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Full Length Research Paper

Green manure from prunings and mineral fertilizer affect phosphorus adsorption and uptake by maize crop in a gliricidia-maize intercropping

D. E. Mweta[1], F. K. Akinnifesi[2*], J. D. K. Saka[1], W. Makumba[2] and N. Chokotho[1]

[1]University of Malawi, Chancellor College, P. O. Box 280, Zomba, Malawi.

[2]World Agroforestry Centre (Malawi), Chitedze Agricultural Research station, P.O. Box 30798, Lilongwe 3, Malawi.

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Gliricidia sepium-maize intercropping has shown to be a suitable option for soil nutrients replenish-ment and for sustainable crop production in Southern Malawi. This study was carried out to understand the effect of green manure on phosphorus sorption and subsequent crop uptake under gliricidia (*G. sepium*)-maize intercropping. The experiment consisted of a factorial combination of two cropping practices (maize with and without gliricidia), three rates of inorganic N fertilizer (0, 46 and 92 kg N/ha), and inorganic phosphorous (P) fertilizer (0, 20 and 40 kg P_2O_5 ha^{-1}) combined. Application of gliricidia prunings and inorganic P fertilizers reduced the P sorption capacity of the soil and maize P uptake. Langmuir P affinity constant and the Freundlich P adsorption constant were significantly reduced with application of gliricidia prunings and inorganic P fertiliser. Combination of gliricidia prunings and inorganic P fertiliser further reduced the P sorption capacity of the soils compared to gliricidia prunings alone. The results indicate that addition of gliricidia prunings increases P availability through reduced P sorption capacity of the soil and recycling of P. combination of gliricidia prunings and inorganic P fertiliser has an added benefit compared to application of either gliricidia prunings or inorganic P fertiliser alone.

Key words: Agroforestry, organic and inorganic fertilizers, P sorption, P uptake.

INTRODUCTION

Soil fertility depletion is the major cause of declining food security in smallholder farms of sub-Saharan Africa and phosphorus (P) is among the nutrients that severely limit crop production (Sanchez et al., 1997) . An average of 660 kg N ha^{-1}, 75kg P ha^{-1} and 450 kg K ha^{-1} are reported lost during the last 30 years from about 200 million hec-tare of land in 37 African countries (Sanchez et al., 1997). In Malawi, P has been reported as the second most limiting nutrient to crop production after nitrogen (Saka et al., 1995; Makumba, 1997) . P deficiency could be over-come by the use of soluble inorganic fertilisers (Mathews et al., 1992; Sanchez et al., 1997). However, correcting soil nutrient deficiency with large applications of inorganic fertiliser is not a viable option for most resource-poor smallholder farmers due to exorbitant resource-poor smallholder farmers due to exorbitant prices on the mar-kets after the removal of subsidies (Carr, 1997). Hence, there is a need for alternative low cost technologies to replenish soil nutrients.

Since early the 1990s, gliricidia (*Gliricidia sepium* (Jacq.) Walp)-maize intercropping has been promoted as an appropriate agroforestry practice in Malawi for soil nutrients replenishment (Akinnifesi et al., 2006, 2007). The fast growth, ability to fix nitrogen, high nitrogen con-tent in the leaves and high biomass production per hec-tare make gliricidia an ideal agroforestry tree for the N-deficient soils of southern Malawi. The maize and gliri-cidia trees are grown concurrently. Regular pruning of the trees at the height of 30 cm above the ground during the maize growing season reduces aboveground competition between trees and crops. When pruned, gliricidia cop-pices profusely, produced leafy biomass up to 6 ton ha^{-1} (Akinnifesi et al., 2006). The prunings are incorporated in the soil as green manure (Makumba et al., 2001). Despite high labour demand, green manuring with gliricidia prun-

*Corresponding author. E-mail: fakinnifesi@africa-online.net, Tel.: +265.1.707.328, Fax: +265.1.707.323.

ings have increased maize production (Akinnifesi et al., 2006, 2007; Makumba et al., 2001; Rao and Mathuva, 2000).

