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MANAGING SOILS FOR BETTER PASTURES:

REDUCING THE GUESS WORK - SOIL TESTING

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Abstract: *At present, soil testing is not a widespread management tool, but its use is likely to increase in the future as the cost:price squeeze intensifies and environmental concerns increase. Despite the large amount of research that has been conducted on phosphorus, soil testing for this nutrient is still not widely accepted. Conflicting research results are a cause of concern to end users. As increasing amounts of "high analysis", low S containing fertilisers enter the market, the need for a soil S test increases. The recently developed KCl-40 test has been found to correlate well with field and glasshouse response to S and is recommended for evaluation. Soil testing for K and trace elements in pastures is not well developed. Soil pH measurements need to be assessed together with measures of phytotoxic Al and Mn for soil acidity assessment to be properly made. The major pitfalls in soil testing are sampling method, timing and sampling depth. Monitor plot sampling is recommended. An interpretation matrix, which takes into account soil test, pasture condition and the management value of the paddock is presented to aid in fertiliser allocation around the property.*

INTRODUCTION

Soil testing is a long established procedure which is used to varying degrees in agriculture throughout the world. It is not used widely in Australia at present but will become increasingly important as the fertiliser cost: product price squeeze increases. In addition, increasing concerns about the contribution of agriculture to water eutrophication and the possibility of regulations concerning fertiliser use will force increased use of this management tool.

RELIABILITY OF SOIL TESTS

At the Soil Test Interpretation Symposium held at Dubbo in 1990, Doyle and Bacon indicated that an ideal soil test will tell:

1. whether or not availability of a particular nutrient in the soil will limit growth of a crop (subject to climatic or other constraints); and,
2. the amount of fertiliser required for optimum plant growth.

This definition is certainly "ideal". It is unrealistic for a soil test taken at a point in time to be used to predict crop yield and hence response in a non-irrigated crop in Australia. Such an expectation from soil tests has contributed to the general scepticism and doubts about soil testing. All that a soil test can tell you is,

1. how much of a particular nutrient is present in the soil at the time of sampling? and,
2. in some cases the amount of nutrient that may become available during the life of the crop or throughout the year in the case of a pasture.

This information has then to be incorporated into some form of model (intuitive, probability tables, dynamic computer) which takes into account climatic conditions and estimated production levels before fertiliser rates can be recommended.

PHOSPHORUS

The picture regarding P soil testing for pastures is confusing. McLachlan (1965) and Spencer *et al.* (1969) found that the sodium bicarbonate (Colwell) test was a satisfactory predictor of soil P levels for pastures. The critical level of 30 ppm found by McLachlan over 18 sites in one year was similar to the 26 ppm value reported by Spencer and Glendinning (1980) over 18 sites. Glasshouse studies conducted by the author on 26 soils of granitic, basaltic and sedimentary origin collected from throughout the Northern Tablelands established a critical level (90% of maximum yield) of 35 ppm, irrespective of parent material.

Recent studies by Holford and Crocker (1988) on 41 sites over a 5 year period conducted on acidic Northern Tablelands soils cast doubts on these earlier studies. A series of 6 extractants (Bray 1, Bray 2, alkaline fluoride, lactate, Olsen and Colwell) were compared. The results showed Bray 1 to be the most predictive and lactate the least predictive of soil P status. It is difficult to understand how the results for the Colwell extract, with an estimated critical level (at 85% maximum yield) of 51 ppm, could be so different from the earlier studies where the Colwell P critical level (at 90% of maximum yield) was in the range of 26-35 ppm, particularly when these earlier values are similar to the critical levels found in other parts of the world for this extractant.

