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INTERPRETING THE OLSEN P SOIL TEST

The Fertiliser Association of New Zealand has recently published a revised edition (2023) of its popular booklet, "Fertiliser Use on Dairy Farms." There is also a sister booklet "Fertiliser Use on Sheep & Beef Farms (revised 2024)." These can be downloaded for free from their website.

These booklets contain a lot of the information required to interpret soil and pasture tests and hence develop fertiliser recommendations for individual farms, but, in this article, I want to focus on one aspect of this process; the interpretation of the Olsen P test.

The Olsen P soil test is important in our New Zealand context. It has been widely calibrated across the major New Zealand soil groups and it has a dual role: it is used to predict relative pasture production in clover-based pastures, and, just as important these days, it is a useful predictor of P runoff to waterways, but this article does not consider this side of the "equation". Much can depend on interpreting it correctly.

Both booklets had their origins in the early 1990s. At that time a large database had been established, summarizing the records from hundreds of fertiliser P field trials, from all over New Zealand, completed in the previous 50 years or so. This data was used to define the relationships between the Olsen P soil test and relative pasture production for the major soil groups, from which **target ranges** were estimated. In the recent editions of these booklets the target ranges were defined as the range in Olsen P required to achieve 97% of the maximum pasture production (Table 1).

Table 1. **Target** Olsen P ranges required to achieve 97% of maximum pasture production for the major soil groups. (Fertiliser Association of New Zealand, 2023 and 2024).

Soil Group	Target Ranges (for 97% maximum production)
Volcanic and Sedimentary soils	20-30
Pumice and Peat soils	35-45

It is important to record that these booklets were not peer reviewed scientific publications. They were written specifically for farmers and farm consultants. They were simplified expressions of the known science, trying to keep the scientific jargon to a minimum. Accordingly they come with some qualifications. Examples of this can be found in the most recent editions:

The target ranges given in this section of the booklet are a guide only.

Where a farm should sit within the target range will be based on economic and environmental consideration.

At Olsen P levels greater than the target ranges, small increases in pasture production (1-2 t DM/ha) may occur which may be profitable. Whether or not higher soil Olsen P levels will result in an economic return will be determined primarily by the relationship between the cost of applied P and returns from milk solids produced.

Whether or not higher soil Olsen P levels will result in an economic return will be determined primarily by the relationship between the cost of applied P and the gross margin per hectare.

In 2006 all of the P field trial data was reviewed, reworked and formally published in the scientific literature, together with a dynamic P model. This paper can be downloaded from my website. “Defining the relationships between pasture production and soil P and the development of a dynamic P model for New Zealand pastures: a review of recent developments.”
https://dougedmeades.com/uploads/files/Pasture_Production_and_Soil_P.pdf

Given this more rigorous approach, the production functions relating Olsen P with relative pasture production were revised, and the **critical** Olsen P levels required to achieve 97% maximum production, together with the confidence intervals, were calculated (Table 2).

Table 2. **Critical** Olsen P levels and confidence intervals (95% probability) required to achieve 97% of maximum production for the major soil groups. (from: Edmeades et. al. 2006, NZ Journal of Agricultural Research)

Soil Group	Mean critical Olsen P and confidence interval required to achieve 97% maximum production
Volcanic	32 (27-38)
Sedimentary	30 (26-32)
Pumice	50 (43-61)
Peat	40 (35-45)

Note that the 95% confidence intervals in Table 2 are broad. This is a measure of the “noise”, the uncertainty, in these estimates. For example, the data in Table 2 indicate that to achieve 97% of maximum production on a volcanic soil, an **average** Olsen P of 32 is required, but it could be, based on probability, between 27 and 38.

The ‘noise’ in these estimates is a consequence of the inherent variability in measuring soil Olsen P (typically the coefficient of variability (CV) is 20%), and the inherent variability in the measurement of pasture production (typical CV 10%).

