Use of paired soil and plant tests to set soil fertility targets for subterranean clover-based pastures

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Abstract

Soil samples (0-10 cm depth) and whole shoots (WS) or youngest open leaves (YOL) from adjacent subterranean clover plants were taken to determine the relationship between herbage P concentrations and the Colwell extractable P concentration of soil. The relationship was similar in years with moist spring conditions (1999 and 2000). However, the P concentrations of clover herbage were low and deficient when the topsoil was dry (2001), irrespective of soil P fertility. Critical herbage P concentrations of 0.32-0.34% of DM (YOL) or 0.27-0.30% (WS) were required to predict the expected critical soil P concentration (20-25 mg P/kg) using 1999-2000 data. However, when conditions other than P-deficiency also constrained plant growth (eg. dry topsoil), paired tests were not an appropriate way to predict the critical soil test value.

Key Words

Critical soil P

Introduction

The primary reason for applying superphosphate to pastures on P-deficient soils is to increase profitability by allowing higher stock numbers to be carried sustainably. Under-fertilizing such a pasture restricts the potential for carrying livestock and over-fertilizing is a poor investment because the residual value of superphosphate applied in excess of current requirements is low. Excessive fertilizer use is also undesirable for environmental reasons. Cost effective use of superphosphate requires knowledge of: (i) the critical P concentration of topsoil for maximum pasture growth, (ii) the potential carrying capacity of the pasture, and (iii) that no other deficiency or toxicity will constrain the response to P-fertilizer. We investigated whether pairing soil tests for extractable P using the Colwell test (1) with assessment of the P concentration of subterranean clover herbage could be used to indicate the soil fertility target for fertilizer management.

Methods

Between mid October and early November (1999-2001), 2 cm diameter soil cores (0-10 cm depth) and whole shoots (WS) or youngest open leaves (YOL) of adjacent subterranean clover plants were sampled from numerous paddocks on a yellow chromosol soil (2) near Canberra. About 20 “paired” samples were taken in each paddock and combined to provide single samples of soil, WS and YOL representing the paddock. The paddocks covered a wide range of soil P-fertility as a result of their different fertilizer histories. Extractable P concentrations in the topsoil ranged from 7 to 60 mg P/kg soil (Colwell test). Most often, the plants were beginning to flower when sampled. Soil conditions were moist in spring 1999 and 2000 with soil water contents of topsoil (0-10 cm depth) being 26.5% and 20.4% (dry soil basis), respectively, at the nearest October-November soil moisture assessments. The water content of this soil at field capacity was 32% (intact cores; 10 MPa). However, topsoil was dry in 2001 after a period of dry weather. Soil water content recorded at the nearest October soil moisture assessment was 11.6%. Water content at wilting point was 8% (1500 MPa). Nevertheless, the clover plants were not visibly water stressed, even when sampled at midday.

Soil samples were air-dried, sieved (2 mm) and analysed for extractable P using the Colwell test (1). Plant material was washed with deionised water to remove any traces of soil, oven dried (70?C), ground in a

puck mill to a fine powder and pressed into pellets for analysis of nutrients including P, S, K, Mg, Mn, Fe, Cu, Zn and Mo by X-ray fluorescence spectroscopy (3).

Results

Relationships between plant tests and between plant and soil tests.

In the years with moist spring conditions, the plant tissue tests indicated that nutrients other than P were generally adequate. This indicated that P fertility was the main variable in the experiment. The exceptions to this were occurrences in 1999 and 2000 of marginal S concentrations in herbage (<0.19% of dry matter [DM]) from one paddock with a poor fertilizer history and very low P status, and in 60% of paddocks in 2001 when the topsoil was dry. Although X-ray fluorescence spectroscopy is not sufficiently sensitive to be used as a reliable indicator of Mo deficiency, it was notable that Mo was also low and below detectable limits (<0.1% of DM) in WS from 50% of paddocks in 2001.

The relationship between the P concentrations of YOL or WS, and the Colwell extractable-P concentration of the soil were described by asymptotic functions (Figure 1). The relationships did not differ substantially in years with moist spring conditions (1999 and 2000). However, the P concentrations of clover plants growing with dry topsoil (2001) were low, irrespective of soil P fertility.

