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Leaves Material Decomposition from Leguminous Trees in an Enriched Fallow

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1. Introduction

In Amazon human activities such as slashing and burning converted large areas of primary forest to intermittently used agricultural land. Thus, the fallow vegetation plays an important role to maintain or restore soil productivity. In the systems with the soil are poor in nutrients and carbon (C) and farmers do not have much subsidies to buy fertilizer, the efficiency with which nutrient in plant residues is used depends on the amount and quality of the organic matter, the rate at which they are mineralized and thus on the time when they are made available relative to crop requirements. It is important to find contrasting litter quality, and mix this organic material with the possibility to alter the pattern of Nitrogen-release and the efficiency of Nitrogen (N) utilization from the residue by a soil microbial biomass and crop system where other sources of mineral N such as fertilizer are limited or excluded.

Soil organic matter (SOM) represents a major proportion of the organic carbon within the terrestrial biosphere and plays an important role in soil fertility (Powlson et al. 2001). An accumulation of organic matter is not only beneficial to soil functions related to agriculture, favouring growth of biomass, promoting and facilitating carbonation processes, reducing erosion and favouring pedogenesis, and developing organic matter-rich horizons recovering degraded or contaminated soils, but also represents a sequestration of C from atmospheric CO_2 (Macías and Arbestain 2010). In contrast, management practices (e.g. slash and burn system in Amazon region) leading to a decline in SOM content release CO_2, the major greenhouse gas (Powlson et al. 2001). SOM also has a range of other environmental functions such as water retention and the regulation of trace greenhouse gases between land surface and the atmosphere.

Fallow trees affect the soil by their litter deposition in terms of quantity and quality, root activity and changes in microclimate brought about by the leaf canopy. However, the intensification of land use, by small farmers in the tropic, has drastically reduced the fallow period with a decline in soil productivity and environmental quality, resulting in a progressive deterioration of natural resources. Therefore, the soil quality has to be restored in shorter time.

Decline in soil productivity and environmental quality and progressive deterioration of natural resources in the tropics have led to a search for new methods to sustain crop production via more efficient nutrient cycling. In Northeastern of Pará (Brazil) the Amazon region was occupied by an intensive colonization process over the last century until today.

The region was to be utilized, initially by clearing the forests for timber and later by the use of the land for subsistence agriculture, based on slash and burn agriculture. In the context of a bilateral German-Brazilian project ("Secondary Forests and Fallow Vegetation in Eastern Amazon – Function and Management", SHIFT project) slash and mulch system are being recommended to realize fire-free land clearing by cutting and chopping the fallow vegetation and leaving mulch layer on site (Denich et al. 2005). In addition, the fallow vegetation is enriched with fast-growing legume trees to support the mulching effect by increasing biomass production and nitrogen input during the fallow period.

The purpose of this technique is to maintain soil organic matter and assure a slow and continuous release of nutrients, improve moisture retention, reduces excessive soil heating and runoff, reduce soil erosion, and prevent weed seed germination (Denich et al. 2005). Hence, mulching may improve flexibility in planting date to cope with unreliable rain due to conserved soil moisture.

The rate of decomposition and the amount of N-mineralization from organic material determines the short-term benefits of tree residues for plant nutrition (Jensen et al. 1995). If burning is to be abandoned, then the synchronization of nutrient release from organic material and nutrient uptake by plants (Addiscott et al. 1991, Myers et al. 1994), accompanying the competition between plant and microorganisms for nutrients (Cattanio et al. 2008), will be the core problem in applied tropical soil biology research. Yield losses in field trials of the SHIFT project have shown that yield losses in mulch practices are evident as compared to burned treatments (Kato et al 1999). The same authors showed that yield losses were eliminated with fertilizer application, indicating nutrient competition with decomposers and/or an unfavorable nutrient release pattern as compared to crop demand was a problem.

The structure and decomposability of leaf litter varies to a large degree, thus affecting the rate of nutrient cycling and the nutrient availability in soil (Priha and Smolander 1997). Soluble C, which includes metabolic and storage C, is of high quality and is primarily responsible for promoting microbial growth and activity. Large amounts of soluble C but little soluble N and P in decomposing plant residues induce net immobilization (Cattanio et al. 2008). The challenge resides in sustaining crop production while maintaining soil fertility through supply and efficient management of organic residues (Isaac et al. 2000). Biederbeck et al. (1994) suggested that it may be possible to manipulate the timing and quality of litter input through appropriate management of mixed stands to improve the synchrony of nutrient release with crop requirements.

Some works in litter manipulated with mixtures was done by Meentemeyer (1978), Melillo et al. (1982), Anderson et al. (1983), Gallardo and Merino (1993), Vitousek et al. (1994), Hobbie (2000), Lonrez et al (2000). But studies with mixtures in soil litter decomposition were scarce (Franagan and van Cleve 1983). Blair et al. (1990) found in litterbags containing mixed residues that there were significantly greater initial releases of N and lower subsequent N immobilization than predicted, and they suggest that it resulted from differences in the decomposer community originated from the mixtures of varied litter resource quality. In the same way, Handayanto et al. (1997), Kuo and Sainju (1998), Zimmer (2002) and Cattanio et al. (2008) showed that soil N-mineralization rate of prunings could be manipulated by mixing different quality materials.

Different organic materials decompose at contrasting rates because they are decomposed differentially by catabolic enzymes produced by saprophytic organisms (Linkins et al. 1984). Furthermore, decomposition rates are affected by nutrient and lignin content of litter (Moorhead et al. 1996), because the initial lignin-to-N and the lignin + polyphenol-to-N ratios are correlated well with the N-mineralization or N accumulation (Constantinides and Fownes 1994; Janssen 1996; Handayanto et al. 1997). In the other hand, the SOM in the organo-mineral fraction of some soils is relatively protected against mineralization and therefore does not immediately influence crop yields in the shortterm (Mapfumo et al. 2007).

The decomposition of organic matter is the key process in soil-plant N cycle (Barraclough 1997), principally governing the availability of this nutrient to crop growth. The chains of processes are very complex, as ammonia NH_4^+, the initial product of N mineralization, can be consumed by several processes (plant uptake, nitrification, immobilization and volatilization). Heterotrophic bacteria involved in the mineralization-immobilization turnover reactions between inorganic and organic pools of N compete more effectively for NH_4^+ than for nitrate NO_3^- (Jansson 1958; Jenkinson et al. 1985; Schimel et al. 1989).

The efficiency with which N in plant residues is used depends on the rate at which they are mineralized and thus on the time when they are made available relative to crop requirements. The present work aims to determine whether, with contrasting legume litter quality in terms of N mineralization, by mixing this organic material of different quality, it will be possible to alter the pattern of N release and the efficiency of utilization of N from the residue by a soil microbial biomass and catch crop.

2. State of the art

In this way four different legume species (*Acacia mangium* Willd., *A. angustissima* Kuntze, *Sclerolobium paniculatum* Vogel and *Inga edulis* Mart.) each used in enrich the fallow were compared with natural fallow vegetation, which is a mixture of different species, and poor soil without added organic material.

- Within this experiment the following points are essential: a) the impact of enriched legume material in soil N mineralization; b) the use of mineralization with the use of contrasting litter quality; c) the influence of organic material quality on soil microbial biomass in terms of N mineralization, immobilization and consumption.

After identifying the contrasting species, two laboratory decomposition experiments with two different techniques will be used to elaborate the effect that mixing these organic materials of different quality has on the pattern of N release and the efficiency of utilization of N from the residue by a soil microbial biomass.

The first decomposition experiment was made using soil incorporated legume leaf material from the two contrasting species, and their mixture, with ^{15}N at natural abundance and fertilized with enriched ^{15}N-urea fertilizer (conventional isotope dilution technique). In parallel, one experiment with the same species and mixture of legume with previously enriched ^{15}N and fertilized with ^{14}N-urea was carried out (pre-labeling plant material).

- Within this experiment the following points are essential: a) the use of contrasting litter quality may improve N-mineralization in terms of the rate at which they are mineralized; b) the quantification the real amount of N stored in the soil microbial biomass; c) the quantification of N-mineralization and immobilization through the use of labeling techniques. These isotope dilution techniques have the objective to quantify the proportion of N that comes from fertilizer or organic matter and is immobilized by soil microbial biomass.

To assess further whether N recovery by rice could be accurately predicted from relationships between pruning-material quality and N mineralization-immobilization, a greenhouse pot experiment was conducted in which the two isotope techniques were used with the same contrasting materials and their mixture, and ^{15}N uptake by rice was measured.

- Within this experiment the following points are essential: a) whether the use of contrasting litter quality may improve N-mineralization rate and thus the time when they make N available to the crop; b) the quantification of N competition between rice and soil microbial biomass; c) the quantification of N-mineralization and immobilization through the use of two techniques of isotope dilution which allow the quantification of the proportion of N coming from fertilizer or organic matter immobilized by soil microbial biomass and used by rice.

One of the hypothesis of this work is that with the elimination of the burning of biomass and the addition of organic matter as mulch, nitrogen immobilization in mulch by microorganisms will be increased and lead to a decrease in the quality of SOM. To confirm this hypothesis a field experiment whit litterbags from different legume treatment was conducted.

- Within this experiment the following points are essential: a) quantifying mulch decomposition during the field incubation on the litter; b) assessing nitrogen and carbon mineralization from mulch system; c) mulch nutrient retention during the field incubation; d) predict of N mineralization.

In generally this study is intended to answer the following questions:

- Can we regulating N release through the use of mixing residues from legume tree material with different patterns of N mineralization?
- Is N immobilization affected by legume tree material and therefore by mixtures?
- Can we fulfill the crop demands with organic matter fertilization (mulching) using materials from enriched fallows?
- What happens with the use of mulch system in terms of N-mineralization and immobilization?

