Decomposition of cover crop residues in a rubber tree plantation in northeast Thailand

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Abstract
This study examines the biomass production and decomposition patterns of two cover crop residues (*Pueraria phaseoloides* and *Vetiveria zizanioides*) cultivated and cut every three months in the inter-ranks of a rubber tree plantation in northeast Thailand. Residue decomposition was monitored during 160 days in the rainy season in 2008 using the litter bag technique. Pueraria, which nodulated successfully, yielded three times less than vetiver. However, pueraria had a higher nutrient content and a lower C/N ratio. The weight loss of residues was described by double exponential models. The decay rate constants (kW) were k1= 0.37 g/g/day and k2= 0.009 g/g/day for pueraria and k1= 0.09 g/g/day and k2= 0.003 g/g/day for vetiver. Pueraria litter released about 43% of its initial N during the period of monitoring whereas a negative value of -16% was estimated for vetiver. *P. phaseoloides* could therefore improve the nutrition of associated rubber trees at short term whereas *V. zizanioides* would rather play a role in the build up of soil organic matter in the long term.

Key Words
Agroforestry, litter decay, organic matter mineralization, nutrient release, nitrogen immobilization, ecosystem services.

Introduction

In northeast Thailand, large areas of land have been deforested after the 1960s to implement cash crops such as cassava and sugarcane. Nowadays, soils are so degraded that the yields are erratic and low. During the past two decades, farmers have been encouraged by governmental policies to plant rubber trees (*Hevea brasiliensis* Muell. Arg.). Because most soils in northeast Thailand have a sandy texture, low fertility and are prone to erosion and leaching of applied fertilizers, the introduction of perennial cover crops in the inter-ranks of the rubber trees is considered as an interesting alternative for ensuring the sustainability of these rubber tree plantations. Many previous research studies showed that cover crops have the potential not only to protect the soil against erosion, but also, to supply high amounts of aerial biomass that can be cut and spread either as mulch at the soil surface or buried. The rate of decomposition of residues may be high enough to release rapidly significant amounts of nutrients in the soil which could then be taken up by an associated or succeeding crop (McDonagh *et al.* 1995). Although the decomposition rates of the residues could be lower when left at the soil surface than if they are buried, the surface mulching would be more efficient to reduce leaching and erosion in situations of high risks (Cheer *et al.* 2006). Moreover, it is a less costly practice as no tillage is needed. Rate of litter decomposition could also vary according to the quality of the residues. It is well known that residues from legumes have a more important impact in the short term on soil fertility, whereas residues from grass plants have a more significant impact in the long term. The difference is often explained by the lower C/N ratio of legumes compared to grass residues. Some recent studies however reported that not only N and C content of residues, but also their protein binding capacity, polyphenols:N ratios (Palm and Sanchez 1991) and lignin:N ratios (Becker *et al.* 1994), could explain differences in the decomposition patterns of residues.

Despite their often reported positive impacts, the use of cover crops in farmers' fields is still uncommon. This is largely due to a lack of research on where and how to introduce cover crops into existing farming systems (Cheer *et al.* 2006). One aspect of this question is to examine, within the actual conditions of farmers' fields, their biomass production and the decomposition pattern of their residues and the rates of their nutrient release into soils. The method of litter bags has been reported by many authors as giving good insight into the question of the decomposition pattern of residues (Kurz-Besson *et al.* 2005)

This study aims at i) quantifying the aerial biomass production of two cover crops growing in the inter-ranks of a young rubber tree plantation in northeast Thailand, and ii) examining the decomposition and nutrient release patterns of the residues from these cover crops after cutting by using the litter bag technique.

Methods

Site

The experiment was established in July 2007 in a three-year-old rubber tree plantation owned by a farmer at Ban Non Tun, Nong Waeng subdistrict, Phra Yuen district, Khon Kaen province, Thailand (16°28'N, 102°45'E). With an elevation of 210 m, this site corresponded to what is commonly named "the upland area" of northeast Thailand. The experiment stretched over a gentle slope of about 5%. As most soils of the upland area, the soil was sandy with low nutrient availability. Weather data indicated an annual average temperature of 25°C and a rainfall amount of 1957 mm in 2008.

