

SHORT COMMUNICATION

Soil organic carbon and nitrogen pools as influenced by polyphenols in different particle size fractions under tropical conditions

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Abstract: Soil organic carbon (SOC) and nitrogen (N) pools are highly dependent on physico-chemical quality and composition of plant litter. Polyphenols are widely spread in the plant kingdom and found in plant litter. They are known to affect the chemical and biological processes in the soil. The objective of this study was to examine the effects of polyphenols on the soil organic matter (SOM) pools in different particle size fractions under tropical conditions. Soils were collected from 19 different sites in wet, dry and intermediate zones of Sri Lanka. The bulk soil was fractionated into three particle size fractions (coarse sand, 2-0.25 mm; fine sand, 0.25-0.05 mm; clay + silt, < 0.05 mm) by dry sieving. Total SOC, total N, labile SOC and polyphenol contents were determined in each fraction. The SOC and N pools were mainly associated with clay + silt fraction. More correlations between the variables were present in clay + silt and fine sand fractions than the coarse sand fraction. Labile SOC decreased with the increase of polyphenol/N ratio in the clay + silt fraction, suggesting the presence of a negative response of polyphenols on microbial growth. Labile SOC, total N and stable SOC increased with polyphenols in fine sand and clay + silt fractions, which indicates a positive response of polyphenols on C sequestration and N accumulation owing to reduced decomposition and chemical immobilization, respectively. However, further studies are necessary to investigate the role played by polyphenols on the SOM decomposition and nutrient cycling of tropics.

Keywords: Labile carbon, organic carbon, polyphenols, stable carbon, total nitrogen, tropical soils.

INTRODUCTION

Plant litter decomposition plays a key role in nutrient cycling, determining the productivity of natural and agroecosystems. It mainly depends on physico-chemical

quality of the litter as well as environmental factors¹ and determines the qualities of the SOC and N pools².

Polyphenolic compounds are widespread in the plant kingdom and are the most abundant group of plant phenolic compounds with known antioxidant properties³. They are relatively resistant to microbial degradation and control many aspects of plant-microbial interactions by increasing or decreasing microbial activity⁴. Many negative feedbacks of polyphenols have been identified whereby plants degrade fertile soils through the production of polyphenol rich litter^{5,6}. Polyphenols convert soil nutrients into unavailable forms, inducing toxicities to microbial population, inhibiting enzyme activities and creating unfavourable condition for seed germination, root growth and nutrient uptake⁷.

However, there are many positive feedbacks of polyphenols reported elsewhere⁸⁻¹⁰. By inhibiting decomposition, polyphenols regulate the formation of humus layer, conserving sequestered carbon and nutrients, creating a more favourable medium for root growth, and complexing Al, Mn and Fe by chelation which reduces potential toxicities such as Al toxicity and P fixation in the soil⁷.

Most of the experimental studies on plant litter quality defined chemical quality indices using various ratios of C, N and polyphenols², and have attempted to predict the litter decomposition and nutrient release^{1,8,11}. However, the role played by polyphenols on the organic matter pools has been under-studied, except for a few temperate studies mentioned above. Further, the quality

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and quantity of the SOM pools vary with the particle size fractions of the soils¹², and the fractionation allows a better understanding of the SOM rather than unfractionated soil¹³. Thus the objective of the present study was to examine the effect of the soil polyphenols on the SOC and N pools of different particle size fractions in some tropical soils.

METHODS AND MATERIALS

Site selection, soil sampling and sample preparation: Sri Lanka has a tropical climate and is divided into wet, intermediate and dry zones based on the intensity of rainfall¹⁴. Soil samples were collected from 16 home gardens, 2 vegetable fields and a cocoa plantation representing a range of soils in dry, wet and intermediate zones. The floor litter layer was removed and three random soil samples were taken from a 0-10 cm depth from each site to prepare a composite sample. The samples were air dried at room temperature and all visible organic debris, living fauna, stones, plant roots etc., were removed. Soil fractionation was done by the dry sieving method. Three hundred and fifty grams of the soil samples were fractionated to 2-0.25 mm, 0.25-0.05 mm and < 0.05 mm using a mechanical sieve shaker. They represented coarse sand, fine sand and clay + silt fraction, respectively.

Chemical Analyses: Soil pH was measured at a ratio of 1:2.5 (w/w) of soil to water, using a pH meter. Total extractable polyphenols was measured by Folin-Denis reagent¹⁵. Labile SOC (microbial biomass C and other easily decomposable C) was measured by the modified permanganate oxidizable C method¹⁶. Total SOC was determined by the wet oxidation method without using external heating, in which organic carbon was oxidized by the acidified dichromate solution¹⁵. Then, stable SOC was calculated by subtracting the labile SOC from the total SOC. Total N was analyzed using the Kjeldhal method¹⁷. Data were analyzed using the Proc GLM procedure and means were separated by Tukey's HSD test. Correlation and regression analyses were performed

to establish relationships. All data were analysed using SAS software¹⁸.