3. Identify contrasting leguminous decomposition on leaf and wood material incorporated in the soil

3.1 Biochemical characteristics of the plant material

In the Brazilian Amazon soil the decomposition of contrasting amended material with regard to the measure quality characteristics show in all treatments a decrease in total-N

content at the end of laboratory incubation period. The initial nutrient content in the organic amendment (wood + leaf material) for different treatments and soils (without added organic matter) is shown in Table 1. In this experiment *I. edulis* and *A. mangium* had an initially higher N content than the other single-legume treatments. But the leaf + wood material added to soil from *S. paniculatum* and *A. mangium* showed an initially higher P concentration. For these two important chemical elements, the mixture of two legumes showed an intermediate concentration in comparison to the single species.

Species	OM	N	C	P	Lignin	Cellulose	Phenol
			mg g^{-1} soil				
A. mangium	**14.15**(0.14)	**0.11**(0.001)	**6.84**(0.07)	**0.004**	**2.61**(0.03)	**5.95**(0.06)	**1.50**(0.02)
m*e¥	**14.33**(0.14)	**0.14**(0.003)	**6.90**(0.07)	**0.007**	**3.16**(0.04)	**5.76**(0.05)	**1.03**(0.01)
I. edulis	**14.11**(0.04)	**0.17**(0.001)	**6.77**(0.02)	**0.009**	**3.59**(0.01)	**5.42**(0.01)	**0.52**(0.00)
S. paniculatum	**14.16**(0.11)	**0.11**(0.001)	**6.83**(0.05)	**0.004**	**3.15**(0.03)	**3.72**(0.03)	**0.82**(0.01)
p*a§	**14.30**(0.14)	**0.15**(0.002)	**6.97**(0.07)	**0.007**	**3.10**(0.03)	**4.53**(0.04)	**1.26**(0.01)
A. angustissima	**14.26**(0.22)	**0.18**(0.005)	**7.01**(0.11)	**0.008**	**3.00**(0.05)	**5.27**(0.08)	**1.67**(0.03)
Fallow	**9.50**(0.06)	**0.08**(0.001)	**4.68**(0.03)	**0.004**	**2.51**(0.02)	**3.91**(0.03)	**1.05**(0.01)
Soil		**1.27**	**16.73**	**0.001**			

¥ In this study, m*e represents a mixture of *A. mangium* and *I. edulis* (50:50 w/w).
§ In this study, p*a represents a mixture of *S. paniculatum* and *A. angustissima* (50:50 w/w).

Table 1. Organic matter added to Amazon sandy soil and the nutrient (selected) content and material quality for different treatments in a laboratory incubation experiment. The number represents Mean (standard deviation), with n = 21.

After 128 days of incubation the significant difference between legume species and mixture were found only for the *S. paniculatum* treatment, which showed the lowest total-N concentration founded in soil. This same species showed a higher initial C-to-N ratio and lignin concentration. In this way, legume species and fallow treatment had a significant positive correlation ($r^2 = 0.59$, $P < 0.01$) with the total-N losses and initial C-to-N ratio. The total-N losses[1] decrease in the following order: *S. paniculatum* > Fallow vegetation > *A. mangium* = *A. angustissima* > soil > *I. edulis*[2]. The mixture of *S. paniculatum* and *A. angustissima* leaf material showed a significant inhibitory effect in the total remaining nitrogen, and only 10.8% of total-N was lost. However, the other mixture did not exhibit statistical differences in relation to the single species.

3.2 Nitrogen mineralization and immobilization

Soil-nitrogen mineralization without added organic matter more than doubled the amount of mineral N in the soil founded during the incubation period (Figure 1). This control treatment showed a rapid initial increase after it became steadier. In contrast, the amended soils showed immobilization-consumption of the native soil-N, reversing into a release of N after about a month for the legume-amended soil, particularly if m*e mixture or *S. paniculatum* were present. The fallow amended soil was slower in immobilizing soil-N, but continued to immobilize over the entire incubation period.

[1]Losses mean the differences of total N concentration in soil between begin and end of incubation period.
[2]">" symbol represents statistical differences at $P < 0.05$, and "=" no statistical difference.

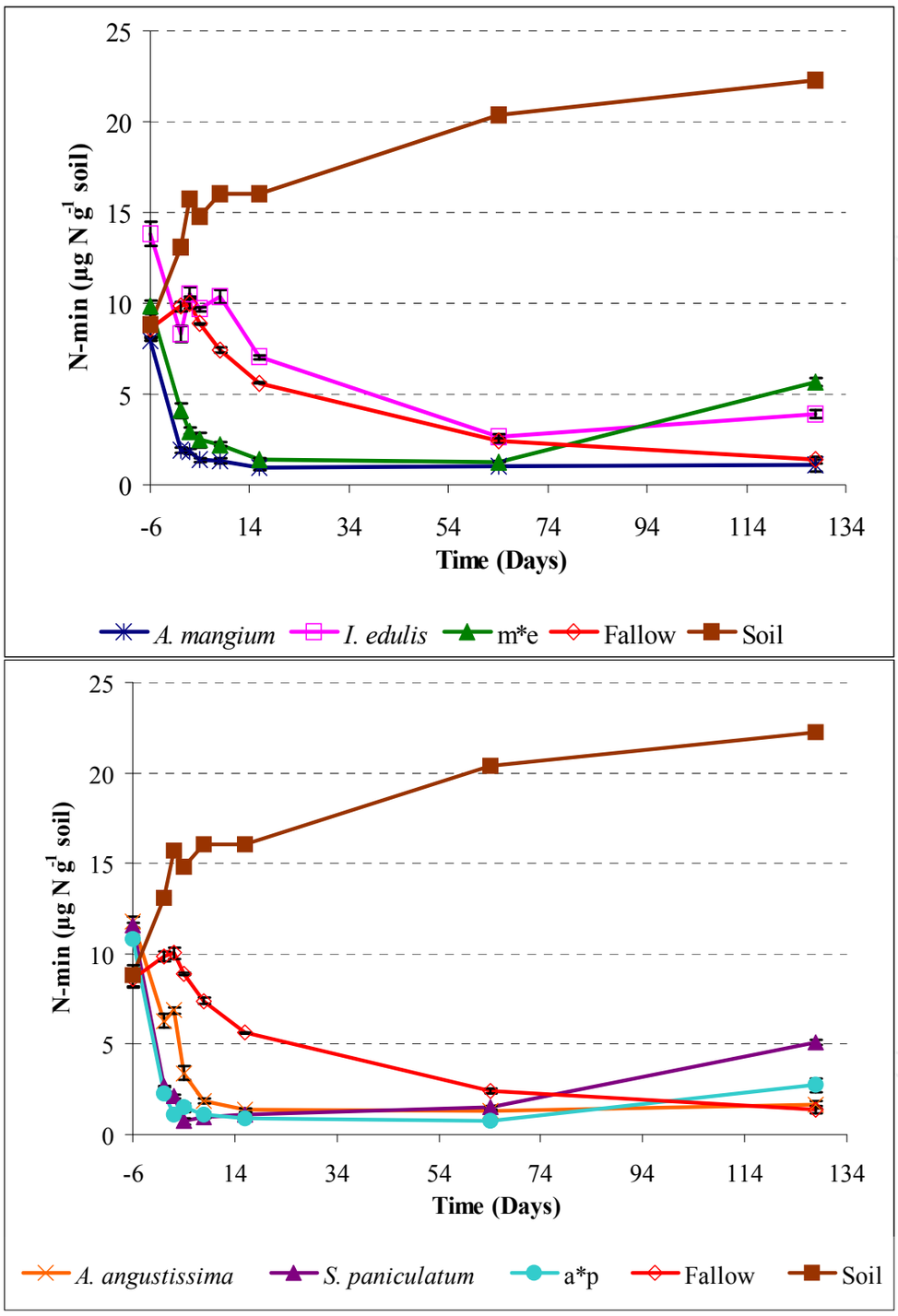

Fig. 1. Soil inorganic N concentration as affected by incorporated wood and leaves from different legumes species in comparison with fallow vegetation (Fallow) and soil with initial organic matter. In all graphics the m*e and p*a symbol correspond to *A. mangium* and *I. edulis* mixture (50:50 w/w), and *A. angustissima* and *S. paniculatum* mixture (50:50 w/w), respectively. Bars represent standard error of the mean.

Total mineral nitrogen in leguminous-amended soil was significantly different with time ($P < 0.01$) for the two species used in the mixtures, and for the interaction species and time ($P < 0.01$). The higher differences were found in the beginning of the incubation period and the final inorganic N content in legume-amended soil ranged from 2.0 to 6.1 mg N kg^{-1} soil compared with 1.6 mg N kg^{-1} soil in the fallow-amended soil and 20.7 mg N kg^{-1} soil in the control soil. Thus, at the end of incubation period, mineral nitrogen decreased in the following order: Soil as control > *S. paniculatum* > *I. edulis* > *A. mangium* > *A. angustissima* > natural fallow.

The decomposition patterns of the mixture and total N-mineralization did not reflect the simple mean of the decomposition patterns of single-species organic matter. The m*e mixture showed a higher increase in total N mineral at the end of the experiment, and that of the single species was comparatively lower in the same period. In the same way a*p mixture did not amount to the arithmetic mean of the N-mineralization in of the two single specie

In these sandy soils from Amazon, initial nitrification was significantly higher for soil without added organic matter, *I. edulis* and Fallow treatment. The *I. edulis* treatment presented a significantly higher consumption of NO_3^--N after approximately 4 days of incubation (Figure 2). Only *I. edulis* and the m*e mixture showed a small increase in NO_3^--N concentration at the end of the experiment; the other treatments showed a NO_3^--N consumption and/or denitrification.

