Crop rotation and liming history affect the availability of soil phosphorus

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Key messages

- A history of lime application resulted in significant increases in soil pH, phosphorus uptake and grain yield.
- Grain yield showed a linear relationship to phosphorus uptake
- Soil pH needs to be considered when making recommendations for fertiliser phosphorus

Aims

To quantify the interaction between soil pH and crop rotation on soil phosphorus availability.

Method

A field trial was conducted at the Wongan Hills Research Station in 2012. The trial site was used from 2009 to 2011 to examine the effect of soil pH and rotation on greenhouse gas emissions in cropping systems in a separate study by Barton (UWA). The treatments for the Barton trial were a factorial of 2 rotations and 2 lime treatments (Table 1) in a randomised block design with 3 replicates. Each plot in the Barton trial was 4 adjacent cone-seeder runs wide, which we split into 4 rates of phosphorus (0, 5, 10 and 20 kg P ha^{-1}) for our trial. The trial design for 2012 was a split-plot design, where the main treatments were the 4 treatments established by Barton and the sub-treatments were rates of P.

Details of fertiliser, herbicides and timing of our measurements are shown in Table 2.

Table 1: Lime and rotation history for the 4 treatments established by Barton.

Main Treatment	2009	2010	2011	2012
1. Lime / Lupin-Wheat	Lupin, Lime @ 3.5t/ha	Wheat	Wheat	Wheat, Lime @ 1t ha
2. Lime / Continuous wheat	Wheat, Lime @ 3.5 t/ha	Wheat	Wheat	Wheat, Lime @ 1t ha
3. No lime / Lupin-Wheat	Lupin	Wheat	Wheat	Wheat
4. No lime / Continuous wheat	Wheat	Wheat	Wheat	Wheat

Table 2: Trial management details 2012

Date	Details
14th June	Roundup @ 2 L ha^{-1}
22nd June	Wheat *cv* Mace sown @ 80 kg ha^{-1}, 15 kg N ha^{-1} drilled as urea. P treatments applied as superphosphate drilled
19th July	Sulphate of Ammonia topdressed on all treatments @ 80 kg ha^{-1} (20 kg N ha^{-1}, 23 kg S ha^{-1})
27th July	Axial @ 300 mL ha^{-1} and Adigor @ 0.5%
13th August	Velocity @ 670 mL ha^{-1} and Hasten @ 1%
14th August	Tiller (stem) counts
17th August	Prosaro @ 300 mL ha^{-1}
1st October	Anthesis cuts
30th October	Maturity cuts
1st Nov	Soil moisture profiles
20th Nov	Machine harvest

Results

Soil chemical analysis

Analysis of soil chemical properties for the main treatments in April 2012 only showed significant differences for soil pH (Table 3). There were also differences between extractable aluminium which corresponded to the change in pH caused by lime application.

Soil P availability

Lime history had a significant effect on soil P availability (Figure 1). P uptake where no fertiliser P is applied is an indicator of soil P availability, and was significantly higher for the main treatments where lime was applied (Main treatments 1 and 2 compared to 3 and 4). For the lime treatments (Main treatments 1 and 2), P uptake where 10 and 20 kg P ha^{-1} was applied was higher in main treatment 1 (lupin-wheat history), although these differences were not statistically significant. Rotation had no effect where no lime was applied: the response to P was very similar (Main treatments 3 and 4).

Table 3: Chemical analysis of soil surface 0-10 cm samples taken April 2012. Data shown are the mean of 3 plots and 20 pogo samples were taken per plot. Different letters for pH indicate a significant difference between treatments. Extractable Al was below detection limits for treatments 1 and 2. PBI is Phosphorus Buffering Index.

Main Treatment 2012	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	PBI	Potassium Colwell	Sulphur	Organic Carbon	pH Level (CaCl2)	Aluminium CaCl2
1. Lime / Lupin-Wheat	6[a]	27[a]	23[a]	18[a]	65[a]	7.60[a]	0.94[a]	6.20[b]	<0.02
2. Lime / Continuous wheat	6[a]	31[a]	19[a]	19[a]	69[a]	8.40[a]	1.22[a]	5.87[b]	<0.02
3. No lime / Lupin-Wheat	7[a]	25[a]	20[a]	15[a]	82[a]	6.63[a]	1.17[a]	4.63[a]	1.90
4. No lime / Continuous wheat	8[a]	25[a]	22[a]	15[a]	76[a]	5.87[a]	0.95[a]	4.57[a]	2.30

Table 4: Extractable Al (mg kg^{-1}) for main treatments April 2012.

