P-dynamics in slash and mulch system in south-east Sulawesi, Indonesia: Impact of different age of fallow vegetation

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Abstract

Different age of fallow regrowth, species composition, total biomass production as well as P concentration of secondary vegetation are suspected to be key factors affecting soil-P availability in the slash and mulch systems of south-east Sulawesi. To test this hypothesis an on-farm field experiment in southeast Sulawesi, Indonesia involving secondary vegetation residue originated from three and seven years old fallow was conducted
The results showed that mulch application increased significantly (P<0.05) the shoot dry weight (SDW) of maize over control by 70% (M_1) and 140% (M_2) for F3 and 27% (M_1) and 110% (M_2) for F7. Total P-uptake increased over control by about 230% (M_1) and 570% (M_2) for F3, and 52% (M_1) and 260% (M_2) for F7. The application of younger material (F3), from F3 doubled P-uptake of maize as compared to the older one (F7). Application of 3-years-old fallow vegetation increased Bray P of unplanted plots over control particularly after 5 weeks and resulted in a higher Bray P than that of older fallow. However, the 7-years-old fallow vegetation did not increase significantly (p>0.05) Bray P concentration in the soil.

Key words: microbial biomass P, available P, P uptake, fallow age

Introduction

Plant materials derive from secondary forest vegetation is an important organic matter resources in providing nutrient organic availability, particularly phosphate that is found deficient in most of humid tropical area. In natural condition availability of P in soil is depended upon the rate of organic matter mineralization and immobilization. One of the most important factor influencing P mineralization and immobilization is the quality (Sharma *et al.*, 1995; Abdullah *et al*., 2000 and Bossuyt *et al*., 2001) and the quantity (Abdullah, unpublished data) of fallow vegetation biomass
Different age of fallow is suspected to affect the availability of soil P if the plant materials of secondary vegetation are amended into soil. This is because fallow age attributes to the biomass production (Franken, 1979 and Singh, 1980), total P concentration and other nutrient stock (Denich, 1989 and La Karimuna, 2000).
A major factor influencing the release of P from plant materials is decomposability of amended plant materials. Transformation of organic material is a process of biological disintegration whereby mineralization of complex organic compounds into simple inorganic forms takes place. Decomposition of plant material from fallow vegetation in tropical forest and organic compound mineralization are the main biological process determining growth and development of vegetation (Tian, 1998).
The transformation of organic phosphate only gives a benefit to development of crops growing on the mulched or residue amended soil if there is a synchronization between P supply released from organic material and the P demand by the crops (Tian, 1998).
The function of organic P transformation from secondary vegetation residue is closely connected with the biomass production of secondary forest vegetation or the number/volume of amended residue, residue quality, decomposition rate of organic residue. These factors in

turn depend on climate conditions, species, soil nutrient status and decomposer biota (Swift *et al*., 1981; and Anderson and Swift, 1983).

Total P content of amended plant materials of fallow vegetation, which is distinguished within fallow age, may lead to induce P-dynamics in the system. To test this hypothesis a field experiment in natural condition involving secondary vegetation residue originated from 3 and 7 years old fallows was conducted to recognize the effect of amended vegetation residue from both fallow age on mineralized and immobilized P and its uptake by plant. The main objectives of the filed experiment are to identify the effect of amendment of residue from secondary forest vegetation on the dynamics of P in the soil, P-uptake and biomass production of maize.

This field experiment was a part of Ph.D.- research project, which did not involve application of mineral P.

Materials and Method

Site description

The field experiment was conducted from September to December 2000 in Buke village, Alangga region, Kendari regency, southeast Sulawesi province, Indonesia.

During field experiment, the average rainfall, relative humidity and temperature were 173 mm month^{-1}, 82% and 27.6^{o}C, respectively.

The soil was characterized by following chemical and physical properties: pH H_20 5.4; pH $CaCl_2$ 4.3; C organic 0.95 %; N total 0.08 %; P Bray-1 2.2 μg P g^{-1}; Olsen P 3.1 μg P g^{-1}; CEC 6.2 me 100g^{-1}

sand 70 %, dusk 21 % and clay 9 %.