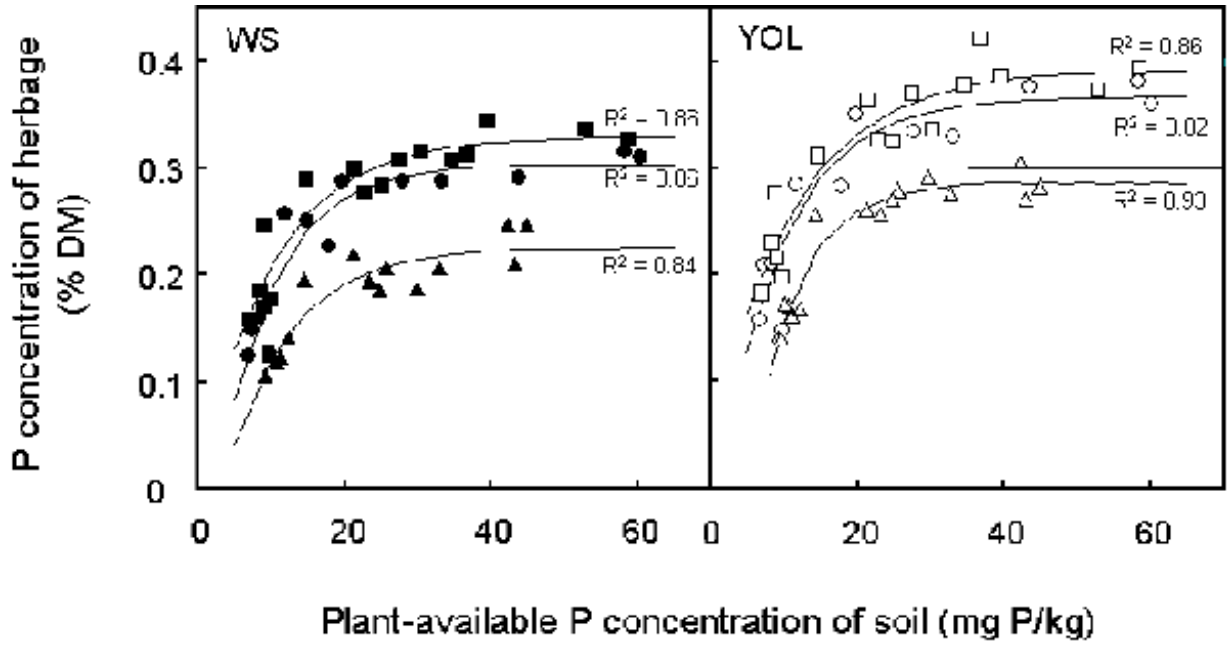

Figure 1. Relationships between the P concentration of whole shoots (WS) or youngest open leaves (YOL) of subterranean clover and the extractable P concentration of topsoil (0-10 cm depth) in 1999 (circles), 2000 (squares) and 2001 (triangles). Each point within a year represents a separate paddock. Solid horizontal lines show the lower boundary, and dashed horizontal lines show the upper boundary for the "marginal" P ranges recommended for subterranean clover plants just prior to flowering (4).

The concentrations of P in YOL were linearly related to the concentrations of P in WS (Figure 2). The relationship was consistent across all years including 2001 when dry topsoil conditions resulted in low herbage P concentrations indicating P-deficient plants.

Can plant tissue tests be used to predict the critical soil test value?

Various experiments placed the target fertility for subterranean clover-based pasture grown on this soil at about 20-25 mg P/kg soil. Large increases in pasture yield were observed when P was applied in spring to paddocks with 7-10 mg P/kg soil (Colwell; 0-10 cm), a small increase on a paddock with 20 mg P/kg soil (significant at *P*<0.06), and no yield response in paddocks with 25-33 mg P/kg soil (unpublished data). In addition, the critical P concentration of soil (0-7.5 cm depth) that corresponded with 90% of maximum yield in subterranean clover pastures across 20 sites on the Southern Tablelands, NSW is reported to be 22 mg P/kg (Colwell test) (5). For a 0-10 cm depth soil sample, this would equate to a Colwell value of about 19 mg P/kg soil.

