PHOSPHORUS NUTRITION OF VETCH IN COTTON-BASED ROTATIONS

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ABSTRACT

Introducing vetch into rotations in cotton-wheat systems of northern NSW has a number of benefits. This study investigated the phosphorus (P) nutrition and response of 3 vetch species grown in soil from long-term rotations at the Australian Cotton Research Institute, Narrabri, NSW. Labile P increased by 36% in the surface soil of long term rotations where vetch was included in the rotation. This resulted in up to 17% more dry matter production of vetch grown in cotton-wheat-vetch rotation soils in a system where legumes remained responsive to P application. Part of this response can be attributed to improved nodulation and N uptake associated with higher available P where vetch is included in the rotation. Of the three vetch varieties examined, Woolypod vetch indicated the greatest P efficiency. The study demonstrated that legume inclusion in rotation improved P status and production as well as providing labile N for following crops.

INTRODUCTION

Legumes increase soil mineral N content, improve soil structure, increase infiltration, enhance water stable aggregates, aid decomposition of high C: N material and increase biological activity (Rochester and Peoples 2005). As a result vetch (*Vicia* spp.) has been used in cotton rotations to enhance these factors, as well as break disease cycles in cotton production and cycle nutrients important for plant growth and yield. Vetch is a vigorous frost-, drought- and disease-tolerant, forage legume that is useful as a break-crop due to its limited regrowth post manuring (Evans *et al.* 2003; Rochester and Peoples 2005). Vetch can contribute up to 130 kg mineral N/ha to a rotation system when green manured (Evans *et al.* 2003). A number of varieties are available, but the most commonly used is the Namoi Woolypod in northern NSW. New varieties are being developed by South Australian researchers, and this study compares the P responsiveness of Namoi Woolypod with Popany and Rasina vetches. The phosphorus (P) status in northern Vertosols is increasingly constraining production of cereals and cotton crops due to depletion associated with long term cropping without replacement (Wang *et al.* 2007). Increasingly researchers are investigating the P benefits of legume break crops, with evidence suggesting that P availability to crops following legume breaks is higher (Bunemann *et al.* 2006)**.** We investigated the long term benefits of including vetch in a rotation on the availability of P to a variety of vetch species.

MATRIALS AND METHODS

Soil was collected from the Australian Cotton Research Institute (ACRI), Myall Vale, Narrabri, NSW, (30º18'23.13"S 149º46'20.89"E), from three treatments within the long term rotation trial described by Hulugalle *et al*. (2012). Approximately 40 kg of surface soil (0-10cm) was collected from 1) cotton – winter fallow – cotton plot (C-C) ; 2) summer and winter fallow – cotton – wheat (stubble incorporated)(C-W), and; 3) summer and winter fallow – cotton – wheat (stubble standing) – summer fallow – vetch (C-W-V) plots from each of the replicated plots. Soil analysis of the plots was undertaken on separate samples taken from replicates within the field trial, whilst the pot trial used a bulk mixture of soil from each rotation.

A full factorial pot trial was established with rotation (n=3), phosphorus status (n=2) and vetch variety (n=3) as the factors, replicated 4 times. Basal nutrients were added to all pots and moisture was maintained at field capacity throughout the trial. Phosphorus was applied at 150 mg/kg to positive P control pots. The vetch species used in the study were Rasina (*Vicia sativa* cv. *Rasina)*, Popany (*Vicia villosa* subsp*. banghalensis)* and Namoi Woolypod (*Vicia villosa* ssp. *dasycarpa* cv. Namoi*)*. Five pre-germinated Woolypod, Popany or Rasina vetch seedlings were planted in each pot and growth conditions were maintained at a temperate 22^{o}C maximum temperature for 8 weeks. Plants were harvested, dried ground and digested for P according to the method of Anderson and Henderson (1986) and N status by combustion on a LECO. Roots were carefully washed from the soil following soaking of the soil and nodules on the root system were counted.

Sequential P fractionation was undertaken on the soil from each rotation according to the method of (Guppy, Menzies *et al.* 2000) and P status was measured using malachite green. Labile P samples were considered to be resin and bicarbonate extractable pools. All data were analysed using a 3-way ANOVA and significant differences ($P<0.05$) were determined using LSD's calculated where significant F-tests were observed.

