7H8

Prasannakumari, P.

15635

28

Phosphorus Mobilization by Leguminous Cover Crops Grown in Rubber Plantations

P. Prasannakumari, M.D. Jessy, Annie Philip, A.N.S. Nair and N. Usha Nair

INTRODUCTION

Phosphorus deficiency is a major factor limiting crop production in tropical and sub-tropical regions. The peculiar mineralogy of tropical soils with high sesquioxide content favour strong retention of phosphate ions limiting phosphorus availability to crop plants (Kamh *et al.*, 1999; Horst *et al.*, 2001). Widespread deficiency of available phosphorus in soils in the traditional rubber growing areas was reported by George (1961). A survey of the rubber growing tracts of Kerala and Kanyakumari district of Tamil Nadu indicated that 75 % of the area have low soil available P status (NBSS and LUP,1999).

Nitrogen fixing legumes which have a net positive excess of cations over anions entering their roots will acidify the rhizosphere by releasing H+ ions to maintain the cation - anion balance. This nitrogen fixation related rhizosphere acidification is reported to enhance the availability of P from rock phosphate (Hinsinger, 1998). Leguminous cover crops are also reported to possess a remarkable capacity to mobilize soil P through root exudates which can directly shift the equilibrium between soil P fractions towards plant available fractions, which could be beneficial to the less P efficient crops grown in association (Jungk *et al.*, 1993; Kamh *et al.*, 1999; Hinsinger,2001; Horst *et al.*,2001). If P efficiency of the crop is due to mobilization of P from the usually less available soil P fractions, then depletion of readily available soil P might be reduced (Hinsinger,2001). Adams and Pate (1992) suggested that root exudation should also increase the solubility of organic P compounds such as phytins and thereby the pool of plant available P.

Leguminous cover crops are established and maintained in rubber plantations for the purpose of conserving soil, improving or maintaining the soil structure, fertility, water holding capacity and other soil physical properties (Soong and Yap, 1976). The most widely grown cover crops in rubber plantations are *Pueraria phaseoloides* and *Mucuna bracteata*. Besides contributing much to the nitrogen requirement through symbiotic nitrogen fixation, cover crops helps in better growth during immature phase and higher yield during mature phase (Watson *et al.*, 1964; Yogaratnam *et al.*, 1984).

The P mobilization efficiency of *Pueraria phaseoloides* and *Mucuna bracteata*, the two commonly cultivated legumes in rubber plantations was studied at the Rubber Research Institute of India, Kottayam, Kerala.

Profuse weed growth was observed in the beds with natural cover and the predominant weeds were *Borreria*, *Chromolaena*, *Corchorus*, *Clerodendron* etc.

Organic carbon showed an increase from the initial value of 1.8% in all the treatments, but there was no significant difference among the three ground covers (Table 28.1). Available P and available K status was significantly higher in the plots where legume cover crops were established. Between cover crops, soil under *Pueraria* recorded higher available P content.

Soil pH was significantly lower in the rhizosphere of *Pueraria* and *Mucuna* compared to the natural cover (Table 28.2), indicating rhizosphere acidification by these cover crops. Acid phosphatase activity in the rhizosphere of legumes (63.4 and 61.3 g nitrophenol/g soil for *Pueraria* and *Mucuna*, respectively) was significantly higher compared to natural cover (46.6 g nitrophenol/g soil).

The distribution of soil P among the different inorganic P fractions indicated that Al-P was significantly lower in the rhizosphere of *Mucuna* compared to *Pueraria* and natural cover, and also compared to pre-treatment value. Fe-P was also significantly lower in the rhizosphere of *Mucuna* compared to *Pueraria*. Ca-P content was significantly lower in the rhizosphere of *Pueraria*.

N accumulation in biomass was significantly higher for legumes (140.8 and 140.5 kg/ha for *Pueraria* and *Mucuna*, respectively) compared to natural cover (61.0kg/ha) (Table 28.4). Phosphorus accumulation did not show significant difference among ground covers, whereas K accumulation was significantly higher for *Pueraria*.

