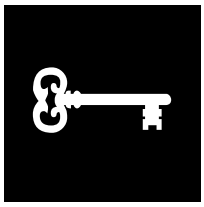
Section

4

4. Diagnostics

4.1 Understanding Soil Tests



Key Learning Objectives

After studying this section you should be able to:

1. Describe the concepts of soil testing to determine soil nutrient status.

2. Describe procedures that can be used to decrease the field variability of soil testing.

3. Explain why soil tests need calibration and how this is done.

4. Discuss the general limitations of soil tests as diagnostic aids and the factors influencing the accuracy of calibration curves.

5. Explain why an information-set wider than a single soil test should be used to decide on fertiliser P and K application rates.

Introduction

In addition to their role as indicators of nutrient availability in soils, soil test results are used directly to estimate the capital amounts of fertiliser P and K that are required to raise crop or pasture productivity to a target or optimum level. In some scenarios, natural variation (even as low as 10 to 20%) in the soil test result can create large (two fold differences) in the amounts of fertiliser recommended by decision support software. There is the risk that those unaware of these natural variations may recommend the application of unnecessary and even excessive amounts of P and K. In this section we first refresh your knowledge of the concepts of soil testing and then outline the factors that cause variations in test values and their interpretation.

Background

Soil testing is one of the main methods used to assist in determining soil fertility in agricultural and horticultural production systems. Soil testing and plant analysis, when coupled with field trials measuring plant yield responses to fertiliser, provide methodologies by which the amount of fertiliser required to raise the fertility and crop yield of a paddock can be estimated. In this section you will study the basis of most of the common soil tests used and learn how to use them correctly. Some of the associated problems and limitations are also covered. This section concerns field and laboratory procedures for carrying out soil testing.

General Concepts and common tests

Field trials to determine the plant growth response to increasing rates of fertiliser applications are a direct method of determining the fertiliser requirement of crops. Unfortunately such trials are costly and time-consuming and the results obtained are site-specific.

When such trials are conducted, 'added value' can be obtained if relationships can be established between soil test values, indicating the nutrient status of the soil, and crop yield. These relationships can be extrapolated to other sites where soils and climates are similar.

Commonly, soil test information is used with other information or expert systems (e.g. Overseer®) to help calculate fertiliser requirements (Figure 4.1.1). Recent developments in fertiliser recommendations tend to rely heavily on accurate soil test information.

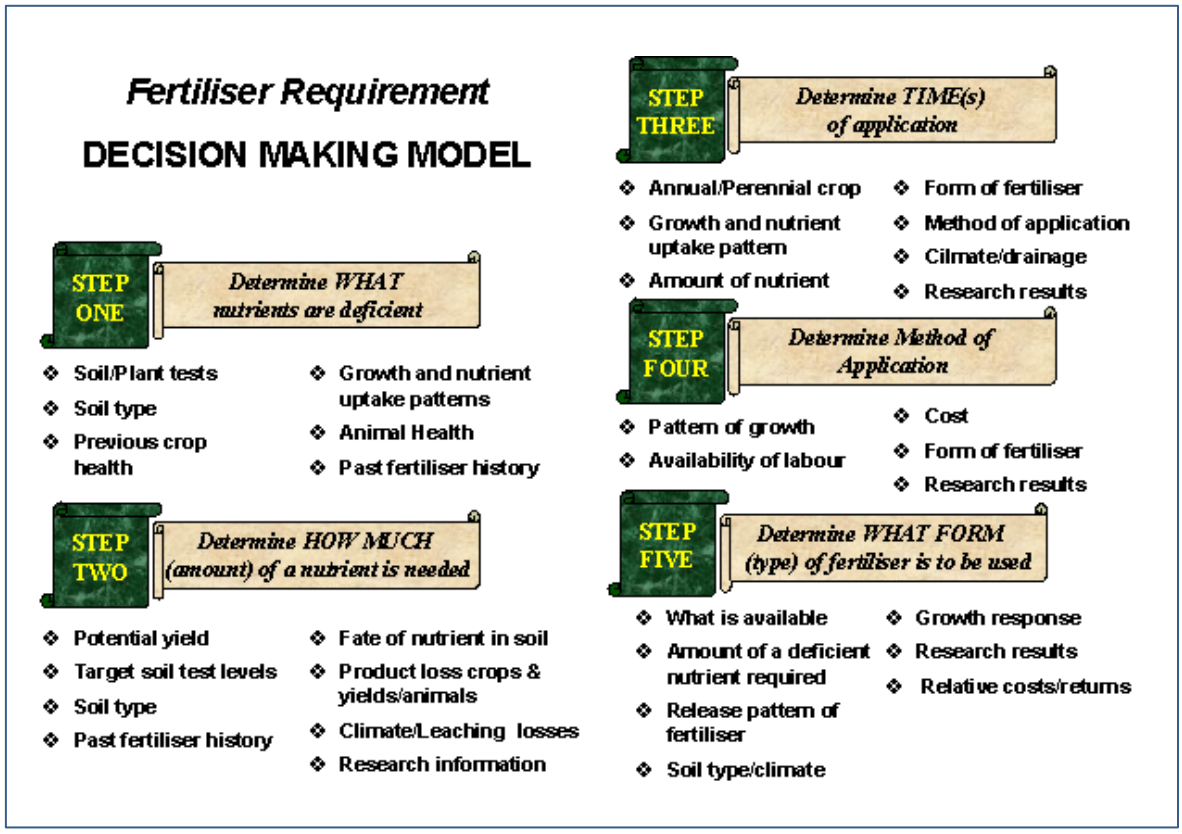


Figure 4.1.1 A decision-making tree for the inclusion of soil test and other information in a fertiliser recommendation

SOIL EXTRACTION TESTS

Definition: "A soil test is an analysis (usually chemical) performed on an air-dried sample of soil to provide information on the availability of plant nutrients in that soil". Soil chemists have attempted to develop tests that will extract the parts and amounts of soil nutrient pools that are plant available (Figure 4.1.2).

So far, soil chemists have not been able to develop chemical assays performed in the laboratory that directly simulate nutrient uptake by plants. What has been developed is a series of soil tests that extract amounts of nutrients from soils that are well correlated with the amounts of nutrient that can be taken up by crop plants. Considerable research has been required to select and standardise appropriate soil testing methods, including:

- appropriate soil sampling depths,
- suitable chemical extractants,
- extraction procedures,
- calibrations of the test results with crop yield responses to changes in a single nutrient factor.

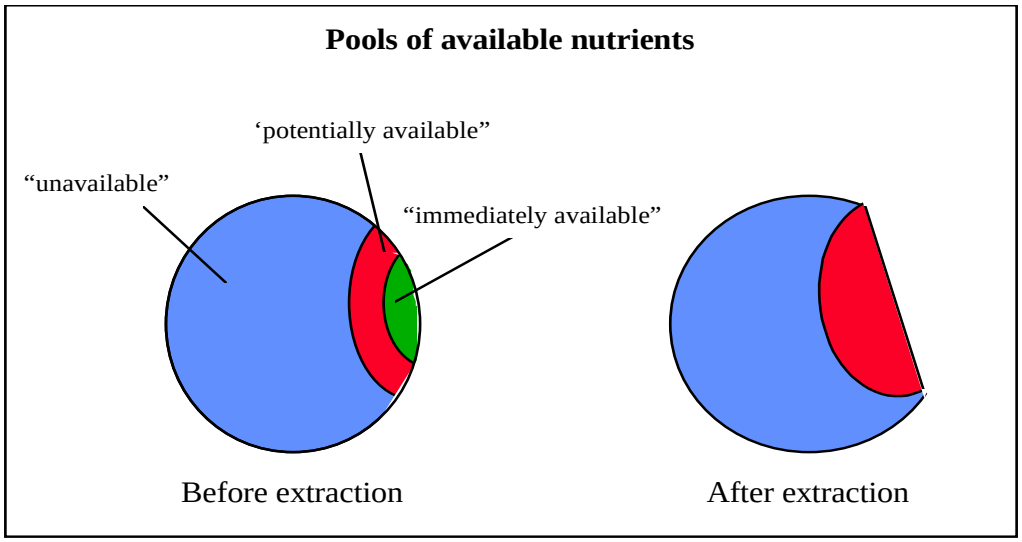


Figure 4.1.2 The concept of nutrient pools in soils being classified into unavailable or non-labile (organic forms resistant to decomposition or insoluble minerals), potentially available or labile (organic forms easily decomposed, sparingly soluble minerals) and immediately available (readily exchangeable, desorbable or already in soil solution).

Soil tests are used to provide some of the information needed to determine:

- the current soil nutrient status.
- the trend in soil nutrient status, or soil chemical characteristics over time.
- which nutrients, or soil chemical characteristics, are limiting plant growth.
- the quantity of fertiliser required to raise the nutrient status to near optimum for plant growth.
- Soil quality status.

Common and some less frequently used soil tests in New Zealand are listed in Table 4.1.1 and Table 4.1.2, respectively.

Table 4.1.1 Commonly used soil tests in New Zealand

Test name	Extracting reagent	Measures
Olsen P	0.5 M $NaHCO_3$ at pH 8.5 (soil:soln, 1:20, 30 min)	Phosphate in soil solution, small amount of P which is adsorbed on Fe and Al oxides and a small amount of organic P
Resin P	Anion and cation resin exchange membranes (soil:soln, 1:30, 16hr)	the above plus a small amount of calcium bound P in limed soils and RPR treated soils.
Extractable Sulphate	0.01M $Ca(H_2PO_4)_2$ (soil:soln, 1:5, 30 min)	Sulphate adsorbed on Fe and Al oxides
Extractable Organic Sulphur	0.01M $Ca(H_2PO_4)_2$ (soil:soln, 1:5, 30 min)	Soluble organic S
Exchangeable Cations Ca^{2+}, K^+, Mg^{2+}, Na^+,	1M NH_4CH_3COO at pH 7 leaching (soil:soln, 1:50, 1hr)	Cations on organic matter and clay surfaces
Soil pH	Water (soil:soln, 1:2.5, overnight)	hydrogen ions
Phosphate retention (anion storage capacity)	1000 ppm P in acetate buffer pH 4.65(soil:soln, 1:5, 16hr)	Storage of phosphate through adsorption onto soil surfaces

Table 4.1.2 Infrequently used soil tests in New Zealand

Soil Test (reference)	Extracting reagent	Nutrient extracted
Bray1 (Bray and Kurtz, 1945)	0.03 M Ammonium fluoride plus 0.025 M Hydrochloric acid (pH 3, soil:soln, 1:7, 1 min)	Phosphate adsorbed on Fe and Al oxides plus a small amount of acid soluble P (care with RPR fertilised soils)
Bray2 (Bray and Kurtz, 1945)	0.03 M Ammonium fluoride plus 0.1 M Hydrochloric acid (pH 1, soil:soln, 1:7, 40 secs)	Phosphate adsorbed on Fe and Al oxides plus slightly greater amounts of acid soluble P (care with RPR fertilised soils)
Colwell (Colwell, 1963)	0.5 M $NaHCO_3$ at pH 8.5 (soil:soln, 1:20, 16 hr)	Phosphate in soil solution, large amount of phosphate adsorbed on Fe and Al oxides plus a small amount of organic P (used in Australia as an alternative to Olsen P, extracts more P than Olsen and optimum value varies based on soil ASC)
Mehlich-3 (Mehlich, 1984)	0.2 M CH_3COOH, 0.25 M NH_4NO_3, 0.015 M NH_4F, 0.013 M HNO_3 and 0.001 M EDTA	Potentially a multi-element extraction for anions and cations (care with RPR fertilised soils)
Mineralisable N (Keeney, (1982).	(soil:soln, 1:4, anaerobic incubation for 15 days, then extraction soil:soln, 1:6, 1M KCl, 20 min)	Decomposes readily degradable organic matter, N released stays as NH_4^+ in anaerobic conditions

Soil test variation

Question:
Why don't soil test values always reflect a major change in fertiliser practice?

