Effect of plant residue quality of secondary forest vegetation on phosphate mineralization and immobilization in soil

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Abstract

Our objectives were to examine if the amendment of secondary forest vegetation residue which are different in quality influence P mineralization and immobilization in the soil. Plant residue from five species of secondary forest vegetation, namely: *Albizia lebeck, Trichospermum Sp., Macaranga hispida, Chromolaena odorata* and *Ficus subulata* were incorporated in a very low-P Oxisol (0,8 ppm Bray-1;pH 5.68 $CaCl_2$) and incubated for 125 days. The species of secondary forest vegetation had different quality of plant material. Different species affected significantly ($p<0.01$) the dynamic of P mineralization and immobilization in the soil. *Chromolaena* produced the highest P mineralization.

Keywords: residue quality, P mineralization, P immobilization

Introduction

The influence of chemical composition of the plant litter/material to the subsequent rate of decomposition and its influence on soil fertility has been recognized since the early stage of agriculture. Many decomposition studies involving different litter source have been conducted to find ways of predicting the rate of litter decomposition and even more importantly, the rate of nutrient release, from chemical composition of the source.

In natural ecosystem, plant residue quality leads to the decomposer community by presenting a diverse range of sources of varying decomposability. The resistance of resource to decay may be related to intrin-

sic factors such as: chemical composition, hardness, mass and particle size. Many research results have demonstrated that the chemical composition of litter such as; water soluble compounds, cellulose and hemicelluloses, N complex and lignin, lignin content, ratio of polyphenol content to N, cellulose and hemicelluloses Breland (1997) are involved in determining the rate of decomposition.

However, there are still not enough specific information about the influence of plant residue quality to the mechanisms of phosphorus mineralization and immobilization. The mechanisms of P released from amended plant residue of different species originating from secondary forest vegetation are important to understand. This understanding contribute to set up a strategy of organic matter utilization and management in the humid tropics in order to sustain the P soil availability.

A laboratory incubation experiment was conducted to identify the effect of the amendment of plant residue from secondary vegetation with different quality on the P-mineralization and immobilization in the soil.

Material and Methods

Shoot material from *Albizia lebeck, Trichospermum Sp. Macaranga hispida*, *Chromolaena odorata* and *Ficus subulata*, some of the dominant species in the secondary forest at Kendari, South-East Sulawesi Province, Indonesia were slashed and used as residue amendment. The air-dry plant residue were a mixture of about 80% of twigs and branches and 20% of leaves, except for *Chromolaena*. It was chopped and ground to pass a 2-mm-screen. The resource quality was characterized by determination of C, N, P, cellulose, hemicellulose, and lignin concentrations in the plant material.

We used a P-fixing soil (relictic Oxisol from Germany), which had very low available P. The soil had very low biological activity due to air-dry

storage for several years. Initial soil chemical properties were derived from samples which were ground to pass a 1-mm-screen (<1mm) and stored in plastic bags until chemical analysis.

The soil was pre-incubated according to Fokin and Radzhabova (1995). Moist soil (70% of water holding capacity) was filled in plastic bags and incubated at a temperature of 25 ^{o}C for 14 days to stabilize the microbial activity.

Each plant material was mixed homogeneously with the soil. The soil mixture represented 0-5 cm of soil depth. The amount of plant residue amendment is 3% (w/w) of the total experimental soil (Denich. 1989). The proportion of woody part and leaves is 80% and 20% respectively (approximation of calculated data from Denich (1989), except for *Chromolaena odorata*, the woody and leafy part are not separated. The amount of amended P for each species is depicted in Table 1.

Table 1. Amount of total P amended into the soil for each species

Species	kg P ha^{-1}	µg P g^{-1}
Ficus subulata	51.8	21.6
Albizia lebeck	41.8	17.4
Chromolaena odorata	86.4	36.0
Macaranga hispida	32.4	13.5
Trichospermum	40.3	16.8

After mixing, the 60 g of substrate was incubated aerobically in the plastics bags at 28 ^{o}C in the dark and supplemented with nutrient solution containing 30 mg N kg^{-1} and 20 mg K kg^{-1} as a basal nutrient for initial activities of soil microbes. One ml of the nutrient solution was injected into plastic bag at five locations to a depth of 1 cm. Distilled water was added as necessary to replace losses due to evaporation.