The study indicates the ability of *Pueraria* and *Mucuna* to mobilize sparingly plant available soil P fractions. This capability is related to root exudation of H^+, OH^-/HCO_3^-, low molecular weight organic acid anions and phosphatase enzymes which strongly influence the bioavailability of soil P in the rhizosphere (Hinsinger, 1998; Kamh, 1999; Neumann and Romheld, 1999 and Horst, 2001). The influence of root exudations in changing the pH of the rhizosphere was reported earlier (Hinsinger, 1998). In the present study also, significant reduction in pH was observed in the rhizosphere of legumes, compared to natural cover, indicating rhizosphere acidification. Nitrogen fixing legumes which have a net positive

Table 28.1. Organic carbon, available P and available K in soil(0-30cm)

P levels(kg/ha) *Pre-treatment*	*OC (%)* *1.80*				*Available P (ppm)* *21.0*				*Av.K(ppm)* *82.0*			
	Pueraria	*Mucuna*	*Natural cover*	*Mean*	*Pueraria*	*Mucuna*	*Natural cover*	*Mean*	*Pueraria*	*Mucuna*	*Natural cove*	*Mean*
0	2.38	2.36	1.88	2.21	35.5	28.3	21.1	28.3	88.5	94.0	74.7	85.7
15	2.44	2.15	2.54	2.38	33.0	31.7	25.2	29.9	103.1	83.7	50.0	78.9
30	2.53	2.20	2.32	2.35	32.2	28.4	25.5	28.7	88.0	95.0	63.6	82.2
45	2.06	1.87	1.55	1.83	33.4	29.5	26.3	29.4	115.5	101.0	69.9	95.5
Mean	2.35	2.15	2.07		33.5	29.5	24.5		98.8	93.4	64.6	
CD (P = 0.05) (crop)		NS				1.33				9.17		
CD (P = 0.05) (P level)		0.32				NS				NS		
CD (P = 0.05) (Crop x P level)		NS				NS				18.3		

NS = Not Significant

Table 28.2. pH and acid phosphatase activity of rhizosphere soil

Pre-treatment	*pH* 4.68				*Acid phosphatase activity (g nitrophenol/g soil)* 35			
P levels(kg/ha)	*Pueraria*	*Mucuna*	*Natural cover*	*Mean*	*Pueraria*	*Mucuna*	*Natural cover*	*Mean*
0	4.38	4.57	4.72	4.56	55.0	63.0	44..5	54.2
15	4.53	4.58	4.62	4.58	70.5	64.0	49.0	61.2
30	4.61	4.64	4.72	4.66	59.0	58.0	53.0	56.7
45	4.64	4.53	4.70	4.62	69.0	60.0	40.0	56.3
Mean	4.54	4.58	4.69		63.4	61.3	46.6	
CD (P = 0.05) (Crop)	0.092	4.66						
CD (P = 0.05) (P level)	NS	NS						
CD (P = 0.05) (Crop x P level)	NS	NS						

NS = Not Significant

Table 28.3. P fractions and total inorganic P in rhizosphere soil

Pre-treatment	Al – P (ppm) 42.25				Fe – P (ppm) 33.36				Ca – P 24.18				Saloid P 2.73				Total inorg. P (ppm) 102.52			
P levels(kg/ha)	Puer-aria	Muc-una	Nat. cover	Mean	Puer-aria	Mu-cuna	Nat. cover	Mean	Puer-aria	Mu-cuna	Nat. cover	Mean	Puer-aria	Mu-cuna	Nat. cover	Mean	Puer-aria	Mu-cuna	Nat. cover	Mean
0	43.4	35.2	43.7	40.8	36.4	21.0	32.3	29.88	13.1	16.9	17.9	16.0	2.7	4.0	3.3	3.3	95.5	77.2	97.2	90.0
15	64.1	38.8	55.6	52.8	28.1	39.6	25.8	31.2	18.7	26.0	21.4	22.0	3.7	4.0	4.2	3.9	114.4	108.4	106.9	109.9
30	61.3	36.1	64.1	53.8	31.1	34.64	34.7	33.5	20.7	24.5	19.8	21.7	3.8	3.3	3.6	3.5	116.7	98.5	122.1	112.5
45	46.4	36.1	63.9	48.8	68.3	20.5	33.2	40.7	15.3	15.5	17.8	16.2	3.6	3.9	3.6	3.7	118.7	76.1	118.6	104.5
Mean	53.8	36.6	56.8		40.9	28.9	31.5		16.9	20.7	19.2		3.4	3.8	3.6		111.4	90.7	111.2	
CD (P = 0.05) (Crop)			3.19				9.48				2.86				0.23				8.66	
CD (P = 0.05) (P level)			3.69				NS				3.30				0.27				9.99	
CD (Crop X P Level)			6.39				18.95				NS				0.47				17.32	