Management of the tree/cover crop stand and residues

The three-year-old rubber tree plantation was made of ranks of trees positioned on swathes of 2 m width and 0.15 m height. The trees were 3.50 m apart on the ranks. The area between two ranks, named the inter-ranks, was 7 m large. In July 2007, two cover crops, pueraria (*Pueraria phaseoloides*) and vetiver (*Vetiveria zizanioides*) cultivar Songkha were planted in the inter-ranks of the plantation in the bottom, middle and top portion of the slope. The cover crops did not receive any fertilizer application whereas the trees received annually 180 g/tree of chemical fertilizer (formula 20-10-12% N-P_2O_5-K_2O). The cover crops were cut every three months and their residues applied as mulch on the soil surface of the inter-ranks. Many nodules were observed on the roots of pueraria, indicating that nitrogen fixation was active. Before the cutting dates of May, August and November 2008, two subplots of 2 m^2 were randomly selected along each inter-rank, and harvested for the biomass estimation of cover crops. In May 2008, samples of the harvested biomass were analysed for their nutrient contents and a litter bag experiment was undertaken.

Evaluation of residues decomposition

A total of 360 nylon bags with 2 mm mesh size and measuring 20 x 20 cm were placed on the soil surface in the inter-ranks. They contained 16.9 g and 13.2 g of dry biomass of vetiver and pueraria respectively, cut into small pieces of 2-3 cm length. Three litter bags per inter-rank were retrieved at 7 days interval during the three first weeks and at 15 days interval thereafter (13 retrieval dates). At each retrieval date, the litter bags were washed with tap water, then oven dried at 65°C and residues were ground (<1 mm) for chemical analysis of N, P, K, Ca, Mg, S contents.

Results

Within this study, despite low-input practices, the biomass production of both cover crops was sufficient to enable the entire surface of the plots to be covered with mulch. The biomass produced by vetiver was about three times higher than the biomass produced by pueraria and no significant effect of the position on the slope was recorded (Table 1).

Table 1. Dry biomass of cover crops at cutting. The standard errors of means are quoted in brackets, n = 6. Values followed by the same letter are not significantly different at 5% level.

Inter-rank treatment	Dry biomass produced (t/ha)		
	Upslope	Midslope	Downslope
Pueraria	1.96 (0.48) b	2.24 (0.20) b	2.71 (0.29) b
Vetiver	6.05 (2.01) a	5.59 (0.57) a	5.09 (0.52) a

Chemical characteristics of pueraria and vetiver dry matter sampled in May 2008, indicated that the N content of pueraria was 4 times higher than in vetiver. P and K and even Ca and Mg were noticeably higher in pueraria than in vetiver. C/N ratio was 14 for pueraria and much higher in vetiver reaching the value of about 66 (Table 2). These results are consistent with numerous reports on the higher nutrient content and lower C/N ratio of legume residues compared to grass residues.

Table 2. Average initial chemical composition and initial weights of residues incorporated in litter bags in May 2008.

Residue	C (%)	N (%)	C/N ratio	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Initial dry weight (g/bag)
Pueraria	45.07	3.18	14.30	0.19	2.15	0.82	0.21	0.17	16.90
Vetiver	51.77	0.79	65.80	0.06	1.54	0.24	0.08	0.08	13.20