At 4, 8, 32, 72 and 125 days of incubation, microbial biomass P with fumigation-extraction method from Brookes, *et al*., (1982), labile inorganic

P ($NaHCO_3$ 0.5 M pH 8.5) were determined on three batch replicates per rate.

Results and Discussions

Quality of amended plant material

As shown on Table 2, base on the nutrient content of the amended plant materials and its chemical compositions influencing the rate of decomposition and nutrient mineralization (Tenney and Walksman, 1929), *Chromolaena* has relatively a higher quality as compared to other species, particularly *Macaranga*. *Chromolaena* has a lower C to N to P ratio and lower lignin, ADF and cellulose content than others. On the other hand, *Macaranga* has very high C to N to P ratio and high lignin content. Meanwhile, *Ficus, Albizia* and *Trichospermum* had relative moderate quality.

Table 2. Several chemical compositions of amended plant material

Species	C-total (%)	N-total (%)	P-total (%)	C/N/P (%)	C/P (%)	ADF (%)	lignin (%)	Cellulose (%)
Ficus	46.1	0.66	0.07	971	664	68.2	22.7	45.5
Albizia	47.4	1.06	0.06	771	819	73.1	19.6	53.3
Chromolaena	46.3	1.79	0.12	221	395	53.3	13.1	40.2
Macaranga	47.9	*0.55*	*0.04*	*1950*	*1073*	72.9	*22.9*	49.9
Trichospermum	46.8	0.70	0.06	1183	832	60.8	19.7	41.1

P mineralization and immobilization

Labile inorganic P (labile P_i) was used as an indicator of mineralization of organic P from plant residue to inorganic form in the soil. Labile P_i ($NaHCO_3$ extracted P) is a pool of P which is sorbed by soil minerals and available for plant. This P pool can be transformed to P inorganic solution or P labile organic pool by microorganisms, according to the modified concept of P flows during decomposition of plant residue as described by Huffman *et al* (1996). P mineralization is different value be-

tween labile P_i of amended soil and labile P_i non amended soil (control).

The mineralization of P from plant residue was affected ($P<0.01$) by the species which is reflecting the quality of amended residue. As shown in Fig 1, more labile P_i was immobilized at the beginning of incubation. The peak of P immobilization took place at 8 days. The level of P immobilization were 0.9, 1.9, 2.8, 2.9 and 3.4 µg P g^{-1} for the soil amended with plant residue from *Chromolaena, Trichospermum, Macaranga, Albizia* and *Ficus,* respectively.

