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Original article

Biological effects of native and exotic plant residues on plant growth, microbial biomass and N availability under controlled conditions

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Abstract

The leaf litter of six tropical tree species (*Acacia holosericea*, *Acacia tortilis*, *Azadirachta indica*, *Casuarina equisetifolia*, *Cordyla pinnata* and *Faidherbia albida*) frequently used in agroforestry plantations in Sahelian and Soudano-Sahelian areas were tested for their influence on soil nitrogen content, microbial biomass and plant growth under controlled greenhouse conditions. Half of the soil was planted with onion (*Allium cepa* L.) seedlings and the other half was not. Two herbaceous species, *Andropogon gayanus* and *Eragrostis tremula*, were also studied. Co-inertia analysis (CIA) and one-way analysis of variance (ANOVA) analysis showed that *C. pinnata* and *F. albida* leaf powder amendment induced the highest plant growth, whereas leaf powder of *E. tremula* is associated to higher microbial biomass and NH_4^+ content. Higher onion seedlings growth is associated with higher concentration of nitrogen and lignin in leaf powders. Conversely, lower plant growth is associated to higher rates of cellulose, hemicellulose and phenols in leaves. Higher rates of cellulose and hemicellulose are associated with higher microbial biomass and NH_4^+, whereas phenols are associated to lower microbial biomass. The results showed that amendment of *A. holosericea* leaf powder (high concentrations of phenol) to the soil resulted in a lower microbial biomass and lower onion seedlings growth. Data showed that the plant residue quality index (PRQI) could be a useful tool to predict the effects of litter materials on root growth in glasshouse conditions. The highest values on soil and plant parameters were recorded with *C. pinnata* litter. While powdered leaf material increased the accessibility of substrates to microbes, more research with *C. pinnata* leaf litter (under a wider range of ecological conditions) is needed. It could add deeper on its agronomic impact in the tropics.

Keywords: Amendment; Tropical leaf litters; Plant growth; Microbial biomass; Nitrogen

1. Introduction

The loss of productivity of soils in Sub-Saharan Africa is often related to the decrease of soil organic matter and nutrient status. Application of organic inputs, such as prunings and crop residues, has to be considered for the development of sustainable agricultural systems [27]. It is well known that amendment of plant residues can improve soils' nutrient content, physical properties and biological activity, as well as crop performance [1,9,30]. Rates of residues decomposition and nutrient release determine the extent to which litter

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materials affect soil properties and plant production [20,34]. Rapid decomposition will provide a boost of nutrients during the period of crop growth, but the impact on soil physical conditions may not be significant. On the contrary, slow decomposition may have a significant influence on soil physical conditions but little effect on soil nutrient availability [38]. Decomposition of plant residues is the result of three processes: fragmentation, catabolism (microbial and animal enzymatic activities) and production of water-soluble materials [34]. The extent to which organic residues decompose depends on environmental conditions (i.e. temperature, moisture, etc.) [22] and the chemical composition of decomposing materials [14,36].

Leaf litter production and its decomposition are the main processes regulating carbon and nitrogen cycles in natural ecosystems and some agro-ecosystems [28]. While the positive effects of trees on soil fertility and crop production have been pointed out [6], it is important to screen the resource quality of tree species potentially used in agroforestry systems for its impact on N mineralization and microbial development. For instance, it is well known that the decomposition of plant residues is related to their C/N ratio, lignin and polyphenol contents [14,5,38].

The aim of this study was to test:

- whether leaf powder amendment is effective in modifying soil nitrogen contents and microbial biomass;
- whether leaf amendment can stimulate plant growth or not;
- whether plant quality index can predict the effects of plant residues on plant growth.

Six ground litters of tropical tree species frequently used in agroforestry plantations in the Sahelian and Soudano-Sahelian areas were tested for the effect on the growth of onion seedlings under glasshouse conditions.

