g. Kamau *et al.*, 2008) and may respond differently to nutrient supply (Kamau *et al.*, 2008). However, little is known about the effects of slope position and genotype on soil SON availability in tea ecosystems. In this study, it was hypothesized that: 1) different genotypes of tea cultivars affect the availability of soil SON directly through the inputs of root litters of varying quantity and quality and indirectly through influencing soil microbial biomass and enzyme activity and thus the production and transformation of soil SON; and 2) different slope positions influence the soil texture, the movement of carbon and nutrients and microclimatic conditions and thus availability of soil SON.

Methods

Site description and sample collection

Two adjacent tea plantations, established at the Research Station of Tea Research Institute (27°13'S, 119°34'E), Fujian Academy of Agricultural Sciences, Fujian Province, China, were selected for this study. The mean annual rainfall and temperature at this site are 1646 mm and 19.3 °C, respectively. The soil type is a Typic Alliti-Udic Ferrosols (Soil Survey Staff 1999). The research sites were located on two adjacent slopes facing in the same direction to the sun, with an average slope of 20°. The two slopes were developed into terrace land with the width of about 3-4 m. The area of each site measures 0.4 ha in which one was planted with Oolong tea (*C. sinensis* (L.) O. Kuntze cv. huangjingui) (designated as 'OT') and the other was planted with Green tea (*C. sinensis* (L.) O. Kuntze cv. Fuyun 6) (designated as 'GT'). The split-plot design was adopted for this particular study, with two major plots (i.e. OT and GT plots) and three secondary plots (i.e. upper, middle and lower slope positions). Each of the secondary plots had three 15×10 m² replicate plots

with an interval of 3 m between each plot as a buffer area. Both OT and GT plantations were managed using conventional cultivation techniques. Fifteen soil cores were randomly collected from each plot at two depths (0-15 and 15-30 cm) in May 2008, using a 7.5 cm diameter auger and bulked.

Chemical analysis

Total C (TC) and N (TN) of soils, leaf litters and roots were analyzed using an isotope ratio mass spectrometer with a Eurovector Elemental Analyser (Isoprime-EuroEA3000, Milan, Italy). Soil CEC, pH (soil:water 1:2.5) and particle size composition were measured using the methods described by Rayment and Higginson (1992). The 2 M KCl extracts were obtained using the modified version of methods described by Chen *et al.* (2005).

Soil microbial analysis

Soil microbial biomass C (MBC) and N (MBN) were measured by the chloroform fumigation-extraction method using an Ec factor of 2.64 (Vance *et al.*, 1987) and an EN factor of 2.22 (Brookes *et al.*, 1985). Soluble organic C and total soluble N in the K₂SO₄ extracts of the fumigated and unfumigated soil samples were determined by the high temperature catalytic oxidation method using SHIMADZU TOC analyzer (fitted with TN unit) (Chen *et al.*, 2005a). The activities of soil protease and L-asparaginase were estimated using the methods by Ladd & Bulter (1972) and Frankenberger & Tabatabai (1991), respectively.

Statistical analysis

Analysis of split plot design with two factors (main factor, genotype of cultivars; secondary factor, slope position) was performed on basic soil properties, SON pools, microbial biomass, enzyme activities, and PLFA profiling data using Statistica Version 6.1 (Statsoft, Inc.). Least significant difference (LSD, $P < 0.05$) was used to separate the means when differences were significant. Pearson linear correlations between SON pools, soil microbial biomass C and N, total soil N and enzyme activity were also conducted in Statistica Version 6.1 (Statsoft, Inc.).

Results

Concentrations of soil SON in KCl extracts (SON_{KCl}) ranged from 27.3 mg kg⁻¹ to 54.1 mg kg⁻¹ and comprising 33.5%-86.5% of total soluble N and 4.5%-15.0% of total soil N (Table 1). Concentrations of SON_{KCl} and SOC_{KCl} were higher in the MS and LS positions than in the US position at both depths (0-15 cm and 15-30 cm) under both the OT and GT plantations, and decreased with soil depth. In addition, concentrations of soil SON_{KCl} and SOC_{KCl} were higher under the OT plantation than under the GT plantation, and decreased with soil depth (Table 1). Concentrations of NH₄⁺-N in KCl extracts were not significantly different among the slope positions except for the 0-15 cm layer under the GT plantation (Table 1), but were lower in the 0-15 cm layer under the OT plantation than under the GT plantation. Concentrations of NO₃⁻-N in KCl soil extracts were significantly higher at both depths in the MS position than in the US and LS positions under both OT and GT plantations, and were significantly lower under the OT plantation than under the GT plantation (Table 1). Trends in soil microbial biomass C and N between the two genotypes and across the slope positions were similar to the SON pools (Figure 1). Soil protease activities were generally higher in the MS and LS positions than in the US position at both depths under both tea plantations (Figure 2). Soil asparaginase activities showed a similar trend across different slope positions to that for the soil protease activity. Soil protease activities were generally higher in the 0-15 cm and 15-30 cm layers under the OT plantation than under the GT plantation, respectively, while there was no significant difference in soil asparaginase activity between the OT and GT plantations (Figure 2). Both soil protease and asparaginase activities decreased with soil depth.