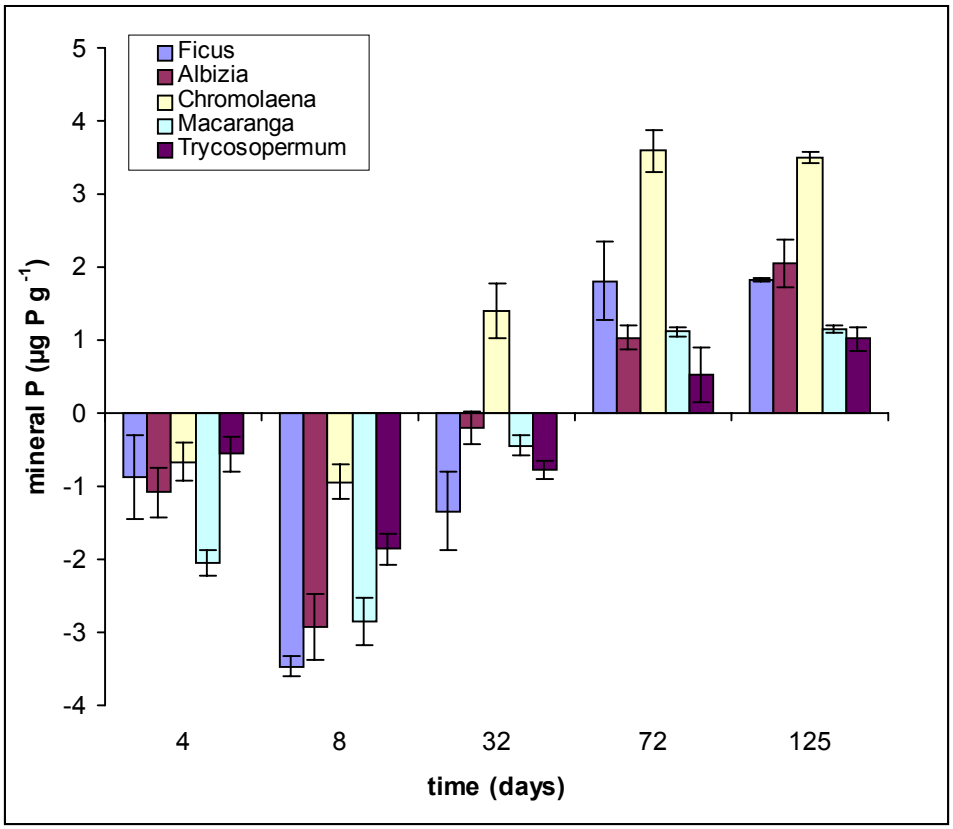

Fig. 1. P mineralization and Immobilization (P min = P_i amended – P_i control)

After 32 days phosphate remineralization increased labile P_i and the availability of P in the *Chromolaena*-amended soil. This P pool could be released from dead cells of microorganisms due to consumption by grazers (Huffman *et al*. , 1996) or competition within their own trophic level. At this incubation period the soil amended with *Chromolaena* start to indicate the mineralization of P. However, P immobilization in the soil

amended with *Trichospermum, Macaranga, Albizia* and *Ficus* was still high. Mineralization of P occurred after 72 days of incubation. The highest rate of P mineralization was found in the soil amended with *Chromolaena* followed by *Albizia, Ficus, Macaranga* and *Trichospermum*, 3.5, 2.1, 1.8, 1.1 and 1.0 µg P g^{-1}, respectively.

The significant depletion of labile P_i in the soil amended with plant residue and high immobilization rate at the beginning of incubation was due to P consumption of soil microbial to maintain their growth (Wood, 1995). Subsequent microbial biomass P increased drastically after the soil amended with plant residue (Fig 2). Amendment of plant residue could increased P concentration in the soil and change the C to N and C to P ratio in the soil. High gap between concentration of C-N and C-P lead to increase the consumption of P by soil microbes to establish their cell. As depicted in Fig. 2. microbial biomass P in the soil was a peak period at 8 days. This is correspondingly with the period when the labile P_i were the lowest.