2. Materials and methods

2.1. Litters

Leaf litter materials were collected from under three exotic (*Azadirachta indica*, *Casuarina equisetifolia* and *Acacia holosericea*) and three native (*Faidherbia albida*, *Acacia tortilis raddiana* and *Cordyla pinnata*) tree species during the dry season in Senegal. Herbaceous species (*Andropogon gayanus* and *Eragrostis tremula*) were collected by cutting standing grass from planted fallows. Litter materials were air-dried for 2 weeks at room temperature, powdered and sieved (0.5 mm).

2.2. Litter characterization

Fibers (hemicellulose, cellulose and lignin) were analyzed by the Goering and Van Soest method (1970) [16] as neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL). Instead of permanganate lignin oxidative attack, 72% sulfuric acid was used for cellulose degradation [31]. Total soluble carbon was extracted by mixing 1 g of litter with 60 ml of cold water for 2 hours and was measured by dichromate chemical oxygen demand (COD) method [7]. Phenolic compounds were extracted according to the tropical soil biology and fertility (TSBF) method [3] by heating 0.5 g of litter at 80 °C in 50 ml of 50% (v/v) methanol in water, to get a phenolic fraction which was considered as the total of phenolic compounds. The phenolic content was determined using Folin–Denis reagent method modified by King and Heath (1967) [19] with tannic acid as a standard. Total nitrogen and carbon were measured by dry combustion with a CHN Analyzer (LECO Corporation, St. Joseph, MI, USA).

Plant residue quality index (PRQI) was calculated according to Tian et al. (1995) [36] and was defined as:

$$\mathrm{PRQI} = 1/[(0.423\mathrm{C/N} + 0.439\mathrm{Lignin} + 0.138\mathrm{Polyphenols})] \times 100$$

(with lignin and polyphenol content expressed as percent of dry weight).

2.3. Glasshouse experiment

For each plant species, leaf powders were mixed at three different levels of concentration (0%, 1% and 5%, w/w) with a non-disinfected sandy soil (pH H_2O 7.9; organic C 0.5%; organic N 0.03%; P 0.24% and K 0.171 meq/100 g). Soil and litter mixtures were placed in 100 ml polythene pots (~100 g). Surface-sterilized onion seeds (*Allium cepa* L.) were germinated on a sterilized sandy soil (140 °C, 40 min). Once the seeds germinated, one seed was planted in each pot. There were 10 replicates per leaf powder combination. One half (five replicates) were planted with onion seedlings and the other half (five replicates) was not planted. Pots were watered daily with tap water and grown under natural light (daylight approximately 12 h, mean day-

time temperature 30 °C). Control treatments for both planted and not planted pots received no leaf powder amendment.

2.4. Soil analysis

After 2 months of incubation the soil of each pot was carefully mixed and 20 g of moist soil was collected to determine microbial biomass using the fumigation–extraction method [2]. It was done by measuring ninhydrin-N reactive compounds extracted from soils using 2 M KCl solution after a 10-day fumigation period. Fumigated and not fumigated soils were suspended in KCl solution (1/3 dry soil/solution, w/v; 2 M final concentration) and shaked at 25 °C for 1 hour. Extracts were filtered (Whatman 0.45 μm) and stored at –20 °C for further analysis. Ninhydrin-reactive nitrogen content was determined colorimetrically by flow injection analysis (Evolution II, Alliance-Instrument, France). Microbial biomass C was estimated from the gain in ninhydrin-reactive N after fumigation, multiplied by 21 [2].

Soil NH_4^+ and NO_3^- concentrations were determined colorimetrically according to the method of Bremner (1965) [8] after 2 months incubation.

The heights of the onion seedlings were measured, shoots and roots were harvested, oven dried (1 week at 65 °C) and weighed.