NS = Not Significant

Table 28.4. Biomass and nutrient accumulation in biomass

P levels(kg/ha)	*Biomass (kg/ha)*				*Nutrient accumulation in biomass (kg/ha)*											
					N				*P*				*K*			
	Puer-aria	*Muc-una*	*Nat. Cover*	*Mean*	*Puer-aria*	*Muc-una*	*Nat. Cover*	*Mean*	*Puer-aria*	*Muc-una*	*Nat. Cover*	*Mean*	*Puer -una*	*Muc-una*	*Nat. Cover*	*Mean*
0	3910.0	4126.7	3366.0	3800.9	112.0	140.8	45.0	99.3	7.7	9.0	5.3	7.3	58.7	36.1	58.7	51.2
15	4631.3	3988.7	4352.0	4323.7	133.3	107.8	63.9	101.7	10.3	6.8	8.8	8.6	69.4	44.9	52.9	55.7
30	4420.0	4201.0	4778.7	4466.6	136.2	134.7	73.6	114.8	9.6	8.0	8.5	8.7	95.7	56.5	47.7	66.6
45	4984.0	4548.0	3900.0	4477.3	181.2	178.7	61.6	140.5	12.3	10.9	7.7	10.3	83.2	70.8	55.7	69.9
Mean	4486.3	4215.9	4099.2		140.8	140.5	61.0		10.0	8.7	7.6		76.8	52.1	53.7	
CD (P = 0.05) (Crop)	NS	35.13	NS	16.86												
CD (P = 0.05) (P Level)	NS	NS	NS	NS												
CD (P = 0.05) (Crop X P Level)	NS	NS	NS	NS												

NS = Not Significant

excess of cations over anions entering their roots (alkaline uptake pattern) will acidify the rhizosphere by releasing H^+ to maintain the cation-anion balance (Augilar and Diest, 1981). This nitrogen fixation related rhizosphere acidification is reported to enhance the availability of P from rock phosphate (Hinsinger,1998).

Enhanced acid phosphatase activity in the rhizosphere of legumes is an indicator of the efficiency of legumes to mobilize P from less available soil P fractions. Acid phosphatase is known to catalyse the hydrolysis of organic P into inorganic P (Hinsinger, 1998; Radersma and Grierson, 2004). Very high acid phosphatase activity observed in the rhizosphere of legumes, allow the legumes to access poorly available organic and inorganic P fractions, and thus increase the pool of soil available P, which could be available to the crops grown in association with legumes (Jungk *et al.*, 1993; Horst *et al.*, 2001).

Root exudates play a significant role in the acquisition of inorganic soil P (Hinsinger, 2001). Ae *et al.* (1990) showed that the peculiar ability of pigeon pea to use poorly soluble Fe phosphate was related to the exudation of piscidic acid, and some of its derivatives, that it enhanced P solubilisation via the chelation of Fe. Hinsinger (2001) also suggested that chelation of Fe and Al by root exuded organic acids result in solubilization of Fe and Al bound phosphates and hence in an increased bioavailability of inorganic P in the rhizosphere. In the present study, depletion was observed for Al-P and Fe-P in the rhizosphere of *Mucuna* and Ca-P in the rhizosphere of *Pueraria*, indicating the efficiency of these legumes to acquire P from these stable residual P fractions.

As the P efficiency of the legumes is due to mobilization from unavailable soil P fractions, such as organic P and the inorganic P fractions, the depletion of readily available P in the soil might be reduced (Horst *et al.*, 2001). A significant increase in available P was observed in the legume soil compared to natural cover, indicating mobilization of P by the legumes.

The better P acquisition capacity of legumes can be beneficial to rubber when grown in association with legumes, as the mobilized P could be available to the main crop, especially in the strongly P fixing soils of the traditional rubber growing tract. Cover crop adds to the P nutrition of rubber also through the recycling of the mobilized P *via* plant residues and enhanced colonization with P mobilizing rhizosphere micro-organisms.

