Supplement

SOIL MICROBES-PLANT COMPETITION FOR P IN THE SOIL AMENDED WITH PLANT MATERIALS FROM FALLOW VEGETATION

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Abstract

The use of plant materials for sustaining soil nutrient in slash-and mulch agricultural system has been reported causing nutrient immobilization by soil microbes, which in turn leads to inhibition of crop growth. Nutrient immobilization occurs mainly at the beginning of plant materials amendment. Immobilization period is very crucial to recognize in order to set a strategy of mulching management in sustainable agricultural system.

A simulation on soil microbes-maize competition was carried out in green house experiment to answer the question whether amendment with plant materials could improve P uptake by maize or whether it would cause reduction of available P due to microbial consumption (immobilization) during growing period.

Three percent (w/w of soil) of the fallow vegetation materials (Ficus, Albizia, Chromolaena, Macaranga and Trycospermum) were mixed with the top part of pre-incubated soil in the pots (1-3 cm). This set of treatment was contrasted with control (without amendment). Seeds of maize were sown at the time of plant materials amendment. Maize growth, soil P availability, P uptake and soil microbial P were investigated during growing period.

Amendment with plant materials into the soil significantly declined the maize biomass and P uptake particularly at 4th and 6th week after sowing. Extension of growing period up to 10 week enables the recovery of P uptake by maize grown on amended soil. The reduction of P uptake was due to declining of P concentration in the plant and inorganic P in the soil solution. At the period, in which, the biomass and uptake of maize grown on the amended soil were lower than those of control, the microbial-biomass P in the amended soil was significantly higher than in the control. The presence of plant on the amended soil resulted in a reduction of microbial biomass P.

***Key words:** plant material amendment, P-uptake, microbial-biomass P, inorganic P*

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Introduction

The activity of soil microorganisms plays a major role in resulting the transformation or mineralization of soil organic phosphorus compounds into dissolved or soluble phosphorus in the soil solution (Coale, 2000). In general, the rate of organic P mineralization is more rapid in tropical soils (Tiessen *et al.*, 1983; Sharpley and Smith, 1983 and Nyami, 1991) where organic P is an important source of available P (Morris *et al.*, 1992).

Direct planting immediately after amendment with plant material might increase the transformation of available inorganic P to microbial biomass P. In the soil amended with plant material, a high concentration of soluble phosphorus in the soil solution stimulates short-term accumulation of organic P into microbial biomass P, which comprises 2-3% of the total organic carbon in soil (Morel *et al.*, 1996), by means of immobilization of phosphorus (McLachlan *et al.*, 1988). In the soil low in available P, during immobilization of P, the concentration of available P for crops may decrease and cause the plant defieient in P. Under these circumstances, it is hypothesized that, the presence of microbes due to plant material amendment might compete with the plants in utilization of released P. This indicates that microbial biomass P plays a central role in P cycling. The biomass P can be an important source of available P in the next cropping period (Hedley *et al.*, 1995).

The main objective of the experiment was to answer the question whether amendment with plant material could improve P uptake by plants or whether it would cause reduction of available P due to microbial consumption (immobilization) as identified in the incubation study.

Materials and Methods

Growth Chamber Preparation

Two weeks before the experiment, the climatic conditions of the growth chamber were established. The average temperature in the growth chamber was set to 27.6±3.8^{0}C; the minimum and maximum temperatures were 24.3±1.9^{0}C and 30.9±1.7^{0}C, respectively. The average relative humidity was 76.0±5.3%, and the minimum and maximum relative humidity values were 71.4±2.3% and 80.7±1.8%, respectively. The daily light period was set for 10 hours (07:00 to 17:00) with a light intensity of 60,000 lux.

Soil Preparation

The soil was from a research station of the Brazilian Pacajus national centre for cashew research (CNPCa/EMBRAPA) and had been stored for several years. The chemical composition of the soil is presented in Table 1. The soil was air-dried and screened by using a 5 mm sieve, and pre-incubated. The

soil moisture was brought to 80% of the total water-holding capacity. The water-holding capacity of the soil was 265±19 g water kg^{-1} air-dry soil.