	Lime		No lime	
Soil depth (cm)	Lupin-Wheat	Continuous wheat	Lupin-Wheat	Continuous wheat
0 to 10	0.7	0.5	1.9	2.9
10 to 20	5.7	4.4	7.7	8.5
20 to 30	3.0	2.1	4.2	5.0
30 to 40	0.4	0.2	0.5	0.5

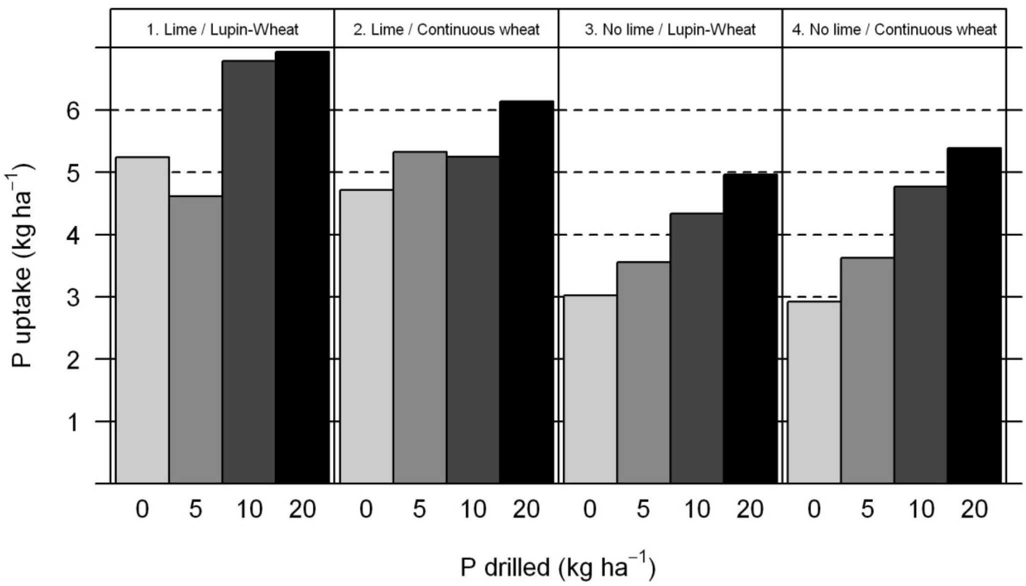

Figure 1: Phosphorus uptake at anthesis. LSD (5%) for all treatments is 1.73 kg P ha^{-1}.

Ryegrass

Ryegrass biomass at flowering was affected by shoot biomass of wheat as well as lime and rotation history (Figure 2). Linear regression showed a negative, though weak (r^2 = 0.24) relationship between ryegrass biomass and wheat shoot biomass: *ryegrass biomass = 364 – 0.052 x wheat shoot biomass*. For treatments with a lupin-wheat history,

ryegrass biomass tended to be lower where lime was applied compared to no lime treatments at an equivalent wheat shoot biomass. However, the opposite occurred for treatments with a continuous wheat history; ryegrass biomass tended to be higher where lime was applied compared to no lime treatments at an equivalent wheat shoot biomass

Grain yield

Lime treatments, rotational history and P rate all had significant effects on grain yield (Figure 3). Overall, the main treatments where lime was applied (1 and 2) had the highest grain yield: the average grain yield for 1. Lime / Lupin-Wheat, 2. Lime / Continuous wheat, 3. No lime / Lupin-Wheat and 4. No lime / Continuous wheat was 2183, 2006, 1688 and 1697 kg ha^{-1} respectively. Significant responses to P fertiliser were only observed in main treatments where lime was applied: 20 P and 10 P for main treatments 1 and 2 respectively. There were no significant responses to P fertiliser where no lime has been applied (3 and 4).

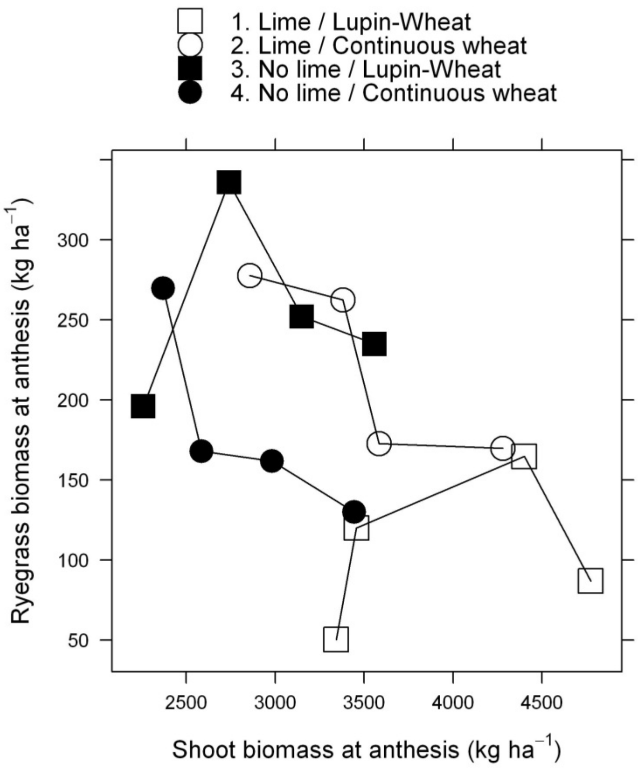

Figure 2: Relationship between ryegrass biomass and wheat shoot biomass at anthesis. Ryegrass was cut from the crop row only.