The short answer:
The reasons are normally two fold. Firstly, if the resample is not taken from exactly the same spot and depth then the large natural, spatial variation in soil extractable nutrient content could be the reason. Secondly, the amounts of nutrient extracted from soils in soil tests are small (1-5%) compared to the total amount of nutrient contained in soil minerals and soil organic matter. Small changes in soil pH or organic matter turnover may influence some soil test values, particularly P and S. Of course there are many other factors that also need to be considered when taking soil samples so that the results will have less variation over time. These are considered in the discussion below:

CAUSES OF SOIL TEST VARIATION

The long answer:
The largest errors in soil test values are associated with soil variability and sampling technique. Designing appropriate paddock soil sampling techniques requires a detailed knowledge of the effects of soil parent materials, soil forming processes, landscape and farming system (see section 2) on the distribution of extractable soil nutrient with respect to the crop rooting zone, timing of the previous fertiliser application and placement of future applications.

Understanding how variation can occur leads to the design of field sampling techniques that reduce soil sample variance. The two types of variation that influence soil test results are:

- **Differences across the land ("spatial variation")**
  Causes of spatial variation are; changes in soil type, slope, drainage characteristics, variation in topsoil depth and changes to the soil caused by previous fertiliser history, uneven fertiliser spreading, patches of dung and urine, and animal camping behaviour with respect to slope, shelter and water bodies.

- **Differences over time ("temporal variation")**
  Causes of temporal variation are; changes in soil moisture and temperature, which affect microbial decomposition activity in the soil, stage of plant growth, recent heavy rainfall (sulphate leaching), the length of time since the last fertiliser application and changes in soil management. Temporal variability may contribute as much as 20% of the overall variability.

REDUCING THE IMPACT OF SOIL TEST VARIATIONS

Research by Baird et al. (1995) has developed a soil sampling technique to remove some of the spatial variability in soil sampling hill country pastures. This same technique should be applied to rolling and flat land.

a) Select areas within each block (uniform management)

These areas will usually be in a single paddock that has had uniform management. The area must be representative of the normal management pattern of a block. For example, areas of the farm used for effluent application, grazing of young stock, cutting hay and silage and dairy grazing should be sampled separately as their soil nutrient concentrations are likely to be influenced by management.

b) Remove soil type and land management variation (spatial)

You should examine the landscape paying close attention to soil forming features, slope, streams and stage of pasture development. Divide the farm into blocks with similar soil types and previous fertiliser use and farm management. An example is given in Figure 4.1.3. See Section 2 for more detail.

Figure 4.1.3 A Waikato hill country landscape.

Within the landscape in the picture above are Brown soils (Yellow-brown earths) and Allophanic soils (Yellow-brown loams) that have marked differences in anion retention capacity, which influences the accumulation of sulphate (Table 4.1.3, Figure 4.1.4) and phosphate (Figure 4.1.5) in the soil profile and the quantity of P fertiliser required to raise soil P status.

Importance of soil sampling depth

The first point to note is that we must sample soil depth accurately in each soil because variations in core depth will have some influence on the soil test result (Table 4.1.3, Figures 4.1.4 and 4.1.5).

Differences in soil test values caused by variation in soil core depth between 5 and 9 cm are relatively small for sulphate on these soils. However, soil cores taken to 15 cm depths (crop sampling depth), will return much higher average sulphate values than those sampled to 7.5 cm (pasture sampling depth), especially for the Allophanic soil (Table 4.1.3). This is because of the large pools of extractable sulphate adsorbed to Fe and Al hydrous-oxides at depths below the main pasture root zone. These trends do not occur in all soils. For example, in Pallic soils (Yellow-grey earths) it is more common to find lower sulphate values below the root zone because the soils ability to adsorb sulphate is poor (Figure 4.1.3).

Where P fertiliser is surface applied, shallower samples will generally result in higher Olsen P concentrations measured due the concentration of P near the surface of the soil (Figure 4.1.5 and 4.1.6), as P is readily adsorbed to Fe and Al hydrous-oxides in the surface soil.

Table 4.1.3 Effect of soil core depth on extractable sulphate levels (mg s/kg soil)

Soil core depth (cm)	Well fertilised Allophanic Soil	Well fertilised Brown Soil	Pallic Soil
7.5	40	10	12
15	76	18	8

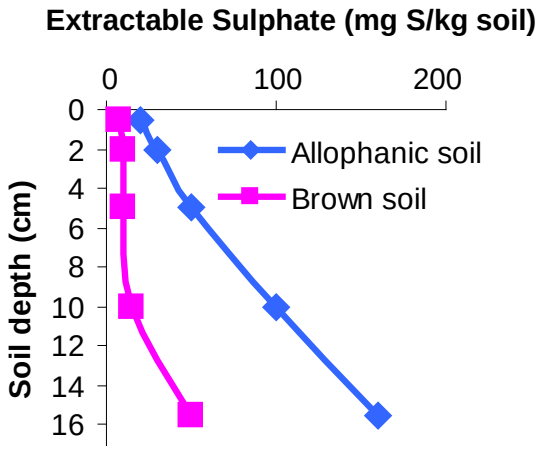


Figure 4.1.4 Changes in extractable soil sulphate with soil depth in a well fertilised paddock containing Brown and Allophanic Soils.

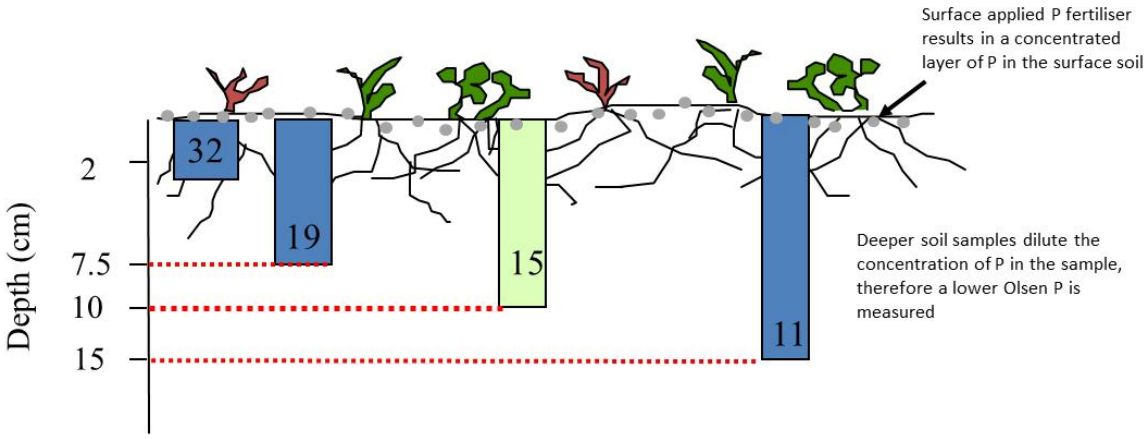


Figure 4.1.5 Effect of soil sampling depth on the Olsen P concentration (mg P/kg soil) measured. Adapted from Fertilising Dairy pastures, Target10 Victoria, Australia.

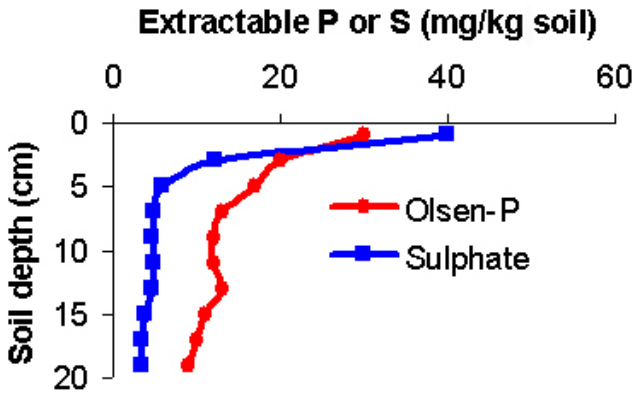


Figure 4.1.6 Variations in soil test values with depth in a Pallic Soil

In contrast, the differences in extractable sulphate between the Allophanic and Brown Soils (Figure 4.1.4) are largely due to the high sulphate sorption capacity of the Allophanic Soil. It is important therefore to keep the two soil types separate using two separate soil sampling transects. In Figure 4.1.7 we identify where the soil types are in the landscape.

Figure 4.1.7 The soils in the landscape and the positioning of transects.

The Allophanic soils, with very high sulphate sorption capacity have formed on the crests of the gently rolling hill that have retained the old volcanic ash showers. Ash from the slopes has been eroded exposing parent materials derived from sedimentary rocks. These materials have weathered to form the Brown Soils with medium sulphate sorption capacity. Once we superimpose the position of the soils in the landscape we can see what difference the alignment of soil sampling transects can make to the result (Table 4.1.4). In most landscapes there is less variability in soil characteristic across slope rather than down slope, thus transects are best placed across slopes.

Table 4.1.4 The effect of soil type on extractable soil sulphate values

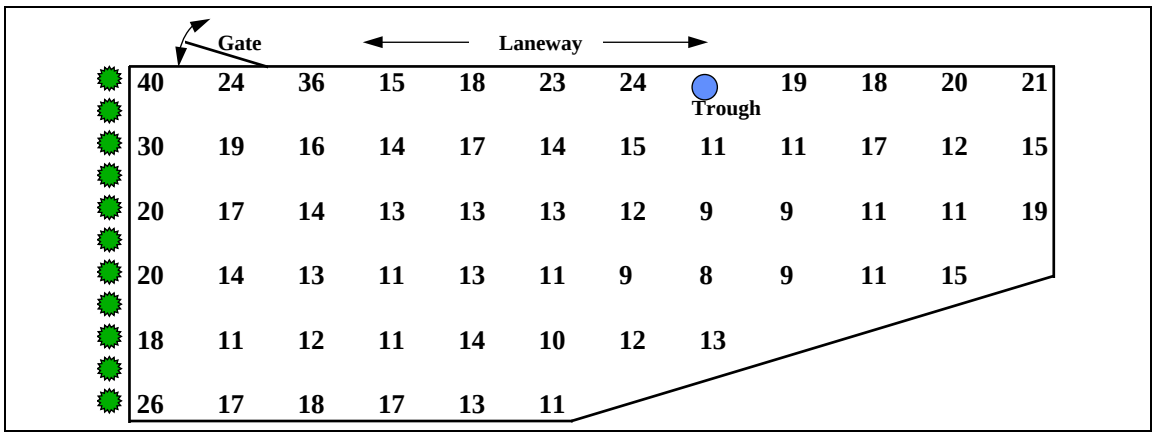
Numbers of cores from Allophanic soil in transect sample	Representative of transect in Figure 3.1.7	Extractable sulphate values (mg S/kg soil)
0	A	10
1		13
2		16
3	B	19
4		22
5		25
6	C	28
7		31
8		34
9		37
10	D	40

c) Avoid dung and urine patches and use the transect system to reduce the resample error (temporal error).

When soil test results are to be used to judge the impact of fertiliser application or a land management change on soil fertility status, then both spatial and temporal variability in soil test values must be minimised if the soil test values are to reflect significant change.

Importance of avoiding elevated nutrient areas

A wide variation in soil nutrient concentrations can exist within paddocks due to uneven dung and urine deposition in areas of the paddocks where animals congregate. Figure 4.1.8 shows the variation of Olsen P concentrations within one paddock that was soil tested using an intensive grid technique, with 20 samples taken randomly around each grid point. Each number in the figure indicates a grid point and the Olsen P concentration around that grid point. The Olsen P concentrations measured ranged from 8 to 40 mg/kg.



Source: Fertilising Dairy pastures manual, Target10 Victoria, Australia

Figure 4.1.8 Variation in Olsen P concentration (mg/kg) within one paddock.

Obviously recent urine and dung spots and stock camping sites are hot spots of available nutrients. The effect of including recent urine spots has a marked effect on soil pH, exchangeable K and extractable sulphate values in soil tests. For example, a two-day-old urine spot may have raised soil pH to 7-9, whereas in moist soil after one or two weeks the pH may have dropped to 5-5.5. Also, exchangeable K values may be as high as 3 meq K/100 g soil in the first 6 weeks after cattle urination.

At least three months must have elapsed since the last fertiliser or lime was applied. This is because recently applied fertiliser can have large effects on test results. This recommendation is in line with research by McDowell et al. (2003) who found that readily extractable P (measured by surface P runoff) returned to base line levels approximately 100 days after P fertiliser application.