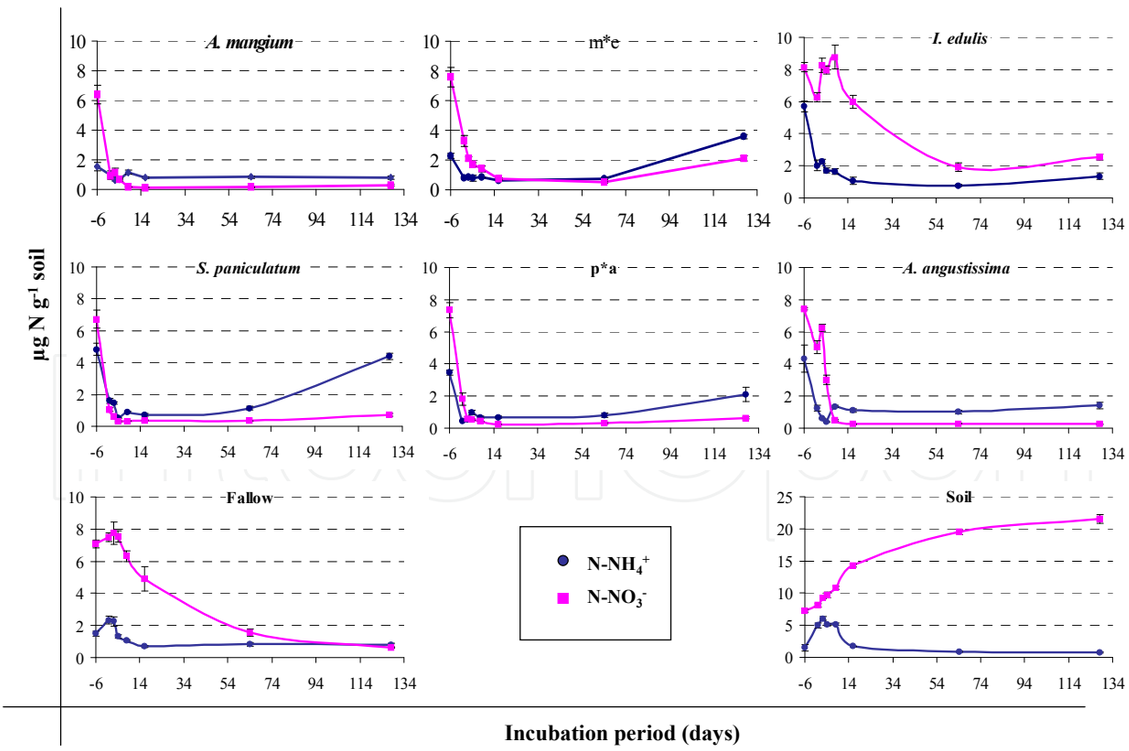

Fig. 2. Concentration of mineral N as influenced by incorporated wood and leaves from different legumes species in comparison with fallow vegetation (Fallow) and soil with initial organic matter (Soil) as control. Bars represent standard error of the mean.

Calculation of net ammonification (*a*, Figure 3) and net nitrification (*n*), in order to have a comparative parameters between treatments, was performed by subtracting soil NH_4^+-N in the time x (t_x) from soil NH_4^+-N in the initial time (t_0) and NO_3^--N in the time x (t_x) from soil NO_3^--N in the initial time (t_0), respectively. Apparent microorganism NH_4^+-N-immobilization (*i*) was calculated by subtracting soil NH_4^+-N microbial biomass in the organic amendment treatment from NH_4^+-N microbial biomass in the control treatment (soil without organic amendment) (Jensen 1997), using the fumigation-extraction method. NO_3^--N consumption (*c*) was calculated by subtracting soil NO_3^--N in the control treatment from soil NO_3^--N in the organic amendment treatment. This is based on the assumption that the mineralization and losses of indigenous soil N were similar in control and residue-treated soils (Jensen 1997).

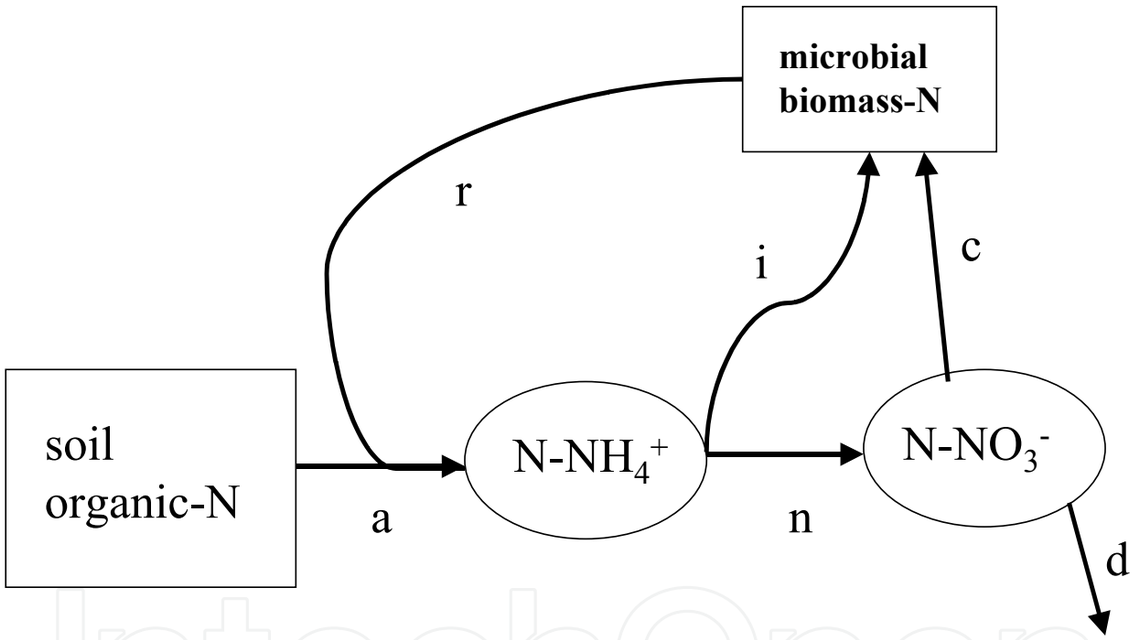

Fig. 3. Flows of soil nitrogen indicated by: (a) apparent N-ammonification, (r) apparent N-remineralization, (n) apparent N-nitrification, (i) apparent NH_4^+-N immobilization, (c) apparent NO_3^--N consumption, (d) denitrification. Adapted from Stark and Schimel (2001).

Apparent ammonification (a) was significantly different ($P < 0.05$) during the incubation period for the majority of treatments (Table 2). Only A. mangium organic material did not show a significant difference in N-ammonification between sampling times during the incubation period. The fallow and I. edulis treatments showed a significantly higher initial N-ammonification. *A. angustissima*, S. paniculatum and A. mangium presented an intermediate initial N-ammonification; with the mixture of two legume species presenting a significantly lower initial nitrogen ammonification (Table 2).

Treatment	Incubation period (days)¥			
	0	16	64	128
A. mangium	1.00^{a}	-0.21^{a}	-0.15^{a}	-0.18^{a}
m*e	0.73^{b}	-0.16^{c}	-0.05^{c}	2.76^{a}
I. edulis	2.25^{a}	-0.95^{b}	-1.26^{b}	-0.68^{b}
S. paniculatum	1.37^{b}	-0.87^{c}	-0.46^{c}	2.79^{a}
p*a	0.42^{ab}	0.23^{b}	0.34^{b}	1.63^{a}
A. angustissima	1.40^{a}	-0.16^{b}	-0.25^{b}	0.15^{b}
Fallow	2.34^{a}	-1.64^{b}	-1.50^{b}	-1.56^{b}
$LSD_{\leq 0.05}$	0.67	0.68	0.80	1.16

Φ Apparent net N-ammonification (*a*) was calculated by subtracting soil NH_4^+-N in the time *n* (t_n) from soil NH_4^+-N in the initial time (t_0).
¥ Values within a line that are followed by different letters are significantly different with the Tukey test ($P < 0.05$).
Least significant difference (LSD) to compare treatments in the same sampling time.

Table 2. Apparent net N-ammonification, a (µg NH_4^+-N g^{-1} soil)Φ as a function of time for different treatments.

The m*e mixture, *S. paniculatum* and p*a mixture showed a significantly higher increase in ammonification at the end of incubation period with 2.03, 1.42 and 1.21 µg NH_4^+-N g^{-1} soil, respectively (Table 2). All other treatments showed a decrease in N-ammonification, particularly so for the fallow and *I. edulis* i.e., -3.96 and -2.93 µg NH_4^+-N g^{-1} soil, respectively. The mixture of these two legume species was significantly better mineralizable than the single species. This interaction was not observed with the other mixture, where *S paniculatum* showed a higher increase when mixed with *A. angustissima*.

The treatments with amendment showed a significant difference ($P < 0.05$) in N nitrification during the incubation period (Table 3). Fallow vegetation, *I. edulis* and *A. angustissima* showed a significantly higher initial nitrification, with m*e, p*a mixture and *S. paniculatum* showing intermediate values, respectively (Table 3). However, a significantly higher nitrification decrease was found in the fallow, *I. edulis* and *A. angustissima*, with variations of 14.4, 10.0 and 9.8 µg N- NO_3^- g^{-1} soil, respectively. *A. mangium* showed a significant lower initial N nitrification. At the end of the incubation period the mineralization decreased in the following order: *S. paniculatum* ≥ *A. mangium* ≥ m*e = p*a > *I. edulis* ≥ *A. angustissima* > Fallow vegetation[3].

[3] "≥" and "=" symbols means that the treatments did not show statistical difference ($P > 0.05$), and ">" symbol showed statistical difference ($P < 0.05$).

Treatment	Incubation period (days)¥			
	0	16	64	128
A. mangium	0.90[a]	-0.76[b]	-0.74[b]	-0.62[b]
m*e	3.29[a]	-2.56[b]	-2.78[b]	-1.18[b]
I. edulis	6.26[a]	-0.28[b]	-4.35[c]	-3.73[c]
S. paniculatum	1.05[a]	-0.68[b]	-0.71[b]	-0.32[b]
p*a	1.83[a]	-1.60[b]	-1.50[b]	-1.18[b]
A. angustissima	5.04[a]	-4.79[b]	-4.77[b]	-4.79[b]
Fallow	7.49[a]	-2.57[b]	-5.91[c]	-6.89[c]
$LSD_{\leq 0.05}$	0.93	1.32	1.28	1.06

Φ Net N nitrification (*n*) was calculated by subtracting soil NO_3^--N in the time *n* (t_n) from soil NO_3^--N in the initial time (t_0).
¥ Values within a line that are followed by different letters are significantly different with the Tukey test ($P < 0.05$).
Least significant difference (LSD) to compare treatments in the same sampling time.