Organic P is most often the dominant form in both the

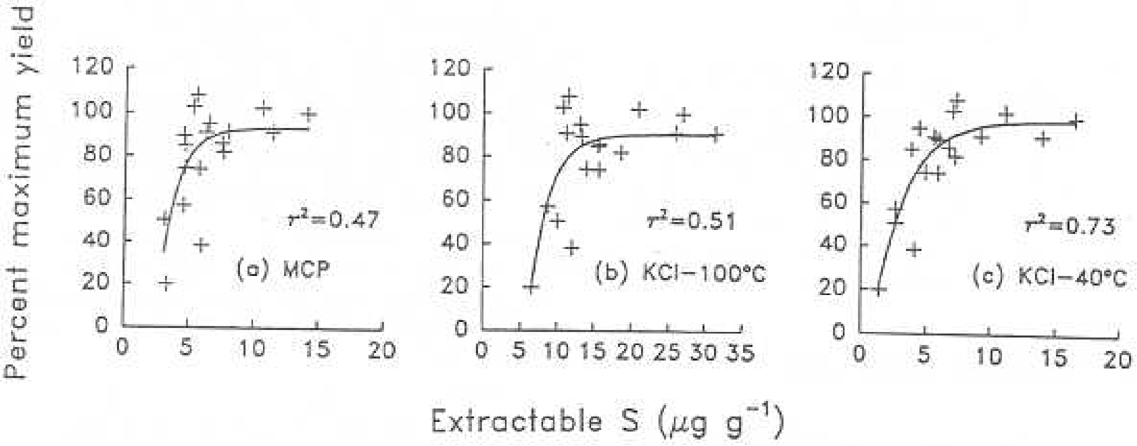

Figure 1: Relationship between per cent maximum dry matter yield of pasture and S extracted by *(a)* MCP, *(b)* KCl-100°C, and *(c)* KCl-40°C.

total soil and the soil solution and is a substantial contributor to plant P uptake once it has been mineralised. Extractants which remove some or all of this organic P, such as sodium bicarbonate, would be expected to correlate better with pasture response than those that extract predominantly inorganic forms such as Bray 1 and 2.

It appears that there is insufficient evidence of the superiority of other P tests for pastures over the Colwell extractant to justify a change. The discontinuity caused by changing soil tests would probably do more harm than the benefits from any alleged increase in precision.

SULPHUR

Soil organic matter (OM) provides an important source of plant available S, but only a fraction of the total organic S pool is involved in the cycling of S in a soil-plant-animal system (Till and May, 1971). The contribution of organic S to plant uptake is influenced by the nature of the soil OM and the activity of the soil microorganisms, which is controlled by the environmental conditions of soil temperature and moisture (Williams, 1967; Sorensen, 1981; Ladd *et al.*, 1985). Variation in these environmental conditions throughout the year result in soil inorganic S being higher in spring, summer and autumn than in winter (Barrow, 1966; Williams, 1968; Ghani *et al.*, 1990). These seasonal variations have important implications for the suitability of various extraction techniques to assess S availability in soils.

Table 1: Coefficient of determination (r^2) for the relationship between extractable sulfur and percentage of maximum yield in 18 pasture soils from northern New South Wales.

Sulphur extraction method	Coefficient of determination^A	Critical level^B
Water	0.45	8.4
0.01 M $Ca(H_2PO_4)_2$ (MCP)	0.47	7.1
0.5 M $NaHCO_3$	0.04^C	-
0.25 KCl heated at 100°C	0.51*	19.1
0.25 KCl heated at 80°C	0.54*	12.4
0.25 KCl heated at 40°C	0.73**	6.5
0.25 KCl heated at 25°C	0.30	6.6
0.25 KCl shaking for 16H at 25°C	0.48*	6.7

Notes

^{A} n = 18; ^{B} Soil S test level at Y = 90% maximum yield; ^{C} linear regression; * and ** significant at $P<0.05$ and $P<0.01$, respectively.

The study of the contribution of organic S to plant uptake has been limited by the analytical procedures used to measure S concentration in the soil solution extract. In general, the extractants used can be grouped according to the forms of S extracted. These are: (1) inorganic S; (2) inorganic S plus various amounts of organic S; and (3) total S. The division between groups (1) and (2) has often been misrepresented and group (1) may include a soluble organic fraction because of the method used to analyse the S concentration in solution.

The inorganic S in the extracted solution is commonly measured by pre-treating the solution to remove the soluble OM and measuring the S concentration by either the reduction, turbidimetric, or ICP-AES methods. If the OM is not removed from the solution and the S concentration in the solution is measured by the reduction, ICP-AES or turbidimetric (after evaporation and digestion) methods, the measured concentration represents the total S concentration in the solution.

The most common method used to extract and measure inorganic S in soil involves extraction with 0.01 M or a 500 ppm solution of mono-calcium phosphate with a solution ratio of 1:5 and a shaking time of 1 hour. The filtrate is then treated with charcoal to remove organic matter and analysed for S using the turbidimetric method. Although widely used, the method has been found to correlate poorly with field responses.

