Improved phosphorus and potassium fertiliser management: redefining the soil test and lupin response relationships in WA

Wen Chen[1, 2], Ross Brennan[2], Geoff Anderson[2], Richard Bell[1] and Mike Bolland[2]

[1]School of Environmental Science, Murdoch University, Western Australia

[2]Department of Agriculture and Food, WA

Key Messages

The estimated critical values of Colwell soil phosphorus needed to achieve 95% maximum lupin yields varies with soil type due to differences in soil phosphorus adsorption. For soil types with a phosphorus retention index (PRI) equal to 1, the critical value for Colwell-soil phosphorus in lupins was 25 mg/kg. However, for soils with a PRI of 2 or 3 the relationship between the Colwell-soil phosphorus test and relative yield was poor. More research is needed to better understand the availability of soil phosphorus in soils with PRI values of more than one.

The derived critical value for the Colwell soil potassium test for lupin grown on grey sands with phosphorus not limiting was 31 mg K/kg.

Aims

When phosphorus requirement experiments in lupins were started in the early 1970s, most soils were highly deficient in phosphorus and consequently lupin yields were highly correlated (r2=0.72) with the Colwell soil-phosphorus test, with a critical value defined as 20 mg P/kg soil. However, as phosphorus was applied to the soil the phosphorus status improved and this has, in turn, altered the ability of the Colwell soil phosphorus test to predict phosphorus response. Over time, various measurements of soil ability to adsorb phosphorus have been developed. The phosphorus retention index (PRI) was introduced during the early 1990s while the phosphorus buffer index (PBI) was introduced during the early 2000s (Bolland et al., 2006). Incursion of an indicator of phosphorus sorption into the phosphorus calibration curves can improve the ability of the phosphorus soil test procedure to predict phosphorus requirements of pastures (Bolland and Russell, 2010). In general, lupins are grown on sands that have a relatively low capacity to adsorb phosphorus. Within the available data base of phosphorus experiments done with lupins, PRI levels can be grouped into PRI=1, PRI=2 and PRI=3. These different PRI levels are known to have an impact on the shape of the phosphorus calibration curve for pastures (Bolland *et al*., 2010). The aim of this paper was to examine whether inclusion of PRI levels in the phosphorus soil test procedure could improve the ability of the Colwell soil phosphorus test to predict phosphorus deficiency in lupins.

While WA soils initially contained adequate indigenous soil potassium for cropping, removal of potassium over time in harvested grain gradually resulted in some soils becoming potassium deficient for grain production. While studies have been done to determine the potassium requirements of lupins grown on grey sands, a calibration for the relationship between relative yield and Colwell soil potassium test has not been reported. An additional aim of this paper was to examine the ability of the Colwell soil potassium test to predict potassium deficiency in lupin grown on grey sands.

Methods

Database

Data were obtained from 394 phosphorus experiments carried out by DAFWA during 1973 to1994. The trials were done mainly on coloured sands (grey, yellow, red and brown) although some experiments were also done on loamy sands and duplex soils. Measurements of the Colwell soil phosphorus test level and PRI were taken from soil samples collected before the experiments. Phosphorus fertiliser was applied at a rate of up to 80 kg P/ha in most experiments, with higher rates used in some experiments. Phosphorus was applied in the form of single super phosphate via top dressing before seeding and drilled, banded or deep-banded at seeding. Grain yield (t/ha) was measured at harvest.

For potassium, a database of 26 experiments was compiled from potassium fertiliser experiments done on grey sands carried out by DAFWA during 1977 and 2003. Colwell soil potassium test levels were determined for the soil samples at the start of the trials. Potassium fertiliser was applied at a rate up to 160 kg K/ha in most experiments by top dressing potassium chloride before seeding. Grain yield (t/ha) was measured at harvest.

Data analysis

A soil test calibration for a specific crop type is the relationship between the measured yield to an applied nutrient at a range of experimental sites and the soil test value for each trial site. In this study, relative crop yield was used to estimate yield responsiveness to reduce variations in yield response to applied nutrient due to site and seasonal conditions, and was calculated using the following equation:

$$\% \text{ relative yield} = 100 \times (\text{yield of unfertilised treatment } (Y_0) / \text{maximum yield obtained } (Y_{max})$$

Historically, several yield response functions (linear-linear, linear-plateau and Mitscherlich) have been used to fit relationships between relative yield and soil test value. The Mitscherlich equation of the following form was used in this study.

$$Y = a - be_{-cx}$$

Where y is relative yield; a, b, and c are constants; and x is the Colwell soil phosphorus or potassium soil test. For each nutrient, a critical value was calculated based on the soil test values (0-10 cm) corresponding to 95 % of the maximum predicted relative yield. The critical value is defined as the critical soil test value below which deficiency is likely to reduce crop grain yield.

Results

Phosphorus

The calibration relationship between relative yield and the Colwell soil phosphorus test (Figure 1a and Table 1) was poor when the regression was fitted to all data. When the data were separated into PRI classes PRI =1 (Figure 1b), PRI=2 (Figure 1c) and PRI=3 (Figure 1d), the relationship for PRI=1 class was improved (Table 1). The derived critical value of the Colwell soil phosphorus test for lupin when PRI=1 across 188 trials was 25 mg P/kg (Table 1). This level is higher than the critical level of 15 mg P/kg soil derived for pastures grown on soils with PRI ranging from 0.35 to 1.00 (Bolland *et al.*, 2010). For the other PRI classes the critical level could not be defined due to low r^2 value for the calibrations.