Table 3. Net N nitrification, *n* (μg NO_3^--N g^{-1} soil) Φ as a function of time for different treatment.

Differences between the treatments were observed for NH_4^+-N immobilization at the beginning of the experiment ($P < 0.05$) (Table 4). Control treatment[4] decreased NH_4^+-N immobilization from 1.69 μg NH_4^+-N g^{-1} soil in the time 0 to 0.27 μg NH_4^+-N g^{-1} soil at the end of the incubation period. The m*e, p*a mixture and *I. edulis* treatments presented a significantly higher initial NH_4^+-N immobilization (Table 4), and the treatments showed a lower initial C-to-N ratio in comparison to *A. mangium* and *S. paniculatum* (Table 1). *A. angustissima* also showed a low initial C-to-N ratio (38.9), which did not explain the low initial N immobilization, but this treatment had a higher initial phenol content (Table 1), which contributed to the low initial N-immobilization (Mafongoya et al. 1998).

Only the m*e and p*a mixtures as well as the *I. edulis* significantly decreased ($P < 0.05$) in net NH_4^+-N immobilization at the end of incubation period. *A. mangium* showed a smaller initial net NH_4^+-N immobilization and a significantly higher ($P < 0.01$) increase in the net NH_4^+-N immobilization at the end of incubation period. Between 64 and 128 days of the incubation period, NH_4^+-N immobilization was not significantly different ($P > 0.05$) for the m*e, *I. edulis*, p*a, *A. angustissima*, and Fallow treatments. However, for this same period, *A. mangium* and *S. paniculatum* experienced a stronger increase in NH_4^+-N immobilization, with 3.32 and 1.18 μg NH_4^+-N g^{-1} soil, respectively.

As with the net immobilization, the microbial consumption of NO_3^--N was noticeably different ($P < 0.01$) between treatments at the beginning of the incubation period (Table 5). The strong differences in net consumption at the beginning of the experiment may reflect the differences in organic material quality. The *A. mangium*, *S. paniculatum* and p*a mixture treatment showed a significantly higher initial NO_3^--N consumption, and fallow vegetation showed the lowest value at the same time. All treatments showed a significant elevation in

[4]Control treatment mean soil without added organic material.

NO_3^--N consumption during the incubation period. But *I. edulis* showed a significantly lower NO_3^--N consumption ($P < 0.01$) at the beginning of the experiment following by fallow treatment.

Treatment	Incubation period (days)¥			
	0	16	64	128
A. mangium	0.76^{b}	0.38^{b}	1.90^{b}	5.22^{a}
m*e	6.46^{a}	2.61^{b}	2.59^{b}	2.28^{b}
I. edulis	4.15^{a}	1.24^{c}	3.34^{ab}	2.59^{b}
S. paniculatum	1.16^{ab}	0.31^{b}	0.85^{ab}	2.34^{a}
p*a	5.92^{a}	1.02^{c}	3.28^{b}	3.44^{b}
A. angustissima	0.95^{ab}	0.19^{c}	0.90^{b}	1.40^{a}
Fallow	1.72^{ab}	2.44^{a}	0.65^{b}	1.33^{ab}
$LSD_{\leq 0.05}$	0.96	0.21	0.25	1.26

Φ Apparent microorganism NH_4^+-N immobilization (*i*) was calculated by subtracting soil NH_4^+-N microbial biomass in the organic amendment treatment from NH_4^+-N microbial biomass in the control treatment (soil without organic amendment).
¥ Values within a line that are followed by different letters are significantly different with the Tukey test ($P < 0.05$).
Least significant difference (LSD) to compare treatments in the same sampling time.

Table 4. Apparent net N-microbial immobilization, i (µg NH_4^+-N g^{-1} soil)Φ as a function of incubation period and treatment.

Treatment	Incubation period (days)¥			
	0	16	64	128
A. mangium	7.20^{d}	14.13^{c}	19.33^{b}	21.24^{a}
m*e	4.81^{c}	13.54^{b}	18.97^{a}	19.41^{a}
I. edulis	1.84^{c}	8.29^{b}	17.57^{a}	18.99^{a}
S. paniculatum	7.05^{d}	13.90^{c}	19.14^{b}	20.79^{a}
p*a	6.27^{d}	14.04^{c}	19.15^{b}	20.87^{a}
A. angustissima	3.06^{d}	14.02^{c}	19.21^{b}	21.27^{a}
Fallow	0.61^{d}	9.35^{c}	17.90^{b}	20.91^{a}
$LSD_{\leq 0.05}$	0.93	1.06	0.25	0.37

Φ Apparent net consumption (*c*) was calculated by subtracting soil NO_3^--N in the control treatment from soil NO_3^--N in the organic amendment treatment in the same incubation period.
¥ Values within a line that are followed by different letters are significantly different with the Tukey test ($P < 0.05$).
Least significant difference (LSD) to compare treatments in the same sampling time.

Table 5. Apparent Net microbial consumption of NO_3^--N, c (µg NO_3^--N g^{-1} soil)Φ as a function of incubation period and treatment.

At the end of the experiment, a significantly lower apparent NO_3^--N consumption was found in *I. edulis* and m*e mixture ($P < 0.05$), in comparison the other treatment (Table 10). Only for these two treatments, NO_3^--N consumption remained constant after 64 days of incubation. The significantly highest consumption of 20.3 µg NO_3^--N g^{-1} soil was found in the Fallow treatment.

In this study the data indicate that the decline of mineral-N was strongly influenced by immobilization and consumption of mineral N by the microflora. Microbial consumption of NO_3^--N was of a greater magnitude than NH_4^+-N immobilization, thus indicate that the decreases observed in net N-mineralization were due to increasing microbial consumption of N. However, immobilization into soil organic matter (SOM) may be attributed to the apparent net N-mineral loss (Bending et al. 1998).

As was shown by Verchot et al. (2001), the results demonstrate that the patterns of N-mineralization are dependent upon differences between microbial production and consumption. These processes are reliant on organic matter quality. Small changes in mineralization, nitrification, immobilization and consumption may possibly have a large impact on soil N availability for the crop system.

The principal loss of C from SOM is through respiration during decomposition (Woomer et al. 1994). All legume-amended soils showed significantly higher cumulative CO_2 production than fallow-amended soil and the control treatment (soil) (Figure 4). The cumulative CO_2 production was significantly higher for mixtures in comparison with the individual species.

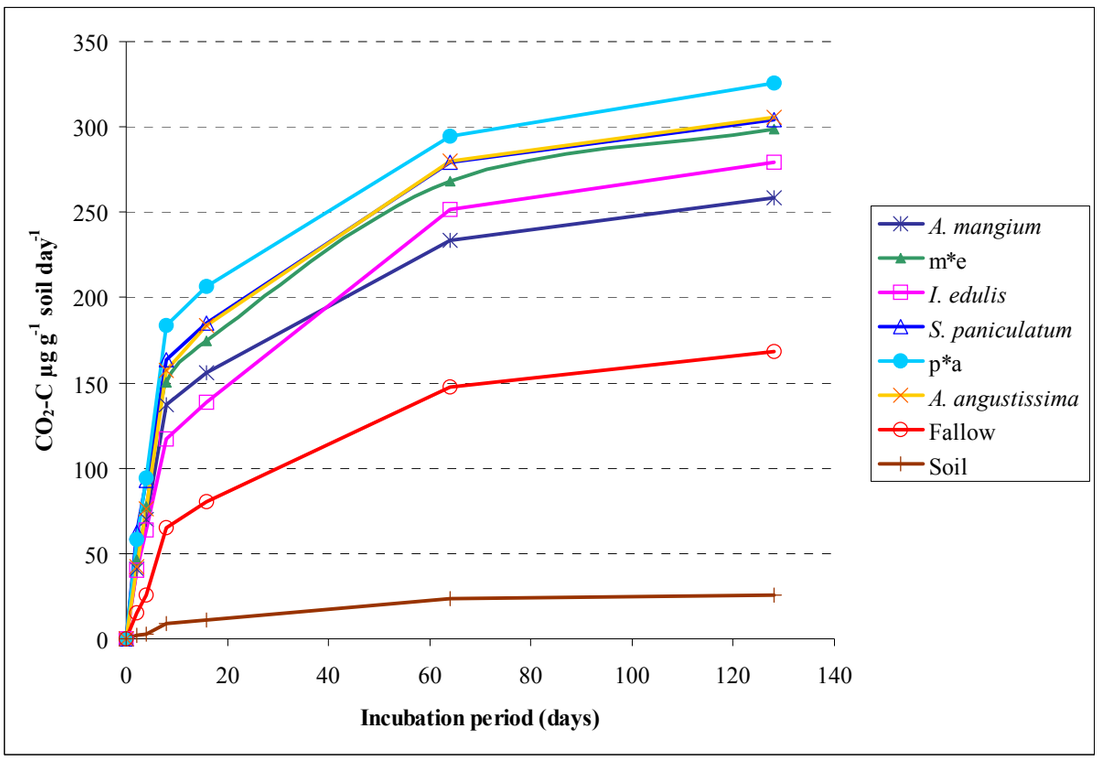

Fig. 4. Accumulative C-CO_2 (µg C g^{-1} soil day^{-1}) production during the incubation period for treatments with different organic matter soil added in comparison with soil without added organic matter as control (Soil).

All treatments showed a strong initial increase in CO_2-C production, which resulted in a high slope of the accumulative CO_2-C curve (Figure 4). It was conform the increase in the initial microbial C, NO_3^- consumption and the high decrease in the initial N mineral.

Soil N mineral decreased with increasing CO_2 production and microbial biomass C. In contrast, N immobilizations by microorganism increased with an increase in CO_2 production due to added organic C, and with a decrease of the N concentrations. This suggests that N dynamics in the legumes amended treatments were highly correlated with organic C dynamics (Figure 5).