Our group at UNE has tackled this problem and developed a new soil S test based on extraction of the soil with 0.25 M KCl. The procedure involves heating 3 g of soil with 20 ml of 0.25 M KCl at 40°C for 3 hours, filtering and measuring total S in the extract (Blair *et al.*, 1991).

This extractant was originally tested against 7 others on 18 pasture sites from Northern NSW (Table 1) and found to be the most highly correlated with pasture response with a critical level (90% of maximum yield) of 6.5 ppm. The higher correlation coefficient for this extractant comes about because of a better prediction in the intermediate range of S levels (Figure 1).

Commercial soil testing laboratories have shown interest in assessing this extractant more widely.

POTASSIUM

Measurements of exchangeable K appear to be the best available to measure soil K status. In the soils of NSW, which have relatively low amounts of variable charge, the standard ammonium acetate or barium chloride methods suffice. Some laboratories measure K in the Colwell extract and this is related to exchangeable K. In other soils, with high amounts of variable charge, other extractants such as unbuffered silver acetate and ammonium acetate may be required.

TRACE ELEMENTS

The DTPA extractant is used widely in soil testing laboratories servicing NSW. Whilst this extractant has been found to correlate satisfactorily with crop response in some overseas studies, there is little verification data available for generally acidic pasture soils in Australia. Such tests should be used as indicators only.

ACIDITY

There is little doubt that pH measured in 0.01 M $CaCl_2$ more closely estimates the pH of the soil solution than measurement in water in the calcium dominated soils of NSW. As a generalisation, pH $CaCl_2$ + 0.7 units = pH H_2O. The change from water to $CaCl_2$ for the measurement of pH, and the resultant decease in measured pH, was introduced to soil testing laboratories without proper information to clients and caused undue anxiety to many producers.

As soils become more acid, ions such as aluminium and manganese became more available. A recent study by McLaughlin *et al.* (1990) has shown that Al measured in extractants such as sodium citrate-dithionite and acid oxalate solutions to be poor predictors of phytotoxic Al levels in soils whilst extractants such as 0.01 M $CaCl_2$ and 1M KCl to be satisfactory.

A pH measurement alone is not a satisfactory measure of the consequences of acidity but must be assessed together with measures of phytotoxic Al and Mn.

PITFALLS OF SOIL TESTING

There are many pitfalls in soil testing as follows:

- sampling method
- timing of sampling
- depth of sampling

Studies conducted by Friesen and Blair (1984) demonstrated that monitor plot sampling was more efficient for pasture soils than zigzag sampling. Monitor plots are particularly useful for monitoring changes in soil nutrient levels over time.

Samples should be taken as close to fertiliser application time as possible. If samples are taken too soon after application then they may be inflated by undissolved or incompletely reacted fertiliser materials.

Sampling pasture soils to a depth of 7.5 cm, as is practiced in NSW, is out of step with the rest of Australia where 10 cm is more common. This needs to be rectified so cross country comparisons can be made. Based on the sampling depth effect on N soil test results found by Taylor *et al.* (1988) and Holford and Doyle (1992) standardisation of 0-15 cm sampling depth should be considered.

Soil test levels can be markedly affected by sampling depth. In a study of 15 pasture soils McLaughlin *et al.* (1990) found marked depth gradients for pH, $CaCl_2$ extractable Al, Bray 1 P, oxidisable organic carbon and exchangeable Ca, Mg and K (Table 2).

If the soil is sampled to a shallow depth, such as when it is hard and dry, then inflated soil test values will be recorded.

INTERPRETATION

The soil test is just one piece of information in the fertiliser decision making process and should be treated so. More and more soil tests are being used, not to help decide whether or not to apply fertiliser to the whole property, but where on the farm can a limited amount of fertiliser be best applied for both short and long term benefit.

For P and S soil test interpretation the following scoring sheet is helpful in using the soil test data. The score for each question is multiplied together and paddocks with the highest score should have top priority for fertiliser application.

1. What is the soil test level in relation to the best estimate of critical level?

high	2
adequate	4
medium	6
low	8

2. What is the pasture condition?

native grass no legume	1
native grass with good legume	2
newly sown good stand	5
legume dominant	4
grass dominant	3
sown species/weed/native	2

Table 2: Variations with depth in nutrient status of top dressed pasture soils from S.E. Australia (McLaughlin *et al.*, 1990).