A B

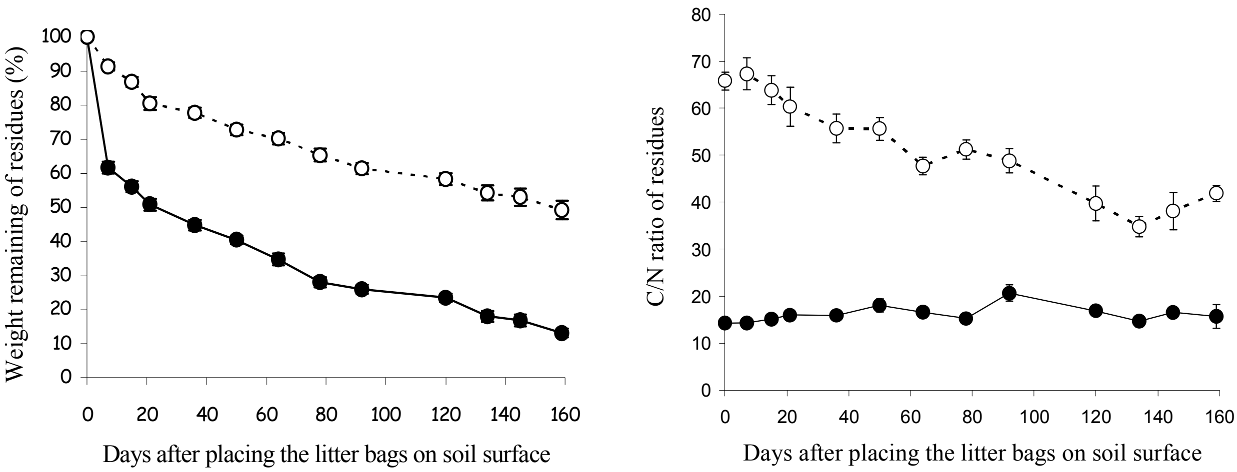


Figure 4. Evolution of the weight (A) and C/N ratio (B) of residues over time. Bars are standard errors of means, n= 9 (□) vetiver (■) pueraria.

Over the course of time, the remaining weight of the residues in the litter bags decreased (figure 1A). After the first week, 60% and 90% of the biomass of pueraria and vetiver remained in the bags, and 13% and 49% remained at the end of the experiment. These curves were fitted by double exponential decay models with decay rate constants (kW) of 0.37 and 0.009 g/g/day, for pueraria and 0.09 and 0.003 g/g/day for vetiver. The first rate was over the period of 7 days for pueraria and 21 days for vetiver. These decomposition patterns were not significantly affected by the position of the litter bags on the field landscape.

The percent of N remaining in the residues decreased over time for pueraria (figure 2A), indicating that the mineralization process was active. About 43%, 49% and 95% of the initial N, P and K of the pueraria residues were released in soil during the 160 days of experiment. In contrast, vetiver tied up about 16% of its initial N content (figure 2A) and released 15% and 94% of its initial P and K (figure 3). The increase trend recorded for vetiver in figure 2A suggested that immobilization process might have occurred.