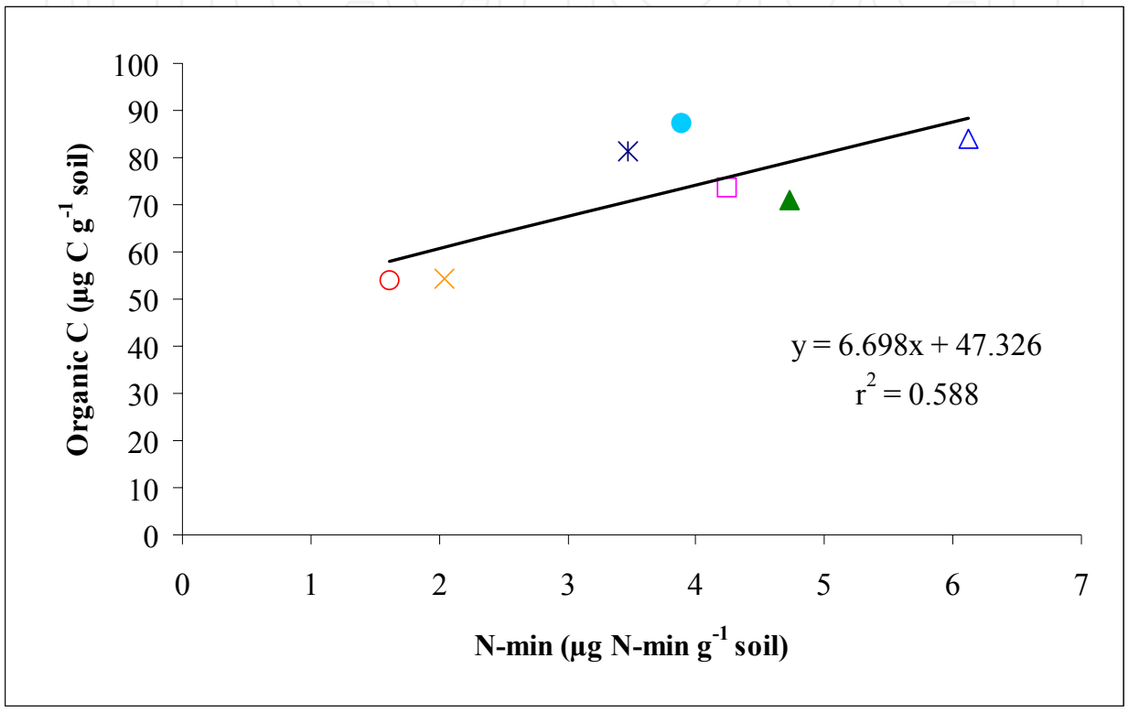

Fig. 5. The relationship between mineral N (N-min) and the extractable organic C resulting from treatment with different legumes, mixture and fallow at the end of incubation period (128 days). The symbols correspond to Fallow (○), *A. angustissima* (×), *A. mangium* (✳), p*a mixture (●), *I. edulis* (□), m*e mixture (▲), *S. paniculatum* (△) treatment.

Since N immobilization is limited by substrate availability in a broad range of ecosystems and soil types, soil organic C concentration would strongly influence N immobilization (Barrett and Burke 2000). The correlation between nitrogen mineralization and carbon mineralization suggests that rapid stabilization of nitrogen is facilitated by an active microbial community and the availability of a readily mineralizable organic substrate. Critical levels of C and plant nutrients, which limit the enzyme activities of microbial decomposition, were found to be important for determining nutrient release (Seneviratne 2000). Soil microbial biomass has been defined as an indicator of soil fertility, long before changes is soil organic matter occur (Powlson and Brookes 1987). Microbial nitrogen NH_4^+ immobilization and NO_3^- consumption appears to be an important variable that needs to be taken into account in studying organic matter decomposition and N mineralization.

The best predictor of N-mineralization was phenol + lignin when all treatments were included in the analyses (Table 6), followed by phenol + lignin-to-N ratios and lignin. Initial N + P-to-phenol ratios were highly correlated with cumulative N-mineralization for leguminous species and mixtures (Table 6).

Object of analyze	Lignin	Phenol + Lignin	Phenol + Lignin N	Phenol N	N + P Phenol
All treatment Φ	-0.812*	-0.826*	-0.819*		
Legume and mixture Ω	-0.813*	-0.798*	-0.768*	-0.830*	0.950**
Single legumes δ	-0.788*	-0.871*	-0.868*	-0.803*	0.916*

Φ All treatment means legumes, mixture and fallow treatments.
Ω mixture means mixture of two legume species.
δ Single legume means legumes species without mixtures treatments. The * is P ≤ 0.05, ** is P ≤ 0.01

Table 6. Correlation coefficients relating the cumulative amount of N-mineralization to initial chemical properties in the treatments.

Soil-incorporated plant lignins degrade to polyphenol, which, with the other plant and microbial polyphenol, become the main constituents of recalcitrant N, containing humic polymers (Haynes 1986). Lignin intertwines also with the cell wall, physically protecting cellulose and other cell wall constituents from degradation (Chesson 1997).

Polyphenols include a range of compounds differing in size, solubility, and reactivity. Also, polyphenol can serve as a carbon substrate for decomposers (Mafongoya et al. 1998) but in general they inhibit the growth or function of decomposers and the other organisms (Swift et al. 1981, Zucker 1982). Defense compounds, including phenolics and terpenoids can also influence rates of litter decomposition, by means of direct inhibitor effects on saprophytic organisms (Palm and Sanchez 1991). Condensed tannins, also known as proanthocyanidins, are the polyphenol most noted for their effects on decomposition and nutrient dynamics. This results from their reactions with proteins and nitrogen (Myers et al. 1994; Mafongoya et al. 1998).

This experiment confirms that the resource quality and mixture of contrasting resource quality affect the N-mineralization and -immobilization processes during decomposition. In agreement with Palm (1995), the following factors must be considered when choosing parameters to describe plant quality: a) the processes of decomposition and N release are controlled by different parameters; b) the critical parameters will depend on the time frame of the crop need; and c) the importance of certain parameters change with the type and the mixture of the plant material. The ultimate aim is to identify robust parameters that predict decomposition and nutrient release.

The decomposition patterns and N-mineralization of the mixture were not the arithmetic mean of the decomposition patterns of the component organic material. In this case, there are interactions between components principally in terms of the rate of decomposition and N release, which was demonstrated in N-mineralization (net and total mineralization), microbial biomass C and extractable organic C.

Mafagoya et al. (1998) identified three types of soluble constituents that result in interactions between organic materials: a) compounds that contain available carbon as a substrate, b) compounds that contain readily available N, and c) soluble polyphenols, which can complex with proteins, rendering them resistant to microbial assault. The results showed in this experiment confirm that the carbon availably and soluble polyphenols may be the important parameters that result in interaction between contrasting organic material.

3.3 Decomposition of contrasting leguminous leaf material and gross N dynamics in soil using rice as an indicator plant

A decomposition study of 15N-labeled plant material (*S. paniculatum, I. edulis*, and mixture, p*e) with contrasting litter quality was conducted to assess the rates of mineralization and immobilization, using rice as an indicator plant (Table 7). N-urea fertilizer (3.92 N mg pot^{-1} with N at natural abundance) and ^{15}N-labeled leguminous organic material from *S. paniculatum* and *I. edulis* with 2.02% N and 0.392 atom % ^{15}N, and 1.93% N and 0.390 atom % ^{15}N, respectively, were used to find the amount of mineral-N coming from organic matter decomposition, and the extent of competition between microorganisms, soil + organic matter fixation, and rice absorption.

Treatment	Soil	Leaf	N	N-fertilizer	^{15}N
	g		mg g^{-1} soil		µg g^{-1} soil
S. paniculatum^{15}	50.62(0.10)	70.66(0.002)	1.62(0.001)	0.08(0.002)	6.36(0.012)
p*e^{15}	50.62(0.11)	70.48(0.001)	1.64(0.001)	0.08(0.001)	6.40(0.009)
I. edulis^{15}	50.52(0.09)	71.00(0.014)	1.69(0.006)	0.08(0.002)	6.61(0.010)
Control	50.68(0.13)			0.08(0.001)	

Φ species name with *14* had leaf with nitrogen at natural abundance and was fertilized with 5.34 atom % ^{15}N. Species name with *15* had leaf with enriched ^{15}N (both species at 0.39 % ^{15}N in leaf material) and was fertilized with fertilizer at natural abundance.

Table 7. Amount of organic matter (OM) mixed with soil in a plastic pot and the total ^{14}N and ^{15}N-excess added with leaf and fertilizer in greenhouse experiment. The numbers represent mean(standard deviation), n = 12.

Total rice biomass and total N in rice was affected by N from the legume leaves in the amended soil during the incubation period (Figure 6). Initial rice dry matter was not statistically different at the time of transplantation. Although the N uptake by rice in the p*e mixture treatment did not differ statistically from that in the *I. edulis* treatment at the end of incubation period, it was significantly higher than the *S. paniculatum* and the control treatments (Figure 6). All treatments showed a significantly ($P < 0.01$) higher total N content in comparison with the control. But the concentration of nitrogen in seedlings of rice were significantly when are used the interaction between two contrasting leguminous material as a source of nitrogen.

