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POTASSIUM: A FORGOTTEN NUTRIENT?

On my office wall at home I have an old advertisement from the Putaruru Press dated March 1932. It is poignant, not just because Putaruru is my hometown, but because the message it contains is just as relevant today. It says:

> *"The man who starves his pasture robs himself: Potash made all the difference."*

In my experience, potassium (K) deficiency in pastures is as widespread today as it was then, and, it is not being diagnosed by the fertiliser reps (see the other articles below in this issue of the Fertiliser Review). I have made strenuous efforts to raise this concern with both fertiliser co-ops who have not been inclined to listen. Indeed there is a "joke" around the industry that I have gone "potty" over potash (K). I reassure you – I have the facts.

FertReseach, the agency for The Fertiliser Industry, commissioned me to review all the available research on the potassium requirements for pastures. This review was co-authored with my old colleagues from research days; Dr Ants Roberts and Dr Alister Metherell (now with Ravensdown) and Mr Jeff Morton (Ballance). The paper was published in the NZ Journal of Agricultural Science in June 2010 (it is available at my website www.agknowledge.co.nz).

Of all the papers I have written, this one had the most difficult 'birth' because it challenged our old views and perceptions about potassium use on pastoral soils. Here are some of the key findings:

Defining the Soil K Production Function

A database was set up recording the data from all the past potassium trials on pasture (804 trials). From this data the relationships between soil K (as measured by the traditional MAF Quick Test – QTK) and the pasture responsiveness to fertiliser K, for the major soil groups, were defined (see Figures 1, 2 and 3 below). It is apparent that there is a lot of 'noise' in the data, meaning that there are factors other than soil K which are affecting the pasture response to applied K. Note in particular the significant number of trials (each dot on the graphs is a trial) which were not responsive to applied K despite low QTK levels, and that the relationships are mostly flat over the range QTK 5 to 10. These relationships lack precision.

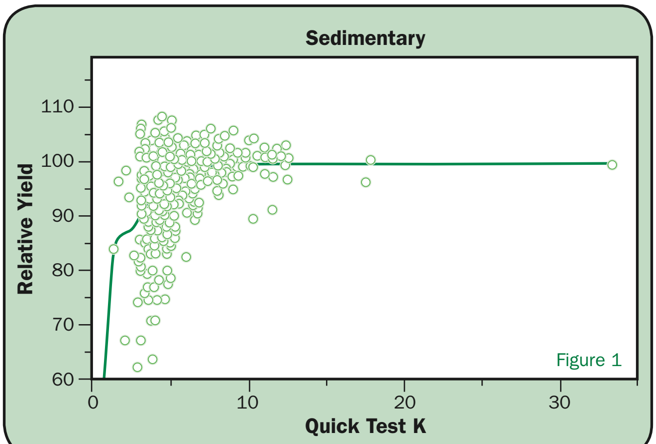


Figure 1

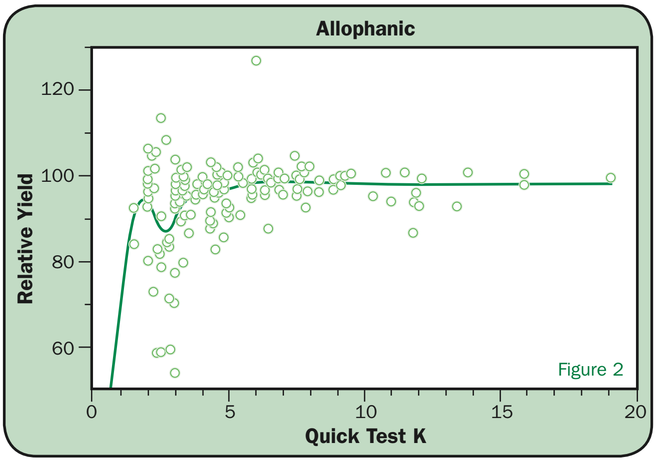


Figure 2

Several reason for this were identified and discussed in the paper:

1. The classic reason for the lack of responsiveness at low QTK is that some soils (the sedimentary soils) have what is called Reserve K. This K is not measured by the QTK but is slowly plant available. It was argued based on this, that these soils were still productive even at low QTK levels.
2. Another factor, and examples are given in the paper, is that it takes time (2-3 years) for pastures to respond to applied K. The implication is that short-term trials (1-2 years) underestimate the real K responsiveness of a site.
3. A third reason is that plants can recover K from below the soil sampling depth of 75mm. Thus, some soils, which are rich in subsoil K below 75mm, may not be responsive to applied K even though the topsoil K (QTK to 75mm) is very low.