Taking this ‘noise’ into account, it is reasonable to condense the data in Table 2 into two groups, as has been done in the revised booklets, as follows:

Table 3. The **critical** Olsen P levels and the confidence intervals, to achieve 97% maximum production for the four soil groups after taking into account the ‘noise’ in the data.

Soil Group	Critical levels and confidence interval for Olsen P to a achieve 97% maximum production
Volcanic and Sedimentary soils	30 (26-38)
Pumice and Peat soils	40 (35-45)

The results in Table 3 for the Pumice and Peat soils are similar to the information presented in the revised booklets (compare Table 1 and Table 3) but the data for the Volcanic and Sedimentary soils are different. To be explicit, the data in the 2024 booklets for these two soil groups suggest that the **target** Olsen P (Table 1) is in the range 20-30, meaning that 97% of maximum production will be achieved if the Olsen P is somewhere between 20-30 and that the specific Olsen P to target when developing a fertiliser plan will include the economics in a given situation.

In contrast, the data in Table 3 indicate that the **critical** level to achieve 97% maximum production is on average Olsen P 30 and that the range in this estimate is 26 to 38. The **critical** Olsen P only relates to production and does not consider economics.

Economics Considerations.

Neither the **production function**, relating Olsen P and relative pasture production, or the **critical** Olsen P values, consider the economics of fertiliser use. To do that we need to introduce another concept – the **economic optimal** Olsen P. Figure 1 shows a stylised **production function** relating relative pasture production and Olsen P (0-75mm).

At low soil Olsen P levels large increases in relative pasture production occur if the Olsen P is increased as a consequence of applying fertiliser P. The gradient is steep and hence “a” is much greater than “b” (see Figure 1), meaning that the dollars made from applying fertiliser P, are much greater than the cost of applying fertiliser. It is economic.

At the ‘top’ of the curve the change in relative pasture production per unit increase in Olsen P is small. i.e., “a” is less than “b”, meaning that the cost of applying more fertiliser P is much greater than the dollar benefit in terms of a likely increase in pasture production. In other words, it is not economic.

What we are looking for is the point along the x axis where “a” is equal to “b.” This point is called the **economic** optimal Olsen P - farming above this is a waste of money and unnecessarily increasing P runoff. Operating below the economic optimal Olsen P means that profits are not being maximized.