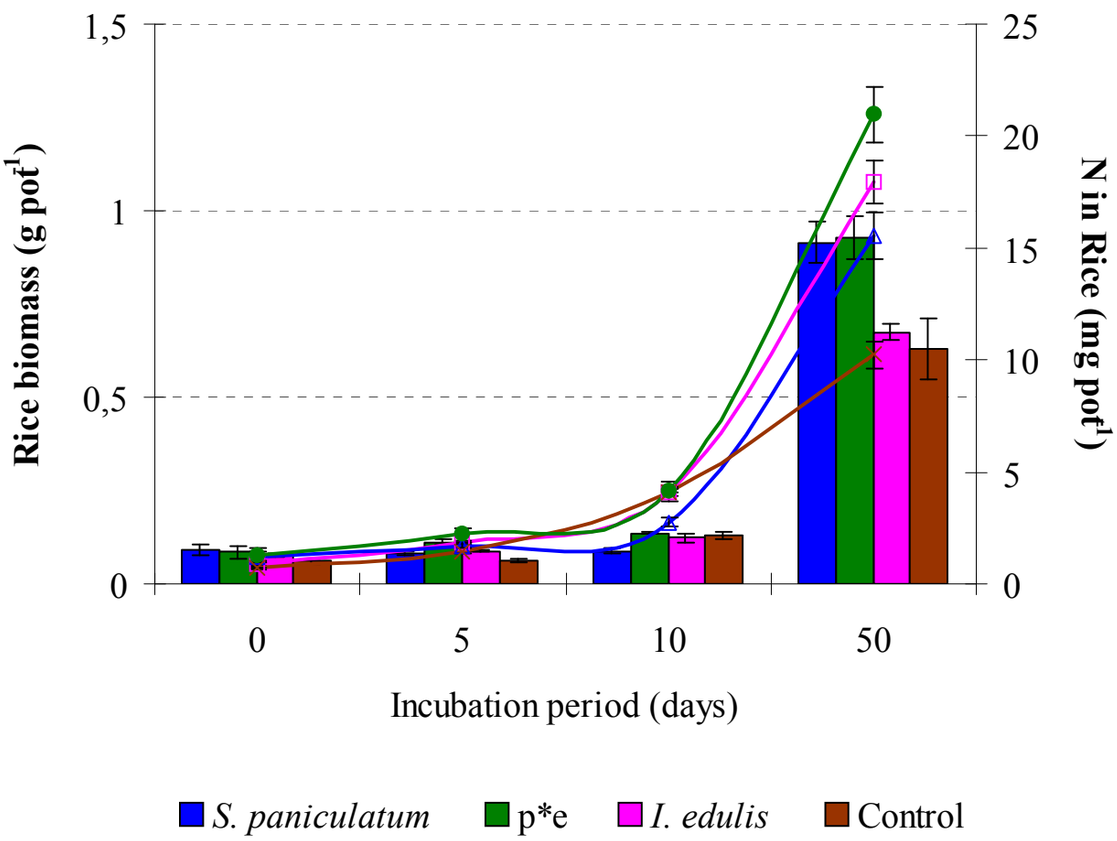

Fig. 6. Rice dry matter (g pot^{-1}, boxes) and total N in plant material (mg N pot^{-1}, lines) growing in soil with leaf-^{14}N legume material and mixture using enriched urea-^{15}N fertilizer. Control was soil that only included urea-^{14}N fertilizer. Bars represent standard error of the mean.

Treatment with the mixture of two legumes species showed a high recovery of N and ^{15}N in comparison to the two legume species (Figure 7). Recovery of ^{15}N from rice was significantly higher ($P < 0.001$) in the *S. paniculatum* treatment than with the *I. edulis* treatment. In contrast, the recovery of total N was higher for the *I. edulis* than for *S. paniculatum*.

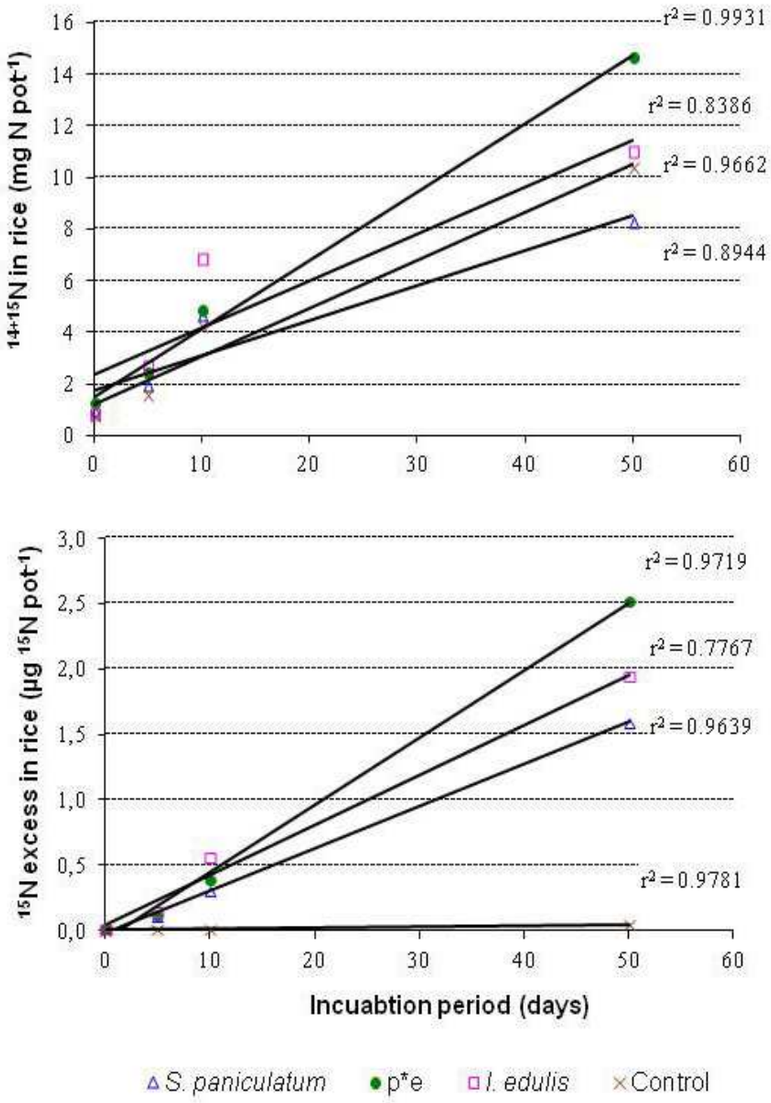

Fig. 7. ^{14}N+^{15}N and ^{15}N recovery in rice for soil treatment with ^{15}N-leaf material of two different legumes species and mixture, and ^{14}N-urea fertilizer in comparison with soil without added leaf material and fertilized with ^{14}N-urea, for different incubation periods. The ^{15}N is expressed as the atom % ^{15}N excess abundance above the background (0.3663 atom %).

The N concentration in rice increased until 10 days after transplanting (Table 8) and, during this phase of rice growth, the legume treatments did not differ from the control ($P > 0.05$). At the end of the incubation period, *S. paniculatum* showed a significantly ($P < 0.01$) lower N final concentration in rice (11.6 mg N g^{-1} dry matter) in comparison with the control (17.4 mg N g^{-1} dry matter), *I. edulis* (18.0 mg N g^{-1} dry matter) and p*e mixture (18.2 mg N g^{-1} dry matter).

The results with leaf enriched with ^{15}N reveal that most of the N absorbed by rice (Table 9), came from the soil, but the interaction between the two leguminous plants was provided to more N for rice after 50 days of incubation (Figure 7).

Treatment / Incubation period (days)	N concentration (mg N g^{-1} rice dry matter)			
	0	5	10	50
S. paniculatum	11.2	18.0	25.3	11.6
p*e	14.3	19.2	27.8	18.2
I. edulis	14.2	19.6	30.4	18.0
Control	11.6	23.4	31.7	17.4
LSD	3.17^{NS}	1.54^{*}	6.40^{NS}	6.45^{*}

LSD compares different treatment at the same sampling time; ^{NS} is not significant; * = P < 0.05

Table 8. Nitrogen concentration in rice (mg N g^{-1} dry matter) for different treatment and control during the incubation time (days). Control was soil without added leaf material and fertilized with N-urea.

Nitrogen microbial immobilization estimated by the fumigation-extraction method showed a contrasting pattern between differently materials (Figure 8 A and B). Generally at the beginning of the experiment, the microbial biomass-N with the small amount of added leaf material behaved exactly opposite to the experiment with the larger amount of leaf material added. The control treatment initially showed a faster decrease in microbial biomass-N.

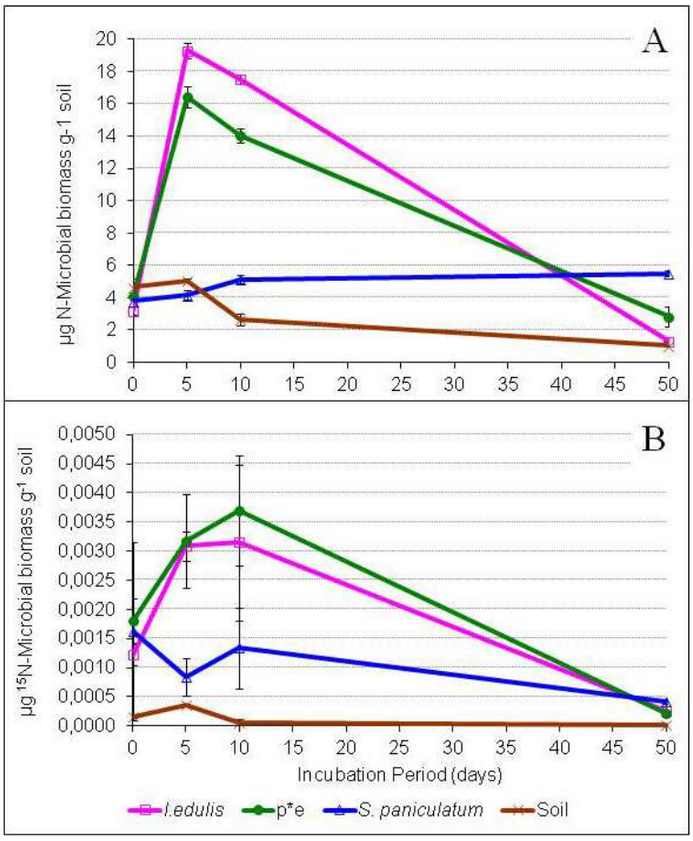

Fig. 8. A) Nitrogen microbial biomass (µg N-microbial biomass g^{-1} soil) during the greenhouse incubation period (days) for samples with leaf material, and (B) ^{15}N microbial biomass (µg ^{15}N-microbial biomass g^{-1} soil) samples with ^{15}N enriched leaf material and fertilized with urea-^{14}N. Soil treatment (as control) was soil without added leaf material and fertilized with urea-^{14}N. The bars represent Standard error of the mean

In the *I. edulis* and p*e mixture treatments, a significantly fast initial N microbial immobilization was observed, which increased toward the end of the experiment. However, at the end of the experiments with this species, a decrease in N immobilization was observed. After five days of incubation, the *S. paniculatum* treatment exhibited an approximately constant N immobilization. The immobilization of N by soil microorganisms seems to explain why most of the N absorbed by the rice comes from the ground. The experiment showed that most of the N released from the leaf material, through the process of decomposition, was immobilized by soil microorganisms (Figure 8).

