Predictive value of resin extraction to determine sulfur and phosphorus response of maize in a range of soils from the New England Tablelands of NSW, Australia

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Abstract
An evaluation of the predictive capacity of resin sulfur (S) and phosphorus (P) extraction was undertaken on 18 soils from the New England Tablelands in northern NSW, Australia. Maize (*Zea mays*) plants were grown for 40 days in a glasshouse in the presence or absence of sulfur and/or phosphorus fertiliser, and relative yield was determined. Comparison of the relative yield response against resin extractable S, monocalcium phosphate (MCP) S and KCl40 S using a Cate-Nelson plot revealed little difference between the three S extraction methods when soil test values were below the identified critical levels. However, values above the critical value were better able to identify where fertiliser was not required in the resin and MCP tests. The inability of the KCl40 test to correctly identify when fertiliser would not be needed was related to the short time frame of the trial where the longer term reserves that it identifies are not able to be exploited by potted plants. Evaluation of P responses was not possible due to the responsiveness of all soils to applied P, despite critical values being above previously determined threshold values for more than one third of the soils examined. It remains unclear why all soils responded to P, however tissue P concentrations match with increasing response to soil P test values. In conclusion, there is no benefit in terms of predicting S response to move to a resin extraction method, and we were unable to determine if benefits would accrue with respect to P resin tests.

Key Words
Sulfur, phosphorus, fertiliser response, critical values, resin extraction.

Introduction
Efficient fertilizer application relies on the ability to predict when applications are likely to result in improved plant growth. Fertilizer application in the absence of plant response remains uneconomic and inefficient. Predicting response commonly relies on extracting soil and relating the soil test values to plant responses either in pot or field trials. Both monocalcium phosphate (MCP) and potassium chloride extraction at 40^{o}C are used to extract soil sulfur (S) and critical values have been established (Blair *et al.* 1991). Similarly, in the New England region of NSW, Australia, Colwell (0.5M sodium bicarbonate) (Colwell 1963) and Bray (acidic ammonium fluoride) (Bray and Kurtz 1945) extractions have been used to predict P response. Earlier studies have concluded that roughly 80% of soils in the New England region are responsive to either S or P or both (Edwards and Duncan 2000) and the region is therefore ideal to compare existing tests against a resin extraction method to simultaneously measure plant available S and P. This paper reports on the comparison of a resin extraction method against standard methods to predict fertilizer response on 18 diverse soils from the New England.

Methods
Soil collection and preparation
Soil was collected from properties within a 100 km radius of Armidale in the New England region of NSW. Soils in this region are generally identified using 4 descriptors; granite soils (light textured soils with low water holding capacity and poor fertility), trap soils (texture contrast soils derived from sedimentary or meta-sedimentary parent materials), black basalt (heavy, smectite clay dominated soils) and red basalt (weathered paleosoils). Representative samples of each of these soils types were collected from the surface 10 cm of predominantly improved pastures, and screened to <1cm. One kg of each of the 4 soil types was placed in 13cm diameter pots and basal nutrients (150 mg N/kg, 50 mg K/kg, 20 mg Ca/kg, 20 mg Mg/kg, 2 mg Zn/kg, 2 mg Cu/kg, 0.2 mg B/kg and 0.2 mg Mo/kg) were applied. The S and P applications were applied as solutions of ammonium phosphate and ammonium sulfate. Sulfur was applied at a non-limiting rate of 20 mg S/kg. Phosphorus was applied at 100 mg P/kg for soils with phosphorus buffer indices (PBI) (Burkitt *et al.* 2002) <200; 200 mg P/kg for soils with PBI values between 200 and 400; and 400 mg P/kg for soils with PBI values above 400.

Plant and soil analysis
Maize (*Zea mays*) seeds were germinated and sown at 3 plants per pot, and maintained through regular watering to field capacity for 40 days. Glasshouse conditions were maintained between 18 and 28^{o}C throughout growth. After 40 days, plants were harvested at the base of the stem, dried at 70^{o}C for 48 hours, weighed, then ground to <2mm and digested using the sealed chamber digestion method (Anderson and Henderson 1986) and analyse for total nutrient concentrations using inductively coupled plasma atomic emission spectroscopy.

Soils were analysed for pH and EC, resin extractable P and S (Prochnow *et al.* 1998), MCP and KCl40 extractable S (Blair *et al.* 1991), Colwell (Colwell 1963) and Bray (Bray and Kurtz 1945) extractable P. A version of the Cate-Nelson statistical test was applied to the results and comparisons were made with each of the soil test extractions as related to relative yield in the absence of applied S or P.

Results
Sulfur soil extractions ranged from 3 to 18 mg S/kg in the resin, MCP and KCl40 extracts (Figure 1). Resin extracts were correlated with both MCP and KCl40 (Resin:MCP – R^2=0.76; Resin:KCl40 – R^2=0.65). Although MCP and KCl40 were not well correlated (MCP:KCl40 – R^2=0.34). In contrast resin P extractions ranged from 1 to 5 mg P/kg with the majority of values <3 mg P/kg, whilst Colwell ranged from 1 to 150 mg P/kg and Bray from 1 to 60 mg/kg. Correlations between extraction methods were only significant between Colwell and Bray (R^2 = 0.58).