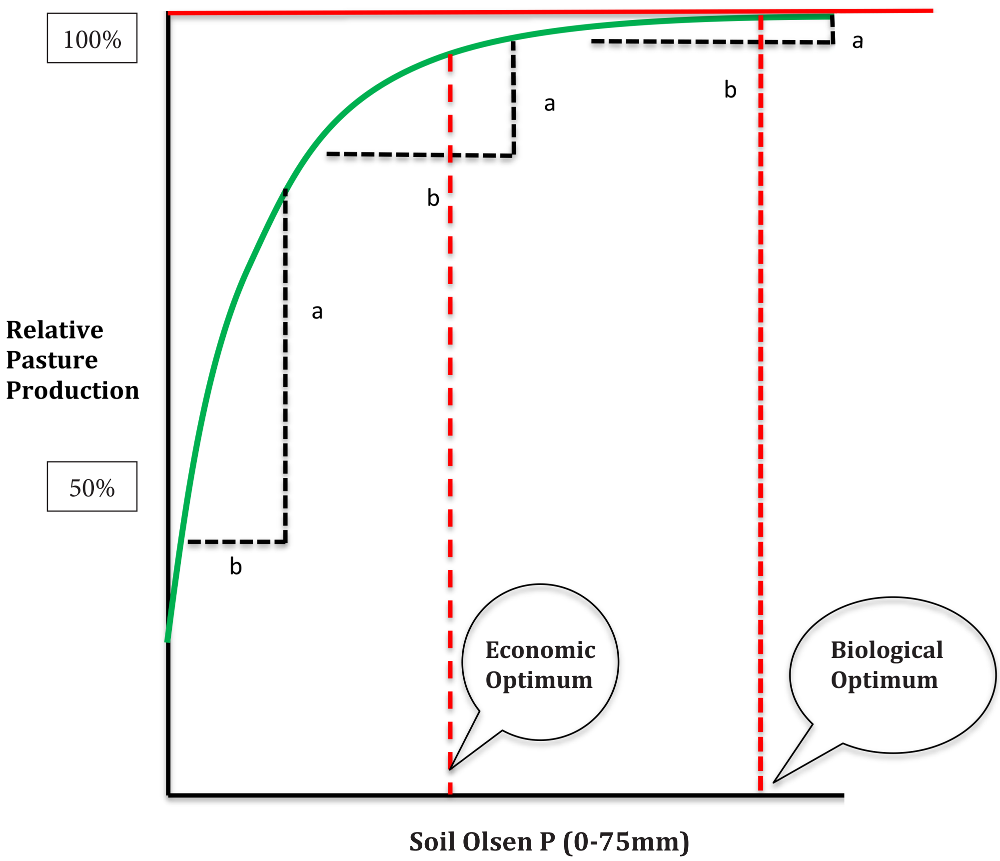

Figure 1 A stylised **production function** relating relative pasture production and Olsen P (0-75mm).

Thus, on the x-axis of the production function there are two important points to consider: the **economic** optimal Olsen P where profitability is optimised and the **agronomic** optimal where pasture production is maximised - they are very different "beasts."

The major factor determining the **economic** optimal Olsen P is the biological efficiency of the farm – how many dollars are made per unit of pasture production grown and converted into saleable product. And a good measure of this is the gross margin (GM) (the gross income minus the variable costs which includes animal health, supplements and power). The more efficient the farm is in terms of converting pasture into dollars, the higher the economic optimal Olsen P.

Dry stock farms

Typical gross margins on dry stock farms are in the range from about $500/ha up to about $2000/ha for intensive beef operations. Accordingly the **economic** optimal Olsen P levels typically range from about 10 up to 25 (Figure 2).

In practice most dry stock farms can be divided into blocks based on land class, which will differ in terms of their productivity and hence gross margin. Thus, the fertiliser policy can be rationalised further by determining economic optimal Olsen P for the different bocks on the farm.

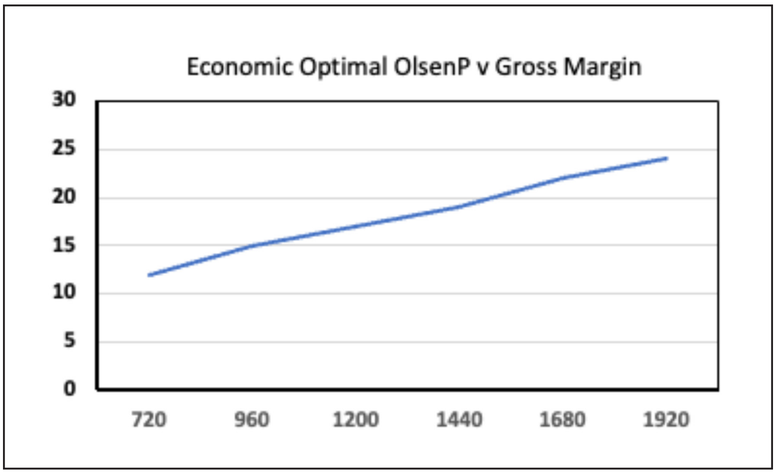

Figure 2 The indicative relationship between farm gross margin (GM/ha) and the economic Olsen P for sedimentary and volcanic soils, assuming typical costs for fertiliser and values for gross margin.

Dairy Farms

In contrast, the gross margins on dairy farms are much higher than on dry-stock farms and can range from $3,000/ha - $5000/ha. Consequently, the **economic** optimal Olsen P levels are much higher. This, of course, is the reason why dairy farms are operated at much higher Olsen P levels, but it also introduces another factor to consider.