The success in using leguminous trees such as gliricidia has been attributed to increased nitrogen supply to plants and improvement of soil chemical and physical parameter in long- term applications (Ikerra et al., 1999). However, addition of green manure can also improve P availability to plants (Yashpal et al., 1993; Haggar et al., 1991). Addition of organic materials may influence nutrient availability through the total nutrients added. Application of organic material alone cannot meet phosphorus requirements due to low P concentration in most organic materials and, therefore, must be supplemented with inorganic P in areas where soil P is deficient (Palm et al., 1997). Most of the phosphorus added to the soil as fertiliser is rapidly bound by soil minerals in chemical forms that are not subject to rapid release. Soluble phosphorus reacts with iron (Fe), and aluminium (Al) to form insoluble Fe and Al phosphates in acid soils and with calcium (Ca) to form insoluble Ca phosphates in alkaline soils (Mullins, 2001). The addition of organic manures can increase P availability by reducing the P sorption capacity of the soils thereby allowing a more complete utilization of soil P by plants (Nziguheba et al., 1998). However, scientific information is scarce on the effect of adding gliricidia prunings on the P sorption capacity of the soil.

The objectives of this study were to determine the effect of (1) gliricidia prunings and inorganic fertiliser on phosphorus sorption in the soil in gliricidia-maize intercropping and (2) effect of gliricidia pruning on P uptake by the maize crop.

MATERIALS AND METHODS

Description of study site

This study was conducted at Makoka Agricultural Research Station (15° 30' S; 35° 15'E). The climate is characteristic of long dry season from April to October followed by short wet season from November to March. The total annual rainfall ranges from 540 to 1602 mm and mean daily temperature varies from 16 to 24 °C with daily maximum range of 21 - 34°C, and a minimum of 10 - 19°C (Akinnifesi et al., 2006). The annual total rainfall for the season (2003/2004) was 625 mm.

Soils at the site have been classified as Ferric Lixisols (FAO/ UNESCO). The top soils are sandy loam with pH (H_2O) ranging from 5.9 to 6.5; CEC of 6.2 to 10 c mol/kg and 30 mg/kg P (Olsen).

Experimental design and management

The treatments were maize with or without intercropping with gliricidia and three rates of N and P fertilizers. The treatments were Laid out in a randomized complete block design with three replicates. The N fertilizer rate was applied at 0, 46 and 92 kg N ha^{-1}, applied at 4 weeks after planting. Inorganic fertilizer rates of 0, 46 and 92 kg N ha^{-1}, corresponding to zero (unfertilized), half (50%) and full (50%) of national fertilizer rates were applied from Calcium Ammonium Nitrate (CAN) fertilizer at four weeks after planting. The recommended N rate for southern Malawi is 96 kg N ha^{-1} by side dressing. Fertilizer was applied to the maize crop only. Initially, three levels of inorganic phosphorus were applied early in the trial (0, 20 and 40 kg P ha^{-1}, corresponding to fertilizer rates of 0, 50 and 100% of the recommended P dose). These P treatments were dis-continued in 1993/94 as phosphorus continued to have no effect on maize yield (Ikerra et al., 1999). Potassium (K) was not applied because it is not a problem in Malawi soils and the initial soil analysis showed high K levels at the site (Akinnifesi et al., 2006). The national fertilizer recommendation did not include K, so farmers generally do not apply it.

The Guatemala provenance of *G. sepium* (ex Retalhaleu, OFI seed No. 60/87) was used in view of its superior growth in Malawi and elsewhere in Southern Africa (Ngulube, 1994). The trees were established from seedling stock in December 1991 as pure stands. Gliricidia plots consisted of four rows of trees planted in every other furrow at 90 cm within tree rows and 150 cm between tree rows (7400 trees ha^{-1}s) . In order to minimize tree root encroachment into adjacent plots or outside the experimental area, iron sheets were vertically installed to 1-m depth around plots. The plot size was 6.75 x 5.1 m, separated by 1-m wide path.