Whilst 72% of the soils examined were S responsive (Figure 1), only 1 soil was not responsive to applied P fertilizer in this study (Figure 1). Hence it was not possible to use soil test values to effectively predict P response, as all soils were responsive to some extent.

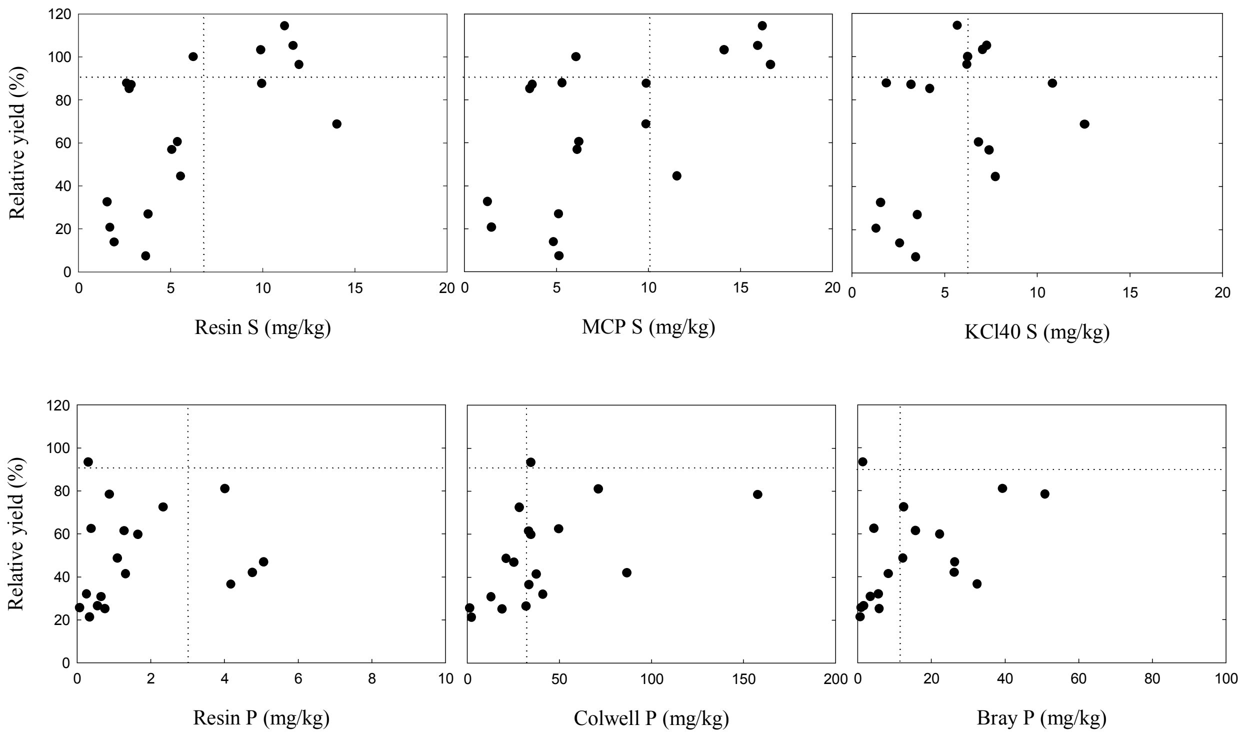

Figure 1 Relationship between soil test values and response of maize (*Zea mays*) plants to applied P or S fertilizer in 18 soils from the New England region of northern NSW, Australia. Known critical values were used to determine Cate-Nelson statistics for extractions other than resin extractions.

Critical S values were determined using Cate-Nelson plots and the predictive capacity of the critical values was compared using the proportion of false positive and false negative responses to fertilizer application (Table 1). There was no difference in the ability of the three soil S extractions to predict when soils would respond to applied S fertilizer (Table 1). However, more than half the soils predicted to be non-responsive according to the KCl40 extraction may have responded to fertilizer in this study.

Table 1. Critical values and predictive response to sulfur application as determined by Cate-Nelson plots for 18 soils from the New England region of northern NSW, Australia.

S test	Critical value (mg/kg)	% correct predictions when < critical value	% correct predictions when >critical value
Resin-S	7	92	67
MCP-S	10	92	80
KCL 40-S	6	89	44

Although soil P extracts were unable to detect significant differences in P response, tissue P concentrations linearly increased (R^2 = 0.24) in response to increasing available soil P reserves (Figure 2). A similar increase in tissue S concentration to increasing available S supply was also observed (R^2 = 0.39) (Figure 2).