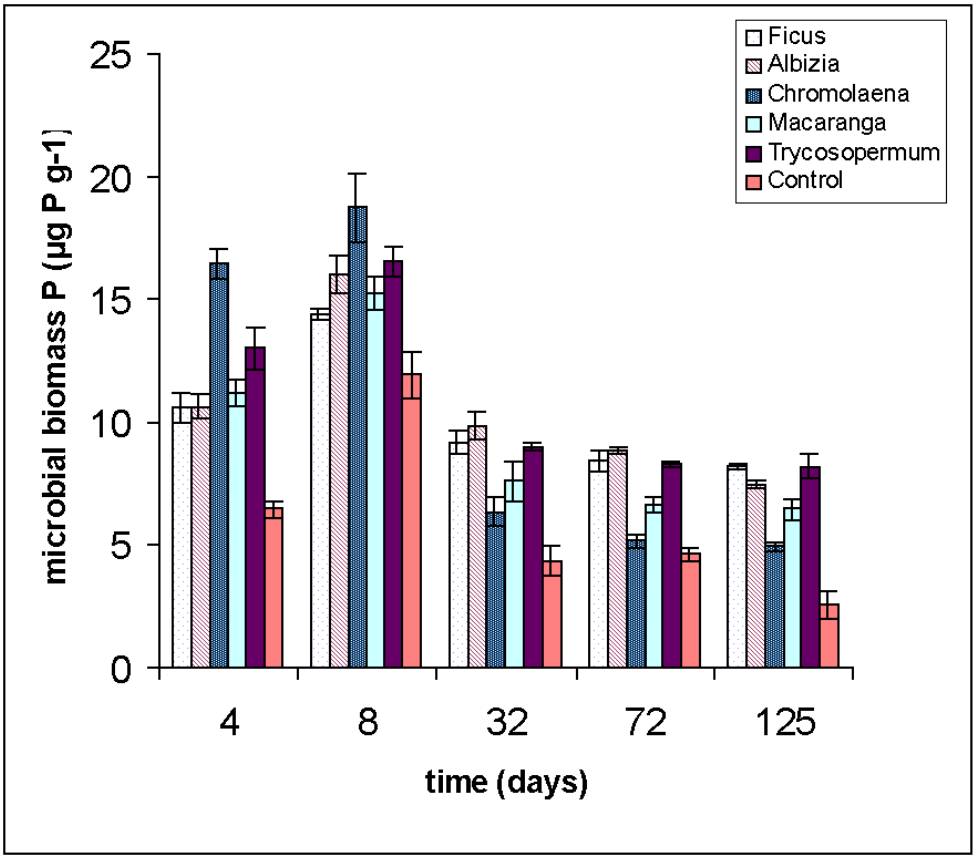

Fig. 2. Microbial biomass P

At the maximum value of microbial biomass P, the different value between amended soil and non-amended soil were 2.5 µg P g^{-1} , 4.1 µg P g^{-1} , 6.8 µg P g^{-1} , 3.3 µg P g^{-1} and 4.6 µg P g^{-1} for *Ficus, Albizia, Chromolaena, Macaranga* and *Trichospermum*, respectively.

The increase of P remineralization from the peak period of immobilized P (8 days) to 72 days and 125 days of incubation is shown in Fig. 3.

Chromolaena which contains high P and low lignin concentration showed a drastic increase of mineralized P (480 and 470% for 72 and 125 days respectively). At these incubation periods microbial activities tended to be stable.

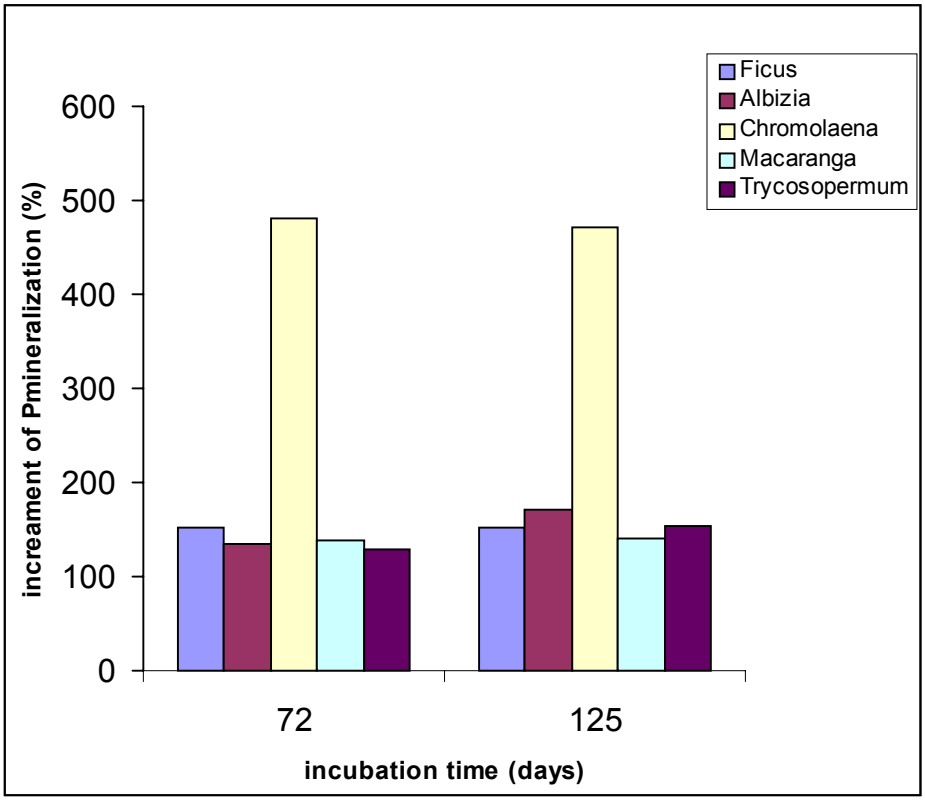

Fig. 3. P mineralization increment from 8 days to 72 and 125 days

Conclusions

According to our data, Amendment of *Chromolaena* into the soil produced the highest level of available P. Amendment of plant residue containing 36 µg Pg^{-1} required shorter time to mineralize than amendment of residue containing lower P. Extension of incubation time from 32 to 125 days could increase the P mineralization.

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