



Fertiliser Review



POTASSIUM

Preface

Potassium (K) deficiency is common in our NZ clover-based pastures. The major symptoms are easy to see: pastures with low clover content (30-40% is good), poor clover persistence, pastures patchy and urine patches obvious if fertiliser N not applied, lack of clover vigour, brown edges on the clover leaves.

I can think of a number of reasons for this absurd situation: ignorance and/or bad advice, technical incompetence to diagnose and correct K deficiency in pastures, not using the correct protocols when soil testing resulting in inflated, high soil K readings, failure to apply the most recent science (see example below), over-use of fertiliser N to cover-up problems like the lack of pasture vigour and persistence and finally, it is not economic to correct K deficiency.

In 2010, I, together with some colleagues, reviewed all of the available research and technology on K use in pastures in NZ. I can report that paper had a difficult 'birth,' and has been largely ignored by the fertiliser industry and farm consultants, for some of the reasons given above. The full review can be found here:

[Edmeades, DC, Morton, JD, Waller, JE, Metherell, AK, Roberts, AHC and Carey, P. (2010) 'The diagnosis and correction of potassium deficiency in New Zealand pastoral soils: a review', New Zealand Journal of Agricultural Research, 53: 2, 151 – 173] or, on my website dougedmeades.com

This review is unashamedly a science review and comes with all the detailed scientific jargon, bells and whistles that that requires. It may be difficult for many laypeople to read. Given the importance of the topic, what follows below is 'cut down' version of the paper hopefully in a readily digestible form. A list of 'Take Home Messages' is added at the end of the article for those who are too busy to delve into the details.

Background

I have been challenged, yet again, on my interpretation of potassium requirements on clover-based pastures. My correspondent referred me to a paper which reported the results from a series of 5 trials on Hill Country soils of the East Coast of the North Island. The soils were K deficient, based on the soil K levels in the untreated control plots (QTK 2-4). There were 5 rates of fertiliser from 0-80 kg K/ha/year in year 1, and 0-160 kg K/ha/year in years 2 and 3. The authors recorded that, apart from one trial in year 3, no statistically significant pasture dry matter responses to fertiliser K were found. They concluded therefore that no fertiliser K was required on these low soil K, East Coast soils. How can these results and this conclusion be reconciled with so much other field trial data?

The Review

A review of all the available K field trials in NZ was published in 2010. It comprised results from 575 field trials, including, it is noted, the results from the 5 field trials mentioned above.

There was a lot of ‘noise’ - uncontrolled variability - in the K production functions, the relationship between relative pasture production and soil K (QTK). Against this background it is hard to see the ‘wood for the trees’ (Figure 1).

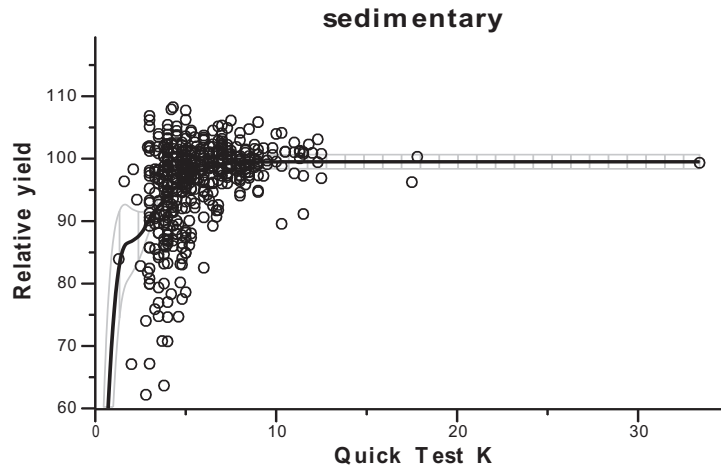


Figure 1 Production function relating Relative Pasture Growth and Soil Quick Test K (each circle represents one field trial of 3 to 5 years. The hatched area is the 95% confidence interval).