The gliricidia trees were cut back in September 1992 to the height of 30 cm. In December 1992, the coppice re-growth was harvested, incorporated into soil and maize planted in the same month. Coppice biomass was harvested again in February 1993, and left to grow until September 1993 when biomass was harvested again. The re-growth was pruned three times during each cropping season. However, because of the erratic rainfall patterns, the pruning regime was varied from 1997/98 to 2001/02, depending on the rain onset and also an additional pruning was included as follows: pruning in late October to early November (1st pruning), late December to early January (2nd), late February (3rd), and late August to early September (4th). This fourth pruning was necessary to encourage more leaf growth and reduce wood biomass. The leaves and small green shoots (twigs) were incorporated while fresh in the soil same day they were pruned and separated. Prunings were incorporated by splitting the ridges open, placing the biomass, burying the prunings to the depth of about 15 cm and reconstituting the ridges. The influence of the time of pruning application on N-uptake and maize yield has been reported elsewhere (Makumba et al., 2005).

Maize hybrid NSCM 41 was planted on ridges at a spacing of 30 cm within rows and 75 cm between rows (44,000 plants ha^{-1}), in both the sole maize as well as intercropping. The maize was planted at least two weeks after incorporation of the October prunings. Two weeks after emergence, the maize seedlings were thinned to one plant per hole, and maize plant population was maintained at 44,000 plants ha^{-1} in all the plots. Maize was weeded twice by hand during the cropping season typical of the traditional farming practice.

Soil sampling and analysis

Soil samples were collected from 0 - 20 cm soil depth of all plots before the first incorporation of biomass. Using an Eldelman auger, five sub samples were collected from each plot. The soil sub samples were mixed thoroughly to obtain a composite sample. Using quartering procedure, a soil sample of about 500 g was taken for laboratory analysis. The soil samples were air-dried and sieved to pass through a 2 mm-sieve. Soil P was determined by Olsen method (Olsen and Somers, 1982).

Determination of P sorption capacity

A 30 ml $CaCl_2$ solution containing phosphorus as potassium dihydrogen phosphate at concentrations of 0, 10, 20, 30, 40 and 50 mg P/L were added to 3.0 g soil in 50 ml extraction bottles. Two drops of toluene were added to retard microbial growth and the bottles were shaken twice a day for 6 days at 150 excursions per minute.

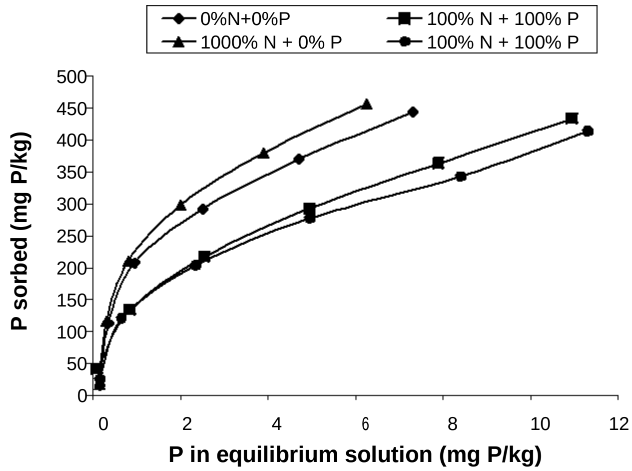

Figure 1. Phosphorus sorption isotherms of some soil samples collected from Gliricidia/maize mixed cropping.

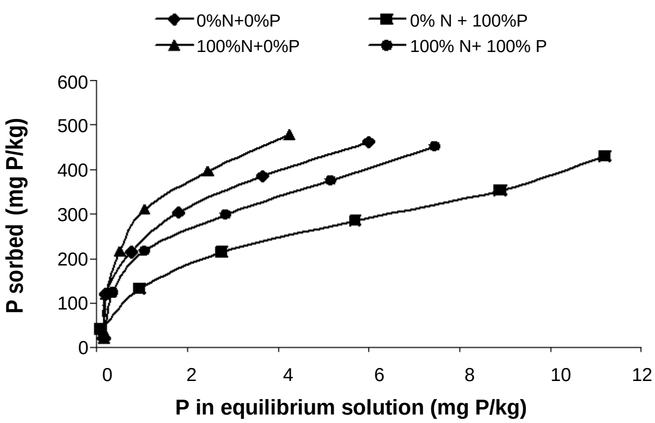

Figure 2. Phosphorus sorption isotherms of some soil samples collected from sole maize cropping