Nitrogen derived from residues (Ndfr; Hood, 2001) of different ^{15}N-legume leaf material was not statistically different between treatments until five days of incubation (Table 9). At ten days, a significantly higher amount of total N in rice came from the *I. edulis* (34.1%) and p*e mixture (31.9%) than from the *S. paniculatum* (25.2%). However, at the end of the incubation period, N in rice originating from the *S. paniculatum* leaf material increased by 11.4% in comparison with a decrease of 3.4% and 2.5% for the p*e mixture and *I. edulis* treatments, respectively, reflecting the slowly biodegradability of *S. paniculatum*.

N derived from residue (Ndfr, %)				
Treatment	Incubation period (days)			
	0	5	10	50
S. paniculatum	8.62	21.5	25.2	36.2
p*e	8.87	21.7	31.9	28.6
I. edulis	7.66	22.4	34.1	31.6
LSD	1.21^{NS}	0.92^{NS}	2.18^{**}	0.66^{**}
N derived from residue (Ndfr, mg)				
S. paniculatum	0.08	0.42	1.17	2.99
p*e	0.11	0.52	1.55	4.18
I. edulis	0.06	0.60	2.31	3.45
LSD	0.03^{*}	0.07^{**}	0.10^{**}	0.73^{*}
N recovered from residue (Nrfr, %)				
S. paniculatum	0.10	0.51	1.45	3.68
p*e	0.14	0.64	1.91	5.16
I. edulis	0.08	0.75	2.90	4.32
LSD	0.03^{*}	0.03^{**}	0.13^{**}	0.84^{*}

Table 9. Nitrogen derived from residue (NdfR) in % and mg, and N recovered from residue (NrfR, %), according to Hoods (2001), during the greenhouse incubation period in soil treated with 15N-leaf legume and 14N-urea fertilizer.

The amount of N derived from residues increased significantly for all treatments during the incubation period (Table 9). The higher increase in N recovered from the added leaf material was found in the p*e mixture treatment, which showed an increase of 4.07 mg N in comparison with 3.39 and 2.91 mg N for the *I. edulis* and *S. paniculatum* treatments, respectively.

With this higher increase, the total N recovered from added legume leaf material was significantly higher for the p*e mixture than the other treatments (Table 9). However, for the first 10 days of the incubation period, the *I. edulis* treatment showed the higher percentage

(3.65%) of total N recovered from the added leaf material in comparison with the p*e mixture (2.55%) and *S. paniculatum* treatments (1.96%).

Lower rates of ^{15}N-recovery could be due to mineralization-immobilization turnover (Thönnissen et al. 2000). The ^{15}N-release from the legume residue into the soil inorganic pool could be exchanged for ^{14}N in microbial biomass, which could lead to a lower ^{15}N-recovery. On the other hand, lower rates for ^{15}N recovery than for total N may result partly from an overestimation of apparent total N recovery and partly from the importance of soil conditions, in terms of C-quality, during the rapid degradation of ^{15}N-labeled material.

A high ($^{14}N+^{15}N$)-microbial biomass was observed at the beginning of the greenhouse experiment for the p*e mixture (Table 10) in comparison to the other treatments. All treatments showed an increase in N absorption from microorganisms during the first five days. This increase was very high for the *I. edulis* treatment, which showed an increase of 500% of the initial concentration, followed by the p*e mixture (27.0%), *S. paniculatum* (10.0%) and control (8.8%).

($^{14}N+^{15}N$)-microbial biomass (µg $^{14}N+^{15}N$ g^{-1} soil)				
Treatment	Incubation period (days)			
	0	5	10	50
S. paniculatum	3.8^{b}	4.2^{c}	5.1^{c}	5.5^{a}
p*e	12.9^{a}	16.4^{b}	14.1^{b}	2.8^{b}
I. edulis	3.2^{b}	19.3^{a}	17.5^{a}	1.3^{c}
Control	4.7^{b}	5.1^{c}	2.7^{d}	1.0^{c}
LSD	1.451***	0.915***	0.310***	0.298***
^{15}N-microbial biomass (µg ^{15}N excess g^{-1} soil)				
S. paniculatum	0.01618^{a}	0.00084^{b}	0.00134^{a}	0.00041^{a}
p*e	0.00180^{b}	0.00316^{a}	0.00369^{a}	0.00021^{ab}
I. edulis	0.00123^{b}	0.00308^{a}	0.00314^{a}	0.00026^{ab}
Control	0.00002^{c}	0.00004^{c}	0.00001^{b}	0.00001^{b}
LSD	0.0018***	0.00070**	0.00307*	0.00025*

LSD compares treatment at the same sampling time; * = P < 0.05; ** = P < 0.01; *** = P < 0.001.

Table 10. ($^{14}N+^{15}N$)-microbial biomass (µg $^{14}N+^{15}N$ g^{-1} soil) and ^{15}N-microbial biomass (µg ^{15}N excess g^{-1} soil) in soil amended with ^{14}N-legume leaf material and enriched ^{15}N-urea fertilizer with rice as an indicator plant. Control was soil without added leaf material and fertilized with N-urea. The ^{15}N excess is expressed as the atom % ^{15}N excess abundance above the background (0.3663 atom %).

The high N-microbial biomass level remained high in the *I. edulis* and p*e mixture treatments for the first 10 days of the greenhouse experiment (Table 10). However, at the end of the incubation period, these treatments showed a significantly higher decrease in the microbial biomass-($^{14}N+^{15}N$), whereas the *S. paniculatum* treatment displayed a significantly high increase in the concentration of $^{14}N+^{15}N$ in the microbial biomass.

In all treatments, a significantly higher microbial biomass-^{15}N was observed during the first 10 days of the incubation period in comparison with the control (Table 10). The initially

higher microbial biomass-^{15}N concentration for the *S. paniculatum* treatment indicated intensive microbial activity leading to decomposition of recalcitrant leaf material in this treatment. However, after fertilizer had been added, the ^{15}N-excess immobilization in the soil increased to 155% of the initial concentration in the *I. edulis* treatment and 105% in the p*e mixture treatment, whereas the *S. paniculatum* treatment showed a decrease of 92% in the microbial biomass- ^{15}N concentration. At the end of the experiment, all legume treatments showed a significant decrease in the microbial biomass-^{15}N, and only the *S. paniculatum* showed a significantly higher microbial ^{15}N-concentration in comparison with control (Table 10).

The decrease in soil mineral nitrogen over time was attributable not only to rice plant uptake, but also to considerable microbial immobilization. The use of a mixture of two contrasting litter qualities (called p*e mixture) improved the nitrogen recovered by rice, which was derived from urea-fertilizer by 35.1% and 41.3% of total fertilized N in comparison with *S. paniculatum* and *I. edulis* treatments, respectively. In the same way, the rice recovery of N derived from the legume material in the p*e mixture improved by 73.3% compared with the *S. paniculatum* treatment, but was 0.9% lower than that of the *I. edulis* treatment.

Moreover, the use of a larger amount of leaf material resulted in a higher increase in N immobilization and mineral-N in the soil, depending on the quality of the leaf material. The total cumulative nitrogen mineralization increased 90.9%, 10.3%, and 18.8% for the *S. paniculatum*, p*e mixture and *I. edulis* treatments, respectively. In the same way, the increases in cumulative microbial biomass-N during the incubation period were 109%, 190% and 344%, respectively.

The p*e mixture treatment showed an intermediate cumulative soil microbial- ^{15}N immobilization, higher cumulative rice biomass and total N, and higher recovery of ^{15}N from urea fertilizer. This indicates that the interaction of two different leguminous species increases the nitrogen absorption by rice through the increase in mineral-N and the decrease of gross microbial-N immobilization.

Decline in soil productivity and environmental quality and progressive deterioration of natural resources in the tropics have led to a search for new methods to sustain crop production via more efficient nutrient cycling. In agricultural ecosystems in the tropics with limited access to fertilizers, plant residues are often used to meet the N requirements of annual food crops (Constantinides and Fownes 1994). The added organic materials are potentially important sources of N, C and P in crop production, especially for resources-poor farmers on tropical agricultural land. In order to successfully manage organic materials, the release and uptake of N by crops must be identified (Hood 2002). But the predictions of net N-mineralization are in many cases unreliable because net N-mineralization is affected by N immobilization and remineralization and losses (Stark and Schimel 2001).

The slash and burn system destroys the above-ground biomass of the fallow vegetation including the litter by burning, which causes loss of nutrients through volatilization and leaching of free nutrients in ash by rainfall. The losses of nitrogen by volatilization and leaching can reach 95-98% (Mackensen et al. 1996). Cerri et al. (1991) observed a reduction of 25% in soil carbon content two years after a plot was cleared, burned and a satisfactorily

managed pasture established. However, Kato (1998) showed no reduction in carbon content in the mineral soil in the slash and burn system, and attributed this to the biomass accumulated by the rice crop.

The concept of pools of organic matter that differ in their susceptibilities to microbial decomposition and their longevity in soil has provided a basis for understanding the dynamic nature of soil organic matter and how nutrient availability is influenced by management practices and changes in the soil environment (Stevenson and Cole 1999). Our study showed that the patterns of the added organic carbon need to be taken into consideration. This was supported by the strong correlation between nitrogen dynamics in the contrasting legumes-amended soil and soil microbial biomass and organic carbon, found in this study.