For this reason, an alternative approach to interpreting the data was examined. The Bayesian functions relating relative pasture production to soil K, for each soil group, were calculated and hence the probability of obtaining a response to fertiliser K, was determined (Figure 2). For the major soil groups the probability of getting a pasture response to fertiliser K is about 70%-80% for soils with low soil K (QTK 2-3). At soil K levels above 10 the chances of a response are very low.

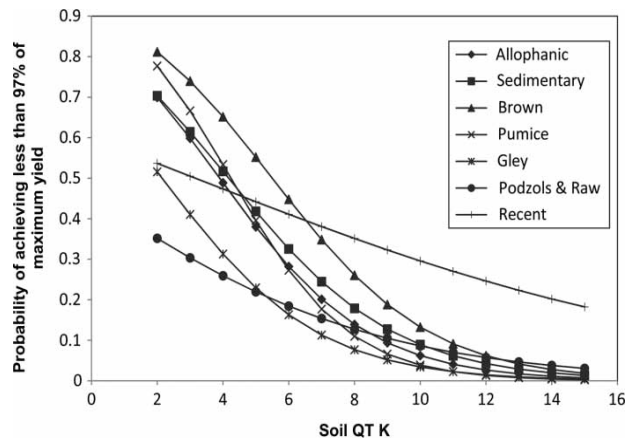


Figure 2 Relationships between soil QTK and the probability of a pasture response to applied K for different soil groups.

A feature of these trials is that there are some trials which were not responsive to fertiliser K application, even though the soil QTK levels are low (<5). Historically this has been interpreted to be due to the presence of slow-release K minerals in the soil, as measured by the TetraPhenol Boron test (TBK). To examine this further, a subset of K trials was selected on which both QTK and the TBK were measured (Figure 3).

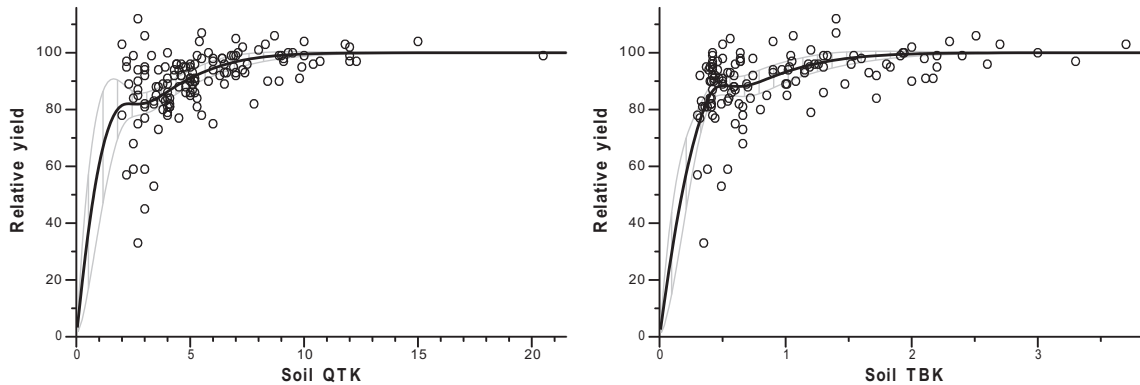


Figure 3 Relationships between Relative Pasture Production and Soil QTK and TBK.

The response functions are similar and suggest that the TBK test, which measures both exchangeable K (i.e. QTK) and the K released from slow-release K minerals, does not greatly improve the prediction of pasture responses to K fertiliser. In other words, the TBK test has little diagnostic value. Further analysis (not shown) showed (see review paper) that most of these non-responsive K trials, with low QTK, are on volcanic soils which do not contain slow-release K minerals. Another explanation was required to interpret these trials.

When re-examining some the accumulated pasture K trials, it became clear that pasture responses to K, on clover-based pastures, are temporal. The results in Figure 5 illustrate this point. This arises because clover has a higher requirement for K than grasses. Put another way, on K deficient soils, clover ‘struggles.’ (Figure 4). As the soil K level is increased the clover component of the pasture increases, returning more and more fixed N to the soil and hence stimulating grass growth and increasing total pasture production.