Table 1. Soil chemical and physical properties

Soil properties		Soil properties	
pH H_2O	5.6	Na (me 100g^{-1})	0.14
$CaCl_2$	4.9	Al (me 100g^{-1})	0.10
C organic (%)	0.73	H (me 100g^{-1})	0.20
N total (%)	0.04		
Available P Bray-1 (μg P g^{-1})	2.3-5.1	Physical properties	
Olsen P	4.0-5.7	Sand (%)	91.5
Water soluble P (μg P g^{-1})	0.29	Silt (%)	3.0
Ca (me 100g^{-1})	0.72	Clay (%)	5.5
Mg (me 100g^{-1})	0.48		
K (me 100g^{-1})	0.08		

Soil Amendment with Plant Material

The plant materials originating from fallow vegetation, namely: *Ficus, Albizia, Chromolaena, Macaranga* and *Trycospermum* were involved in this experiment. Each pot contained 2 kg of dry soil. Three percent (60 g/pot) of the plant material was mixed with the top part of soil in the pots (1-3 cm). The soil-plant material mixture was placed on the top of the soil in the pots.

Maize Growing

Immediately after adding the plant material to the soil, four maize seeds per pot were planted at a depth of 1-2 cm. At 4 days after planting, the two smallest plants were culled and the vigorous plants were retained. At 7 days after planting, a nutrient supplement (Lange Ness, 1998) was given. During the first 4 weeks of the growing period, the pots were watered once a day in the morning by replenishment to 80% of the water holding capacity.

Plant and Soil Sampling

Plant harvesting was conducted at 2, 4, 6, and 10 weeks after planting. At each harvesting, the fresh biomass production of maize, which consisted of leaf, stem and root, was determined. The plant fractions (leaf, stem and root) were dried at 70°C for 48 h to determine the dry weight production.

Experimental Design and Statistical Analysis

Two groups of growth media, composed of soil with plant material and soil without plant material (control), were used in this experiment. Both media were divided into two groups: planted and unplanted, generating four combinations of treatments. Each treatment was replicated 4 times and sampled at each harvest period.

Results and Discussion

Biomass Production

As shown in Figure 1, in comparison to the control, adding plant material to the soil led to reduced shoot dry weight (SDW) ($p<0.05$). During the first two weeks of growth, SDW of control and amended soil showed no differences. However, after the two 2 weeks, the SDW of the amended soil was lower than that of the control. The inerease in SDW from the first week of growth to the 10th week was 9 times for the amended soil, compared to 12 times for the control. Compared to the SDW, amendment with plant material tended to increase the root dry weight (RDW) over the control. Apparently, the adding of plant material improved the physical properties of the soil (Li *et al.*, 1985 and Tate 1985).

A lower SDW in the amended soil than in the control may reflect a decline in nutrient availability due to nutrient immobilization after plant material was added. This was associated with the change of the C/N ratio after treatment and/or reduction of available P. Amendment with plant material at the beginning resulted in a C/N ratio up to 28±4 compared to the C/N ratio of the control, which was significantly lower (16±3). However, the C/N ratio of both soils tended to narrow (16 and 14 for amended and control, respectively) towards the end of the experiment.

Phosphorus Uptake

As depicted in Figure 2, the plant material resulted in a lower ($p<0.05$) P uptake at the 4th and 6th week of growth in contrast to the control. The leaf P-uptake of the control plants was deereased with extension of the growing time up to 10 weeks, but it was relatively stable after the 4th week when the soil was amended with plant material. Four to 6 weeks after sowing, stem P-uptake of amended soil was lower than that of the control.

By 10 weeks, the stem P-uptake for amended soil was the same as for the control. There was a tendency for stem P-uptake to increase with increasing

maize age. Amendment of the soil with plant material significantly ($p<0.05$) increased root P-uptake, particularly 4 weeks after sowing.