2.5. Statistical analysis

For each concentration of ground leaves, data were treated with one-way analysis of variance (ANOVA). Means were compared using PLSD Fisher test ($P < 0.05$). Co-inertia analysis (CIA) was used to analyze the relationship between the plant characteristics, mineral and microbial characteristics of the soil and litter materials (their origins and chemical characteristics). CIA [11] is a multivariate analysis technique that describes the relationships between two data tables. Classical methods, like principal components analysis (PCA), aim at summarizing one table by searching orthogonal axes on which the projection of the sampling points (rows of the table) have the highest possible variance. This characteristic ensures that the associated graphs (factor maps) will represent the initial data in the best way. To extract information common to both tables, canonical correlation analysis methods search successive pairs of axes (one for each table) with a maximum correlation. The problem is that it often leads to axes with a very high correlation, but with very low percentage of explained variance. To overcome this difficulty, CIA looks for pairs of axes with maximum covariance (instead of correlation). Moreover, Monte-Carlo tests can be used to check the significance of the relationships evidenced by CIA between the two tables. Computations and graphical displays were made with the free ADE-4 software [35]. Regression analyses were carried out with the software packages Statview for Macintosh™.

3. Results

Among plant residues used for this study, three plant species were exotic and three were native from West Africa. They had a large variability in chemical composition of litter materials (Table 1). The PRQI values ranged from 2.8 to 6.5 (Table 1). No relationship between the type of leaf litter (herbaceous or tree species, native or exotic plants) and PRQI values were found.

CIA of the global relationships between leaf litter chemical characteristics and soil and onion seedlings characteristics are shown in Fig. 1. The four graphics

Table 1
Chemical composition and PRQI of leaf litter materials

Leaf litter	Sol. OM[a] (mg g^{-1})	Total phenols (mg g^{-1})	Lignin (%)	Cellulose (%)	Hemicell. (%)[b]	C (mg g^{-1})	N (mg g^{-1})	C/N	PRQI[c]
A. holosericea	159.3	175	19.9	13.6	10.1	539.2	9.14	58.9	2.8
A. tortilis	78.4	22.7	25.6	23.6	13.3	453.9	20.3	22.4	4.8
A. gayanus	91.0	10.3	10	37.2	28.1	457.1	9.0	50.8	3.8
A. indica	134.0	20	23.4	19.3	11.1	442.6	13.9	31.9	4.2
C. equisetifolia	157.0	39.6	20.4	32.2	15.1	471.9	13.6	34.8	4.1
C. pinnata	123.0	13.7	34.1	13.0	14.7	488.1	23.7	20.6	6.5
E. tremula	99.0	7.7	8.1	32.7	28.3	381.7	9.1	41.7	4.6
F. albida	76.8	12.5	21.3	19.6	11.3	428.3	20.0	21.4	5.4

[a] Soluble organic matter.
[b] Hemicellulose.
[c] Calculation for PRQI: 1 / [(0.423 C/N + 0.138 Polyphenols)] × 100.