RESULTS AND DISCUSSION

Soil pH varied from 4.20 to 8.33 in different sites sampled (Table 1). Labile C and total N showed very high variabilities whereas stable C had a relatively low variability among sites. The SOC and N pools among the three particle size fractions increased in the order of: coarse sand < fine sand < clay + silt (Table 2). Their calculated C/N ratios increased in the order of: coarse sand = clay + silt < fine sand. Those pools were highly associated with the clay + silt fraction than the other two fractions. Similar results have been reported by many researchers¹⁹⁻²¹. In general, sand sized fractions mainly consist of macro-organic matter which are much susceptible to microbial mineralization. On the other hand, clay and silt sized particles are enriched in microbial products and plant derived aromatic compounds, which are inaccessible to microbes. Therefore, the SOM is preserved in the fine fractions as the primary reservoir of C and N^{22,23}.

A negative relationship was observed between the labile SOC and polyphenol/N ratio in clay + silt fraction (Figure 1). Many studies have shown that polyphenols decrease the N availability^{8,24,25,26}. It has been reported that the polyphenol/N ratio is a determinant of the N release of organic materials with limited N concentrations < 1%²⁶. In agreement with that, present study indicated that the relationship was significant when soil total N concentrations were < 0.42%. In both studies, the C/N ratios of the substrates were comparable (i.e. 31 against 37). Phenolic compounds have been shown to increase N immobilization through protein complexation, thus decreasing the N availability for microbial growth²⁷. This was confirmed by the observed positive correlation between polyphenols and total N in both fine sand and clay + silt fractions (Table 3). This process enhances N

Table 1: Initial soil properties of the sites studied

Soil character	Range	Mean	CV (%)
pH	4.20 - 8.33	6.45	16.39
Polyphenols (g/100 g)	2.14 - 6.99	4.20	27.73
Labile C (g/100 g)	0.23 - 1.89	0.98	60.20
Stable C (g/100 g)	1.01 - 4.77	2.35	43.01
Total C (g/100 g)	1.44 - 5.63	3.33	39.23
Total N (g/100 g)	0.025 - 0.15	0.062	50.26

CV- coefficient of variation

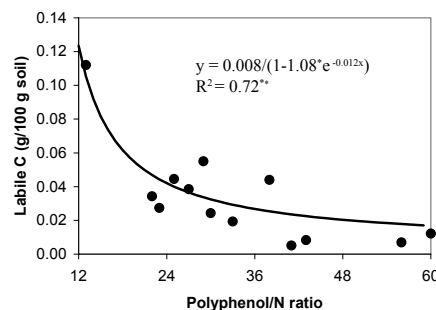


Figure 1: Relationship between labile SOC and polyphenol/N ratio in clay + silt fraction of the soils studied

Table 2: Distribution of organic carbon and nitrogen pools in different particle size fractions of the soils studied

	Polyphenol	Labile C	Total SOC	Total N	Polyphenol/N
	(g/100 g soil)				ratio
Coarse sand	6.00 a	0.1259 b	2.86 b	0.078 b	116a
Fine sand	4.32 b	0.1562 b	4.27 b	0.111 b	49.1b
Clay + silt	5.38 ab	0.2277 a	7.34 a	0.202 a	32.7b
MSD (0.05)	1.06	0.0564	2.58	0.042	43.7
CV (%)	25.5	41.8	67.4	40.5	83.4

Values in the same column followed by different letters are significantly different at 5% probability level.

MSD-minimum significant difference. CV-coefficient of variation.

Table 3: Correlation coefficients (r) between the soil organic carbon and nitrogen pools of different particle size fractions of the soils studied

		Labile C	Stable C	Total N
Polyphenol	Coarse sand	0.040 ns	-0.198 ns	-0.319 ns
	Fine sand	0.601 **	0.480 *	0.414 ns
	Clay + silt	0.734 **	0.446 ns	0.614**
Labile C	Coarse sand	-	0.294 ns	-0.039 ns
	Fine sand	-	0.729 **	0.748 **
	Clay + silt	-	0.332 ns	0.845 **
Stable C	Coarse sand	-	-	0.629 **
	Fine sand	-	-	0.935 **
	Clay + silt	-	-	0.391 ns

ns- not significant at 5% probability level.

* significant at 5% probability level.

** highly significant (probability < 1%).

conservation and sequestration into a large unavailable pool of the SOM^{7,28}. Consequently, it decreases microbial biomass C in the soil, which is positively correlated with the labile C content^{29,30}. In addition, polyphenols may interfere in enzyme functions or decomposer metabolism, resulting in the reduction in microbial growth³¹.

In the fine sand and clay + silt fractions, there were positive correlations between polyphenols and labile SOC. This could be due to degradation and use of polyphenols as food sources by laccase producing microbes³². It has been reported that phenolics primarily increase microbial activity when biota use phenolic compounds as a C source^{9,10}. On the other hand, some fungi can produce polyphenolic compounds as secondary metabolites. Consequently, polyphenol content increases with polyphenol-producing fungal population⁸, which contributes to labile SOC pool. The labile SOC content was positively correlated with the total N content in clay + silt and fine sand fractions, indicating the immobilization of N in the microbial biomass (Table 3).

This study indicates that polyphenols play a role in controlling N availability and labile SOC and hence stable C accumulation in the fine soil fractions, but it is not clear in the coarse fraction. The fractionation of the soils revealed that, this control occurs in the fine fractions, which would otherwise be masked by the coarse fraction. Thus, it is clear that soil polyphenols affect positively as well as negatively on the SOC and N pools not only in temperate conditions, but also in the tropics. Such effects in the coarse fraction have not been reported. On the basis of the above findings, it is necessary that further studies be carried out to investigate the role played by polyphenols on the SOM decomposition and nutrient cycling in the tropics.

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