Figure 4 From a field trial on a pumice soil. Plot on the left, soil QTK 4. Plot on the right, soil QTK 7. The increase in annual pasture production due to capital K inputs was 30%-40%.

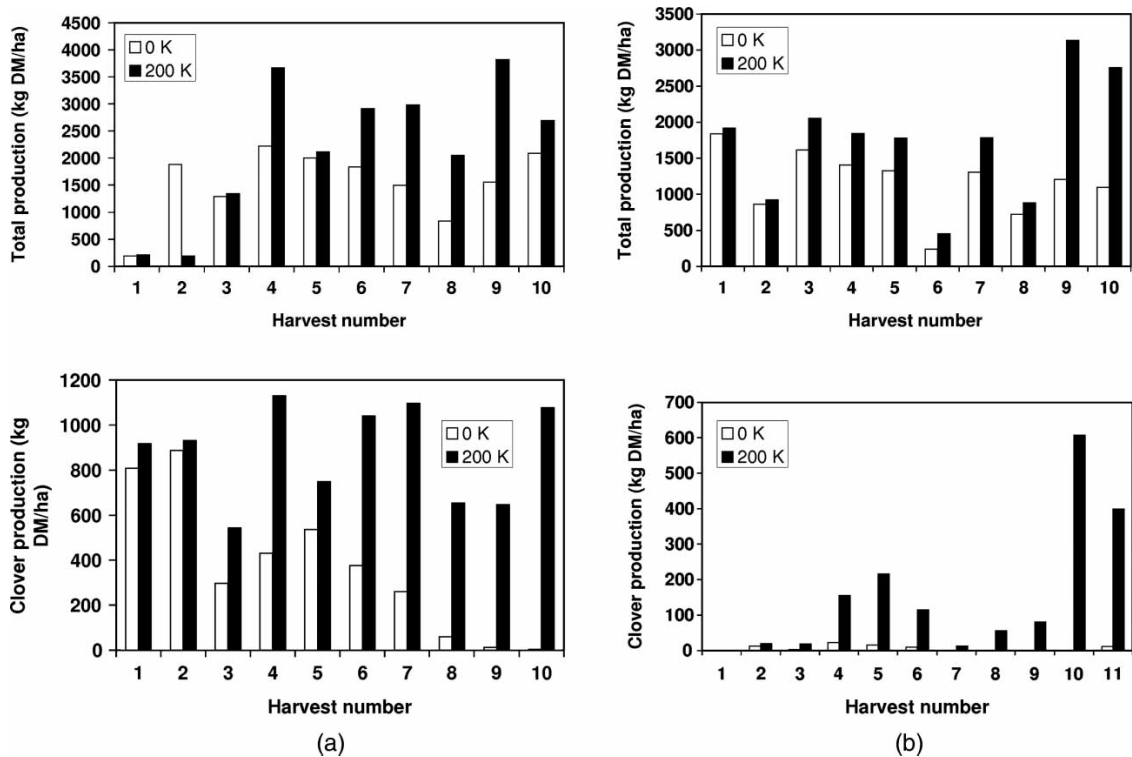


Figure 5 Effect of potassium application on total pasture production and clover production at each harvest on (a) a sedimentary soil (QTK 5, 260 kg K/ha/ yr. 2.5 years duration) and (b) a volcanic soil (QTK 4, 200 kg K/ha/yr. 2 years duration).

This biological process takes time (Figure 5) to develop. With this in mind the data in Figure 3 was modified by setting aside the results from the first year of each trial, remembering that for multi-year trials, the recorded relative yields for each trial were calculated by averaging the annual responses. This procedure removed those trials with low soil K status which showed little response to K fertiliser (compare Figures 3 & 6).