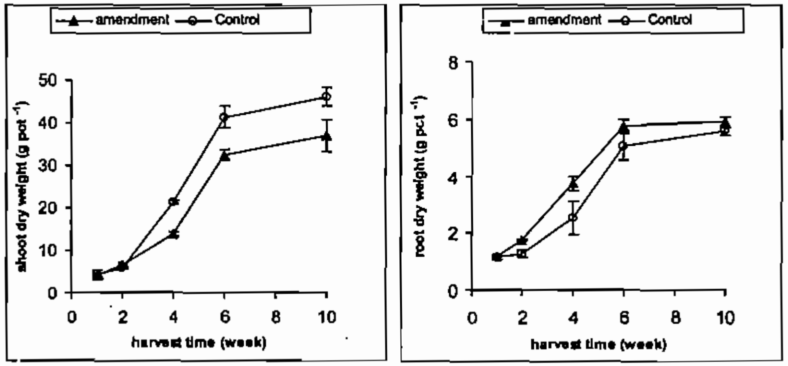

Figure 1. Effect of plant material amendment on Biomass production of maize

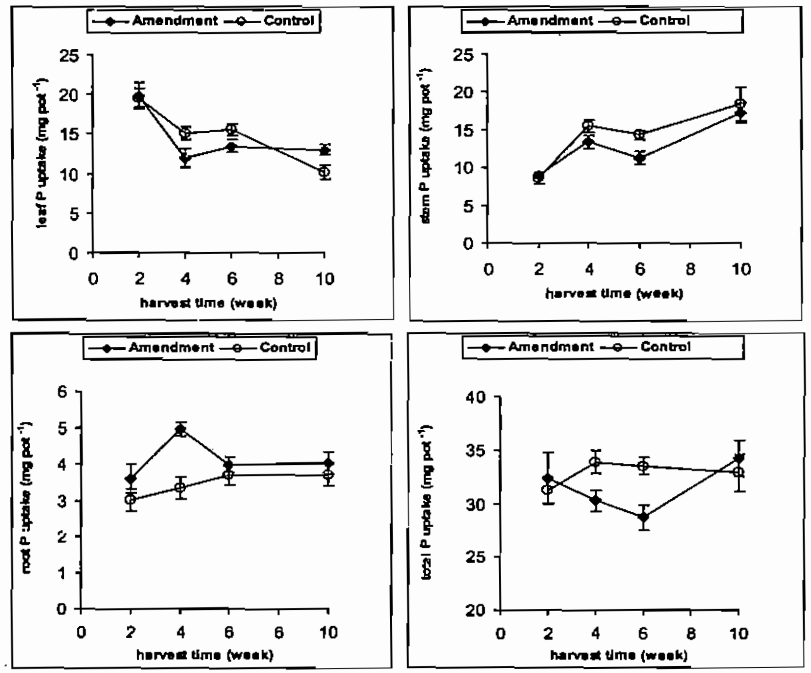

Figure 2. Effect of plant material amendment on P-uptake of maize

Total P-uptake was considerably influenced ($p<0.05$) by amendment with plant material. No differences were observed between the total P-uptake in the control or amended soil at the beginning of the growing period. However, by the 4th and 6th week, total P-uptake in plants grown on amended soil was 11% and 14% respectively lower, than that of the control, but this difference disappeared by the 10th week. This corresponded with the concentration of available P in the soil.

The reduction of the P uptake by the maize as a result of plant material amendment was determined mainly by a reduction in the biomass production of the maize, and a reduction in the P concentration of the plant fractions, except in roots as we found in this experiment. Immobilization during plant growth seemed to be a major factor inducing the lower P uptake by plants grown on amended soil. The reduction of available P in amended soil was determined by the competition between root uptake and P immobilization by soil microbes. This was indicated by the microbial biomass P value, which rose and reached a maximum level over this period.

Inorganic P Soil Solution (Sp_i)

This P form can immediately be taken up by the plant roots. Amendment with plant material increased SP_i about 25% as compared to the control at planting time due to the release of readily available inorganic P from the plant material (Figure 3). In the soil without plants, amendment with plant material resulted in a lower concentration of SP_i at week 4 and 6, but higher at week 10 than that of the control. The presence of roots in the soil significantly reduced ($p<0.05$) inorganic P of the soil solution, suggesting that P in the soil solution was taken up by plant roots. However, inorganic P of the soil solution of amended soil was not significantly different from inorganic P of the soil solution of the control.