If care is taken to avoid obvious stock campsites, recent urine and dung patches and if the resampling is conducted at approximately the same time of year at a similar soil

temperatures and soil moisture content, then much of the variability in soil tests within a soil type (within a transect) can be reduced.

Soil sampling guidelines

1. Select a long, straight sampling line ("transect") across each of the chosen areas. In hill country, this should be on the areas contributing to the most pasture production. Commonly, these are the mid-slope areas on easy and steep hill country.
2. Sample at a similar time of the year, each year to ensure soil temperatures and moisture contents are similar between years. Avoid very wet or very dry periods of the year.
3. Avoid all dung and urine patches, tracks, gateways, headlands, trees, hedges, water troughs and stock camps. Avoid sampling within 3 months of fertiliser application, excluding nitrogen fertiliser application (i.e. urea).
4. Take up to 20 core samples, evenly spaced, per transect, using a clean soil coring device or auger. Each core must be 7.5 cm deep for pasture soils and 15 cm for arable soils – throw away any short cores. Bulk the samples from each transect and place samples in an airtight, clearly labelled bag. Keep the sample as cool as possible (do not leave in the direct sun) and send it to the laboratory to arrive within 48 hours of sampling.
5. If the terrain is not suitable for one long transect, use two shorter transects and bulk the samples together.
6. Select an accurate and reliable laboratory which is accredited for the soil tests you are undertaking and use this same laboratory over time (see below).
7. Mark each end of the transect line permanently with a spring-loaded fibreglass rod or apply paint to fence posts. A survey peg in the ground at each end is a good back-up marker. Record the location of the transect markers on a farm map and take a GPS reference at each end of the transect, if possible. In addition:
    - Note the paddocks used for each block
    - Draw in the approximate transect lines across the paddocks
    - Note any obvious features near the end pegs (trees, power lines, etc.)

For further information see DairyNZ Factsheet 7-3 Soil testing.
http://www.dairynz.co.nz/file/fileid/44080

ALL PADDOCK SOIL SAMPLING

On intensive dairy farms, where variation between soil types is minimal, the use of all paddock soil testing can be a useful approach to determine the 'between paddock' variability in soil test results and to allow more targeted nutrient management. Where paddock management has varied in the past, soil test differences between individual paddocks can be large and this variation can be missed when management areas are sampled as one block. Figure 4.1.9 illustrates the type of fertiliser recommendation which may result from block sampling several management units, with yellow colours indicating a healthy nutrient status requiring a maintenance-only application, and red colours indicating soil nutrient levels that are excessively high, and orange colours falling in between.

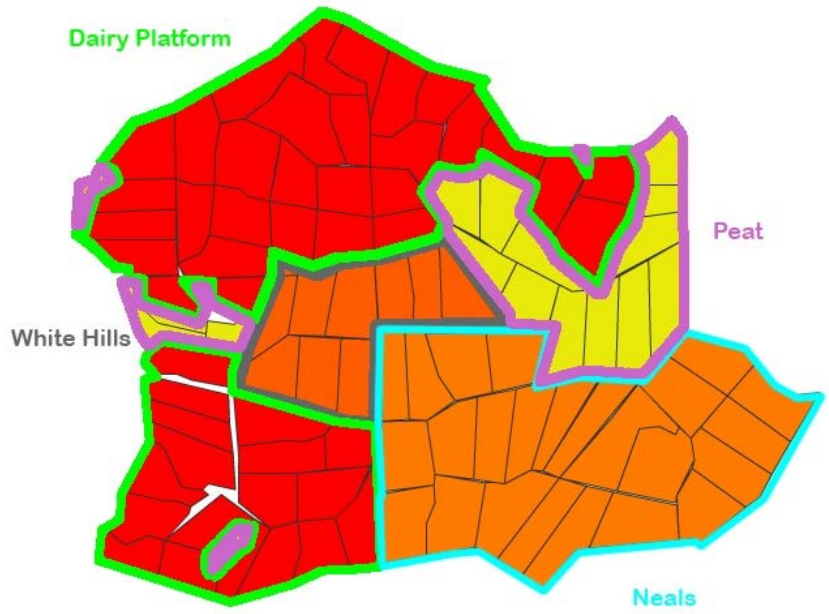


Figure 4.1.9 Example of the likely fertiliser recommendations from using a block soil sampling approach. Yellow: optimum nutrient status requiring a maintenance only application, Red: excessively high and Orange: medium fertility (Courtesy of Hill Laboratories).

When every paddock on a farm is soil sampled, fertiliser recommendations can be tailored to individual paddock requirements (Figure 4.1.10). In some situations, this approach can save considerable amounts of money and can potentially improve pasture production (where individual paddock nutrient levels were low) and reduce the risk of nutrient loss to the environment (where individual paddock nutrient levels were high). However, it is important to weigh up the costs involved with sampling and the potential savings, before all paddock soil sampling is used.

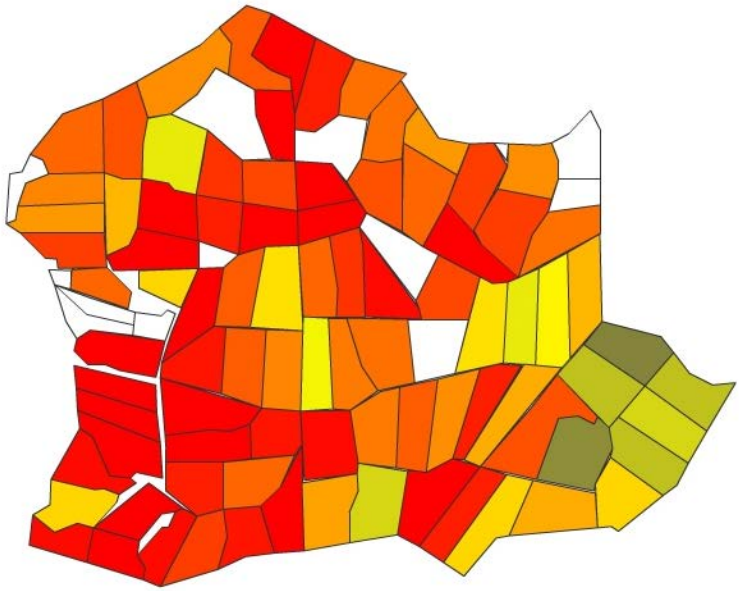


Figure 4.1.10 Example of the nutrient requirements of individual paddocks, after an all paddock soil sampling approach was used. Green: below optimum, Yellow: optimum nutrient status requiring a maintenance only application, Red: excessively high and Orange: medium fertility (Courtesy of Hill Laboratories).

Selecting good soil testing laboratories

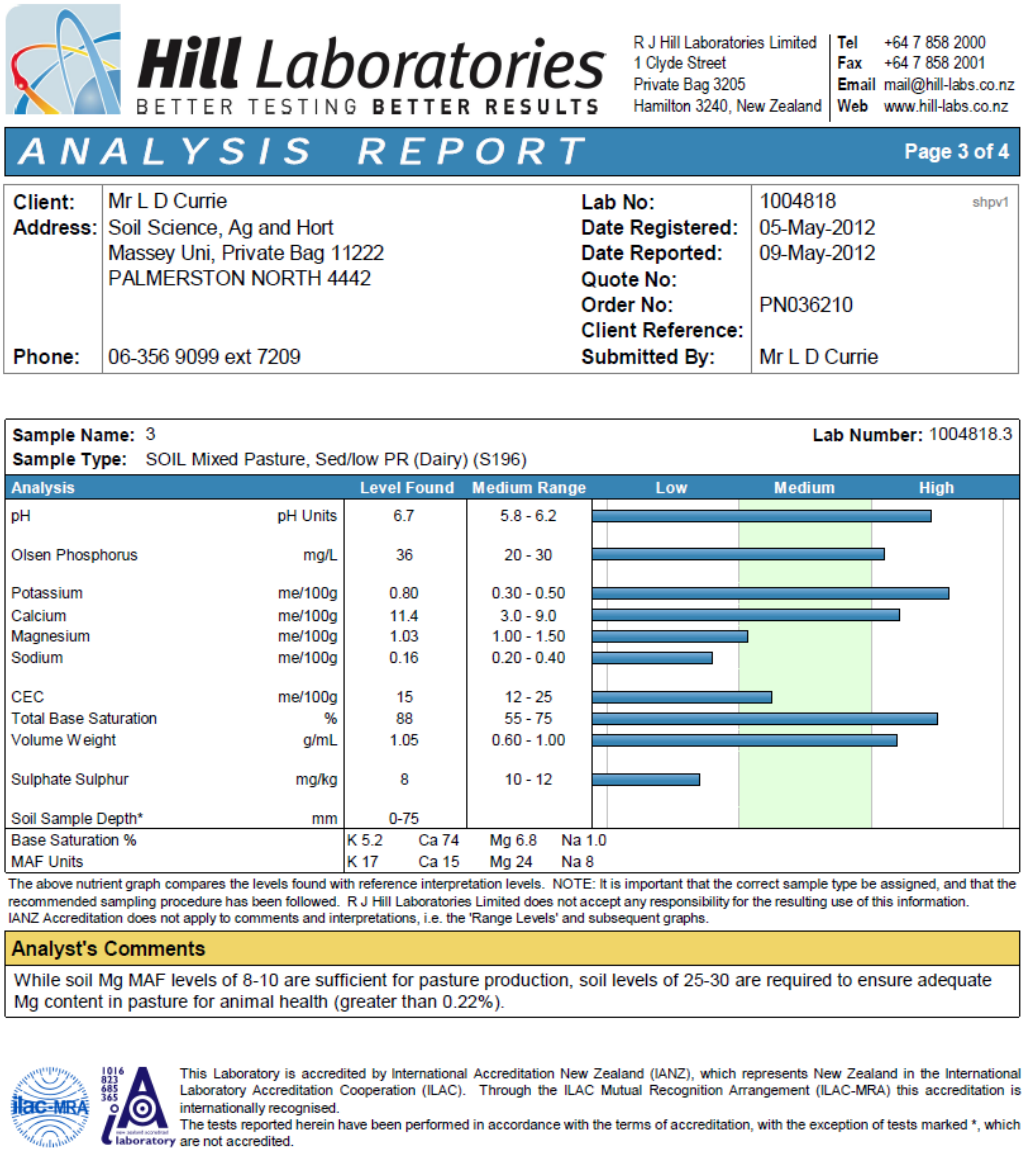
Additional soil test variation can occur due to the laboratory testing process itself, so it is important to carefully select a reliable soil testing laboratory and continue to use the same laboratory over time. Even if the best standards are followed, soil test results will always vary from laboratory to laboratory, so using the same laboratory reduces this variation. There are a number of testing accreditation programs operating in New Zealand which assess the accuracy of soil and plant testing programs and can be used to help identify reliable laboratories.

Laboratory accreditation

There are only a small number of soil testing laboratories in New Zealand and most of the major laboratories are accredited through the International Accreditation New Zealand (IANZ) scheme, which accredits individual soil testing methods (i.e. the Olsen P test). The Certificate of Accreditation can be downloaded for individual laboratories from the IANZ website (www.ianz.govt.nz/directory) and these certificates specify the individual soil and plant testing methods that the laboratory is accredited for. Most of the major New Zealand laboratories participate in the New Zealand Soil Round Robin Proficiency series which is co-ordinated by Massey University. This proficiency series assesses the accuracy each laboratory analyses a single soil sample and the results from this testing that are fed back to the laboratories to aid improvement. In addition, some of the major New Zealand laboratories participate in the Australasian Soil and Plant Analysis Council (ASPAC) proficiency testing, which assesses the accuracy that each laboratory analyses a single Australasian soil sample. The ASPAC website (www.aspac-australasia.com) lists the laboratories which participate in the proficiency program and also which individual soil and plant methods the laboratories have gained proficiency in.

TRANSECTS AND HERBAGE SAMPLES

The same soil sampling transects can be used for herbage samples (see section 4.2 for further detail). When inputting herbage nutrient concentrations to Overseer®, it is recommended that a minimum of 6 well-spaced measurements be taken over a period of 4 years or more, in order to achieve meaningful results. Molybdenum measurements should be done on clover in summer.