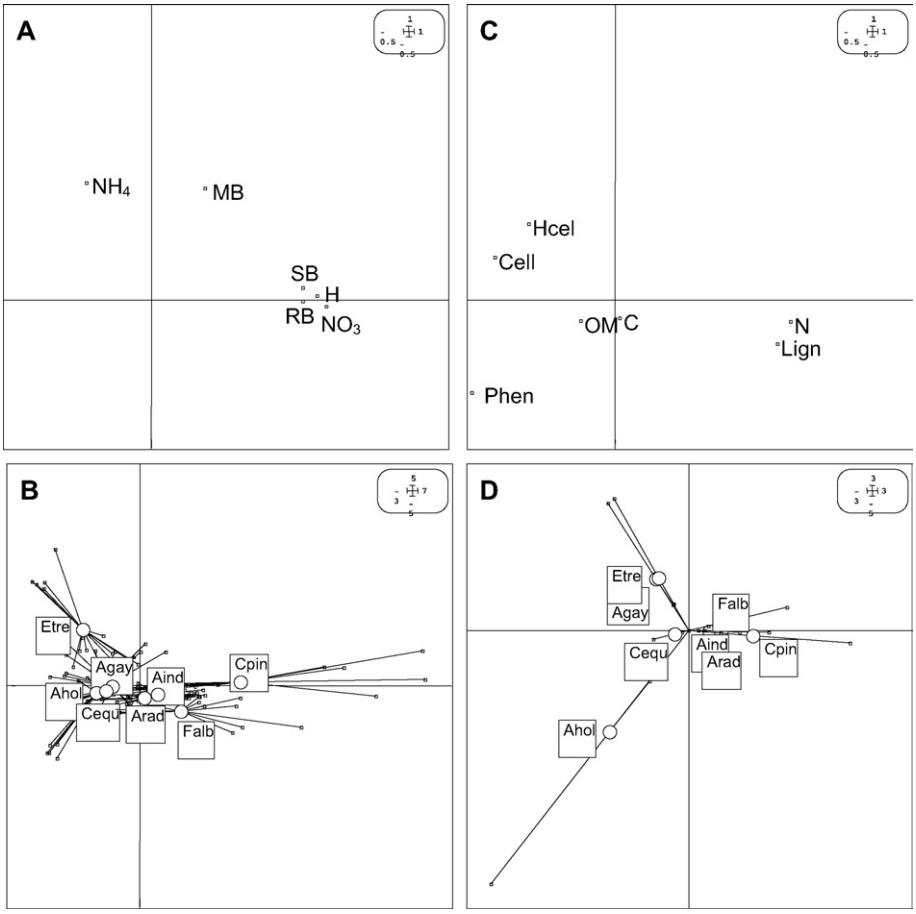

Fig. 1. CIA of the global relationships between leaf litter chemical characteristics and soil and onion seedlings characteristics. A: Factor map of plant growth, microbial biomass and soil mineral nitrogen (MB: microbial biomass; SB: shoot biomass; RB: root biomass). B: Factor map of leaf litter materials origins (Etre: *E. tremula*; Ahol: *A. holosericea*; Agay: *A. gayanus*; Cequ: *C. equisetifolia*; Aind: *A. indica*; Arad: *A. tortilis*; Falb: *F. albida*; Cpin: *C. pinnata*). C: Factor map of leaf litter materials chemical characteristics variables (Hcel: hemicellulose; Cell: cellulose; Phen: total phenols; OM: organic matter; C: carbon; N: nitrogen; Lign: lignin). D: Factor map of leaf litter materials origins (for the legend, see Fig. 1B).

(1A, 1B, 1C, and 1D) can be superimposed and allow to analyze the relationships between these variables, according to leaf powder tree species. The Monte-Carlo test shows that the hypothesis of absence of relationship can be rejected with a very low error risk ($P < 0.001$).

Fig. 1A shows that the first co-inertia axis (horizontal axis, 79% of explained co-inertia) corresponds to a plant growth gradient, with high values on the right, together with NO_3^- concentration. The second co-inertia axis (vertical axis, 19% of explained co-inertia) shows that microbial biomass and NH_4^+ soil content are independent from the onion seedlings growth gradient.

Fig. 1B shows the leaf litter origin for each sample. On the horizontal axis, it is clear that samples corresponding to the highest plant growth are those that received *C. pinnata* and *F. albida* leaf powders. On the vertical axis, samples treated with leaf powder of *E. tremula* are associated to high microbial biomass and soil NH_4^+ content.

On Fig. 1C, the horizontal axis shows that high onion seedlings growth is associated with high concentrations of nitrogen and lignin in leaf powders. On the contrary, high rates of cellulose, hemicellulose and phenols in leaves are associated to lower plant growth. On the vertical axis, high rates of cellulose and hemicellulose are associated with high microbial biomass and NH_4^+. On the contrary, phenols are associated to low microbial biomass.

Fig. 1D confirms that *C. pinnata* leaf powder is characterized by high concentrations of nitrogen and lignin, and is associated to high onion seedlings growth. *E. tremula* and *A. gayanus* leaf powders have high concentrations of cellulose and hemicellulose, correspond-

ing to high microbial biomass and NH_4^+, but to low onion seedlings growth. *A. holosericea* leaf powder has high concentrations of phenols, corresponding to low microbial biomass and low onion seedlings growth.