Although cover crop has long been a component of *Hevea* cultivation, its importance has diminished in recent years due to a shift towards intercropping in immature phase. However, for farming systems to remain productive and sustainable in the long term, it will be necessary to replenish the resources of organic matter and nutrients which are removed or lost from the soil through renewable resources.

References

Adams, M.A. and Pate, J.S. 1992. Availability of organic ond inorganic forms of phosphorus to lupins (Lupinus Spp.) *Plant and Soil*, **145**:107-13.

Ae, N., Okada, K., Yoshihara, T. and Johansen, C. 1990. Phosphorus uptake by pigeon pea and its role in cropping systems of the Indian subcontinent, *Science* **248**:477-80.

Augilar, A.S. and Diest, V. 1981. Rock phosphate mobilization induced by the alkaline uptake pattern of legumes utilizing symbiotically fixed nitrogen. *Plant and Soil*, **61**:27-42.

Bagayoka, M., Alvey, S., Neumann,G and Buerkert, A. 2000. Root induced increase in soil pH and nutrient availability to field grown cerealsand legumes on acid sandy soils of Sudano- Sahelian West Africa, *Plant and Soil*, **225**:117-27.

Bray, R.H and Kurtz,L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci. **59**:39-45.

Gardner, W.K and Boundy, K.A. 1983. The acquisition of phosphorus by *lupinus albus* l. iv. the effect of interplanting wheat and white lupin on the growth and mineral composition of the two species. *Plant and Soil* **70**:391-402.

George, C.M. 1961. *Mature Rubber Manuring : Effect of fertilizers* on yield. *Rubb. Bd. Bull.* **7**:37-40.

Hinsinger, P .2001. Bioavailability of soil inorganic P in the rhizosphere as affected by root induced chemical changes-A Review, *Plant and Soil*, **237**:173-95.

Hinsinger, P. 1998. How do plant roots aquire mineral nutrients? chemical processes involved in the rhizosphere. *Advances in Agronomy* (Ed. Sparkes, D.L) Academic Press, London, pp. 225-65.

Horst, W.J, Kamh, M., Jibrin, J.M, and Chude,V.O. 2001. Agronomic measures for increasing P availability to crops. *Plant and Soil*, **237**:211-23.

Jungk,A., Seeling, B, and Gerke, J. 1993. Mobilisation of different phosphate fractions in the rhizosphere, *Plant and Soil*, **155/156**:91-94.

Kamh, M., Horst, W.J., Amer. F., Mostafa, H. and Maier, P. 1999. Mobilisation of soil and fertilizer phosphate by cover crops, *Plant and Soil*, **211**:19-27.

NBSS and LUP. 1999. Resource soil survey and mapping of rubber growing soils of Kerala and Tamil Nadu. *National Bureau of Soil Survey and Land Use Planning*, Indian Council of Agricultural Research, New Delhi, 111p.

Neumann, G and Romheld,V. 1999. Root exudation of carboxylic acids and protons in phosphorus deficient plants. *Plant and Soil*, **211**:121-30.

Peterson, G.W and Corey, R.R. 1966. A modified chang and jackson procedure for routine fractionation of inorganic phosphates, *Soil Sci. Soc. Am. Proc.*, **30**:563-65.

Piper, C.S. 1966. *Soil and Plant Analysis*, Hans Publishers, Bombay, 368p.

Radersma, S and Grierson, P. 2004. Phosphorus mobilization in agroforestry:organic anions, phosphatase activity and *phosphorus fractions in the rhizosphere. Plant and Soil*, **259**:209-19.

Soong, N.K, and Yap, W.C. 1976. Effect of cover management on physical properties of rubber growing soils. *J. Rubber Research Institute of Malaya*, **24**(3):145-49.

Tabatabai, M and Bremner, J. 1969. Use of P- nitrophenyl phosphatefor assay of soil phosphatase activity. *Soil Biol Biochem.* **1**: 301-07.

Watson, G.A., Weng, D.P and Narayana, R. 1964. Effect of cover plants on soil nutrient status and growth of hevea: IV. Leguminous creepers compared with grasses micania cordata and mixed indigenous covers on four soil types. *J Rubber Research Institute of Malaya*, **18**(3):123-45.

Yogaratnam, N., Perera, A.M.A and De Mel, G.J. 1984. Management of ground cover for optimum production. *Proceedings of The International Rubber Conference*, 1984 Colombo, Sri Lanka, **1**(2):521-27.