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ANALYSIS REPORT — Page 3 of 4

Client:	Mr L D Currie	**Lab No:**	1004818	shpv1
Address:	Soil Science, Ag and Hort Massey Uni, Private Bag 11222 PALMERSTON NORTH 4442	**Date Registered:** **Date Reported:** **Quote No:** **Order No:** **Client Reference:**	05-May-2012 09-May-2012 PN036210	
Phone:	06-356 9099 ext 7209	**Submitted By:**	Mr L D Currie	

Sample Name: 3 — **Lab Number:** 1004818.3
Sample Type: SOIL Mixed Pasture, Sed/low PR (Dairy) (S196)

Analysis		Level Found	Medium Range
pH	pH Units	6.7	5.8 - 6.2
Olsen Phosphorus	mg/L	36	20 - 30
Potassium	me/100g	0.80	0.30 - 0.50
Calcium	me/100g	11.4	3.0 - 9.0
Magnesium	me/100g	1.03	1.00 - 1.50
Sodium	me/100g	0.16	0.20 - 0.40
CEC	me/100g	15	12 - 25
Total Base Saturation	%	88	55 - 75
Volume Weight	g/mL	1.05	0.60 - 1.00
Sulphate Sulphur	mg/kg	8	10 - 12
Soil Sample Depth*	mm	0-75	
Base Saturation %		K 5.2 Ca 74 Mg 6.8 Na 1.0	
MAF Units		K 17 Ca 15 Mg 24 Na 8	

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

Analyst's Comments

While soil Mg MAF levels of 8-10 are sufficient for pasture production, soil levels of 25-30 are required to ensure adequate Mg content in pasture for animal health (greater than 0.22%).

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Figure 4.1.11 An example of a standard soil test report for a dairy pasture soil (Courtesy of Hill Laboratories).

The Use of Soil Test Calibration Curves in Fertiliser Recommendations

INTRODUCTION

In this section we cover the two types of soil test calibration, firstly the calibration of the soil test values against plant yield and secondly the calibration of rates of fertiliser application against a change in soil test value.

The diagnostic value of a soil test is related to the way in which it has been correlated (calibrated) to a measure of plant or animal productivity. Soil test methods which have not been calibrated for New Zealand soil and climate conditions and the pasture/crop of interest should be avoided as the result they generate cannot be related to anything meaningful. The use of the traditional and well established soil testing methods is recommended as these methods have been extensively calibrated and have been tried and tested over time.

You will be familiar with the way analytical laboratories report soil test results along with interpretive information (see example in Figure 4.1.11). It is important to take care with laboratory soil test interpretation information, as the laboratory is only able to report on the information it receives and it is useful to cross reference the interpretation with a knowledgeable, local source which is familiar with the soil types, pasture/crop requirements and climate of the area in question.

Also, you will be familiar with the 'normalised' national average response curves used to represent relationships between soil test values and relative yield (see examples in Figure 4.1.12).

Sensible interpretations of soil test values require an understanding of how the normalised curves are developed and the errors involved in their direct interpretation. In this section, soil tests for phosphorus are used as examples to explain how calibration curves are developed and to explain why 'national average curves' need care in interpretation.

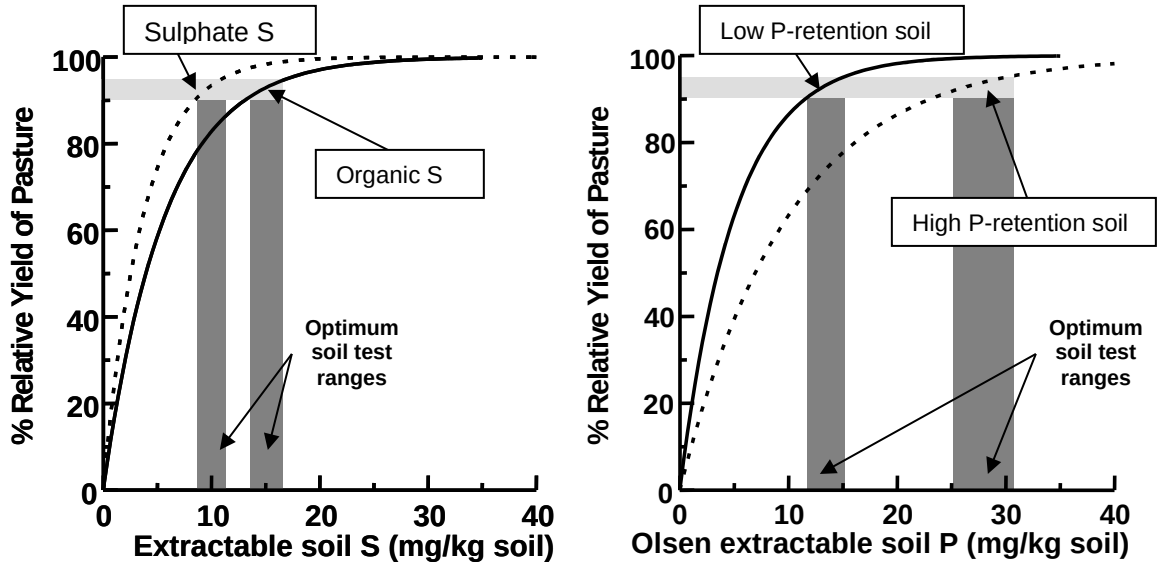

Figure 4.1.12 An example of a 'normalised' national average response curves used for interpreting soil test results.

HOW ARE SOIL TEST/ YIELD RESPONSE CURVES DEVELOPED?

The soil test/yield response curve in Figure 4.1.12 was established as follows. A number of marginally P deficient, permanent pasture trial sites were chosen on contrasting soil groups (the MAFtech 'National forms of phosphate fertiliser trials'). Over a period of 6 years, different rates (above and below P maintenance requirements) of triple superphosphate were applied to replicate plots at each site. Soil testing at the end of 6 years revealed a range of Olsen P test values within and across sites. At each site, Olsen P values increased with increased rates of TSP application during the 6 years. In the sixth year, a capital dressing of P (as TSP) was added to ½ of each plot ('split plot') irrespective of the plots' previous TSP history. The percentage increase in pasture yield (during year seven) on the ½ plot receiving the capital P was graphed against the plot's year six Olsen P test value. The graph shows that as the Olsen P values rise, the percentage increases in pasture yield diminish (Figure 4.1.12).

Calculating yield increases using a 'split plot' technique as described above reduces the error caused by spatial variation in soil properties, however you will notice that the curvilinear line of best fit ('average response function') (Fig. 4.1.12) has difficulty predicting actual % increase in yield for Olsen values between 8 and 25.

Soil test/relative pasture yield response curves plotted in Figure 4.1.12 are the inverse to the relationship in Figure 4.1.13.

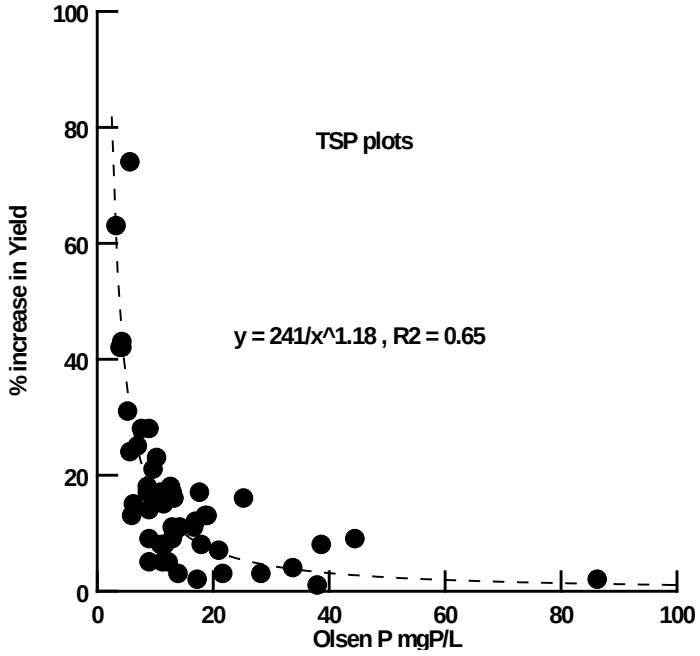

Figure 4.1.13. Experimental results showing percentage increase in pasture yield due to triple superphosphate (TSP) addition to plots with different initial Olsen P test values (data from Saggar et al. 1999).

SOIL TEST CALIBRATION AGAINST PLANT YIELD USING RELATIVE YIELD

The ideal nature of crop yield response to increasing soil P test value is curvilinear, rising to a maximum yield plateau where P no longer limits plant growth (Figure 4.1.13). Differences in climate, other nutrient availability and soil characteristics cause variations in the actual maximum yield from year to year and trial site to trial site. If the maximum yield at each site (or in each season) can be measured or estimated then yield data at each site can be transformed into percentages of maximum yield for that site. This allows comparisons of data between sites, and allows all data to be plotted using the same axes.

Curvilinear or linear response-plateau models are fitted to the relative yield data to test the predictive power of the soil test.

The choice of model influences the description of the data and the soil test value that is required to alleviate P deficiency (Anderson and Nelson, 1975). Common models used are:

Mitscherlich: $Y = a\ (1 - e^{-cx})$
Quadratic: $Y = a + bx + cx^2$
Logarithmic $Y = a + b \log (x)$
Sigmoidal $Y = a/(1 + bcx)$ where $(0 < c < 1)$
Linear-plateau model $Y = a + bx$,
(where x = 1, if x is above critical level; and where x = < 1, if x is below critical level)

An appropriate model will give the highest coefficient of determination (R^2). The best fit model can then be used to partition soil test values into groups where low, medium or high a response to fertiliser P is expected. If fertilising for maximum yield, a critical soil test value

above which 90% of maximum yield is expected can be chosen. This is commonly called the 'external P requirement' or 'biological optimum' soil test value. The fertiliser requirement to raise a soil test within a certain group to the external P requirement of a high value crop can be calculated from the trial data. The soil test can then be used as a diagnostic tool for fertiliser requirements, and is transferable between similar soils, climates and crops. For arable crops this is the most common method of making fertiliser recommendations.

Figure 4.1.14 shows 4 calibration curves. The curve of Sinclair et al. (1997) summarises pasture relative yields in mowing trials as they change with increasing Olsen P soil test values obtained from 19 sites in the MAF National Series of Phosphate trials (1982/3-1987/89). The curve of Saggar et al. (1999) summarises the pasture yields at 12 of these same sites in 1990. The volcanic PKS and sedimentary PKS curves are the calibration curves used in Overseer®.

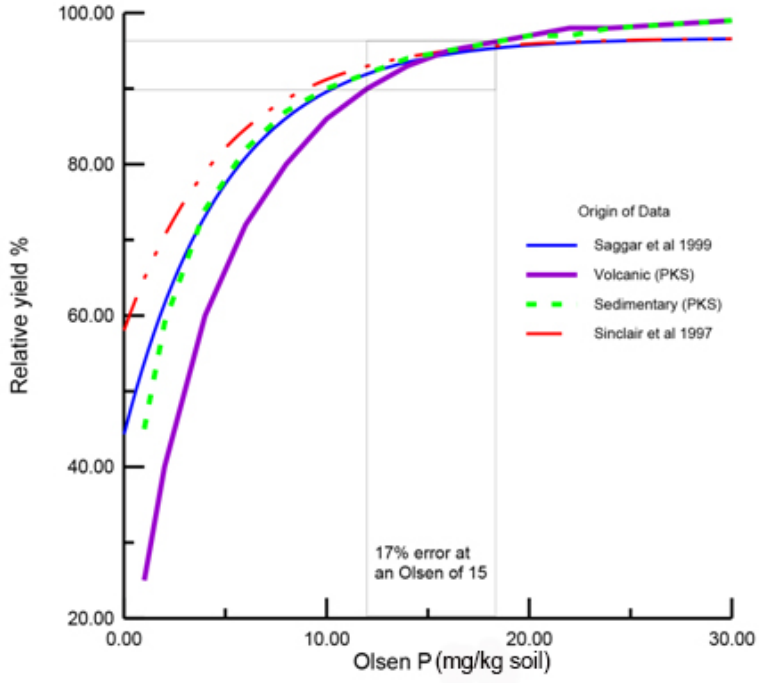

Figure 4.1.14 Normalised average curves for calibrating relative pasture yield to Olsen P soil test values.