On day 6, the samples were filtered through Whatman No. 1 filter paper and the filtrate was saved for phosphorus analysis (Fox and Kamprath, 1970). Phosphorus in the filtrates was analysed colorimetrically by molybdate-ascorbic acid method (Murphy and Riley, 1962). The amount of P sorbed was calculated as the difference between the amount of P added and that remaining in solution. The adsorption data were plotted according to the Langmuir and Freundlich adsorption equation. The Langmuir equation is given as follows:

$$\frac{c}{q} = \frac{1}{kb} + \frac{c}{b}$$

Where, q is amount of P adsorbed in weight per unit weight of adsorbent, k is constant related to binding strength (affinity constant), c is equilibrium, P concentration in grams per unit volume, and b is maximum amount of adsorbate that can be adsorbed. Thus the plot of c/q against c will give a straight line and hence k (1/intercept) and b (1/gradient) can be obtained. The amount of P retained to obtain 0.2 mg P/L in solution was calculated from the fitted line. Traditionally sorption at a P concentration of 0.2 mg P L^{-1} has been proposed as a standard for the P requirement of different soils (Fox and Kamprath, 1970).

The Freundlich equation is given as:

$$\log q = n \log c + \log k$$

Where, q is amount of P adsorbed (mg P kg^{-1} soil), c is equilibrium, P is concentration in soil solution (mg P L^{-1}), n and k are constants for each adsorption isotherm. A plot of log q against log c will give a straight line from where the value of the constants n (gradient) and log k (intercept) can be obtained.

Plant analysis

The long term maize yield and gliricidia biomass yield have been published elsewhere (Akinnifesi et al., 2006). Only the maize yield harvested in mid-June 2004 is reported in this paper. Maize yield was measured from the net plot of size 6.0 m x 4.1 m. Maize stover was harvested by cutting all the stover at the base just above the soil surface in the net plot. A sample of stover was taken and dried in an oven at 70°C for 48 h to determine dry matter content and was used to correct the weight of dry-matter yield of stover. The maize cobs were weighed before shelling and the grain yield was weighed after shelling and weight recorded. Samples of grain was collected and dried in an oven at 70°C for 48 h and dry matter con-tent was determined. The dried plant materials (stover and grain) were finely ground and analysed for total P and N after H_2SO_4/H_2O_2 digestion. N and P present in grain and stover was calculated as the product of its dry-matter yield and P content. Total N and P uptake reported is the sum of the amounts present in the stover and grain.

Data analysis

Analysis of variance was carried out using Genstat (Genstat for Windows, 1999) to test the effects of different treatments on dry matter yield, grain yield, total N and P uptake, and P sorption parameters. Effects were judged to be significant at the 5% probability level.

RESULTS AND DISCUSSIONS

The soil chemical properties under sole maize and gliricidia/maize intercropping after 12 years of continuous cropping in Makoka had been reported by Akinnifesi et al. (2006; 2007). It showed that continuous application of gliricidia prunings increased the soil pH, soil organic matter, and exchangeable cations [not presented in this study].

P sorption capacity

The isotherms of some soil samples from sole cropping and gliricidia/maize intercropping are shown in Figures 1 and 2. The adsorption data conformed to both Langmuir and Freundlich isotherm equations. Good fit of Langmuir and Freundlich equations to P sorption data have been reported by several researchers (Dubus and Becker, 2001; Polyzopoulos et al., 1985). Coefficient of determination (R^2) values of greater than 0.95 were obtained for both the Langmuir and Freundlich plots. The higher R^2

values for Freundlich plots suggest that this model described the P sorption isotherms in the soil samples under study better than the Langmuir model. Superiority of Freundlich model over Langmuir's has also been reported (Fitter and Sutton, 1975).

The Langmuir isotherm is based on the theoretical principle that only a single adsorption layer exists on the adsorbent and therefore, does not adequately describe P sorption on soil surfaces as heterogeneous as the soil colloids (Polyzopoulos et al., 1985). Freundlich isotherm assumes exponential decrease of bonding energy with coverage, which is considered as more realistic assumption.