A B

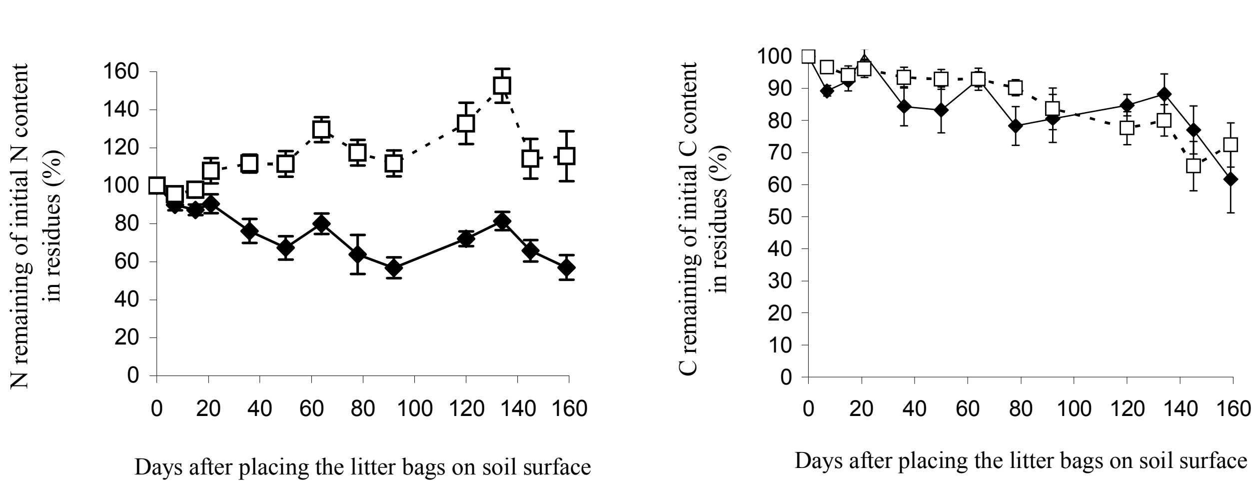
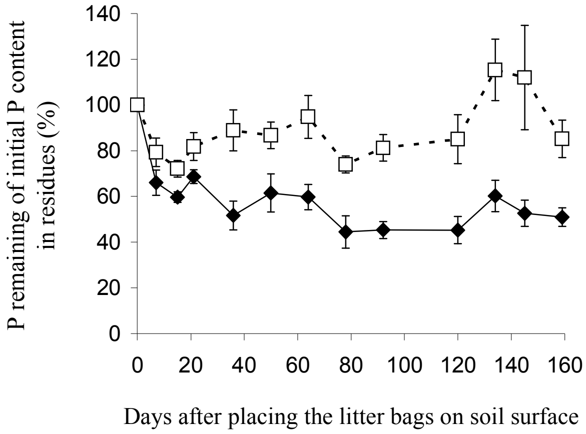


Figure 5. Evolution of the % N (A) and % C (B) content remaining in residues over time. Bars are standard errors of means, n = 9 (□) vetiver (■) pueraria.

This is consistent with the high C/N of 66 of these residues (figure 1B), and with the slight decrease of their C content (figure 2B) over time. However, our hypothesis of microbial immobilization is not in accordance with Fosu *et al*. (2006) who considered that this process was not accounted for by the litter bag method. However, other studies using the litter bag technique reported such increase of remaining N content in residues of tropical grasses over time (Robbins *et al.* 1989; McDonagh *et al.* 1995; Aerts *et al.* 2006).

A



B

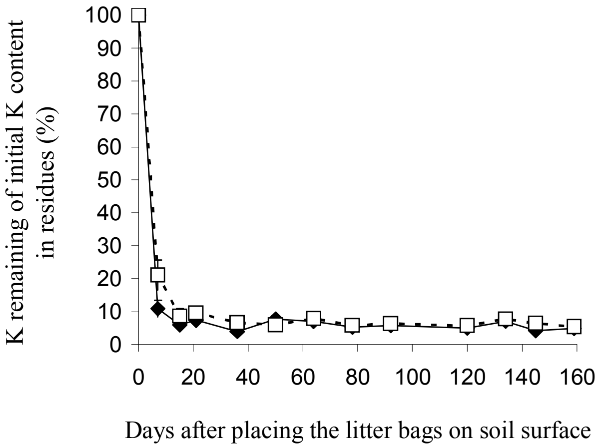


Figure 6. Evolution of % P (A) and % K (B) content remaining in residues over time. Bars are standard errors of means, n = 9 (□) vetiver (■) pueraria.

Conclusion

A high production of cover crop biomass was achieved in the inter-ranks of a young rubber tree plantation during the rainy season in 2008 in northeast Thailand under low input management. The results clearly showed that *Pueraria phaseoloides* could contribute at very short term to improve the nutrition of the associated rubber trees by releasing nutrients into the soil from its residues. In contrast, *Vetiveria zizanioides* might reduce at short term the availability of indigenous soil N and would rather play on the build up of the soil organic matter in the long term.

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