Conclusions

It has been clearly demonstrated that the genotype and the slope position are key factors controlling the availability of soil SON in tea plantations. Concentrations of soil SON under the OT plantation were generally greater than under the GT plantation, while concentrations of soil SON were greater in the MS and LS positions than in the US position. Organic matter inputs (mainly root litters) of different quantity and quality under different genotypes of tea cultivars were largely responsible for the differences in the SON availability. The variation in soil SON availability at different slope positions may be attributed to different physical and chemical environments (clay content, moisture and soil total C and N etc.) resulting from the downward movement of soil and associated C and nutrients along the slope through the leaching and surface runoff due to the high rainfall and steep slope. Soil microbial biomass and organic N-related enzyme

activities (protease and asparaginase) played a vital role in the production and transformation of SON under different genotypes and at different slope positions. Further studies should focus on how the quality and quantity of root and leaf litters affect the SON production, what key functional groups of soil microbial community are involved in the SON transformation and the chemical nature of SON as affected by the genotype and the slope position.

Table 1. Soil soluble inorganic N ($\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$) and organic N (SON_{KCl}) in 2 M KCl extracts under adjacent Oolong tea and Green tea plantations in subtropical China*.

Soil soluble N and C	Oolong tea				Green tea			
	US	MS	LS	Mean	US	MS	LS	Mean
0-15 cm								
$\text{NO}_3^-\text{-N}$ (mg kg^{-1})	0.3a	1.1a	0.0a	0.5b	1.3b	23.6a	0.0b	8.3a
$\text{NH}_4^+\text{-N}$ (mg kg^{-1})	10.6a	10.6a	13.1a	11.4b	12.0b	23.5a	15.5b	17.0a
$\text{SON}_{\text{KCl}}^\dagger$ (mg kg^{-1})	41.7b	52.8a	52.6a	49.0a	30.5b	54.1a	49.4a	44.7a
$\text{SOC}_{\text{KCl}}^\ddagger$ (mg kg^{-1})	460.6b	551.1a	548.1a	519.9a	272.6c	478.6a	369.6b	373.6b
C: N_{KCl} ratio§	11.1a	10.4a	10.4a	10.6a	8.9a	8.8a	7.5b	8.4b
15-30 cm								
$\text{NO}_3^-\text{-N}$ (mg kg^{-1})	0.5a	2.0a	0.0a	0.8b	3.5b	13.4a	1.2b	6.0a
$\text{NH}_4^+\text{-N}$ (mg kg^{-1})	13.0a	12.9a	10.4a	12.1a	11.8a	14.2a	14.4a	13.5a
$\text{SON}_{\text{KCl}}^\dagger$ (mg kg^{-1})	36.0b	48.2a	47.5a	43.9a	27.3b	41.8a	37.7a	35.6b
$\text{SOC}_{\text{KCl}}^\ddagger$ (mg kg^{-1})	442.5b	522.4a	509.8a	491.6a	239.3b	323.2a	268.2ab	276.9b
C: N_{KCl} ratio§	12.3a	10.8b	10.7b	11.2a	8.8a	7.7ab	7.1b	7.8b

*Data in the column US (Upper slope), MS (Middle slope) and LS (Lower slope) under each tea cultivar are mean values ($n = 3$), which are compared among different slope positions within each tea cultivar and each depth; data in the column 'Mean' are mean values across different slope positions under each tea cultivar and within each depth ($n = 18$), which are compared between tea cultivars. These values are not different at the 5% level of significance if followed by the same letter.

$^\dagger\text{SON}_{\text{KCl}}$, soluble organic N in 2 M KCl extracts; $^\ddagger\text{SOC}_{\text{KCl}}$, soluble organic carbon in 2 M KCl extracts; $^\S\text{C:N}_{\text{KCl}}$ ratio, the ratio of SOC to SON in 2 M KCl extracts.