The sorption parameters from Freundlich equation and P sorbed at soil solution concentration of 0.2 mg P L^{-1} calculated from Langmuir equation determined at planting are presented in Table 1. Addition of gliricidia prunings did not have significant effect ($P > 0.05$) on P sorption maximum capacity of the soils. Based on absolute values, P sorption maximum was higher in sole maize plots than in gliricidia-maize plots. Maximum adsorption value (b) of 512.3 P/kg obtained in sole maize plots was similar to the 510.7mg P/kg in gliricidia-maize plots. Both inorganic N and P fertilisation did not have any significant effect ($P > 0.05$) on the P sorption maximum capacity of the soils. The Langmuir affinity (binding energy) constant (k) significantly ($P < 0.001$) decreased from 0.911 L/mg P to 0.637 L/mg P with addition of gliricidia prunings and from 1.237 L/mg P to 0.485 L/mg with inorganic P addition. Addition of inorganic N significantly increased the P affinity constant with increasing rate of inorganic N application. The amount of P sorbed by the soil samples at 0.2 mg P L^{-1} in solution (standard P requirement) ranged from 39.8 to 166.8 mg P/kg (Table 1). The standard P requirement significantly decreased ($P < 0.001$) following addition of gliricidia prunings and inorganic P application but significantly increased with increasing rate of inorganic N application.

The Freundlich phosphate adsorption coefficient (k) value is regarded as a hypothetical index of phosphorus sorbed from a solution having a unit equilibrium concentration (Sanyal and De Datta, 1991). The phosphate adsorption constant values significantly decreased ($P < 0.001$) from 201.8 to 177.5 mg P/kg and from 1.23 to 0.51 mg P/kg following addition of gliricidia prunings and inorganic P significantly respectively while increasing ($p < 0.001$) with inorganic N addition.

Significant decrease of the P affinity constant, adsorption constant and standard P requirement with addition of gliricidia prunings and inorganic P fertilisers indicates that P was loosely bound in soils where gliricidia prunings and inorganic P were applied suggesting increasing P availability. Gliricidia prunings and inorganic P application significantly reduced P sorption capacity of the soil. These findings are in conformity with high P uptake values following application of gliricidia prunings and inorganic P presented in Table 2. Competition with phosphate anion for adsorption sites by organic anions produced from the decomposition of plant materials and saturation of adsorption sites by P added to the soil have been proposed as responsible for the decrease in P adsorption capacity (Iyamuremye and Dick, 1996; Nziguheba et al., 1998; Mullins, 1991). Lopez-Hernandez (1986) reported reduced P sorption by soils in the presence of organic oxyanions, oxalate and malate. Nziguheba et al. (1998) reported that application of *Tithonia diversifolia* reduced the P sorption in the soil and suggested that competition for adsorption sites between organic anions and phosphate ions as the possible explanation. The decrease in P sorption capacity of the soils following addition of gliricidia prunings could possibly be explained by this mechanism. The effect of the added inorganic P could possibly be explained by the second mechanism; saturation of adsorption sites by the added P. Mullins (1991) reported a decrease in P sorption of the soils with P fertilisation and attributed this to saturation of P sorption sites with inorganic P addition.

Significant increase of P affinity constant, adsorption constant and standard P requirement with addition of N fertilisers suggest increased P sorption in the soil. Changes in pH could probably explain significant increase in P sorption following addition of inorganic N. A decrease in P sorption with increasing pH has been reported and this has been attributed to increased charge repulsion between P ions and surface negative charges, to increased concentration of hydroxyl ions (OH^-), leading to competition with P ions for adsorption sites (Eze and Loganathan, 1990). Significant decrease in pH with N fertilisation was observed in this trial. Therefore, it would be expected that P sorption would increase with increasing rate of inorganic N application.

Maize grain and total aboveground maize biomass yield

Gliricidia prunings and inorganic N and P significantly ($P < 0.001$) increased maize grain and total biomass yield as compared to the control. Maize grain yields of 4.9 ton ha^{-1} and 2.4 ton ha^{-1} and biomass yields of 9.8 ton ha^{-1} and 4.4 ton ha^{-1} were obtained in gliricidia-maize intercropping and sole maize cropping respectively (Table 2) representing an increase of over 100%. Both grain and biomass yields responded significantly ($P < 0.001$) to inorganic N and P application; grain and biomass yields continued to increase with increasing rates of inorganic N and P. These results are consistent with findings of Makumba et al. (2001) and Rao and Mathuva (2000), who reported 68 and 27% higher maize yields with application of gliricidia prunings over the control. Larbi et al. (1993) reported an increase of 89% in maize yields following applications of gliricidia prunings. A significant interaction ($P < 0.01$) between production system and N rate was observed with higher yield obtained following addition of gliricidia prunings with highest inorganic N rate

Table 1. Mean values of Langmuir maximum adsorption capacity (b), binding energy constants (k), and phosphate adsorption constants (k) as estimated by Langmuir and Freundlich isotherm plots at planting.