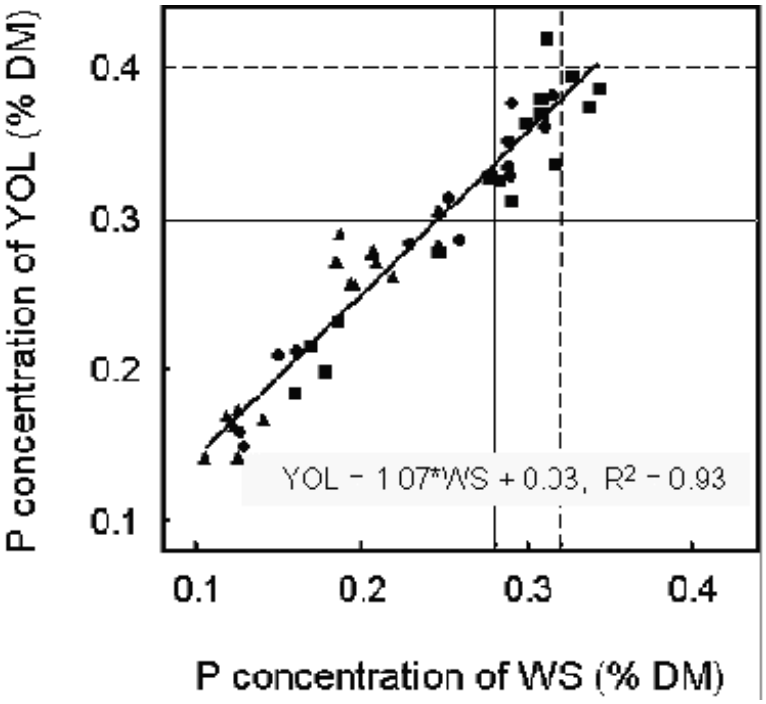

Figure 2. Relationship between the P concentration in YOL and WS from adjacent subterranean clover plants in paddocks that covered a wide range of soil P fertility levels. Plants were sampled in mid spring of 1999 (circles), 2000 (squares) and 2001 (triangles). Solid lines represent lower, and dashed lines represent upper "marginal" P concentrations recommended for subterranean clover plants just prior to flowering (4).

The relationships between the P concentrations of YOL and WS of subterranean clover, and between the P concentrations of herbage and the Colwell soil test for extractable P were strong (Figures 1 and 2). The relationship between P concentrations of herbage and the Colwell soil test was consistent in those years when no other factor was constraining plant growth. This indicated that it should be feasible to predict the critical Colwell test value using paired plant and soil tests. It was intended to use the critical herbage P concentrations that are recommended for subterranean clover (4) to predict the critical Colwell test value for soil. However, it became apparent that this would be difficult to do. The data revealed three factors that need to be resolved for such predictions to be reliable.

(i) A range of herbage P concentrations is usually specified to reflect "marginal" P conditions. The range recommended for WS of subterranean clover just prior to flowering is 0.28%-0.32% of DM and that for YOL is 0.30%-0.40% of DM (4). If the upper and lower boundaries for the marginal ranges of P concentration were used with data from years with moist spring conditions to predict the critical soil test value for this soil, very wide critical ranges were specified: ie. 15 to >60 and 19 to >36 mg P/kg soil using the "marginal" ranges for YOL and WS, respectively. This is too wide a target for practical management of soil fertility. The lower value predicted using the P concentrations in YOL was too low (ie. less than 20 mg P/kg soil). The upper values predicted from YOL and WS data were too high. In fact, the P concentrations

of YOL and WS in only a few paddocks exceeded the recommended upper boundary for “marginal” P conditions even when plants were growing with very high soil P fertility (50-60 mg P/kg soil). Normally “adequate” and even “luxury” P concentrations would be expected in plants grown with high soil fertility.

(ii) It was expected that the equivalent boundaries of the upper and lower “marginal” P ranges for YOL and WS would intersect at the regression between the two variables (Fig. 2). However, this was not the case and the data may be indicating that the P concentration range recommended for YOL is inconsistent with that recommended for WS.

(iii) When conditions other than P-deficiency had the potential to also constrain plant growth (eg. dry topsoil), the relationship between the P concentrations of herbage and soil was not indicative of the critical soil test value. Phosphorus is strongly stratified in most pasture soils (5) and, in this case although the plants were not visibly moisture stressed, it is likely that the availability of P was reduced by the dry surface soil conditions.

The published guidelines for plant analysis specify that plants should be sampled during “active growth prior to flowering” and the possibility that some of these apparent inconsistencies were due to plants having been sampled shortly after flowering had commenced can be entirely discounted. The dilemma for the present experiment was that it is difficult to achieve rapid subterranean clover growth before flowering in Canberra because of the relatively low temperatures experienced before October.

Conclusion

This experiment indicated that the relationship between the concentrations of P in subterranean clover herbage and the Colwell test for extractable P in soil was consistent between years provided that conditions for plant growth were otherwise ideal. The P concentration of herbage clearly indicated when soil P conditions were deficient for pasture growth, but it was a relatively poor indicator of supra-optimal soil fertility. On this basis, it should be possible to use paired plant and soil testing to predict the critical Colwell test value for a soil and to monitor progress towards such a target in soil fertility management programs. However, there is still some uncertainty about how to apply the critical P concentrations of WS and YOL published for subterranean clover. In this experiment, P concentrations of 0.32-0.34% of DM for YOL or 0.27-0.30% for WS would have predicted the expected critical soil P concentration (20-25 mg P/kg). Reliable indications were only achieved in years when plant growth was not influenced by other factors (eg. dry surface soil). Similar problems might be expected in situations where low temperatures, other nutrient deficiencies or toxicities, etc. were constraining plant growth. This restricts the use of paired plant and soil testing to moist spring conditions and circumstances where P is clearly the major factor limiting growth.

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