Our results indicate that grain yield response to the main treatments and P treatments was driven by growing conditions prior to anthesis. For all treatments, machine harvest grain yield showed the strongest correlation with anthesis biomass (r = 0.64), very similar to maturity biomass (r = 0.63), P uptake at flowering (r = 0.55) and harvest index (r = 0.55) and heads per square metre at tillering (r = 0.46). While harvest index tended to be higher as grain yield increased, there were no significant effects of main treatment or P rate on this. Grain size distribution was not affected by the main or P treatments and was not well related to grain yield.

Soil Moisture

Soil moisture profiles taken at physiological maturity showed differences between lime treatments though they were not statistically significant. Cores for soil moisture measurement were taken from main treatments 1 and 3, from the 0 and 20 P only. For main treatment 1, the total stored water in 0-100 cm was 60 and 63 for the 0 and 20 P treatments respectively. For main treatment 3, the total stored water in 0-100 cm was 69 mm for both the 0 and 20 P treatments. The LSD (5%) for all treatments was 22 mm.

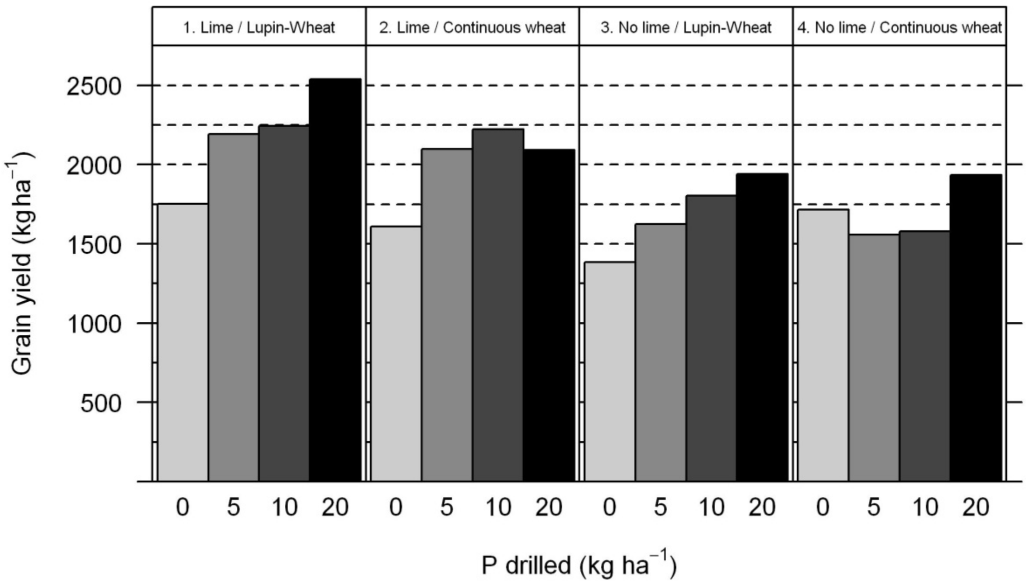

Figure 3: Machine harvest grain yield. LSD ($p<0.05$) for all treatments is 577 kg/ha.

The differences observed in stored soil moisture between the lime and no lime treatments are relatively small and do not explain the difference observed in grain yield. For example, at a water use efficiency of 15 kg grain / mm, crop access to an additional 9 mm stored soil water in the 0 P treatments would result in a yield gain of 135 kg ha^{-1}, whereas the yield difference was 368 kg ha^{-1}. In addition the trend in stored soil water does not match the trend in grain yield: the stored soil moisture was the same for the 0 and 20 P treatments was the same for the no lime treatments although there was a difference in grain yield of 555 kg ha^{-1}.

Conclusion

In this field trial lime history had a greater effect than rotation history on soil P availability and grain yield. Yield potential was highest where lime was applied and it appears that fertiliser P is used more effectively in lime treatments, though we are not able to quantify this because yield potential has also been constrained in the no lime treatments.

The effect of wheat biomass and treatment history on weed biomass is an important outcome of this work. Weed biomass declined as wheat biomass increased, and in general wheat biomass was greatest in plots with a lime history and P rates of 5 kg ha^{-1} and greater.

Grain yield response to our main and P treatments was driven by crop growth prior to anthesis.

Key Words: lime, soil pH, soil acidity, phosphorus, wheat, crop rotation

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