Microbial-biomass P during Growth

Microbial biomass P of both planted and unplanted soil increased considerably when plant material was added. At the beginning of the growing period, when the plant roots had not yet developed, soil amendment with plant material increased microbial biomass P seven- to fourteen-fold as compared to the control (Figure 4). However, once the roots had developed, particularly after the 2nd week, microbial biomass P stabilized, and between 6 and 10 weeks even declined.

The reduction in microbial biomass P due to plant roots was clearly identified in the amended soil. Microbial biomass competed with the roots in utilization of inorganic P in amended soil. This was supported by a significant negative correlation between P uptake by the plant and microbial biomass P ($P_{uptake} = 54.03 - 1.44P_{mic}$; $r = 0.60$) in the soil, suggesting that P uptake by the plant reduced microbial biomass P.

Microbial-biomass P of the control in both planted and unplanted soil were not different. In the control, there was a little competition in P utilization between soil microbes and plant roots, because in the control soil there was no addition of nutrient originating from plant material, which can stimulate the activity of soil microbes.

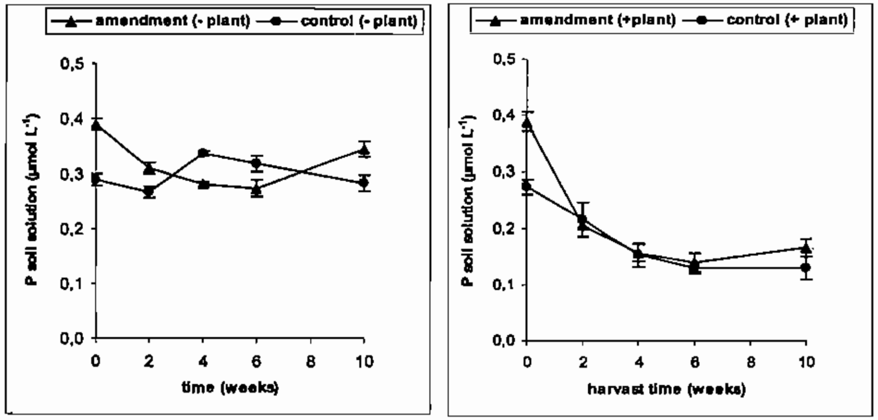

Figure 3. Effect of plant material amendment on plant P available

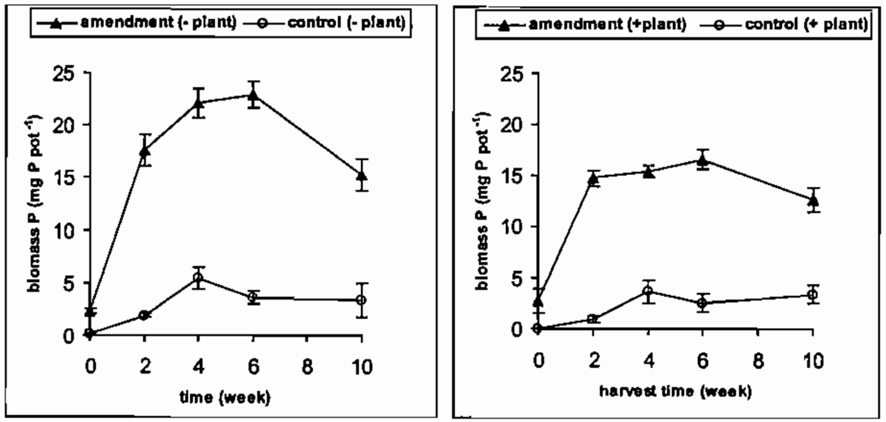

Figure 4. Effect of plant material amendment on P-microbial biomass

Conclusion

According to the results of the experiment in growth chamber, it is clearly observed that planting maize immediately after amendment (incorporation) of poor quality plant material in large quantities caused high immobilization of P in the beginning of the growing period, which, as a consequence, led to a reduced biomass production and total P uptake. Later in the season, remineralization of P occurred and increased the availability of P. In this study a significant negative correlation between soil microbial biomass P and P uptake by roots was observed, suggesting that the presence of root in the system compete soil microbes for P.

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