Production system	N rate (kg ha^{-1})	P rate (kg ha^{-1})	Langmuir				Freundlich	
			b (mg P/kg	K (L/mg P)	P sorbed at 0.2 mg/L	r^2	K (mg P/kg)	r^2
Sole maize	0	0	518.6	0.69	61.4	0.97	189.6	0.99
	0	20	517.6	0.51	51.2	0.96	163.1	0.98
	0	40	530.7	0.53	46.3	0.97	155.9	0.99
	46	0	501.3	2.49	166.8	0.98	311.1	0.99
	46	20	509.9	0.68	60.3	0.97	186.1	1.00
	46	40	513.8	0.59	51.8	0.96	170.1	1.00
	92	0	488.5	1.68	130.0	0.98	283.2	0.98
	92	20	509.9	0.62	55.9	0.97	180.6	0.98
	92	40	520.8	0.60	54.5	0.97	195.1	1.00
Mean			**512.3**	**0.93**	**75.3**		**203.9**	
Gliricidia-maize	0	0	506.5	0.87	74.6	0.99	207.6	0.97
	0	20	513.0	0.54	49.7	0.99	182.9	0.99
	0	40	535.4	0.40	40.0	0.95	150.6	0.98
	46	0	496.9	0.95	81.2	0.97	220.5	0.99
	46	20	509.2	0.63	56.5	0.98	182.2	0.99
	46	40	506.0	0.52	47.0	0.96	162.7	0.99
	92	0	518.1	0.72	64.6	0.99	194.4	0.98
	92	20	528.3	0.63	59.8	0.97	189.0	0.99
	92	40	482.6	0.44	39.8	0.98	124.4	0.99
Mean			**510.7**	**0.63**	**57.0**		**179.5**	
LSD $_{(0.05)}$								
AF			15.32	0.095	7.18		10.02	
N			18.76	0.116	8.80		12.27	
P			18.76	0.116	8.80		12.27	
AF*N			26.54	0.164	12.44		17.35	
AF*P			26.54	0.164	12.44		17.35	
N*P			32.50	0.200	15.24		21.25	
AF*N*P			45.96	0.284	21.55		30.06	
CV(%)			5.4	21.7	19.4		9.3	

(92 kg N ha^{-1}). This suggests that integration of gliricidia prunings and inorganic sources of nutrients had an added benefit.

P and N uptake by maize

Addition of gliricidia prunings significantly increased (*P* < 0.001) total N uptake by maize crop. N uptake was 121.6 kg ha^{-1} following application of gliricidia prunings compared to 47.5 kg ha^{-1} in sole cropping (Table 2). N uptake significantly increased (*P* <0.001) with inorganic N and P application. The increased biomass yield, N and P uptake with addition of gliricidia prunings and inorganic fertilisers can be interpreted as a response to greater N and P availability in the soil. This is consistent with observations of Makumba (2003) that due to higher crop yields in gliricidia-maize intercropping, nutrient depletion is also likely to be higher. Therefore, in the long run external nutrient inputs will be required to sustain the systems. The P uptake for the highest inorganic P rate was 7.87 kg ha^{-1} while total P uptake for the mixed intercropping with no application of inorganic P was 13.06 kg ha^{-1}. Thus in the absence of inorganic P fertilisers, gliricidia-maize intercropping was better in increasing phosphorus uptake by maize.