Land and Plot Preparation

Three-years-old fallow vegetation was cleared. All of above ground biomass was slashed, but the root was retained in the soil. The plots dimension was 2 m x 2 m, and the distance among plots was 1.5 m. To test the effect of roots on soil parameters, plots without maize were included.

Mulch Preparation

The mulch used in this experiment was the fallow vegetation, which was originated from three- (F3) and seven (F7) years old of fallow. The F3 was slashed and cumulated from the land that used for the experiment, and the F7 was from neighbor site and transported to the cleared 3 years old fallow. The plant materials were then chopped with a size of 2-4cm long, mixed and put on the soil surface. The amount of slashed vegetation were equal to applied plant materials in M1 treatment: 2.4 kg plot^{-1} (leaf) and 6.4 kg plot^{-1} (wood) for F3 and 4.0 kg plot^{-1} (leaf) and 33.2 kg plot^{-1} (wood) for F7. The M2 treatment was a double amount of M2.

Mulching caused addition of total P to soil, amounting: 8 g plot^{-1} (M1) and 16 g plot^{-1} (M2) for F3 and 16 g plot^{-1} (M1) and 32 g plot^{-1} (M2) for F7.

Maize Sowing and Fertilization

The Maize cv. Hybrid CP1 was grown on 2 m x 2 m plots without soil tillage, with 50 plants per plot. Maize sowing was carried out one week after mulching. The soil was fertilized with 150 kg N ha^{-1} and 60 kg K ha^{-1}. Nitrogen was applied 14 days after sawing, while K was applied at sowing time. The fertilizers were spread in the furrow between plants.

Soil and Plant Sampling

Soil sampling (0-10cm) had been conducted before the land was cleared and at 0, 2.5, 5 and 10 week after sowing to identify the chemical and physical properties of original soil and to

evaluate soil P dynamic. The same sampling method was also carried out in the plots without plants. The soil samples were divided into two parts: one part was air dried for P analysis, and the other part was remained moist, and kept in plastics bag and stored in freezer for microbial biomass P analysis a month later. The plant sampling was taken when the plants were harvested (10 weeks after sowing). Fresh and dry weight of shoot was recorded.
Shoot dry weight, shoot uptake, soil available P and microbial biomass P were determined.

Experimental Design and Statistical Analysis
The split-plot design was used in the experiment. The main plots were two different of fallow age, which consisted of 3-years (F3) and 7-years (F7) old fallow vegetation. Within fallow age, three different levels of mulch, which composed M_0 = no mulch, M_1= is equal to the biomass production of fallow vegetation and $M_2 = 2M_1$, were set up. Each treatment combination was 3 times replicated. The same number of plots without involving plants was included. The data was analyzed with analysis of variance using SYSTAT version 5. To contrast the average among the treatments Least Significant Differences at level 5% was utilized.

Results and Discussion

Shoot dry weight
Amendment of fallow vegetation significantly ($p<0.05$) increased shoot dry weight (SDW) of maize over control (Mo) (Fig.1). The increment of SDW as a result of M_1 application was about 70% and 27% for F3 and F7, respectively as compared to Mo. Meanwhile amendment of M2 resulted in considerable increases of SDW up to 140% and 110% for F3 and F7, respectively as contrasted to control. Amendment of plant material from F3 resulted in a higher level of SDW than that of F7. This may correlate to higher decomposability of plant material of F3 than that of F7. As it was found in the field that F3 composed of succulent vegetation such as *Chromolaena odorata*, *Melastoma polyanthum* and *Lantana camara* as supported by La Karimuna (2000). According to incubation study conducted by Abdullah (2000), Chromolaena contributed to high release of available P. In such soil, which low in available P, amendment of organic P derived from plant material is suspected increase the availability of P. This was proven by increase of available P (see Bray P and $NaHCO_3$-extractable inorganic P).