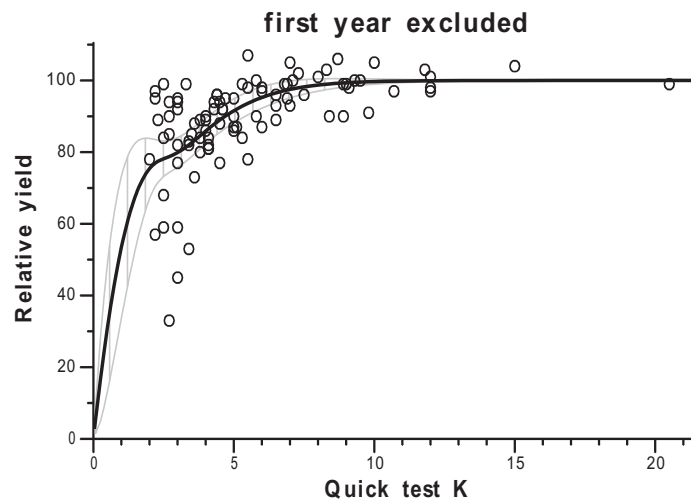


Figure 6 The relationship between soil QTK and relative pasture production for a subset of trials excluding the year 1 data (The hatched area represents the 95% confidence interval).

Figure 6 represents the 'cleanest' (the least amount of uncontrolled variability) set of data defining the relationship between soil QTK status and pasture responsiveness to K fertiliser. Importantly, it is consistent with the interpretation of probability data in Figure 2 and, when these results are considered together, and allowing for the inherent errors in this type of data, the best estimate of the optimal soil QTK to achieve near maximum pasture production is about 7-10. This conclusion applies to all major soil groups; sedimentary, volcanic, pumice and peat soils.

Economics

Some argue that it is not economic to correct soil K deficiency. This is nonsense. This is equivalent to saying it is not economic for those with Type 1 diabetes to take insulin! Yes, large capital K inputs are required, just as was required for P, when breaking in new land.

The rule of thumb is 70 kg K/ha (150 kg potash/ha) to increase the QTK by 1 unit. To move from a soil QTK of 4 to the optimal (QTK 7) requires about 210 kg K/ha. But look at the upside; large pasture responses to fertiliser K occur at low soil QT<5 levels. From Figure 6 it is **predicted** that at QTK 4, the increase in annual production is 30%-40%. The photo in Figure 4 is from a field trial on a pumice soil (QTK 4) which ran for a number of years, and the average annual pasture response was exactly that, 30% to 40%. Think this through! A 30%-40% increase in production for a one-off capital K cost after which a maintenance K fertiliser only is required.

And there are strategies to deal with this problem: the capital K inputs required to achieve the optimal QTK can be factored in over-time to suit the budget. On farms which are at or above optimal Olsen P levels, withholding P inputs for 12 months, without any loss in production, and redirecting the fertiliser budget to a capital K program is another option. Once the optimal soil QTK have been achieved, it is a simply matter to return to a maintenance program of P, K and S

A change in mindset is required. The amounts of K in the soil/pasture cycle are about the same as for N. What is different is that we are not familiar with the idea of applying capital fertiliser K, but by comparison, we have been doing it year-on-year with capital N inputs at comparable rates of 100-200 kg N/yr.

Five Field Trials

Returning now to the results of the five K trials mentioned in the background. Recall that there were 5 trials on low soil K sites (QTK 3-4). The trials were run for 3 years and the effect of fertiliser K on pasture dry matter production was measured on 15 occasions – 15 harvests. The data was analysed on a harvest-by-harvest basis and it was reported that the effects of K were not statistically significant on all, but one occasion.

Closer examination of the data shows that the annual production from the 5 trials was 1% in year 1, 10% in year 2 and 25% in year 3. This temporal effect is clearly evident in the data (Figure 7), and is consistent with the results in Figure 5.