RESULTS

Labile P (the sum of resin and bicarbonate extractable P) in the vetch rotation was 36% greater than the continuous cotton rotation (Table 1). Total P was12% higher in the surface soil of the vetch rotation relative to continuous cotton and cotton-wheat rotations (Table 1). Woolypod vetch produced 21 and 11 % greater dry matter than Popany and Rasina respectively (Table 2). The application of P increased vetch dry weight by 37% ($P<0.001$) (Table 2). The cotton-wheat-vetch rotation produced 15 and 17 % more dry matter than the continuous cotton and cotton-wheat rotations respectively ($P=0.003$) (Table 2). In the majority of treatments the addition of superphosphate resulted in a threefold increase in P uptake (Table 3). The exception is the C-W-V rotation where P uptake doubled, except for Rasina which had a P uptake four times greater when P was added. Phosphorus uptake was up to 22% higher from soil from the vetch rotation (Table 3). Within each species, N uptake was similar where P was applied to soil from each rotation (Table 4). However, in the absence of P, N uptake was up to 36% higher from soil collected from the vetch rotation (Table 4).

Addition of P increased nodulation by 43%. Nodulation was higher in the C-W-V rotation in the absence of P (Table 5).

DISCUSSION

The long-term presence of vetch in the rotation significantly increased labile P with flow on consequences for N nutrition and growth. All three varieties of vetch trialled were more productive when grown in soil where vetch was part of the rotation. These results are related to two factors, increased labile P and the increased nodulation (and hence N availability). The increase in nodulation in vetch rotation soil may be related to a higher rhizobial population associated with a history of vetch growth in the rotation. However, the ability of soils supplemented with P to achieve similar nodulation where vetch was not part of the rotation suggests that it was in fact the higher P nutrition of the vetch soil that resulted in higher nodulation and N uptake.

Producers in northern NSW have incorporated Namoi Woolypod vetch into rotations due to its drought and frost tolerance seeking disease break benefits and fixed N. Another advantage may be better P use efficiency. Woolypod vetch achieved the highest growth as a percentage of P unlimited growth in all rotations, implying a much greater efficiency of P utilisation under constrained conditions. Further research is necessary to elucidate both the increased efficiency of Woolypod vetch and mechanisms underlying increased labile P where vetch is included in the rotation. The study demonstrates that legume inclusion in rotation improves P status and production as well as providing labile N for following crops.

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Table 1. Labile and total P (mg/kg) of a cracking clay (0-10 cm) after 7 years of a rotation trial including various combinations of cotton, wheat or vetch.

Rotation	Labile P (mg/kg)	Total P concentration (mg/kg)
Cotton-cotton	47	590
Cotton - wheat	43	590
Cotton-wheat-vetch	67*	670*

*indicates significant difference within a column (P<0.05)

Table 2. Vetch dry matter production (g/pot) in a Vertosol soil collected from rotations with continuous cotton, cotton-wheat or cotton-wheat-vetch following eight weeks growth in a glasshouse with and without P addition.

	Continuous cotton		Cotton -wheat		Cotton-wheat-vetch	
	-P	+P	-P	+P	-P	+P
Popany	0.56*	1.13*	0.63*	1.29	0.92	1.33
Woolypod	0.90	1.53	0.83	1.49*	1.23*	1.39
Rasina	0.85	1.41	0.76	1.22	1.09	1.55*

*indicates significant difference within a column (P<0.05)

Table 3. Vetch phosphorus uptake (µg/pot) in a cracking clay from rotations with continuous cotton, cotton-wheat or cotton-wheat-vetch following eight weeks growth in a glasshouse with and without P addition.

	Continuous cotton		Cotton -wheat		Cotton-wheat-vetch	
	-P	+P	-P	+P	-P	+P
Popany	140*	480*	180*	580	320*	610*
Woolypod	180	600	190	660	380*	700*
Rasina	170	570	190	500*	270*	810*

*indicates significant difference within a column (P<0.05)

Table 4. Vetch nitrogen uptake (mg/pot) in a cracking clay from rotations with continuous cotton, cotton-wheat or cotton-wheat-vetch following eight weeks growth in a glasshouse with and without P addition.

	Continuous cotton		Cotton -wheat		Cotton-wheat-vetch	
	-P	+P	-P	+P	-P	+P
Popany	2.2*	4.4*	2.4*	4.6	4.0	5.5
Woolypod	3.2*	6.1*	3.2	6.3*	5.0*	6.5*
Rasina	2.7*	5.5*	2.9	4.2	3.6	4.9

*indicates significant difference within a column (P<0.05)

Table 5. Nodule numbers of vetch grown in a cracking clay from rotations with continuous cotton, cotton-wheat or cotton-wheat-vetch following eight weeks growth in a glasshouse with and without P addition.

	Continuous cotton		Cotton -wheat		Cotton-wheat-vetch	
	-P	+P	-P	+P	-P	+P
Popany	4	31	11	24	22	32
Woolypod	17	27	16	15	30	30
Rasina	11	31	21	27	39	33

*indicates significant difference within a column (P<0.05)