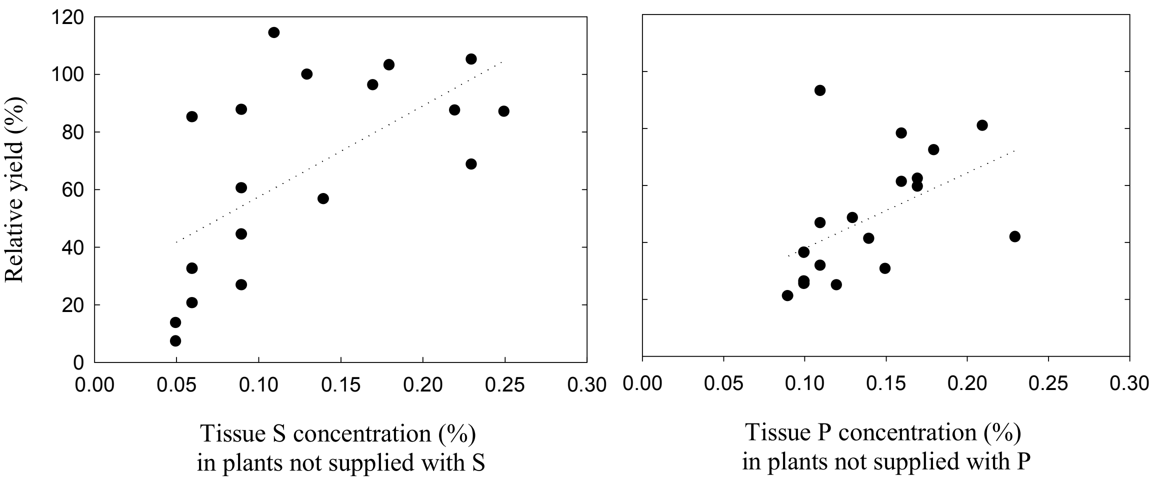

Figure 2. Tissue sulfur (S) and phosphorus (P) concentration in maize (*Zea mays*) plants in the absence of either P or S as related to the maximum yield grown in 18 diverse soils from the New England region of northern NSW, Australia.

Discussion

Extraction of soil S using resins did not significantly improve the predictive capacity to detect plant S responses over standard methods. Critical values determined for the MCP and KCl40 methods are in the range of those previously determined (Blair *et al.* 1991). This study therefore provides no support for changing standard soil S tests to the potentially more efficient P and S extraction using resins. The failure of the KCl40 test to accurately predict responsiveness above the critical soil test value in this study most likely relates to the short time frame of the study. KCl40 extractions typically sample a more representative fraction of available soil S, including that released through mineralisation of organic S compounds. Hence correlations are better over longer time frames. Over short incubation studies, it is often difficult to detect significant differences between methods that focus on inorganic S sources. Adequate tissue S concentrations for plants this age are >0.20% with one study citing a critical value for maize of 0.08% when grown in soil (Reuter and Robinson 1997). All plants in this study with less than 0.08% tissue S concentration were responsive to applied S.

It remains unclear why almost all soils examined in this study were responsive to applied P. In this study, more than one third of soils, according to soil test values and known predictive levels, were P unresponsive. Approximately 80% of soils in the New England were responsive to P in a study focussing on landholders who self-selected for soil nutrient advice. Explanations may involve i) conditions in the pot trial slowing the availability of native soil P; ii) conditions in the trial increasing the relative availability of applied fertiliser P; or; iii) interactions with other nutrients inducing P responsive conditions. Tissue concentrations for all other nutrients examined were in normal ranges, with no evidence of either toxic or deficient nutrient interactions likely, eliminating (iii), thus leaving either (i) or (ii) as potential options, or a combination of both. Adequate P concentrations are generally >0.22% tissue P for plants this age (Reuter and Robinson 1997), and all plants that were responsive to P and fell outside this range. This suggests that the release of P from native soil P pools was slower in this study than expected. No mechanism for this has yet been found.

Conclusion

Resin S and P extractions do not provide better predictive accuracy on soil S or P responsiveness in a wide range of New England soils.

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References

Anderson DL, Henderson LJ (1986) Sealed chamber digestion for plant nutrient analysis. *Agronomy Journal* **78**, 937-938.

Blair GJ, Chinoim N, Lefroy RDB, Anderson GC, Crocker GJ (1991) A soil sulphur test for pastures and crops. *Australian Journal of Soil Research* **29**, 619-626.

Bray RH, Kurtz LT (1945) Determination of total, organic, and available forms of phosphorus in soils. *Soil Science* **59**, 39-45.

Burkitt LL, Moody PW, Gourley CJP, Hannah MC (2002) A simple phosphorus buffering index for Australian soils. *Australian Journal of Soil Research* **40**, 497-513.

Colwell JD (1963) The estimation of the phosphorus fertiliser requirements of wheat in southern New South Wales by soil analysis. *Australian Journal of Experimental Agriculture and Animal Husbandry* **3**, 190-197.

Edwards C, Duncan M (2000) A review of 700 soil samples collected in the Armidale district between 1989-1999. In '15th Annual Conference of the Grassland Society' pp. 108-109.

Prochnow LI, Pismel FS, Cantarella H, Vitti GC, Corrente JE, Kiehl JC (1998) Use of ion-exchange resin to evaluate the bioavailability of sulfur in the soil. *Communications in Soil Science and Plant Analysis* **29**, 1833-1841.

Reuter DJ, Robinson BJ (1997) 'Plant Analysis: An Interpretation Manual.' (CSIRO: Collingwood).