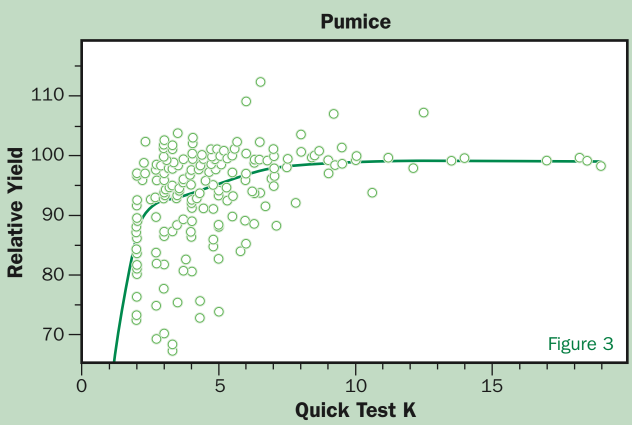


Figure 3

Probability of K Response

In an attempt to overcome these limitations in the data, a different approach was adopted. Rather than plotting the relative pasture yield against soil QTK we plotted the probability of getting a K response (see Figure 4).

This implies that if you want to be certain that pasture production is not limited by K, a QTK of near 10 is required on all except the recent soils.

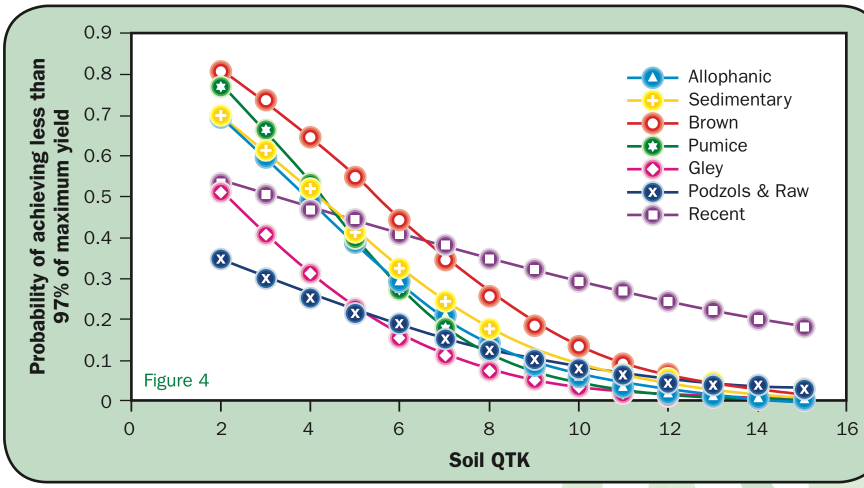


Figure 4

Reserve K

We also examined a subset of trials, including both volcanic (no Reserve K) and sedimentary (containing Reserve K) soils (Figure 5 a and b). These response functions look tighter, cleaner and with less noise. But the surprising thing is that the Reserve K test (referred to as TBK, which measures QTK plus Reserve K) did not improve the relationship with pasture response to K. In fact they look very similar. In other words the Reserve K test does not add any new information. Both tests (QTK and Reserve K) are equally useful as predictors of K responsiveness on both sedimentary and volcanic soil, but the QTK is much simpler and of course costs less.