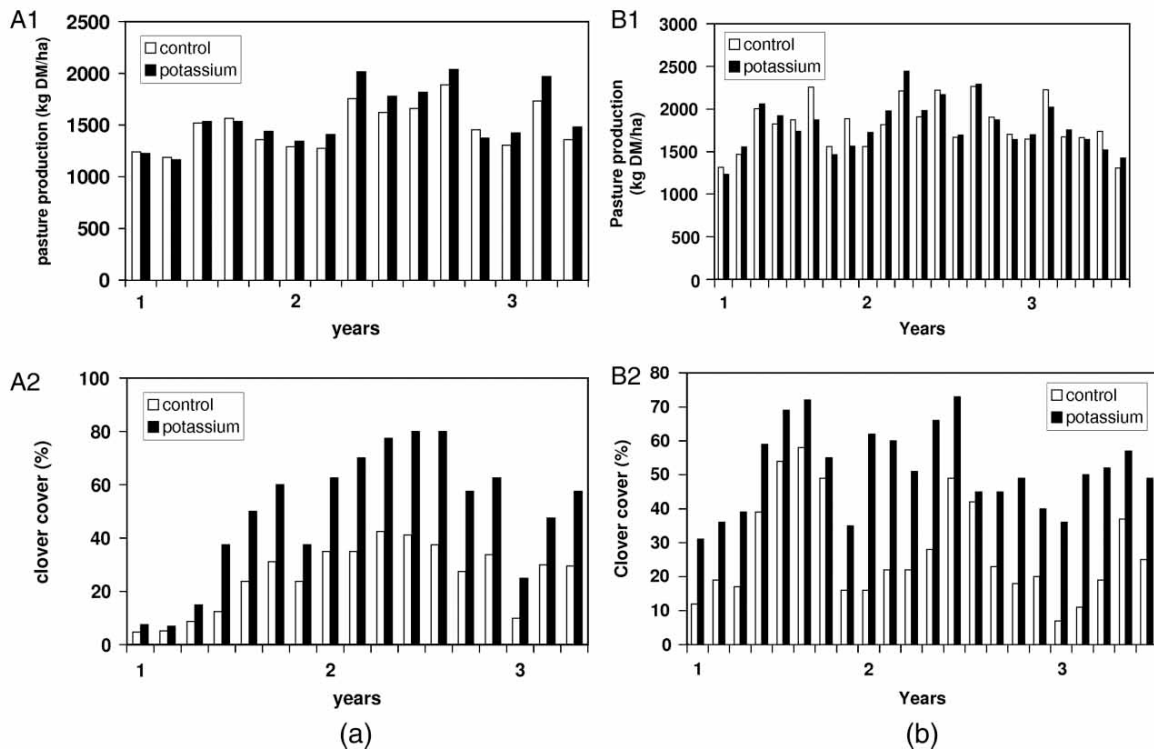


Figure 7 The effect of potassium applications (80 kg /ha/yr) on pasture production (kg DM ha/ per harvest) and pasture clover cover (% as measured visually) at each harvest date over three years on two trials on Hill Country on the East Coast of NZ.

Applying the logic above, and setting aside the first year’s results, indicates that the average response to K across these 5 sites over the last 2 years of the trials, is about 17%. The average QTK on the control plots is in the range 3-4. This result can be predicted with some confidence from the data in Figure 6 – at QTK 3-4 the predicted average response over the 5 sites should be about 20% - QED, an acronym for the Latin phrase – “the point is proven”.

The Proper Scientific Approach?

The interpretation of the five trials highlights the old biometrical dilemma. When the results from a given trial are not statistically significant, two questions arise; is the treatment, in this case fertiliser K, ineffective or, is the trial design not sufficiently powerful to detect the observed effects. Essentially; are the number of replicates large enough, given the size of treatment effects and the background 'noise' – the variability inherent in this type of research?

When this question arises, it is necessary to look at the **whole** set of data (from these 5 trial) in the context of **all** the information available concerning the nature of K responses in clover-based pastures, as has been done above. When this analysis is properly completed, it is reasonable to conclude that the results from these 5 trials are not unique in the NZ context.