For the un-planted soil and at 1% leaf litter amendment, NH_4^+ concentration was significantly higher in *A. holosericea* and *E. tremula* leaf litter treatments, NO_3^- concentration was significantly higher in *A. indica* amended soil, microbial biomass was significantly larger in *A. gayanus*, *A. indica*, *C. equisetifolia* and *C. pinnata* treatments and was significantly lower in *F. albida* treatment than in the un-amended control soil (Table 2). For 5% leaf litter amendment in comparison to the control, NH_4^+ concentration was significantly higher in *C. pinnata* and *E. tremula* amended soils, NO_3^- concentration was significantly higher in *A. tortilis*, *F. albida* and *C. pinnata* treatments, microbial biomass was significantly larger in all the treatments with exception of *A. holosericea* leaf litter amendment (Table 2).

For the planted soil and at 1% leaf litter amendment, NH_4^+ concentration was significantly higher than in the un-amended soil (control) in *A. holosericea* and *E. tremula* leaf litter treatments (same as in the un-planted soil), NO_3^- concentration was significantly higher in *A. tortilis* amended soil, microbial biomass was significantly larger in *A. tortilis*, *A. gayanus*, *A. indica*, *C. equisetifolia* and *C. pinnata* treatments (Table 3). When leaf litter materials were added to the soil at 5% concentration, NH_4^+ concentration was significantly higher in *E. tremula* amended soil and microbial biomass significantly increased in most of the treatments (with exception of *A. holosericea* leaf litter amendment) (Table 3). Compared to the control, NO_3^- concentration was significantly higher in *A. tortilis*, *A. indica*, *C. pinnata* and *F. albida* treatments while it was decreased with *A. holosericea*, *A. gayanus* and *C. equisetifolia* leaf litter amendments (Table 3).

At 1% concentration, the height of onion seedlings was significantly stimulated with *A. indica* and *C. pinnata* amendments and inhibited in *A. holosericea* and *C. equisetifolia* treatments (Table 4). Compared to the control, shoot growth was increased with *A. indica* and *F. albida* amendments whereas it was decreased in *A. holosericea, A. gayanus, C. equisetifolia* and *E. tremula* treatments (Table 4). The root biomass was significantly lower in *C. equisetifolia* and *E. tremula* treatments (Table 4).

At 5% concentration, the height of onion seedlings was enhanced with *C. pinnata* and *F. albida* amendments (Table 4). Shoot and root growth were decreased with most of the leaf litter treatments, with exception of *C. pinnata* and *F. albida* where they were stimulated (Table 4).

In the un-planted soil, significant positive relationships were found between leaf litter chemical characteristics (soluble organic matter, lignin, hemicellulose, C and N) and soil NH_4^+content. Soil NO_3^- content was

Table 2
Soil microbial biomass, NH_4^+ and NO_3^- concentrations in the un-planted soil 2 months after litter application at 1% and 5% rates. For each leaf powder concentration, data in the same column followed by the same letter are not significantly different according to the one-way ANOVA ($P < 0.05$). Means reported with standard errors

Leaf litter origin	NH_4^+ (μg N g^{-1})	NO_3^- (μg N g^{-1})	Microbial biomass (μg C g^{-1})
1% *concentration*			
Control	0.2 (0.1) a	2.9 (0.4) a	13.0 (1.6) b
A. holosericea	0.9 (0.03) b	0.9 (0.2) a	11.4 (1.3) ab
A. tortilis	0.0 (0.0) a	4.4 (0.6) a	6.2 (1.1) ab
A. gayanus	0.0 (0.0) a	2.4 (0.2) a	26.2 (1.3) c
A. indica	0.0 (0.0) a	27.5 (13.3) b	25.8 (1.8) c
C. equisetifolia	0.0 (0.0) a	1.5 (0.1) a	25.4 (0.5) c
C. pinnata	0.0 (0.0) a	9.6 (1.1) a	34.4 (0.5) c
E. tremula	1.2 (0.5) b	3.7 (0.7) a	13.0 (0.9) b
F. albida	0.0 (0.0) a	3.7 (0.3) a	2.0 (1.1) a
5% *concentration*			
Control	0.2 (0.1) a	2.9 (0.4) a	13.0 (1.6) a
A. holosericea	0.5 (0.1) a	1.1 (0.4) a	15.0 (1.1) ab
A. tortilis	0.0 (0.0) a	13.9 (1.0) b	22.0 (0.6) bc
A. gayanus	0.0 (0.0) a	0.4 (0.1) a	35.2 (0.6) d
A. indica	0.0 (0.0) a	8.1 (0.9) ab	36.4 (2.2) d
C. equisetifolia	0.0 (0.0) a	0.1 (0.0) a	35.6 (5.3) d
C. pinnata	4.4 (0.6) c	60.3 (11.6) c	35.6 (1.3) d
E. tremula	1.6 (0.3) b	1.5 (0.6) a	28.6 (2.2) cd
F. albida	0.0 (0.0) a	15.5 (1.5) b	22.2 (3.1) bc