We can conclude that all curves, although derived from different experimental work, are similar in shape and form and are representative of the relationships commonly used to assist in calculating fertiliser P requirements. The curves indicate that near maximum yields occur at Olsen P values that exceed 20, while Olsen P values close to 10 are associated with submaximal yields.

Higher Olsen P tests appear to be required to maximise yield on high-P sorption Volcanic soils (Figure 4.1.14).

ERRORS IN PREDICTING RELATIVE YIELD FROM THE REPRESENTATIVE SOIL TEST VALUE

Sinclair et al. (1997) demonstrated that the Olsen P test from a single fertiliser treatment at one site could be expected to vary by 17% (Figure 4.1.14). Given the diminishing return shape of the curves, as soil test values approach the optimum, there is little error involved in predicting relative yield. Larger errors in predicting relative yield would occur at lower soil test values.

At a paddock scale on a hill country farm this 'spatial' variation in estimating the representative Olsen soil test can be as high as 40-60% (Baird et al 1995) but can be reduced to 15-20% by selection of appropriate sampling transects.

ARE THE 'NORMALISED' NATIONAL AVERAGE RESPONSE CURVES APPROPRIATE FOR EACH FARM?

To answer this question let us examine the spread of data behind the Sinclair et al., 1997 calibration curve. The average curve explains only 27.6% of the variation observed in the spread of data (Figure 4.1.15). Notably a wide range of relative pasture yields can be obtained at sub-optimal soil test values.

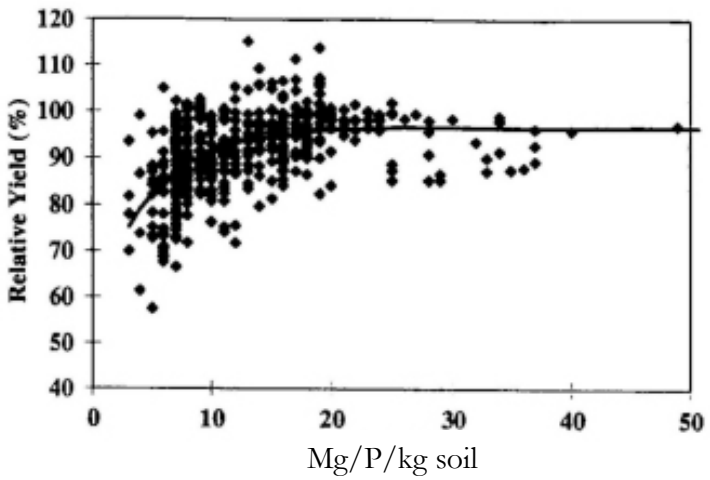

Figure 4.1.15. Relationship between relative yield of pasture and Olsen P soil test values (redrawn from Sinclair et al. (1997)).

Sinclair et al (1997) took the average curve and examined how good it was at explaining the relationship between % relative pasture yield and Olsen P values at 17 of the 19 sites. The result (Figure 4.1.16) is somewhat sobering! Sinclair et al (1997) concluded that Olsen P soil tests from farms could not accurately predict relative pasture yield. These data, however, did show that when Olsen P values exceed 20 a near maximum relative yield can be produced.

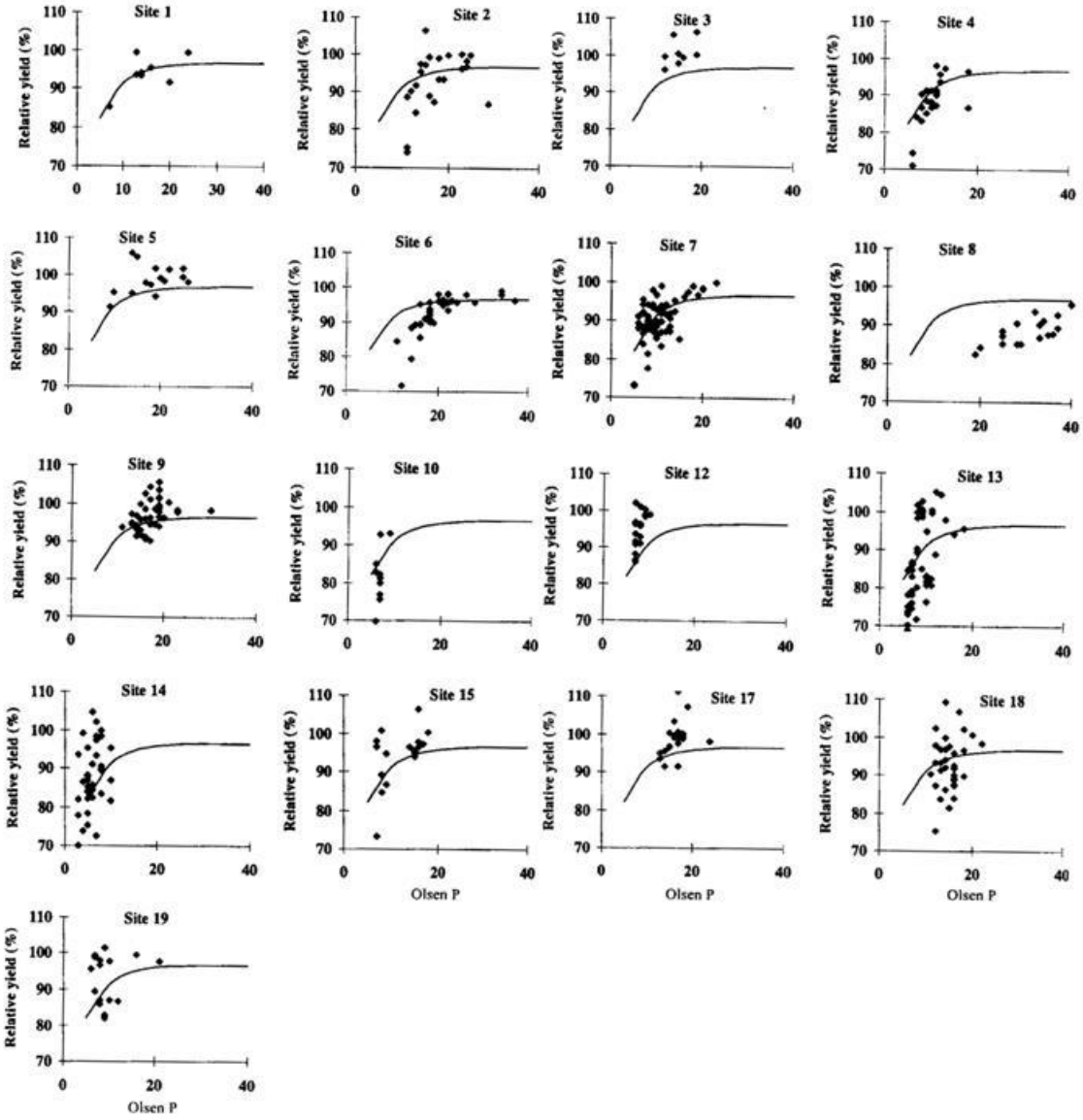

Figure 4.1.16. Relative pasture yield and Olsen P test values at each of the pasture trial sites described by Sinclair et al. (1997).

WHAT ARE THE CAUSES OF THE SITE-TO-SITE VARIATION IN THE PASTURE YIELD/OLSEN P TEST RESPONSE FUNCTIONS?

What must be remembered is that soil P status is just one of many factors influencing pasture growth rates. Two of the more important factors are: the seasonal availability of water and soil N availability (as influenced by legume % in the sward and time since pasture development).

The data (Figure 4.1.17) of Halvorson and Black (1985) is used to demonstrate the effect of variation in the plant available water on the shape of calibration curves. These wheat field trials were conducted under the same uniform soil and climatic conditions but in different seasons.

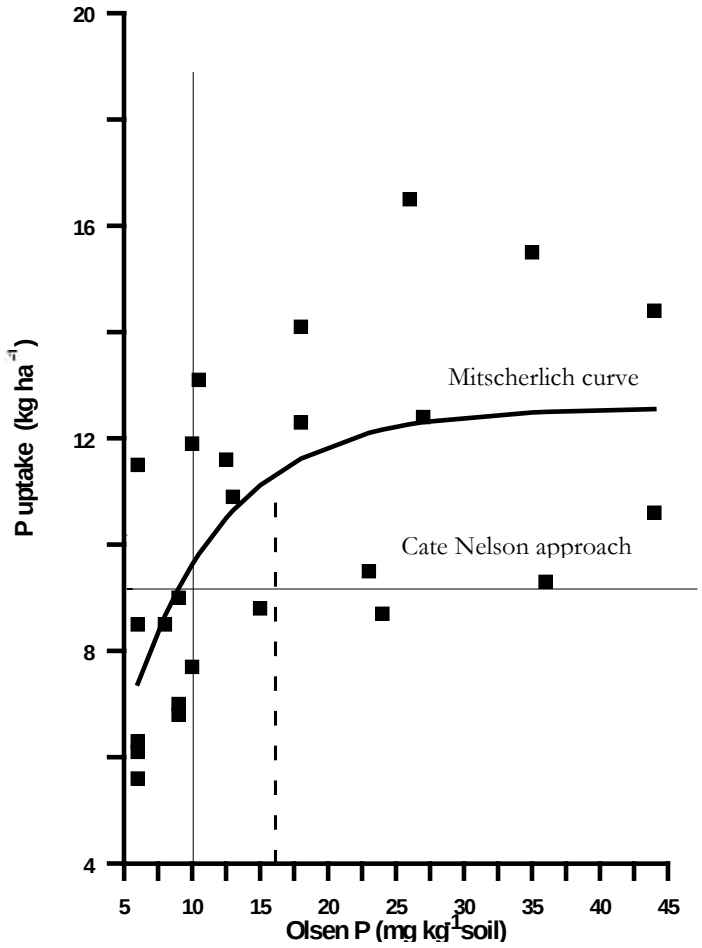

Figure 4.1.17 The relationship between P uptake by spring wheat in five different years and Olsen P test. Note the significantly lower critical Olsen P (10) selected by the Cate-Nelson approach than that (16) selected by 90% of maximum yield described by Mitscherlich equation (source of data: Halvorson and Black, 1985)

When the data are sorted into their year group, 5 separate calibration curves can be developed (Figure 4.1.18). The major difference between years was the available water content, which had a major impact on P uptake and wheat yield.

External factors affecting plant P demand and supply, change the shape of calibration curves by influencing plant root growth independently of soil P status (soil test values). Soil moisture stress inhibits plant root growth and, in addition, decreases the diffusion of inorganic P to root surfaces and the mineralisation of organic P. In dry soils, P limitation occurs earlier than N or S limitation particularly on high P-sorbing soils because decreases in soil water content may increase soil solution NO_3^- and $SO_4^=$ concentration, but P concentration may change little or not at all. As soil volumetric water content increases, P diffusion rates to roots increase, which may allow higher plant P uptake for a given soil test value. Consequently, plant yield and plant P demand increase so that the higher yield maxima can only be maintained by further elevating the soil test P value.