The **production functions** are curvilinear and they become almost ‘flat’ at higher Olsen P levels (Figure 1). In this mathematical ‘no mans’ land it is impossible to define the Olsen P to achieve a relative pasture production of 100% and for this reason the best we can do is to define the Olsen P to reach 97% maximum production, accepting that this criteria is somewhat arbitrary.

As has been noted, the **critical Olsen P** and the range in **confidence interval** have no economic meaning. To take that step, we now must consider the economics of applying fertiliser to dairy farms, repeating that the major factor to consider is the GM. They are very high and when you run the numbers it turns out that the economic optimal Olsen P on high producing dairy farms (MS/ha > 1000 MS/ha) are in the range 35-40 for the volcanic and sedimentary soils, and 40-45 on the pumice and peat soils. On low producing dairy farms the relevant ranges are 30 - 35 and 35 - 40 respectively (Table 4).

Table 4. Estimated ranges in Olsen P to achieve **economic** optimal pasture production.

Production	Volcanic and Sedimentary soils	Pumice and Peat soils
High (>1000 kg MS/ha)	35-40	40-45
Low (<1000 kg MS/ha)	30-35	35-40

These estimated ranges assume that the economic goal for the farm is to optimise the profitability by maximising the production and utilisation from clover-based pastures.

REGENERATIVE AGRICULTURE – UPDATE

The Government has committed a large amount of R&D dollars to investigate the many claims made about Regenerative Agriculture (RA). I promised to keep you up to date on this topic.

In **Fertiliser Review 46** we reported the results from a survey comparing the meat quality from 9 conventional farms and 9 regenerative farms - there was little difference. In **Fertiliser Review 47** we looked at some definitions of RA - it appears that RA escapes definition. And then we asked the question; can RA affect climate change by sequestering more carbon in soils? Answer, no.

In **Fertiliser Review 48** we reported the financial data from 32 farms, (16 conventional and 16 RA farms), covering a 4-year period up to 2022. In short, while there was no difference in farm expenses, gross farm income was higher on the Conventional farms ($1,705/ha) versus the RA farms ($1,060/ha).

The results from a further survey, conducted in 2023, have now been published (Journal of the Zealand Grasslands, 84, 2022). In this survey many measurements were made comparing soil and pasture attributes, and farm management, from 13 conventional and 13 RA farms.

Cutting to the chase, the authors conclusion was blunt: “Overall, there were many similarities between regenerative and conventionally managed pastures, inferring that conventional farms in New Zealand are regenerative in many aspects.” One of the few statistically significant comparisons, and indeed one the most interesting result, was the greater legume content (13%) in the RA pastures relative the conventional pasture (4%). This was attributed to the respective fertiliser policies. The conventional farmers used synthetic fertilisers including nitrogen whereas the RA farmers used a veritable range of alternative organic - type fertilisers. We did not need research on RA to explain this observation.

Surveys of this type have limited interpretive value – they provide a snapshot at a specific time. This is acknowledged by the respective authors. Long-term scientifically designed and conducted trials are required.

Indeed, two long - term field trials (both are into their 3rd year), are now underway, one in the Hawkes Bay (On-Farm Research) and the other in the Manawatu (Massey University). Both trials are designed to investigate some of the theories being promulgated by RA protagonists.

As an example, RA practitioners believe that pastures should contain multiply species. To test this 18 species were sown in the Massey dairy trial and 19 in the Massey sheep pasture. It has been reported that after 2 years "the species which dominated were ryegrass and white clover, cocksfoot, red clover and plantain". And we are told this result is "not surprising, when looking at the amount of breeding and selection that has gone into these varieties over the years." Once again we could have predicted this outcome from first principles.

Thus, it seems to me at this stage, that the important information emerging from these surveys and the field trials is not new. This begs the question: Why are we undertaking this research? Why are we asking these questions of RA when infact the answers can already be predicted based on known science? Dare I suggest we are wasting scarce research dollars!