Take Home Messages

The key points from the potassium (K) review are:

1. The optimal soil QTK for near maximum pasture production on clover-based pastures is 7-10. This applies to all soil groups; sedimentary, volcanic, pumice and peat soils.
2. The soil TBK test is of little diagnostic value.
3. Clover is more sensitive to K deficiency than grasses.
4. The ideal pasture contains 30%-40% clover.
5. A well fertilised clover-based pasture can fix 100-200 kg K/ha/year.
6. Clover has a higher feed-value for ruminants than grasses.
7. Pastures will become clover-dominant initially, after correcting soil K deficiency.
8. It can take time (12 months) for clover-based pastures to fully respond to potassium (K) fertiliser, when correcting soil K deficiency, and hence building-up soil N levels so that grass growth is optimised.
9. It is economic to apply capital fertiliser K inputs, and strategies have been developed to deal with this.
10. Once the optimal soil K levels have been reached a maintenance K program can be continued.



FREE-LIVING NITROGEN BACTERIA

We are all familiar with the knowledge, or at least we should be, that clover plants – our ubiquitous forage legume - have nodules on their roots and that these nodules contain rhizobia, which fix (convert) nitrogen (N) from atmosphere in a form that the plant can utilise to make protein (N). In return the rhizobia get their source of energy from the plant in the form of carbohydrates. This relationship is symbiotic – both partners benefit from the association. This one of the most obvious biochemical processes that New Zealand agriculture relies upon on. Typical clover N inputs to the soil range from 100 to 200 kg N/ha/yr and it is estimated that this adds about \$1.7B worth of N to our pastoral soils.

Our soils also contain free-living bacteria – they do not need a host plant to survive. This fact has also been known for a long time but it was always believed that the amounts of N they fixed and added to most well-drained soils is small. In the context of the amounts of N in the pastoral N cycle the amounts are trivial.

This maybe about to change. World-wide the race is on to see if these free-living bacteria can be somehow harnessed to the benefit of world-wide agriculture. Think of seeds, grasses and crops that could be “inoculated” with free-living N fixing bacteria and were as effective quantitatively as the rhizobia-clover N story.

Two such products are already on the market in New Zealand. Agraforum NZ is currently marketing a product called BioN, which, according to the advertising, “harnesses living microbes that capture nitrogen directly from the air – fixing up to 80 kg N /ha over just 8 weeks.” It is claimed that BioN gives “Equal or better results than urea”. Gerhard Veermaak, the inventor of this product from South Africa, tells me that in addition to the free-living N fixing bacteria, BioN contains another bacterium which fixes carbon and provides the N-fixing bacteria with a source of energy, analogous to the clover plant supplying energy to rhizobia. After an initial ‘proof of concept’ glasshouse experiment on maize, trials are now underway to test the product in the field on a range of crops. Agraforum has told me that trials are currently

underway on pastures in Canterbury and Southland. I am told that Agraforum will not release the results publicly until a full biometrical analysis has been completed.

Bioconsortia, an American company, has developed a seed treatment which contains free-living N fixing bacteria. This product, called ‘AlwaysN’ is now available in NZ through its NZ distributor H & T. They claim that the Always N microbes, which feed off plant exudates, interact with the growing roots hairs to fix atmospheric nitrogen, and can fix the equivalent of 15-30 kg fertiliser N per hectare. The Bioconsortia website tells us that they have conducted many trials in the USA on a wide range of crops, but there are no details regarding the experimental design and conduct of these trials, and importantly, no biometrical analysis of this data is available. The local company H & T says that it has trials in progress in the Manawatu and Waikato on pasture, maize, barley and brassicas.

Until the full details regarding the results of these field trial, together with information on the design, conduct and biometrical analysis of these trials are publicly available, it is not possible to fully assess the veracity of this product. I look forward to seeing the results from these trials.

If it can be proven that free-living bacteria can be found, or indeed manufactured via gene technology, that can fix agronomically significant quantities of N from the atmosphere, it would be an enormous agricultural breakthrough world-wide. The stakes are indeed high and when the stakes are high the science must be of excellent quality!

A word of caution. Scientists from Holland have recently (2024) published a very comprehensive review of all the available evidence on this subject. Their conclusion is stark. “Despite more than 50 years of research, no robust evidence suggests that inoculation of cereals and other non-legumes with free-living and/or endophytic bacteria leads to fixation of agronomically significant quantities of dinitrogen gas (N₂) from the atmosphere.