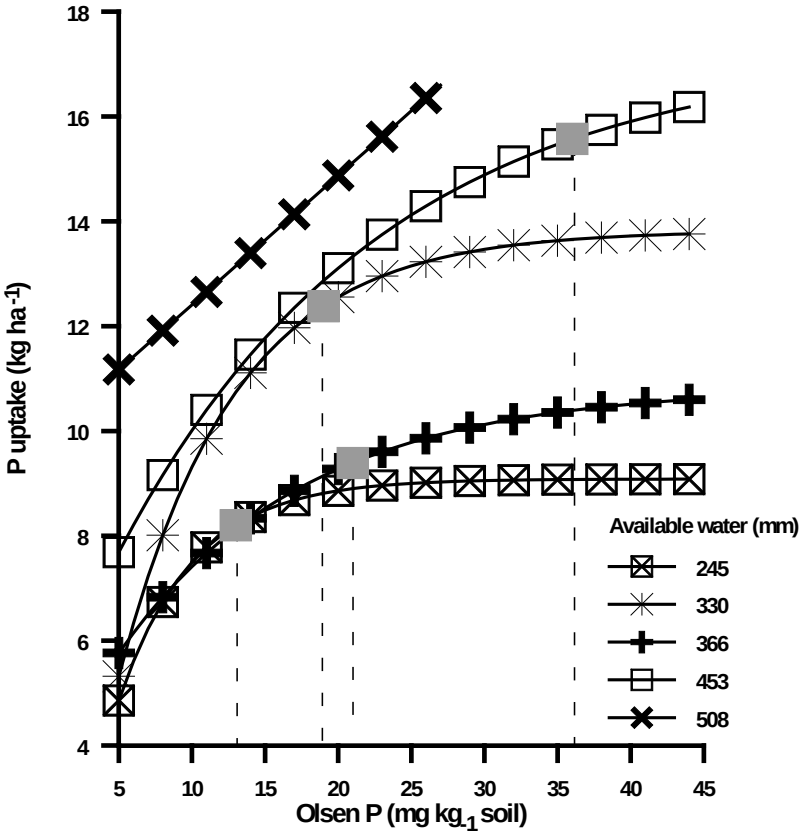

Figure 4.1.18. Relationships between P uptake by spring wheat and Olsen P test for five years with different amounts of available water. Note differences in critical Olsen P (----) test level for each year (source of data: Figure 4.1.17).

Banding or seed placement of P fertiliser can increase the relative P-supplying power of the soil. A larger amount of soluble P applied to a smaller soil volume will increase solution P concentration and decrease the soils' P sorbing capacity. Banding and placement of P also

lead to greater errors in soil testing, with it being difficult to sample the fertilised zone where plant roots may proliferate (depending on soil moisture regime). It is appropriate to establish separate calibration curves for soil tests for various P placement methods, irrigation or reduced tillage operations (which concentrate P in the surface soil).

EFFECT OF FORM OF P FERTILISER ON SOIL P TEST/PASTURE YIELD RESPONSE CURVES

In weakly to moderately weathered soils, the Olsen P test (0.5 M $NaHCO_3$ at pH 8.5) extracts P associated with Fe and Al hydrous oxides. Soluble fertiliser P mostly enters these soil fractions and, therefore, is reflected in the soil test. Sparingly soluble P fertilisers such as reactive PR (RPR) products have proved valuable on such soils and small tonnages are being used as direct application P fertiliser. RPRs dissolve only slowly to replenish the P associated with Fe and Al oxides, that has been depleted by plant growth. As RPRs are not soluble in $NaHCO_3$, a single "snap-shot" Olsen P measurement will not estimate the P to be released from the RPR during the growing seasons. Where the rate of RPR dissolution is substantial, Olsen-P calibrations based on yield responses in soils fertilised with soluble P can underestimate the yield response to RPR.

It was experimentally shown that yields on plots fertilised for 6 years with RPR (Perrott et al. 1993) were higher than predicted from the Olsen P test values for those plots (Figure 4.1.19). It was found that on average after 6 years annual RPR application, Olsen values needed multiplying by 1.69 if an Olsen P response curve, generated using single superphosphate fertiliser, was to be used to predict yield.

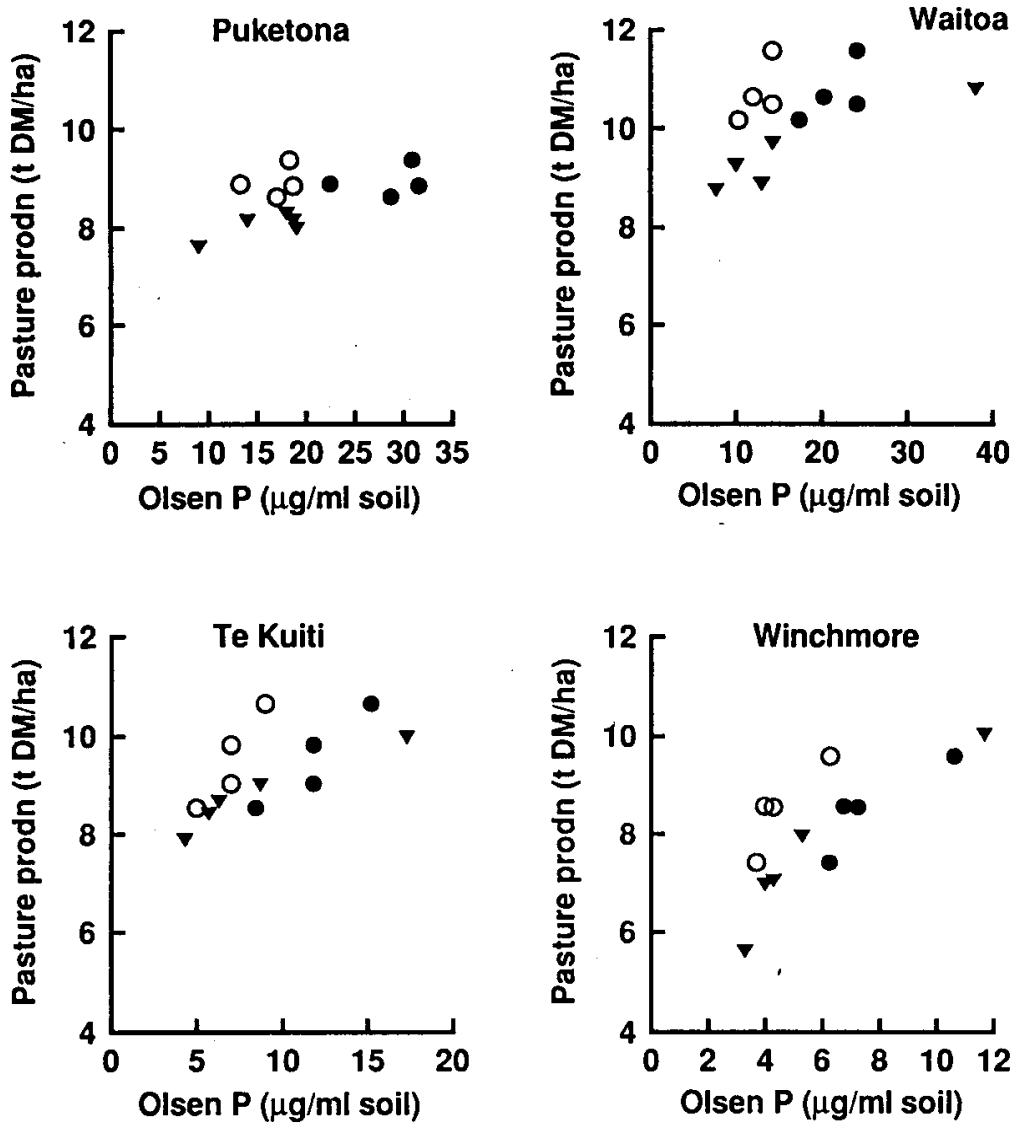

Figure 4.1.19 Relationship between pasture production and Olsen P for TSP (▼) and RPR (○) treated soils. (●) represents multiplying Olsens values on RPR plots by 1.69 (Perrott et al. 1993).

The reason for the under prediction of yield on RPR fertilised plots is that plant roots can access P that will be released from the undissolved RPR residue but this P is not extracted in the high pH 8.5 Olsen extract.

Mixed anion-cation exchange resin membranes, that extract P from soil samples at their natural soil pH do, however, include some residual RPR-P in their measure of soil P status. Saggar *et al.* (1999) have shown that P extracted by mixed anion-cation exchange resin membranes was better than Olsen P at predicting growth on several New Zealand soils fertilised with TSP and RPR (Figure 4.1.20).

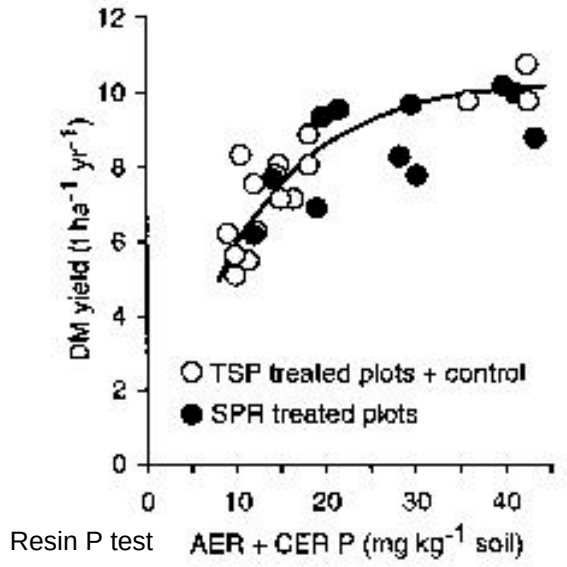

Figure 4.1.20. Relationship between pasture yield (DM yield in t/ha/year) and Resin P test values (Perrott et al. 1993).

The outcome is that a single calibration curve can be used for both RPR and SSP fertilised areas when predicting pasture relative yield. If the topdressing history is unknown or it is known that RPR based fertilisers have been used, then Resin-P may provide less risk (Figure 4.1.21) in predicting the P responsiveness of pastures.

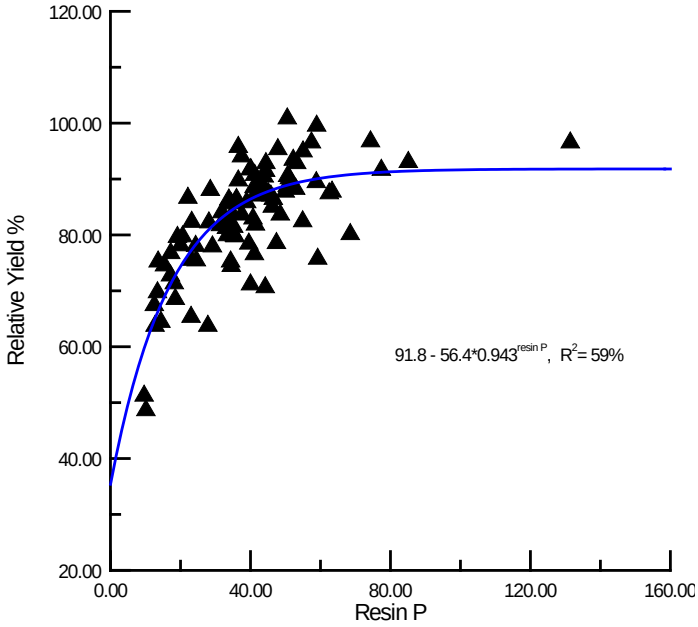

Figure 4.1.21. The relationship between Resin P and relative yield of pasture (Saggar et al. 1999).

Fertiliser rate and change in soil test value

Determining how much soluble nutrient needs to be applied as fertiliser to raise soil test values to desired levels (e.g. near optimum levels for production systems with high gross margins) relies on field trial evidence. Such trials that have, by design, applied nutrients at rates greater than the amounts lost each year have caused the plant available pool to increase and that increase has been indicated by changes in soil test values.

At best, scientists have been able to interpret the trial data by indicating ranges of nutrient applied that are most likely to change the soil test value by one unit (Table 4.1.5). Note that these rates refer to additional fertiliser that must be applied after nutrient losses (due to product-removal, transfer loss and leaching loss) have been replaced by maintenance fertiliser application.

Table 4.1.5 Approximate additional amounts of soluble nutrients (kg/ha) required to raise soil tests by one unit[1] (sources Cornforth 1998, During 1984, Roberts and Morton 2009)

Soil parent materials		**Sedimentary**	**Ash**	**Pumice**
Soil test or soil status		**Amount of nutrient required per hectare (kg/ha)**		
Olsen (mg/L)	**P**	4-7	7-18	4-15
Exch. K (Quick test)	**K**	100-250[2]	45-80	35-60
Sulphur required to prevent S deficiency[3]	**S**	30-40	20-30	40-50

1. Additional above maintenance 2. Values are for Yellow-grey earths. 3. Sulphate not incorporated into the organic matter tends to leach in winter drainage. Key to raising S test is to raise organic matter and S:C ratio in organic matter.