PHOSPHORUS FIXATION - AN OLD PORKY

In the very first Fertiliser Review (Fertiliser Review No 1 October 1998) I wrote, "No other concept in soil science has been so misrepresented and misused as soil P fixation. It has been and still is used to sell all sorts of useless fertilisers and soil amendments to unsuspecting farmers." I followed this up with another article in Fertiliser Review No 2 (March 1999). I thought these offerings could put this 'old porky' to bed.

[Note: the Fertiliser Review Nos 1 and 2 are available on the agKnowledge website for those who wish to see my 'take' on 'phosphate fixation,' now referred to an Anion Storage Capacity ASC]

Not so. A recent article in the NZ Farmer (September 2024) screams: "Farmers fixated by phosphate." The implication is clear. Farmers are wasting money applying phosphate fertiliser because there is already heaps of fixed P already in the soil. All that is required is some lime to unlock it.

There were a number of factual errors in the article. Dealing with them first. It reported that soils should be limed to a pH 6.2 to 6.3. The optimal soil pH for clover-based pastoral soils is in the range 5.8-6.0. Also, the article makes general use of term "P - sparing," referring to the effect that lime can have on the plant availability of P in soils. This effect is known to occur in SOME soils – the yellow brown soils in the Wairarapa for example, but even then the effect is too small to be of practical value. For instance, I would not recommend withholding fertiliser P inputs because lime had been applied. Looked at bluntly: lime is not a fertiliser.

Certainly there is a case for withholding P inputs and redirecting the expenditure into a liming program. Fertiliser P is expensive, relative lime, and thus it can be a good tactic financially, providing the soil P nutrient tank (the Olsen P level) is already at or above optimal (see article on Optimal P in this issue). This works well for P because it largely stays put in the topsoil (i.e. the P losses are low) and, providing you start with optimal Olsen P levels, the rate of decline in Olsen P, when P is withheld, is about 1-2 units per year.

This is not the same with the other major nutrients, K and S. They do not have large soil tanks and the loses relative to P, are much higher (from leaching in particular). Withholding inputs of these nutrients is not advised, assuming the goal is a maintain optimal production.

THE ENIGMA OF SOIL POTASSIUM

Potassium (K) deficiency is common in New Zealand pastoral soils. It appears that we have developed an aversion to using fertiliser K and the reasons for this are difficult to comprehend. After all, it is one of the 16 essential nutrients and if levels are below optimal (Quick Test K 7-10) the clover content, the most important component of our clover-based pastures, will be limited. Part of the problem is that we fail to appreciate how much K is required in our pastoral soils.

The amount of K in the soil/pasture/animal cycle is about 10 times that for P and S. Consider for a moment that K concentrations in pasture dry matter are about 3-4%, similar to the concentrations of nitrogen (N), whereas pasture P and S concentrations are about 0.3-0.4%. Farmers have become accustomed to applying annual fertiliser N inputs of 100-200 kg N/ha, but balk at the prospect of applying similar rates of K fertiliser! We need to refresh our understanding of K.

The soil K Quick Test (QTK) is directly related to the total amount of plant available K in the topsoil (i.e. A horizon, 18.5 cm) (Figure 2). The optimal QTK for clover-based pastoral soil is 7- 10 and this represents about 240 to 340 kg K/ha of plant available K.