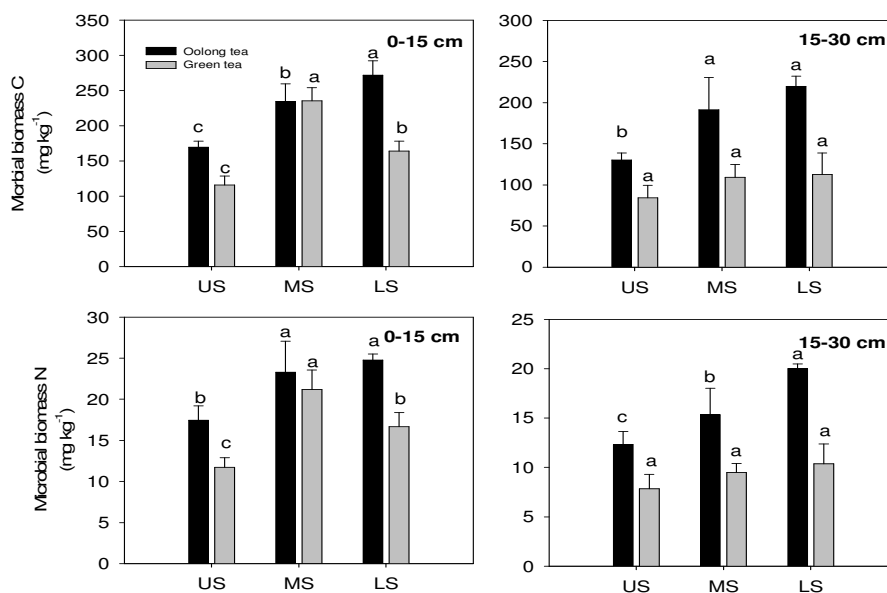


Figure 1. Soil microbial biomass C and N at different slope positions (US, upper slope; MS, middle slope; LS, lower slope) under adjacent Oolong tea and Green tea plantations in subtropical China. Error bars indicate the standard error of the mean ($n = 3$). Lower case letter indicate statistically significant differences among the slope positions under each tea cultivar.

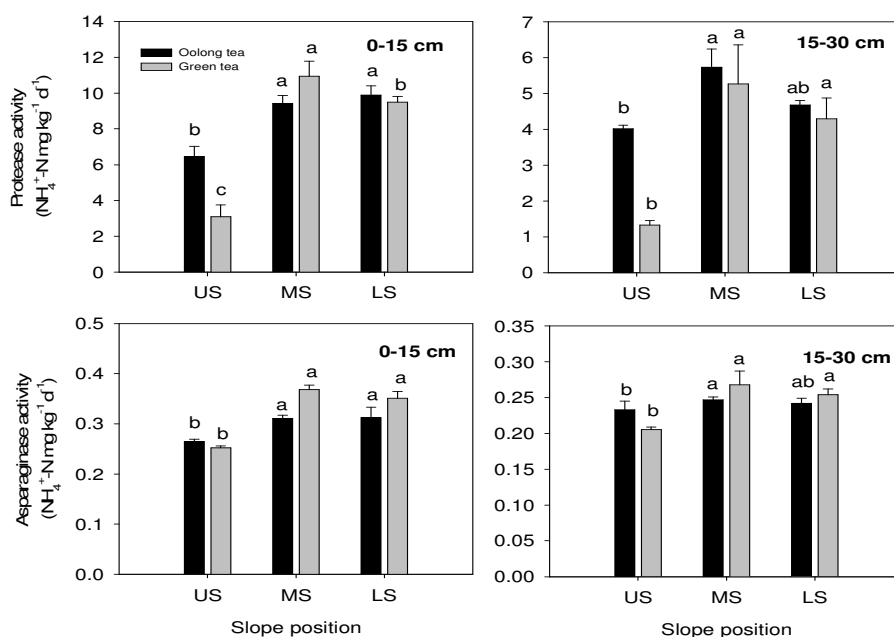


Figure 2. Activities of soil proteases and asparaginases at different slope positions (US, upper slope; MS, middle slope; LS, lower slope) under adjacent Oolong tea and Green tea plantations in subtropical China. Error bars indicate the standard error of the mean (n = 3). Lower case letter indicate statistically significant differences among the slope positions under each tea cultivar.

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