In practice, these rates of nutrient application /change in soil test unit should be applied and monitored carefully because a wide range of soil test change outcomes are possible.

The wide range of outcomes results from:

- the short range order variability of soil nutrient status in the landscape (already discussed, particularly for K),
- the diversity of soil properties with soil groups and variability of climate and productivity from year to year that influence the fate of nutrients applied to soil,
- our inability to predict annual losses of nutrients (maintenance rates) accurately, particularly as land management varies markedly from farm to farm (e.g. cultivation practices and pasture utilisation).

For example, in many well-developed pasture soils, organic P may make up 600 –1000 kg P/ha/15cm. Changes in soil organic matter decomposition rates, as the soil fertility is raised, or changes with fluctuating soil moisture and temperature, influences the labile P pool extracted by the Olsen P test. Thus the Olsen P test can increase when hard animal grazing and pugging ('hoof and toothing') is used to develop hill country and little fertiliser is applied. Conversely, applied P may 'disappear' into the organic matter pool without increasing Olsen P values if low fertility, long-term cultivated land is resown in permanent pasture.

All the information discussed above is neatly summarised in 'Fertiliser Use for New Zealand Dairy Farms' which can be downloaded from the Fertiliser Association of New Zealand website at http://www.fertiliser.org.nz/Site/resource_center/Booklets.aspx

COPING WITH FIELD VARIATION IN SOIL TESTS

There are two main uses of calibrated soil test information:

- to identify whether the soil available nutrient status is limiting plant productivity and whether fertiliser input is likely to be profitable,
- to identify near optimum soil available nutrient status and indicate whether further fertiliser use may be unprofitable and unwanted, in terms of increasing the risk of P enrichment of drainage waters.

Below we illustrate how soil test variation can impact on P fertiliser recommendations using the Overseer® nutrient budgeting software. Despite using the transect approach we can still expect that there will be around 20% uncertainty in the soil test values for Olsen P, exchangeable K and extractable S. For example, an Olsen P soil test result around the optimum for an Allophanic soil of 24 mg P/L may represent a paddock on a dairy farm that may still give a profitable response to extra P fertiliser. The paddock sampled by the transect and the bulked soil core method could have produced a result somewhere between 19 and 29 mg P/L (i.e. 24 mg P/L ± 20%). So the question that should be considered is: "how different would the fertiliser P recommendation be if the soil test value was 19 mg P/L as opposed to 29 mg P/L?"

This variation results in maintenance P fertiliser recommendations ranging from 34-49 kg P/ha/year, whereas the total P fertiliser recommendations which include capital requirements, more than double if the actual Olsen P value is 19 (requires 155 kg P/ha fertiliser) compared to 29 mg P/L (requires 60 kg P/ha fertiliser) (Table 4.1.6). This difference would more than double the P fertiliser bill and is worth bearing in mind when determining P fertiliser recommendations.

Table 4.1.6 Variations in maintenance and capital P fertiliser recommendations estimated by Overseer® based on expected variations around an Olsen P value of 24 mg P/L (±20%).

Olsen P of 24 mg P/L (±20%)	Olsen P		
Olsen P (mg P/L)	19	24	29
Maintenance (kg P/ha)	34	39	49
Capital (kg P/ha)*	121	66	11
Maintenance + Capital (kg P/ha)*	155	105	60

**Based on achieving the upper limit of the optimum Olsen P concentration for an Allophanic/Ash soil of 30 mg P/L.*

Now let us examine how the fertiliser recommendations vary when the Olsen P test values exceed the optimum (circa 40 mg P/L) for the same Allophanic soil type. The paddock sampled by the transect and the bulked soil core method could have produced an Olsen P result somewhere between 32 and 48 mg P/L.

Notice that the recommendations for maintenance P are similar (Table 4.1.7) for the three variations in soil test value (40 ± 8 mg P/L), but an Olsen P of 30 mg P/L is considered to be optimum, so the variation in soil test P values could mean that unnecessary P fertiliser is being applied. In contrast to the previous example (Table 4.1.6), the likely variation in soil test results has less impact on P fertiliser recommendations when Olsen P is close to or exceeds the optimum value, as capital P is not required.

Table 4.1.7 Variations in maintenance and capital P fertiliser recommendations estimated by Overseer® based on expected variations around an Olsen P value of 40 mg P/L (±20%).

Olsen P of 40 mg P/L (±20%)	Olsen P		
Olsen P (mg P/L)	32	40	48
Maintenance (kg P/ha)	46	52**	57**
Capital (kg P/ha)*	0	0	0
Maintenance + Capital (kg P/ha)*	46	0	0

*Based on achieving the upper limit of the optimum Olsen P concentration for an Allophanic/Ash soil of 30 mg P/L.

** Maintenance P would not normally be recommended on Olsen P concentrations which exceed 30 mg P/L, as soil P should be mined in this case.

MAINTENANCE FERTILISER P- A PRUDENT CHOICE AT NEAR OPTIMUM SOIL NUTRIENT STATUS

Thus when Olsen soil test values are within 10% of optimum values, on pastures already carrying heavy stocking rates it may be prudent to use maintenance fertiliser recommendations until more than one year's worth of soil test and farm production data can be collected to better define the soil fertility status. Choosing maintenance avoids the risk of high soil P loading, which could potentially contribute to the P enrichment of drainage, surface runoff and surface water (see Section 5.2).

Concluding Remarks

This section has covered some of the types of errors that impact on the accuracy of soil test interpretation. By being aware of the inaccuracies that exist, the value of the information gained from soil tests can be improved by using good practice, including:

- Good sampling techniques, such as the use of a transect system to locate sampling sites for repeated sampling. This should reduce the field variation around your soil test value to plus or minus 20%.
- Use of historical soil test trends
- Develop a solid understanding of how models like Overseer® determine optimum or maintenance fertiliser strategies. In particular, become familiar with how small changes in soil test values affect the prediction of maintenance requirements.
- Consider the impact that the fertiliser recommendation may have on the wider environment.

Test Your Knowledge

1. What are the important aspects to consider when taking a soil sample?

2. Why is soil testing depth important?

3. What is All Paddock Soil Sampling and what are the advantages and disadvantages of using this approach?

4. What are some of the issues that need to be considered when selecting a soil testing laboratory?

5. How are pasture calibration curves used to determine target soil test ranges?

6. What are some of the issues associated with target soil test ranges?

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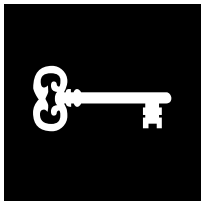
4.2 Understanding Plant Tests



Key Learning Objectives:

After studying this section you should be able to:

1. List and discuss reasons for taking plant samples for analysis
2. Describe the main principles behind the use of plant analysis as a diagnostic tool
3. Explain why the selection of plant parts, age of plant and timing of sampling are critical to the success of plant analysis as a diagnostic tool?
4. List and discuss factors that affect plant composition
5. Discuss the concept of a "critical" concentration of a nutrient in plant tissue.

Introduction

Plant analysis plays an important role in the nutrient management of agricultural and horticultural production systems. In particular, total elemental analysis of plant tissue is commonly used to assist in fertiliser recommendations. However, to assist in using plant tests effectively the following questions should be asked:

- What are the advantages and limitations of the techniques used and the information they provide?
- What procedures should be followed to improve the value of plant analytical data?

Plant analysis

GENERAL CONCEPTS

Assessment of plant nutrient status can be conducted by visual examination, by measured growth response to applied nutrients or by elemental analysis of plant tissue or sap.

VISUAL EXAMINATION

Some yield-limiting nutrient deficiencies (Figure 4.2.1, A) and excesses (D) produce symptoms on the leaves or other parts of the plant that are sufficiently characteristic to allow field diagnosis. Examples of some of the more clearly identifiable visual symptoms are:

- nitrogen remobilisation from older leaves to new leaves, causing premature senescence of older leaves (can be confused with S deficiency).
- potassium (leaf edge and tip burn) deficiency of pasture legumes.

- calcium deficiency of maize (growing points die, shortened stubby lateral roots).
- magnesium deficiency (interveinal chlorosis in older leaves)

(The cation deficiencies are unlikely to occur on most mineral soils with sandy loam to silt loam or clay loam textures in New Zealand, but can be observed on raw sand and pumice and peat soils).

Because visual symptoms do appear in commercial crops and pastures, it is helpful to be familiar with some of the common deficiency and toxicity symptoms. However, for clear visual symptoms to be produced there has to be a substantial disruption of plant metabolism. Almost inevitably, this means that if well-developed symptoms appear, there has already been some reduction in growth and possibly also in the yield potential of the crop. For example, Figure 4.2.1 represents the general concept of how visual symptoms may not be present in region "B" but changes in plant nutrient concentration between points 'x' and 'y' can have a substantial affect on yield.

Additional information is required when visual symptoms are not sufficient to provide a clear diagnosis. Sometimes simple experiments can be used in the field to narrow down the cause of the symptoms. Such methods include applying fertiliser strips to narrow down the limiting nutrient. However, the most widely used confirmatory test is quantitative elemental analysis.

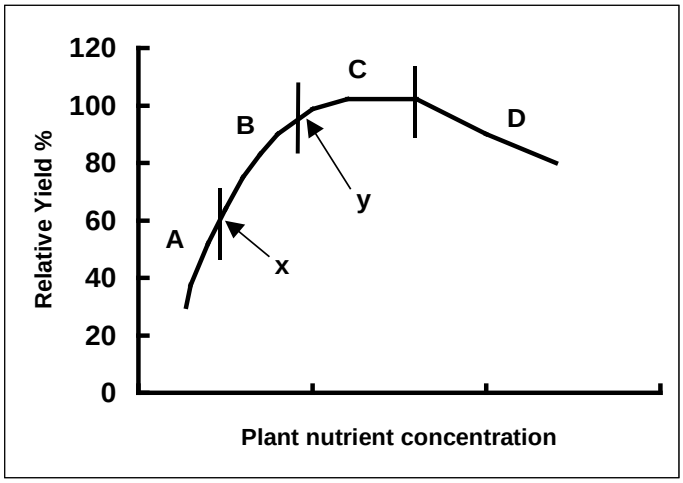


Figure 4.2.1. The generalised relationship between plant growth (relative yield) and plant nutrient concentration.

CHEMICAL ANALYSIS

The advantage of elemental analysis is that it can be used not only to confirm visual symptoms but also to:

- check the nutrient status of plants showing no visible symptoms of deficiency or excess
- measure plant nutrient uptake – to assess the effectiveness of a fertiliser programme or individual fertiliser
- monitor the fertility status of nutrients which are very mobile and difficult to determine through soil testing, such as N
- assess its nutritive value for livestock (e.g. Mg levels in pasture during early lactation)
- provide an indicator of fruit quality characteristics (e.g. Ca as indicator of kiwifruit storage quality).

It is rare, however, that simple, single-factor relationships exist between the concentration of a nutrient element in plant tissue and the yield of the crop (Figure 4.2.1). This only occurs when a marked deficiency of one nutrient limits plant growth severely (region A in Figure 4.2.1) and reduces the plant tissue concentration of that element. Addition of fertiliser containing that element will increase plant growth (region B in Figure 4.2.1) and as the availability of that element ceases to limit plant growth the elemental concentration in the plant tissue will increase (region C in Figure 4.2.1); sometimes to a level that is phytotoxic which restricts yield (region D in Figure 4.2.1).

Carefully controlled, plant growth response experiments employing single-factor nutrient addition has been used to establish *Critical Concentration*s (Figure 4.2.1, *point Y*). These are values below which growth rate, yield or quality declines appreciably from optimum levels. In the 'real world' these critical concentrations cover a range of values. This is because, whilst plant nutrient concentration can be an indicator of soil fertility, soil fertility is only one of many factors influencing uptake and accumulation of nutrients by plants. Other factors include:

- climate,
- soil physical conditions,
- the incidence of pests and disease, and
- nutrient interactions

Therefore, plant analysis is often used to complement soil analysis. However, in some cases, such as for deep-rooted crops (e.g. fruit crops) plant analysis has a distinct advantage over soil tests as a nutrient diagnostic tool, because it reflects the nutrient availability in soil to the entire root system.