Table 3
Soil microbial biomass, NH_4^+ and NO_3^- concentrations in the planted soil 2 months after litter application at 1% and 5% rates. For each leaf litter concentration, data in the same column followed by the same letter are not significantly different according to the one-way ANOVA ($P < 0.05$). Means reported with standard errors

Leaf litter origin	NH_4^+ (μg N g^{-1})	NO_3^- (μg N g^{-1})	Microbial biomass (μg C g^{-1})
1% *concentration*			
Control	0.5 (0.1) a	4.6 abc	15.2 (1.5) ab
A. holosericea	1.6 (0.2) b	1.9 ab	13.8 (0.6) ab
A. tortilis	0.0 (0.0) a	11.5 d	27.6 (0.9) de
A. gayanus	0.0 (0.0) a	3.2 ab	24.6 (2.5) cd
A. indica	0.0 (0.0) a	1.7 a	24.0 (1.5) bcd
C. equisetifolia	0.0 (0.0) a	3.1 ab	60.2 (7.9) f
C. pinnata	0.0 (0.0) a	5.4 abc	37.4 (0.8) e
E. tremula	2.6 (0.1) c	6.1 bc	10.6 (2.2) a
F. albida	0.0 (0.0) a	7.8 cd	16.2 (1.3) abc
5% *concentration*			
Control	0.5 (0.1) a	4.6 (0.7) b	15.2 (1.5) a
A. holosericea	0.1 (0.1) a	0.3 (0.2) a	24.0 (2.6) ab
A. tortilis	0.0 (0.0) a	28.4 2.5) c	78.2 (7.5) d
A. gayanus	0.0 (0.0) a	0.2 (0.1) a	123.8 (7.8) f
A. indica	0.0 (0.0) a	29.6 (3.1) c	92.8 (3.9) e
C. equisetifolia	0.0 (0.0) a	0.1 (0.1) a	72.4 (2.8) d
C. pinnata	0.1 (0.1) a	136.7 (2.5) d	105.2 (6.3) e
E. tremula	1.6 (0.3) b	1.5 (0.6) ab	28.6 (2.2) b
F. albida	0.0 (0.0) a	30.5 (1.9) c	50.6 (9.4) c

Table 4
Growth of onion seedlings 2 months after litter application at 1% and 5% rates. For each leaf litter concentration, data in the same column followed by the same letter are not significantly different according to the one-way ANOVA ($P < 0.05$). Means reported with standard errors