Addition of gliricidia prunings significantly increased (*P* < 0.001) total P uptake as compared to the sole maize control. On average, total P uptake was 14.6 kg ha^{-1} in gliricidia -maize intercropping and 6.6 kg ha^{-1} in sole maize (Table 3). These observations suggest that addition of gliricidia prunings increased P availability to the plants although there is no P increase in the soil. Our results concur with those reported by Yash et al. (1993) and Haggar et al. (1991). P uptake significantly increased (P < 0.05) with inorganic P fertilisation indicating increased P availability and confirming the important role of inorganic fertilisers in overcoming P deficiency (Mathews et al., 1992; Sanchez et al., 1997). The higher P uptake

Table 2. Maize grain yield, total maize aboveground biomass yield (grain + stover), and N uptake in sole maize and Gliricidia simultaneous intercropping in 2004 at Makoka.

Production system	N rate (kg ha^{-1})	P rate (kg ha^{-1})	Maize grain yield (t ha^{-1})	Biomass yield (t ha^{-1})	N uptake (kg ha^{-1})
Sole maize	0	0	1.06	2.47	25.4
	0	20	1.24	2.83	24.7
	0	40	1.34	3.14	27.1
	46	0	2.85	4.99	46.6
	46	20	3.10	5.67	53.6
	46	40	3.63	6.51	67.7
	92	0	1.89	3.31	42.4
	92	20	2.77	5.11	62.1
	92	40	3.46	5.98	78.2
Mean			**2.37**	**4.44**	**47.5**
Gliricidia-maize	0	0	4.42	8.57	121.0
	0	20	4.57	9.46	89.0
	0	40	5.02	11.11	110.1
	46	0	4.33	7.30	98.3
	46	20	4.61	8.99	119.8
	46	40	5.89	10.90	140.7
	92	0	4.95	9.91	133.8
	92	20	5.12	10.31	140.9
	92	40	5.64	11.19	140.8
Mean			**4.95**	**9.75**	**121.6**
LSD $_{(0.05)}$					
AF			0.15	.0.36	4.97
N			0.19	0.44	6.09
P			0.19	0.44	6.09
AF*N			0.27	0.62	8.61
AF*P			0.27	0.62	8.61
N*P			0.33	0.76	10.54
AF*N*P			0.46	1.08	14.91
CV(%)			6.0	7.2	10.5

in the plots that received gliricidia prunings is attributed to P-recycling by trees. On average, the P uptake for the highest inorganic P rate (40 kg P ha^{-1}) in sole maize was 7.9 kg ha^{-1} while total P uptake for the mixed intercropping without addition of inorganic P was 13.1 kg ha^{-1}. This probably suggests the effect of the organic matter in the solubilization of soil P.

Conclusions

Application of gliricidia prunings either alone or in combination with inorganic fertilisers significantly increased maize grain yield, total biomass yield and total P uptake by maize plants. This increase was due to the decrease in the P sorption capacity of the soil with application of gliricidia prunings and all levels of added inorganic P. Application of gliricidia prunings and inorganic P fertilisers decreased the P affinity constant, P requirement and P adsorption constant. These results indicate that soil P availability can be enhanced through application of gliricidia prunings and inorganic P fertilisers. It is concluded that integration of gliricidia prunings and inorganic P fertiliser reduces P sorption capacity at all levels of added P. This indicates added benefits from the integration of integration of gliricidia prunings and inorganic fertilisers. We therefore recommend application of gliricidia prunings in combination with inorganic fertilisers to enhance availability of soil P for more utilization by the maize plants.

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Table 3. Total P uptake (kg ha^{-1}) by maize in sole maize and gliricidia-maize simultaneous intercropping at Makoka in 2004

Production system	N fertilizer rate (kg ha^{-1})	P-fertilizer rate (kg ha^{-1})	Mean		
Sole maize		**0**	**20**	**40**	
0		4.55	4.05	5.03	4.52
46		7.22	9.00	9.14	8.45
92		4.89	6.40	9.44	6.91
Mean		**5.53**	**6.48**	**7.87**	**6.63**
Gliricidia-maize	0	14.54	13.81	19.16	15.84
	46	10.39	14.07	14.80	13.07
	92	14.25	14.53	15.58	14.79
Mean		**13.06**	**14.14**	**16.51**	**14.57**
LSD$_{(0.05)}$					
AF			0.37		
N			0.46		
AF*N			0.46		
AF*P			0.65		
N*P			0.65		
AF*N*P			0.79		
CV(%)			1.12		

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