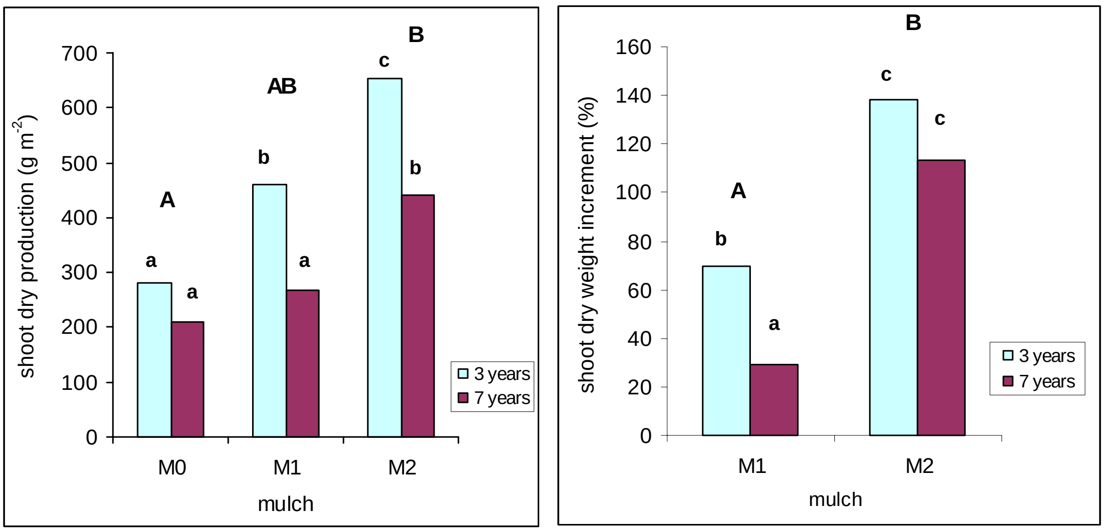

Fig. 1 Shoot dry weight of maize

Shoot P-uptake

Shoot P uptake was increased significantly ($p<0.05$) by mulching. As depicted in Fig. 2, application of M1 and M2 originating from 3 years fallow vegetation increased shoot P uptake by 150% and 320%, respectively, while amendment of M1 and M2 of F7 resulted in increases of P-uptake about 20% and 95% as compared to control. This is because the concentration of P in shoot was increased significantly by mulching of M1 and M2 of both fallow vegetation. Mulching of M1 and M2 from F3 increased P concentration in the shoot about 0.8 mg g^{-1} and 1.1 mg g^{-1}, respectively. Meanwhile mulching of M1 and M2 from F7 increased P concentration in shoot 0.6 mg g^{-1} and 0.9 mg g^{-1}, respectively.
Concentration of P in shoot was relatively higher in F3 than in F7, suggesting that amendment of F3 contributed to higher release of P than amendment of F7.