WHEN AND WHAT TO SAMPLE

Plant or sward sampling methods need to be appropriate and consistent for the results to be useful. This is because interpretation criteria are specific to plant species, part of the plant sampled and growth stage of the plant. Sampling instructions are usually available on a species basis and can be obtained from some analytical laboratories. It is important to be familiar with the common methods used because pasture and arable or horticultural crops have specific requirements for the types of samples collected, when samples should be taken, and the type of analysis to be used.

If plant nutritional problems are suspected then plant tissue samples should be taken from areas that show symptoms but are still relatively healthy. If no symptoms are evident then plant material should be sampled in a pattern that is representative of a whole paddock or orchard.

Similar to the soil sampling procedure, marked transects can be used to reduce variations in herbage nutrient concentrations caused by slope, aspect and time. These transects should avoid gateways, water troughs, shelter-belts and obvious animal camping areas. However, leaf nutrient concentration changes markedly with the physiological stage of growth. Therefore, leaf samples for nutrient diagnosis should be taken at the same stage of growth rather than on a strict calendar basis. For pastures, the optimum time to sample is when pasture is about to be grazed, as this reflects the nutrient concentrations the animals are ingesting. It is important to consider that the concentrations of nutrients will generally increase following fertiliser application, so plant tissue testing should be scheduled to avoid any recent fertiliser applications.

Contamination by soil should be avoided, particularly if trace element analysis is required. In such cases, herbage samples can be rinsed in distilled water, or, a clean supply of rain water. High Fe concentrations (> 300 mg/gm dry matter) are a tell tale sign of soil contamination. With some soils, contamination is also likely to result in elevated Cu, Zn and Co herbage concentrations.

PASTURE

Although grass and clover have similar levels of many nutrients they differ in others (e.g. Mo and B). Therefore the advisor should note the botanical composition of the pasture from where the sample was taken. For the assessment of animal health requirements, analytical laboratories usually require a mixed-pasture sample (Table 4.2.1 and 4.2.3) taken from the sward height accessible to the grazing animal. An additional sample of white clover only, can be used to assess whether the correct levels of nutrients are available to sustain healthy clover growth, which is important both for provision of biologically fixed nitrogen and for quality pasture production (Table 4.2.2).

Protocol for sampling mixed pasture

1. Pasture samples should be taken at the same physiological stage and mixed pasture swards should be sampled when pasture is at the optimum grazing stage in order to accurately reflect the pasture nutrient concentration that animals are ingesting.
2. Pasture samples should be taken at the same time of day, preferably around 2 hours after dawn using clean scissors or shears.
3. Samples should be taken to grazing height (5cm above the soil surface).
4. Approximately 20 samples (each about a handful in size) should be taken along a transect, taking care to avoid dung and urine patches and non-representative areas.

Protocol for sampling clover pasture

In addition to the above recommendations, when sampling clover it is recommended that small, stunted plants or plants with unusual leaf colour are sampled and that approximately 100 clover leaves and stems are taken per sample, rather than sampling the whole sward to a height of 5cm. The first mature leaf and petiole should be sampled (Figure 4.2.2).

Figure 4.2.2 Ideal sampling points for white clover

Table 4.2.1 Optimum concentrations of elements in a mixed pasture (ryegrass clover)

Major Elements					
N	***P***	***K***	***S***	***Mg***	***Ca***
% in Dry matter					
4.5 – 5.0	0.35 – 0.40	2.5 – 3.0	0.28 – 0.35	0.18 – 0.22	0.3 –0.50
Trace Elements					
Fe	***Mn***	***Zn***	***Cu***	***B*[1]**	**Mo[1]**
ppm					
50 - 65	25 - 30	16 - 19	6 - 7	15 - 16	0.15 – 0.20

Source A.H.C Roberts and J. Morton, 1999 (AgResearch New Zealand)
[1]Clover sample only, for Mo deficiency N % <4.5

Soil tests are unreliable for assessing trace element status because they are present in small quantities in the soil, making the relationship between soil content and plant and animal requirements hard to define.

Table 4.2.2 Optimum concentrations of elements in a clover from a ryegrass/clover sward

Trace element	Pasture species	Deficient (ppm)	Marginal (ppm)	Adequate (ppm)
Molybdenum (Mo)	Clover	<0.10[1]		>0.10
Copper (Cu)	"	<5	5-7	>7
Boron (B)	"	<13	13-14	>14
Zinc (Zn)	"	<12	12-15	>15
Manganese (Mn)	"	<20	20-24	>24
Iron (Fe)	"	<45	45-49	>49

Source: Morton et al., 1999

[1](For Mo deficiency to occur clover N must be below 4.5%)

Pasture analysis is essential to assess trace element status (Table 4.2.3) for good animal nutrition, however additional animal tissue, enzyme or blood tests may be required to diagnose whether a mineral deficiency exists in the grazing animal. In New Zealand, soils derived from andesitic ash may be low in Co and Se, while soils derived from rhyolitic pumice are typically deficient in Co and Se and low in Na. Boron (B) may also be deficient for plant growth, particularly lucerne and brassicas. Peats are typically deficient in Cu, Se and Mo, although some peats can be very high in Mo and low in Na (Morton et al., 1999).

Table 4.2.3 Concentrations of trace elements in mixed pasture that meet grazing animal requirements when on a fully fed grass diet.

Trace element	Animal species	Pasture species	Deficient (ppm)	Marginal (ppm)	Adequate (ppm)
Cobalt (Co)	Sheep	Mixed	<0.08	0.08-0.10	>0.10
	Cattle/deer	"	<0.04	0.04-0.06	>0.06
Selenium (Se)	All	"	<0.03		>0.03
Copper (Cu)[1]	Sheep	"	<5	5-10	>10
	Cattle/deer	"	<7	7-10	>10
Iodine (I)	All	"	<0.15	0.15-0.25	>0.25

Source: Morton et al., 1999

[1](Depends on pasture Mo and Fe levels)

Toxicities of some trace elements can occur naturally (manganese, molybdenum and selenium toxicity) or result from excessive use of trace element-bearing fertiliser. The lower level of toxic concentrations for sheep and cattle are Co 35 ppm, Se 5 ppm, Cu 20 ppm, Zn 900 ppm, Mn 400 ppm and Fe 500 ppm (contained in pasture tissue) (Morton et al., 1999).

The best time to sample pasture for trace element status is shown in Table 4.2.4.

Table 4.2.4 Recommended sampling times to assess trace element status of pasture species.

Trace element	Pasture species	New Zealand Seasonal time	Physiological stage
Cobalt (Co)	Mixed	Late spring	Rapid growth
Selenium (Se)	"	Late spring	Rapid growth
Copper (Cu)[1]	"	Early spring	Animal Cu low
Iodine (I)	"	Early autumn	Rapid regrowth
Molybendum (Mo)	Clover	Summer	Rapid growth
Boron (B)	Clover	Summer	Rapid growth

Source: Morton et al., 1999

ARABLE AND HORTICULTURAL CROPS

For some crops, regular plant analysis is carried out at strategic times during the growing season to ensure that optimum nutrient levels (Table 4.2.5) are being maintained and imbalances are detected before they seriously affect crop yields. The leaves, usually including the petiole, are the part of the plant that is most widely sampled, however it is important to consult the plant testing laboratory to get advice on the best way to sample, as sampling protocols vary from crop to crop. Usually the youngest fully expanded leaf is preferred since nutrient composition is most stable at this time.

Table 4.2.5 Optimum nutrient ranges for cereals.

Element	Wheat, barley, oats	Maize
N (%)	2.1 - 3.0	2.3 - 3.3
P(%)	0.21 - 0.50	0.18 - 0.32
S(%)	0.15 - 0.40	0.13 - 0.25
K (%)	1.5 - 3.0	1.71 - 2.25
Mg (%)	0.15 - 0.50	0.13 - 0.24
Ca (%)	0.20 - 0.50	0.21 - 0.50
Mn (ppm)	26 - 100	20 - 150
Zn (ppm)	15 - 70	21 - 70
Cu (ppm)	5 - 25	6 - 20
B (ppm)	2 - 10	6 - 20
Mo (ppm)		0.10 - 0.50
Plant part:	Whole plant above ground	Ear leaf
Growth stage:	Head emergence from boot	Ear silking

Source: Morton et al, 1998

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

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ANALYSIS REPORT

Client:	NPK Simpson	**Lab No:**	500249 shpv1
Address:	MoreDosh Farms	**Date Registered:**	25-Aug-2011
	Somewhere	**Date Reported:**	26-Aug-2011
	SOUTH ISLAND	**Quote No:**	
		Order No:	
		Client Reference:	Example report - ExtFed + Al
		Submitted By:	Hill Labs internal jobs

Sample Name: Spring **Lab Number:** 500249.1
Sample Type: Mixed Pasture, Dairy (P1)

Analysis		Level Found	Medium Range	Low / Medium / High
Nitrogen*	%	3.1	4.0 - 5.0	
Phosphorus	%	0.51	0.38 - 0.45	
Potassium	%	2.6	2.5 - 3.0	
Sulphur	%	0.38	0.30 - 0.40	
Calcium	%	0.51	0.60 - 1.00	
Magnesium	%	0.22	0.20 - 0.30	
Sodium	%	0.30	0.15 - 0.30	
Iron	mg/kg	156	100 - 250	
Manganese	mg/kg	134	60 - 150	
Zinc	mg/kg	30	30 - 50	
Copper	mg/kg	10	10 - 12	
Boron	mg/kg	10		
Molybdenum	mg/kg	1.44	0.50 - 1.2	
Cobalt	mg/kg	0.19	0.10 - 0.20	
Selenium	mg/kg	0.20	0.08 - 0.15	
Chloride*	%	0.91	0.30 - 2.4	
Dry Matter*	%	20.4	12.0 - 25.0	
Crude Protein*	%DM	20.3	20.0 - 30.0	
Acid Detergent Fibre*	%DM	24.1	20.0 - 30.0	
Neutral Detergent Fibre*	%DM	41.7	30.0 - 45.0	
Ash*	%DM	9.2	7.0 - 14.0	
Soluble Sugars*	%DM	12.1		
Starch*	%DM	1.0		
Digestibility of Organic Matter in Dry Matter (DOMD)*	%	73.2	65.0 - 80.0	
Metabolisable Energy*	MJ/kgDM	11.7	9.0 - 12.0	

Grass Staggers Index*	me	1.5	(<1.8 recommended, >2.2 increased risk)
K/Na Ratio*		9	(<10 recommended, >20 increased risk)
Ca/P Ratio*		1.0	(>1.5 recommended, <1.2 increased risk)
DCAD*	me	303	(<200 recommended, >200 increased risk)

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

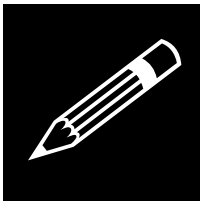
This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Figure 4.2.3 Example of reporting format for mixed clover/ryegrass pasture (courtesy Hill Laboratories).

The 'normal range' in the Hill Laboratories reporting format above (Figure 4.2.3) refers to the analysis of plants that are not expected to give a yield response to further addition of a nutrient by fertiliser application. In addition, for elements such as cobalt (Co) and selenium (Se), the normal range may refer to herbage levels that meet animal requirements.

Laboratory accreditation

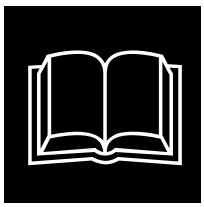
In addition to ASPAC, Wageningen University in the Netherlands co-ordinates the International Plant-analytical Exchange Programme (IPE), which tests the proficiency of laboratories analying common plant tissue samples. These accreditation programs are designed to maintain the standard and quality of plant tissue testing and it is recommended that consumers request information about a laboratory's accreditation status before selecting a laboratory.



Test Your Knowledge

1. How is plant tissue analysis useful and how can it be used to compliment soil sampling?

2. What issues need to be considered when taking a mixed pasture sward sample for analysis?



Recommended Reading

Read Chapter 9, pp 305-320. In Havlin et al. (1999), Soil Fertility and Fertilisers 6th Edition , Prentice Hall, New Jersey US.

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