PROBITAS

Recall the product Probitas – a silica-based fertiliser which, it was claimed, converted radiant energy from the sun into electrical energy which stimulates the soil via electrolysis to release otherwise unavailable nutrients. In 2007 the company Probitas Ltd and its owner Ewan Campbell were fined a total of \$260,000 under the Fair Trading Act 1986 for misleading advertising. I was retained as an Expert Witness on behalf of the Commerce Commission, who brought the action against Probitas.

In 2007 Mr Campbell and his wife incorporated a company, Cambrian Fresh Ltd, which operated an organic butchery and produce shop. It employed 7 staff. In 2016 he was jailed for four years and 9 months for \$1.45m worth of tax evasions. He claimed: "I sit in court knowing the tax laws in New Zealand don't apply to me. At present I have nothing [which] says I have been convicted of any crime. I don't accept anything contended by this court, only a dismissal."

Despite these setbacks, Mr Campbell is back in business. His new venture is called EcoFarmAotearoa. His website offers a dozen or so videos on all manner

of topics. It appears that he has found a 'formula' to get rid of weeds and facial eczema, and enhance soil and animal health: the process we now learn is called 'biological transmutation', a theory developed by a French scientist Louis Kervran back in the 1970s, which purports to show how soil biology can convert magnesium into calcium, silicon into calcium and calcium and sodium into potassium. To my mind this sounds like a modern take on alchemy! He uses this, together with Albrecht's debunked Ratio Theory, to explain why soil test results can change over time and how this information can be used as the basis for appropriate fertiliser advice.

My Advice

I recommend this website, and the associated videos, to those who are interested in the question: How effective is the Fair-Trading Act, and our tax laws for that matter, at protecting all citizens against people like Mr Campbell, who appears to be above science and the law?



FERTILISER ADVICE AND AI

I have in front of me an AI generated Fertiliser Recommendation Report for a generic Waikato dairy farm. The report is 5 pages long and is presented in 7 sections: Executive Summary; Introduction; Waikato Ash Soils Characteristics; Nutrient Requirements for Pasture Production; Practical Fertiliser Programme; Resource Management Act Compliance; Monitoring and Adaptive Management; Economic Considerations; Conclusions and Recommendations. These sections contain mostly generic information which is of little practical use when offering farm specific fertiliser advice.

The Olsen P on this generic farm we are told, is currently 28, the soil QTK is 6 and the pH 5.7. The other important soil test results are not given. The recommended nutrient inputs are (kg/ha/yr.) 25 - 30 kg P, 40 - 60 kg K, and 20 - 25 kg S.

Apart from stating that a well-managed Waikato dairy should achieve 12,000 – 16,000 kg DM /ha/yr. no farm specific goals are offered. This is the major limitation when it comes offering farm specific fertiliser advice.

In my opinion the minimum set of information required to offer a basic farm specific fertiliser program for a dairy farm should include:

- A farm visit and pasture assessment, including pasture vigour and clover content, weed loading, presence or absence of excreta patches, farm topography.
- A clear expression of the farm type (Dairy NZ System Types 1 to 5) including supplementary feed.
- A clear expression of the farm goals; including production, social and environmental
- A set of current soil test results covering all the discrete blocks on the farm and some indication as to whether these results are consistent with pasture assessment?
- Past soil tests and fertiliser history if available.
- Clover-only tests if required.
- Nutrient inputs required to meet the farm goals.
- Least-cost Fertiliser Requirements to achieve the required nutrient inputs.

It is accepted that other analysis may be required to meet Code of Practice requirements These can readily be clipped onto the basic fertiliser recommendation.

Clearly the Fertiliser Recommendation Report offered via Chat GPT does not meet these specifications and therefore I would not recommend this approach. However, the Report does contain some excellent advice at the bottom of page 5 and in small print.

This recommendation is based on current best practice for Waikato dairy farming. Individual farm programmes should be tailored to specific soil test results and farm system requirements. Consult with a qualified farm consultant or fertiliser representative for farm-specific advice.