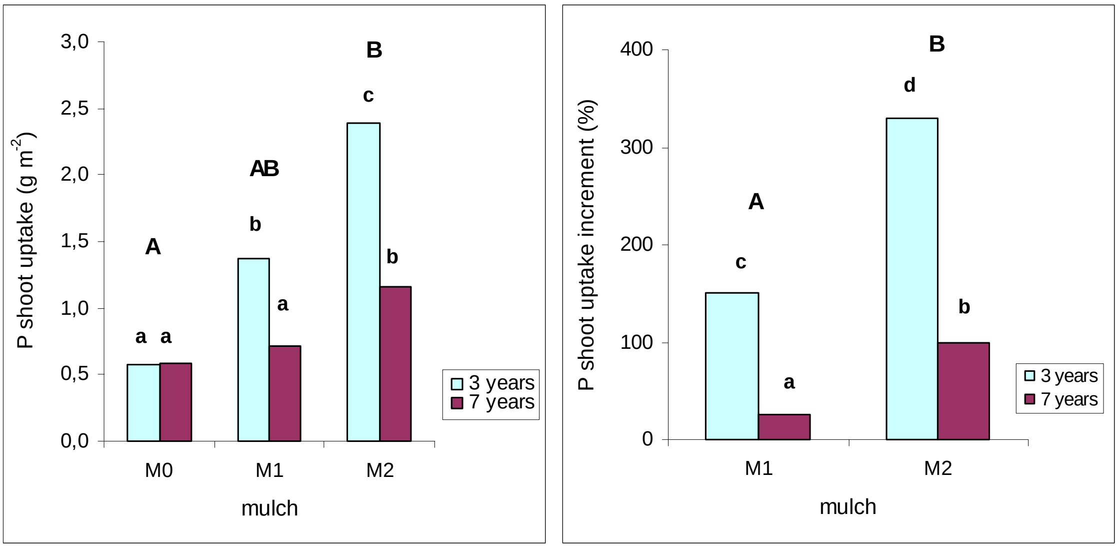

Fig. 2. Shoot P-uptake

Plant available P

In this field experiment, Bray P and $NaHCO_3$-extractable inorganic P ($NaHCO_3$-Pi) were determined to identify the availability of P for plant growth. Application of mulch influenced significantly ($p<0.05$) Bray P. As presented in Table 1 application of 3-years-old fallow vegetation resulted in higher Bray P of unplanted plots than that of control, particularly after 5 weeks. However, mulching the 7-years-old fallow vegetation on unplanted plots did not increase significantly ($p>0.05$) Bray P concentration in the soil, as compared to control. Application of M1 and M2 from both fallow vegetation did not distinguish statistically the concentration of Bray P in the soil. The existence of mulch from the younger fallow vegetation on the soil surface for 5 weeks or more resulted in higher concentration of Bray P in the soil, this did not occur in the plots mulched with the older fallow vegetation. These phenomena may be as an appropriate explanation of SDW and uptake increase by application of mulch, particularly application of 3-years-old fallow vegetation.
The presence of plant on the plots declined the concentration of P in the soil, due to P uptake by plant roots.

Table 7.7. Plant available P (µg P g^{-1})

			Bray P				NaHCO3-extractable Pi			
			Week							
			0	2.5	5	10	0	2.5	5	10
Control	Unplanted		2.7	2.8	3.5	2.3	7.9	5.9	6.8	5.7
	Planted		2.5	2.2	2.1	1.1	6.6	4.6	4.3	2.9
3 year	Unplanted	M1	1.8	4.1	6.1	5.2	6.0	7.4	8.7	7.5
		M2	2.3	3.0	8.4	6.7	6.7	7.2	12.2	11.0
	Planted	M1	1.8	2.2	1.3	1.8	5.6	5.3	3.6	4.0
		M2	2.3	2.6	1.6	1.9	5.6	5.9	4.0	4.5
7 year	Unplanted	M1	2.6	3	3.7	3.2	6.4	6.9	9.8	9.7
		M2	2.2	3.5	4.3	3.4	6.5	8.3	12.1	11.9
	Planted	M1	2.2	2.2	2.1	1.5	5.8	5.4	4.0	4.4
		M2	2.0	2.5	2.3	2.1	5.1	6.1	4.5	4.7
LSD 0.05			0.9	1.0	2.5	1.8	2.1	2.3	3.8	3.6

Application of mulch affected $NaHCO_3$-extractable inorganic P (Pi). As shown in Table 1. application of M1 did not change Pi concentration in the soil, meanwhile application of M2 from both fallow vegetation into unplanted plots increased Pi over control after 5 weeks by about 2-folds. Meanwhile Effect of fallow age and mulch quantity were not identified along experiment. There was a tendency that Pi concentration of mulched soil increased as the sampling time was delayed from 5 to 10 weeks, while Pi of control was relatively stable. This might be due to organic P mineralization from the amended fallow vegetation, which underwent decomposing after 5 weeks. Different from Bray P, Pi was relative less affected by mulching (age of fallow vegetation and mulch quantity) before 5 weeks.

Conclusions

Utilization of slashed fallow vegetation as plant material for mulching improved shoot dry weight and P uptake of maize and availability of P in the soils. Increasing the quantity of slashed fallow vegetation in mulching system tended to increase shoot dry weight, P-uptake and soil P availability. Amendment of plant material originated from 3-years-old fallow vegetation resulted in higher shoot dry weight, P uptake and soil P availability than amendment of plant material of older one.

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