Leaf litter origin	Height (cm)	Shoot biomass (mg dry weight)	Root biomass (mg dry weight)
1% *concentration*			
Control	21.7 (0.6) cd	48.3 (2.5) b	19.8 (1.4) bc
A. holosericea	18.3 (0.7) ab	17.6 (0.9) a	17.6 (2.1) abc
A. tortilis	24.9 (0.6) de	58.0 (5.9) bc	24.8 (3.5) c
A. gayanus	21.5 (1.3) bcd	32.0 (5.9) a	14.0 (1.5) ab
A. indica	28.6 (0.7) e	79.8 (2.8) d	23.6 (0.7) c
C. equisetifolia	14.7 (1.4) a	21.8 (0.7) a	10.4 (0.7) a
C. pinnata	26.2 (0.8) e	62.0 (6.9) bcd	26.4 (1.8) c
E. tremula	19.1(0.8) bc	29.4 (2.6) a	8.4 (2.2) a
F. albida	21.5 (1.8) bcd	66.2 (16.2) cd	13.4 (1.6) ab
5% *concentration*			
Control	21.7 (0.6) c	48.3 (2.5) b	19.8 (1.4) b
A. holosericea	7.9 (0.7) a	8.8 (0.8) a	5.6 (0.4) a
A. tortilis	18.9 (1.2) bc	20.8 (3.2) a	11.6 (1.4) a
A. gayanus	5.5 (0.7) a	8.0 (0.6) a	4.0 (0.0) a
A. indica	17.3 (0.6) b	22.6 (0.8) a	10.4 (1.8) a
C. equisetifolia	5.8 (0.9) a	10.6 (0.8) a	6.8 (0.9) a
C. pinnata	27.0 (1.7) d	84.4 (8.9) c	49.0 (6.8) d
E. tremula	9.5 (1.5) a	11.0 (1.9) a	10.4 (1.5) a
F. albida	26.9 (0.6) d	86.0 (12.1) c	28.8 (4.4) c

positively correlated to soluble organic matter, lignin, C and N leaf litter concentrations. Microbial biomass was positively correlated to the chemical characteristics of leaf materials except with total phenols (Table 5).

Plant growth (height, shoot biomass) was negatively correlated to the amount of soluble organic matter, total phenols, cellulose, hemicellulose and C soil contents, whereas root biomass was correlated with total phenols, cellulose and hemicellulose soil contents (Table 6). No significant relationships have been found between N litter content and the plant growth. Soil NO_3^- content was positively correlated with most of the chemical characteristics of the leaf litter materials, except for total phenols and cellulose, whereas soil NH_4^+ content

Table 5
Regression coefficients (R values) between chemical characteristics of the leaf litter materials and soil NH_4^+, NO_3^-, microbial biomass concentrations in the non-planted soil. Symbols "+" and "–" in front of the regression coefficient indicate whether the correlation is positive or negative, respectively

	NH_4^+	NO_3^-	Microbial biomass
Soluble organic matter	+0.252**	+0.229*	+0.543***
Total phenols	+0.030 NS[(a)]	–0.062 NS	+0.029 NS
Lignin	+0.367***	+0.510***	+0.501***
Cellulose	+0.077 NS	+0.042 NS	+0.555***
Hemicellulose	+0.253**	+0.130 NS	+0.549***
C	+0.246**	+0.279**	+0.532***
N	+0.354***	+0.507***	+0.496***

*Significant at $P < 0.05$; **significant at $P < 0.01$; ***significant at $P < 0.001$. [(a)] NS: not significant.

Table 6
Regression coefficients (R values) between chemical characteristics of the leaf litter materials and soil NH_4^+, NO_3^-, microbial biomass concentrations and plant growth in the planted soil. Symbols "+" and "–" in front of the regression coefficient indicate whether the correlation is positive or negative, respectively

	NH_4^+	NO_3^-	Microbial biomass	Height	Shoot biomass	Root biomass
Soluble organic matter	–0.163 NS[(a)]	+0.355***	+0.656***	–0.533***	–0.339***	–0.163 NS
Total phenols	–0.091 NS	–0.036 NS	+0.068 NS	–0.449***	–0.354***	–0.256**
Lignin	–0.262**	–0.679***	+0.723***	–0.166 NS	+0.032 NS	+0.141 NS
Cellulose	–0.088 NS	+0.126 NS	+0.704***	–0.619***	–0.424***	–0.312***
Hemicellulose	+0.005 NS	+0.227*	+0.674***	–0.570***	–0.375***	–0.219*
C	–0.189*	+0.416***	+0.727***	–0.466***	–0.277**	–0.119 NS
N	–0.234*	+0.673***	+0.729***	–0.123 NS	+0.023 NS	+0.166 NS

*Significant at $P < 0.05$; **significant at $P < 0.01$; ***significant at $P < 0.001$. [(a)] NS: not significant.