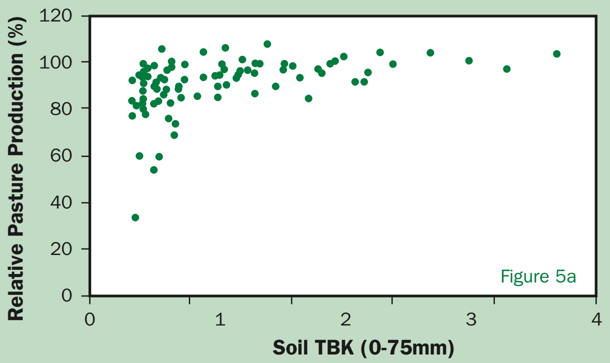


Figure 5a

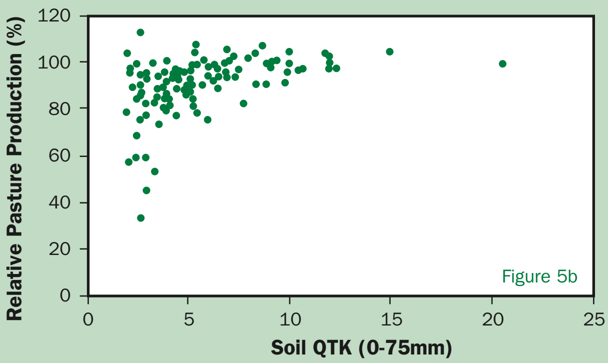


Figure 5b

Increasing Soil K Levels

There is a paucity of data on this subject. What there is, is not precise and suggests that about 120kg K/ha (range 50 to 200kg K/ha) is required on sedimentary soils and about 70kg K/ha (range 40 to 80kg K/ha) on volcanic and pumice soils to increase the soil K levels by I unit. Yes that is right – large amounts are required over and above maintenance! Potassium is like N, and unlike P and S – large amounts are required because large amounts are cycling around in the soil-pasture-animal system.

Potassium Maintenance Requirements

Maintenance K requirements depend on the initial soil K level. To maintain levels of about QTK 4, 20-30kg K/ha are required annually. To maintain levels in the range QTK 8-10 requires inputs of 75 to 150kg K/ha per year.

What does all this mean?

The messages I take from this are:

1. Abandon the Reserve K test – it adds nothing to the diagnosis and management of K deficiency in pastoral soils.
2. The distinction we have made historically between sedimentary (soils with reserve K) and other soils (like the pumices and volcanic soils with no reserve K), in terms of diagnosing and managing K deficiency, is no longer tenable.
3. We need to recalibrate our thinking about K requirements. Large amounts of K are required to increase soil K levels and large amounts are required to maintain soil K levels. Remember, in terms of the amounts cycling around the soil-pasture animal system, K is like N.

Resistance to Change

Since publishing these results I have meet with staunch resistance as to why we should not change. Here are the main sticky points:

1. You cannot raise soil K levels

Wrong – you can, providing enough is applied. Go check the soil K levels on the effluent block!

2. Potassium is too expensive

Nonsense. Potassium costs about $1.70/kg compared with fertiliser N at $2.20/kg. Dairy farmers at least will gladly apply 150 to 200kg N/ha and, relative to K (which has long-term effects on clover and hence clover N inputs), the effects of fertiliser N are short-term (4-6 weeks).

3. It is not economic to correct K deficiency

Rubbish. Pasture (clover and ryegrass) is the cheapest feed on the farm at about 2-3 cent/kg. Fertiliser-feed grass cost about 10-12 cents and maize and PKE are over 30 cents. Get over it!

4. Potassium inputs create animal health problems

I agree there is this potential in terms of bloat because correcting a K deficiency results initially in large increases in clover. There is no evidence that K inputs increase metabolic problems or reproductive performance (see Fertiliser Review No 16).

ALL PADDOCK SOIL TESTING

A new craze is upon us. This one promoted by Hill Laboratories – “All Paddock Soil Testing.” Is it a good idea? To answer this we need to get into a bit of simple statistics.

Soil tests are variable over time (seasons) and space (position). This is called natural variability because it is in the nature of things. Soils are not naturally uniform (think of the depth of topsoil or the drainage characteristics). In addition we introduce more variability (animals do not return their dung and urine evenly) and furthermore we treat different areas of the farm differently (effluent blocks for example). Farmers are of course aware of natural variability i.e. animals are not a uniform weight and do not produce the same amount of product. These are obvious examples.

This type of variability does not mean that measuring soil nutrient levels or weighing animals is a waste of time. It simply means we have to be aware of it and factor it into our thinking and management.

For soil tests we know what the typical variability is for the different soil tests. For Olsen P it is about +/-20%. For the more mobile nutrients it is higher (about 30% for K and S). For soil pH it is lower (about 10%).

What do these numbers mean?

Let us use Olsen P readings by way of example. Say you took a soil sample (20 cores) from a paddock and the reading was 25. With a CV of 20% it means that the 'true' Olsen P could be anywhere in the range of +/- 20% (i.e. from 20 to 30). In other words, if you went to the same paddock and took another sample (20 cores) the reading could be 20 or 30 or some number in between. The point is this; it is dangerous to interpret soil tests literally (i.e. the soil test is exactly 25). It is more accurate and correct to think; the soil P level in this paddock is between 20 to 30. That is why soil scientists talk about the ideal range for Olsen P for dairy farms, for example on pumice soils, as being between 40-45, or the economic optimal Olsen P range for a sheep and beef farmer on hill country is 20-25.