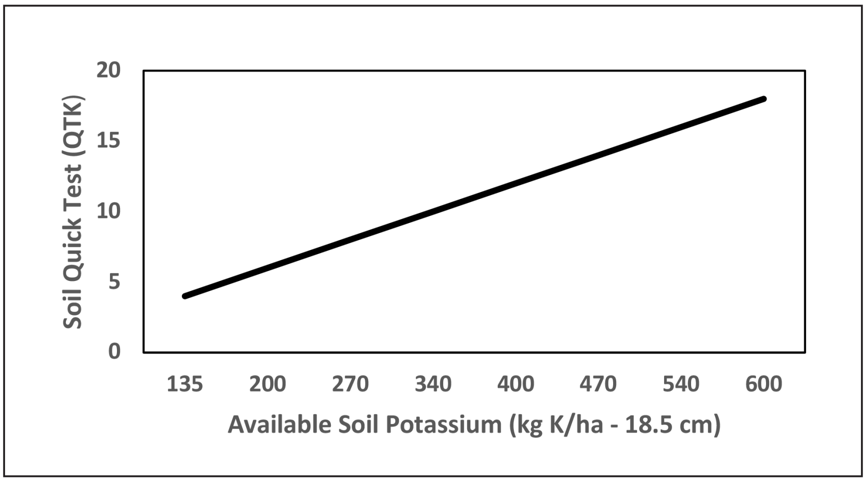

Figure 2 Relationship between available K in topsoil (18.5 cm) and Quick Test K (QTK)

Compare the size of this pool of available K in the soil with the losses of K from the system which include: removal of K in products, leaching, runoff and transfer to non-productive areas. Typically, to make good these losses of K, and hence maintain soil K levels, on a high producing dairy farm, requires 80-100 kg K/ha/yr. By way of contrast, the losses of K from a productive dry-stock farm are about 20-30 kg K/ha/yr, and the K removed in a hay crop is about 30-40 kg K/ha for a per tonne of dry matter (DM).

Now for some simple calculations. Assume you have purchased a farm which has a QTK level in the optimal range, let us say 8. At this QTK level the total plant available K in the topsoil will be about 270 kg K/ha (Figure 2). It is decided to convert it to a high producing dairy farm. It is estimated that the total K losses are about 90 K/ha/yr. Thus, if no fertiliser K was applied there will be soil K reserves for about 3 years (270/90). Alternatively, if the farm was converted to an intensive livestock block, the soil K reserves would last (270/30) about 9 years. At the extreme, if the land was used solely to make hay/silage/baleage, which is to be sold off-farm (assume 2 harvests of about 2 tonnes/ha each, per year) the K reserves would be enough for 2 years (270/160).

These numbers can be worked the other way. Suppose the new farm had a QTK 4 and the goal was to optimise pasture production asap (i.e. in 12 months), an increase in QTK from 4 to 7 would be required, and to do this 210 kg K/ha/year (3 x 70) would be required **over and above** the normal maintenance input.

When looked at from this perspective it should be no surprise that the incidence of K deficiency in clover-based pastures is so high. The problem situations are easy to identify:

1. Dry stock farms on sedimentary soils: Traditionally they have not used K fertiliser because the soils initially had plenty of K. The historically successful recipe was superphosphate, lime and some molybdenum. But they have been farming this way for many years and, as a consequence, they have used up all the plant available soil K reserves and now wonder why the pastures have runout of K and the clover is gone.

2. These same group of farmers are told not to worry – they are advised by their consultant that although the soil QTK is low, there is plenty of what is called Reserve K as measured by the TBK test. This test is not calibrated. If the soil QTK is low (<7) and the clover content and vigour of the pasture is poor there is a high probability that soil K is deficient.

3. Farmers who have converted to dairying and hence have greatly increased the need for K are wondering why their pastures are so ‘sick’. Chances are they have been told to increase the fertiliser N inputs. This simply covers up the problem – it does not solve it.

4. Some farmers believe, or have been told by their consultant, that applying potassium will cause animal health problems (see Fertiliser Review No 16 Potassium: Maligned or Malignant)

5. Farmers who are wondering why the hay paddocks are not ‘pulling their weight.’

My advice

Go and take a hard look at your pastures, preferably with a Pasture Visual Assessments (PVA) booklet in hand (https://agknowledge.myshopify.com/products/pasture-visual-accessment-pva). The visual symptoms of K deficiency are very obvious when you know what you are looking for.