Table 7
Regression coefficients (R values) between plant growth (height, shoot and root biomass) after leaf litter amendments at two rates (1% and 5%, w/w). Symbols "+" and "–" in front of the regression coefficient indicate whether the correlation is positive or negative, respectively

	Height	Shoot biomass	Root biomass
1% *concentration*			
PRQI	+0.124 NS[(a)]	–0.166 NS	+0.414**
5% *concentration*			
PRQI	0.040 NS	+0.033 NS	+0.341*

* Significant at $P < 0.05$; ** significant at $P < 0.01$; *** significant at $P < 0.001$. [(a)] NS: not significant.

was negatively correlated with lignin, C and N (Table 6). For both rates of leaf litter amendment, PRQI values were positively correlated only with root biomass (Table 7).

4. Discussion

Previous studies have shown that initial N concentration of different plant materials was highly correlated with mineral N availability [14,37]. Our data support these results. It has been demonstrated that high polyphenol content in leaves could decrease litter decomposition by inhibiting the soil microbial activity [17]. It has also been reported that N release was reduced at high lignin concentrations [4].

In our experiment, lignin content of leaf litter materials was significantly related to NO_3^- content and microbial biomass. Although it is known that lignin is highly resistant to microbial decomposition [12,21,33], indigenous soil microflora could use this compound. These results contradict most of the data reported in the literature [10,13,26]. These conflicting results could be partly due to differences in the range of chemical characteristics that were considered, but also to differences in experimental design. For instance, grinding of plant residues increases relationships between substrates and decomposer organisms with the soil matrix and it also stimulates colonization of the residues and microbial activity.

The impact of the different litter material on plant growth varied. Any single parameter of the litter composition could explain this variation, since leaf chemical characteristics were negatively linked to almost every plant parameter. On the contrary positive relationships were obtained between some of these parameters (soluble organic matter, cellulose and hemicellulose contents) and NO_3^- and microbial biomass concentration in both planted and not planted soils. Although abundant literature has been published on

the importance of the quality of organic input on the soil functioning and productivity [18,29], the definition of an index used to predict the magnitude of their effect on soil functioning remains subject of discussions. For example, this index takes into account the chemical characteristics of the litter ground materials (C/N ratio, lignin and plyphenols) but ignores the influences of soil fauna such as termites and earthworms. Data resulted from the present study showed that the PRQI could be a more useful tool to predict the effects of litter materials on plant growth in glasshouse conditions compared to the others tested parameters. The index encompasses several parameters such as C, N, lignin and polyphenols contents [36]. It is highly correlated to root biomass. Among the different litters tested, the highest impact on soil and plant parameters was recorded in the presence of *C. pinnata* litter. A similar conclusion was drawn from a field experiment, where millet biomass was enhanced in the vicinity of this tree [24]. Nevertheless, research with *C. pinnata* leaf litter under a wider range of ecological conditions is needed to specify this PRQI value in order to add valuable insight on its agronomic impact in the tropics.

It is well known that the capacity of soils to supply nitrogen to plants is linked to the amount and the nature of soil organic matter [25]. The potential for intensification of tree planting with leguminous tree species in order to enhance the soil N status will therefore depend on the importance of N_2 fixation or N acquisition from the soil [15]. Mycorrhizal fungi are a ubiquitous component of most ecosystems throughout the world and play an important role in soil processes [32]. In particular, mycorrhizal symbiosis increases nitrogen uptake from the soil [4]. Consequently, the soil richness in symbiotic fungal propagules (mycorrhizal soil infectivity) must be taken in account in the PRQI to predict the effects of plant residues on plant growth. The type of mycorrhiza is also important. Ectomycorrhizal tree species are especially efficient at using organic nitrogen [23].

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