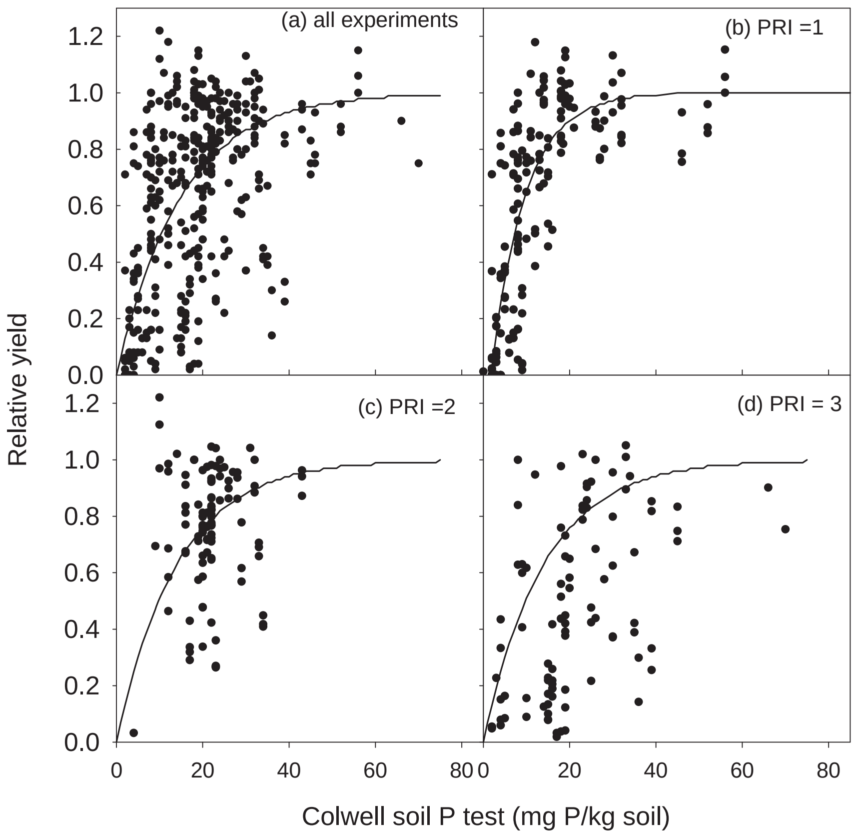

Figure 1. Relationship between Colwell soil P test and relative yield when (a) the whole data set is used (b) experiments with PRI=1, (c) experiments with soil PRI=2 and (d) experiments with soil PRI=3

Table 1. Summary of Colwell soil P test calibrations for lupins

Experiments	Number of observations	R^2	Soil test critical level (mg /kg)
All experiments	394	0.36	44
Experiments with soil PRI=1	188	0.71	25
Experiments with soil PRI=2	108	0.10	-
Experiments with soil PRI=3	97	0.17	-

Potassium

The Colwell soil potassium test was related to relative lupin yield for experiments carried out on grey sands when phosphorus was not limiting (Figure 2). The critical Colwell soil potassium test was defined as 31 mg K/kg soil (Table 2).

Table 2. Summary of the Colwell soil K calibrations for lupins

Experiments	Number of Observations	R^2	Soil test critical level (mg/kg)
P not limiting	26	0.80	31

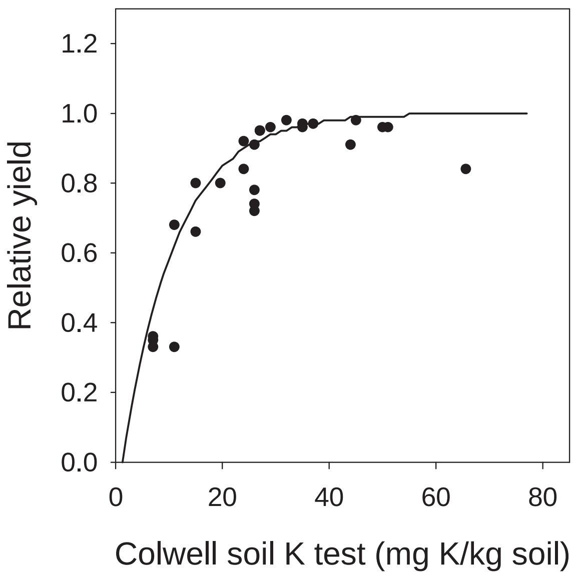

Figure 2. Relationship between the Colwell soil potassium test (mg K/kg soil) and relative yield for experiments carried out on grey sands when phosphorus was not limiting production.

Conclusion

The derived critical value for the Colwell soil phosphorus test for lupins across soils with a PRI equal to 1.0 (188 trials) was 25 mg P/kg. For other soils with different PRI classes, PRI =2 and PRI=3, the critical level could not be defined at present due to low r^2 values for the calibration curve.

For lupin crops grown on grey sands and with adequate phosphorus, the critical value of the Colwell soil potassium test was 31 mg K/kg.

Key Words

Phosphorus, potassium, critical level

Acknowledgments

The Grains Research and Development Corporation, Department of Agriculture and Food Western Australia and Murdoch University.

Project No.: Making Better Fertiliser Decisions in WA Cropping Systems (UMU 00030)
Paper reviewed by: Mike Wong, CSIRO

References

Bolland MDA, Allen DG and Barrow NJ (2006) Sorption of phosphorus by soils. How it is measured in Western Australia. Department of Agriculture and Food WA, Bulletin 4591.

Bolland MDA and Russell WK (2010) Changes in chemical properties of 48 intensively grazed, rain-fed dairy paddocks on sandy soils over 11 years of liming in south-western Australia. *Australian Journal of Soil Research* 48 682–92.