Soil depth (cm)	pH_{Ca}^{A}	Bray 1-P^A (mg.kg)	Al_{Ca}^{A} (mg/kg)	OC^{B+} (%)	Exchangeable cations		
					Ca	Mg (cmol$_c$/kg)^B	K
0-2	4.56a^C	44.8a	4.0a	6.6a	6.8a	1.6a	0.6a
2-4	4.20b	15.9b	14.3b	4.4b	3.2b	0.7b	0.4b
4-6	4.16b	11.3c	17.9c	3.1c	1.9c	0.5c	0.3c
6-10	4.17b	8.2d	18.2c	1.8d^D	1.3d	0.3d^D	0.2d^D
0-10	4.19	13.3	13.7	3.1e	2.5	0.5	0.3

Notes

^{A} mean of 15 sites; ^{B} mean of 4 sites; ^{C} means within a column followed by the same letter are not significantly different at $P<0.05$; ^{D} arithmetic mean of 6-8 and 8-10 depths.

3. What is the management value of the paddock? Is it in a key location where it aids in stock management *ie*. near yards, shed, can stock be moved easily from this paddock to a series of other locations.

low	1
medium	2
high	3

Once the priorities have been allocated the paddocks to receive fertiliser and the amount to be applied should be decided on the basis of available finance.

Such decisions are most important in good income years where they have a marked bearing on the ability to produce quality products in the next financial trough.

TISSUE TESTING VERSUS SOIL TESTING

Tissue testing indicates the current nutrient status of the plant and cannot indicate what nutrient deficiencies are likely to occur in the future. They, like soil tests, are most helpful in planning ahead rather than correcting deficiencies that exist now.

Because of the variable mobility of nutrients in plants it is important to select the appropriate leaf tissue for analysis. For micronutrients in legumes the youngest fully expanded leaf is a common sampling tissue. The only problem is such tissues are often difficult to collect in grazed pastures.

Tissue samples have most to offer for micronutrient analyses where relatively good standards have been established and where soil test calibrations for pastures are not well established. They can also be very useful in areas where a portion of a paddock or the farm is not performing up to expectations. By collecting samples of the same species, at the same physiological age, from areas which are performing differently a comparison of nutrient levels between the two samples can be made to identify if nutrients are responsible for the problem. This procedure does not rely on good external standards.

NEW DEVELOPMENTS IN SOIL TESTING

The introduction of Inductively Coupled Plasma (ICP) analytical equipment into laboratories has increased the capacity to undertake multi-element analyses. Unfortunately soil extraction techniques have not kept pace with this development.

The Mehlich (1983) extractant developed in the USA is an attempt to develop a universal extractant, but to our knowledge it has not been assessed on Australian pasture soils.

Peter Sale and his colleagues at La Trobe University are evaluating a resin extraction technique to measure all nutrients in the soil solution. Because of the inability of this procedure to measure nutrients potentially mineralisable from organic matter there are reservations about its diagnostic efficacy. This perhaps could be over come by pre-treating the sample to stimulate mineralisation

Peter Vickery and his colleagues at CSIRO continue to work on remote sensing techniques to assess nutrient status. Developments have been made in selecting wave bands to identify particular nutrient problems for particular species. The resolution of satellite pictures for use in high rainfall areas, where most fertilisers are used, is still inadequate for individual paddock fertiliser decisions to be made. Hopefully this will improve in the future.

Numerous computer programs have been developed to aid fertiliser decision making (DECIDE, FARMAID, SUPERATE). These have not met with widespread acceptance. Future developments will most likely include a more mechanistic approach to modelling where climatic risk can be factored into the model. This, together with the inclusion of a series of product price scenarios, will enable a better estimate of the likely short and long term benefits to be estimated and these weighed against the cost of fertilisers.

One thing that is certain is that farmers terms of trade will continue to decline in the foreseeable future, so fertiliser decision making is going to become more, not less difficult. The establishment of a series of monitor plots on properties and the introduction of regular and systematic soil testing programs and their recording in readily accessible forms, using computers, will greatly assist in fertiliser decision making. When matched with better paddock performance records, producers will be better able to target inputs to the most productive areas of the property and to develop new areas in the most appropriate ways. This may include planting substantial areas of second grade land to productive tree species for profit and/or conservation.

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