Dissolved organic substances contribute to plant nutrition with nitrogen. Due to their water solubility there is a considerable risk that leaching of these substances will result in enhanced soil degradation. The dynamics of dissolved organic substances is influenced by the quantity and the quality of soil organic matter, the sorption characteristics of the soils and the microbial activity. All these parameters are modified by land use.

When immobilization and mobilization processes of N in soil are managed, it is important to quantify the real amount of N stored in the soil microbial biomass (Joergensen and Mueller 1996). Transient immobilization of soil N in the microbial biomass may contribute to improved conservation of soil N sources (Jensen 1997).

The higher initial concentrations of soil inorganic nitrogen in the high-N treatments would unlikely increase nitrogen immobilization significantly in the absence of added organic matter because nitrogen immobilization is generally limited by available carbon (Recous et al. 1988, Bremer and Kuikman 1997). Thus, fertilizer added as urea-N did not lead to differences in total mineral-N and microbial biomass-N in soil without added organic material during the incubation period (Table 11). Urea increased total microbial biomass-N and decreased total mineral-N, which suggests that fertilizer increased microbial biomass and thus nitrogen consumption by soil microorganism.

On the other hand, the increase in soil organic carbon and nitrogen due to added legume leaf + wood material resulted in a decrease in N-min and microbial biomass in comparison with control treatment (Table 11). Assuming that the fumigation-extraction method did not measure the fungal N-absorption, resulting in a underestimation of N-immobilization, and that the mineralization and losses of indigenous soil nitrogen were similar in the control and residue-treated soil, the real nitrogen immobilization and consumption was 63.2 and 37.7 μg N g^{-1} soil for *S. paniculatum* and *I. edulis* treatment, respectively. This means that the nitrogen in microbial biomass (microbial nitrogen immobilization and consumption) was approximately 9.3 and 1.0 times more than the mineral-N found in the same treatments, respectively.

The withdrawal of the wood material and added nitrogen as fertilizer yielded a strong increase in N-mineralization in comparison with wood material only and control. This suggests that these soils in this Amazon region are very nitrogen and carbon limiting and the microbial competition is very intensive.

S. paniculatum	**N-mineral (µg N g^{-1} soil)**		**N-microbial biomass (µg N g^{-1} soil)**	
Incubation period (days)	leaf + wood material	leaf material + fertilizer	leaf + wood material	leaf material + fertilizer
0	**2.7**(0.04)	**19.5**(1.81)	**0.6**(0.50)	**4.8**(1.33)
4	**0.5**(0.14)	**15.5**(1.42)	**0.8**(0.06)	**5.2**(1.88)
16	**0.7**(0.11)	**13.4**(0.28)	**0.3**(0.09)	**6.3**(3.38)
64	**1.1**(0.12)	**31.5**(1.46)	**0.1**(0.07)	**5.5**(0.71)
Total	**5.0**	**79.9**	**1.8**	**21.8**
I. edulis	Total N-mineral (µg N g^{-1} soil)		Total N-microbial biomass (µg N g^{-1} soil)	
Incubation period (days)	leaf + wood material	leaf material + fertilizer	leaf + wood material	leaf material + fertilizer
0	**8.3**(0.44)	**54.5**(0.84)	**3.6**(0.24)	**19.3**(3.48)
4	**9.7**(0.08)	**51.7**(0.80)	**1.1**(0.14)	**18.2**(1.82)
16	**7.1**(0.11)	**57.7**(1.23)	**1.2**(0.10)	**19.4**(1.62)
64	**2.7**(0.09)	**52.0**(1.66)	**2.6**(0.17)	**14.2**(2.61)
Total	**27.8**	**215.9**	**8.5**	**71.1**
Control	Total N-mineral (µg N g^{-1} soil)		Total N-microbial biomass (µg N g^{-1} soil)	
Incubation period (days)		fertilizer		fertilizer
0	**13.1**(0.16)	**17.8**(2.04)	**1.3**(0.25)	**4.8**(0.36)
4	**14.8**(0.26)	**12.9**(0.95)	**4.9**(0.25)	**1.8**(0.41)
16	**16.0**(0.09)	**13.3**(0.10)	**2.2**(0.08)	**0.7**(0.55)
64	**20.4**(0.13)	**12.7**(0.18)	**1.3**(0.01)	**4.6**(1.37)
Total	**64.3**	**56.7**	**9.7**	**11.9**

Φ Nitrogen-mineral was examined with steam distillation procedure.
Ψ N-microbial biomass was measured with fumigation-extraction procedure.

Table 11. Nitrogen-mineralΦ (µg N g^{-1} soil) and N-microbial biomassΨ (µg N g^{-1} soil) for incorporated leaf+wood material in comparison with incorporated leaf material+Urea as fertilizer, during the incubation time and total. The numbers represent mean (Standard error).

Microbial immobilization of labelled nitrogen was unaffected by rice plant growth, but was strongly affected by organic matter and nitrogen addition. Immobilization of nitrogen by organic matter decomposers was determined primarily by the amount and accessibility of available nitrogen. Differences in nitrogen immobilization by decomposers of the legume organic matter were greatest between N treatments, but were also affected by mixture of two contrasting legume materials

Rice growth and nitrogen accumulation closely reflected the differences in chemical composition and mineralization between the residues and their mixture. Approximately the same amount of nitrogen was added in all legume treatments, and yet the amount of

nitrogen accumulated differed with the legume quality. The use of a mixture of two contrasting litter qualities improved the rice recovery of nitrogen derived from urea-fertilizer and the rice recovery of nitrogen derived from legume material.

This study showed that the quality and the quantity of organic carbon presented an important factor affecting soil nitrogen mineralization and immobilization. Changes in soil carbon substrates influenced the dynamics of soil inorganic nitrogen because of the importance of labile carbon in the microbial immobilization and consumption of nitrogen. Compton and Boone (2002) showed that the light fraction of soil organic matter incorporated more ^{15}N than the heavy fraction per unit of carbon, which indicated that not simply the amount but the composition of organic matter controls its function as a site for N incorporation.

Soil microbial biomass immobilizes a higher amount of the residue N mulched or incorporated into the soil and this needs to be taken into consideration. On the other hand, soil microbial biomass immobilization is a labile repository of nitrogen, their turnover and remineralization may conserve this N in the system and release this N for later plant use.

Legume-enriched mulch material had different patterns of mulch decomposition and nutrient release. As was pointed out earlier by Constantinides and Fownes (1994), Fox et al. (1990), the contents of N, lignin and polyphenol are the principal chemical factors controlling degradability of plant material. The high correlation with the ratio of N + P-to-phenol and N-mineralization implies that the plant nutrients which limit microbial action govern decomposition and nutrient release. This is likely associated with the formation of stable polymers with many forms of N binding N released to the soil by the incorporated organic matter.

4. Conclusion

The use of fast-growing legumes for fallow enrichment, as for example *A. mangium*, does not necessarily translate directly in a CO_2 sequestration, because the fast decomposition rate. Species, contrasting in lignin and polyphenol concentration with higher N- and P-content must be used for enrichment fallow. The *I. edulis* and *S. paniculatum*, two Amazon species, showed greater promise as enrichment candidates, because of their high organic C input in combination with low losses of OM.

Since immobilization of N is generally determined by the amount of decomposable carbon present in the soil rather than by the amount of inorganic N, the addition of compost showing a wide C-to-N ratio accelerates N-immobilization through increased microbial activity. Contrasting leguminous species had different patterns of net N-mineralization and immobilization in comparison with the single species. The use of two contrasting leguminous species increased the nitrogen absorption by rice through the increase of mineral N and decrease of microbial N-immobilization.

Soil microbial biomass immobilizes a higher amount of the residue N mulched or incorporated into the soil and this needs to be taken into consideration. On the other hand, soil microbial biomass immobilization is a labile repository of nitrogen, their turnover and remineralization may conserve N in the system and release this N for later plant use. Managing soil biological processes is a key aspect of sustainable development. The

researchers must better understand soil organisms, their functions and their interactions with the chemical and physical environment. Many aspects of soil biology and ecology are worthy of research in view of their fundamental scientific interest and their role in ecosystem functioning.

The high correlation with the ratio of N + P-to-phenol and N-mineralization implies that the plant nutrients which limit microbial action govern decomposition and nutrient release. This is likely associated with the formation of stable polymers with many forms of N binding N released to the soil by the incorporated organic matter.

The slash-and-mulch systems with thick mulch mats need to be improved for the synchronization of nutrient release from organic material and nutrient uptake by crop systems. The use of contrasting plant material in terms of litter quality, C reduction in the vegetation with the selective removal of wood, and soil incorporation of fallow residues need to be further tested. On the other hand, the increase of agriculture in the Amazon region cannot be done by the increase of deforestation and the scope of an increase in fertilizer use is limited. Thus, the intensification and improvement of currently managed land would have to be attempted. Fallow-mulch system is a considerable challenge and calls for more research. The agricultural policy in the Amazon region could promote organic agriculture with incentives to production and facilitating the commercialization of Amazon organic agricultural products.

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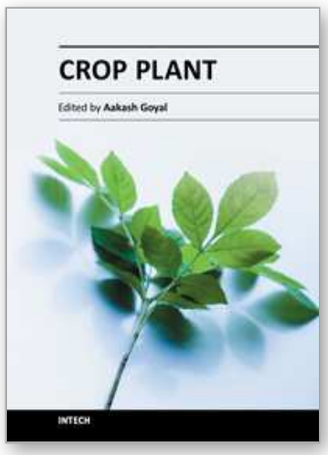

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This book provides us a thorough overview of Crop Plant with current advance in research. Divided into two section based on the chapters contents. Chapter 1 provides information about markers and next generation sequencing technology and its use. Chapter 2 is about how we can use Silicon for Drought tolerance. Chapter 3 is to deal with the major problem of rising CO2 and O3 causing environmental pollution. Chapter 4 covers the phenomena of RNAi and its use, application in crop science. Chapter 5 is a review for boron deficiency in soils and how to deal with it for better crops. Chapter 6-10 provide some information regarding recent works going on in crop science.

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