Now lets say you have two paddocks side by side. You take a soil test (20 cores) from one and get a reading of 20, and from the other you get a reading of 30. Assuming that the optimal soil test for your farm was about 30, it is likely, if you knew nothing about soil test variability, that you would apply a maintenance fertiliser P to the paddock with Olsen P 30 (to maintain a level of 30) and apply a capital fertiliser P input to the paddock with an Olsen P of 20, to bring it up to 30.

By not appreciating soil variability you have ignored the likelihood that the P status of both paddocks is the same (i.e. about Olsen P 25) and hence the paddocks should be treated the same. And therein lies the stupidity of "All Paddock Soil Testing." You end up chasing variability, which costs more money (extra soil tests – see later) and adds more complexity with different fertiliser mixes for different paddocks – for no financial advantage.

Soil scientists have known about soil test variability for years and worked out soil testing strategies to cope with it. The solution lies in the word, stratification. Most experienced soil scientists when confronted with a "new" farm, and certainly this is my approach, go around the farm to get a "feel" for it and then sit down with the farmer, a farm map, and stratify the farm. This involves dividing the farm into blocks of similar soil group, slope, land use, and past management history. Then a soil test (20 cores) would be collected from a transect (it could be one paddock or several paddocks) which best represents each unique block. By doing this, the majority of the variability across the farm is eliminated. If the soil tests from each block are similar, allowing for the normal variability, then they can be averaged and treated the same in terms of fertiliser input. If not, each block can be fertilised differently.

Once again farmers are well used to the idea of removing or managing variability by stratification. Prior to lambing the flock will be divided into hoggets, single and multiples. Dairy farmers will often run multiple herds based on age or body weight. There is no rocket science here. It is the application of common sense.

An Example

A client in Southland has two dairy farms and the fertiliser company had collected soil samples from each paddock on both farms. The fertiliser company then grouped the soil tests in 4 categories in terms of fertiliser advice: no fertiliser P, Maintenance P, Capital P (30kg/ha) and Capital P (60kg/ha). Confused, the farmers contacted me.

We also soil tested the farms using the normal 'block' process described above. After assessing the farms we identified five blocks on one farm and seven on the other and then took representative soil samples from each block. Our results are shown below together with the all paddock data collected by the fertiliser company.

Method	Farm 1		Farm 2	
	Olsen P	Soil pH	Olsen P	Soil pH
All paddock	32 (18-50)[1]	5.8	26 (18-45)[1]	5.6
Stratified Blocks	26 (22-31)[2]	5.7	24 (20-33)[2]	5.7

Notes 1) mean and range in brackets - both 31 samples
2) mean and range in brackets - Farm 1 (5 samples), Farm 2 (7 samples)

The point is obvious – the results are almost identical allowing for the normal variability associated with soil tests. Stratifying the sampling (sampling the farms in blocks of similar soil group, slope, land use etc) takes out most of the variability.

For the stratified results the range of Olsen P on Farm 1 was 22-31 and 20-33 on Farm 2. This is entirely within the normal variability of soil tests and hence it makes sense to apply the same fertiliser across each farm. There was simply no need to fertilise areas within each farm differently.

Both farms had 31 paddocks and so the cost of the soil tests (leaving aside the cost of actually collecting the samples) was about 31 x $60.00 = $1,860.00. The cost of the soil tests, using the traditional block method was between $300.00 to $470.00. A difference in excess of $1,000.00 for no additional benefit to the farmer! Adding value – yeah right.

Concluding Thoughts

I have, in the last few editions of the Fertiliser Review, taken Hill Laboratories to task (Fertiliser Review No.'s 25 and 26) for the lack of rigor and science in some of their soil and plant tests. All Paddocks Soil Testing is a gimmick. It lacks science rigor and ignores past science and experience. The only beneficiary is Hill Laboratory and there is no upside for the farmer.

ABRON

A client asked me to provide an assessment of the fertiliser advice offered to him by Abron. Abron Living Soil Solutions is a 'New Age' company that practices pseudo (false)-science (see Fertiliser Review No 25 and also the paper "Pseudo-science: A threat to Agriculture?" at www.agknowldedge.co.nz). What follows is my edited report.

Soil tests

Based on the information provided, three soil tests (assuming 0-75mm) were collected by Abron in August 2009 from three blocks and a further five samples (0-75mm), one assumes from similar areas within the farm, were collected by one of the mainstream fertiliser companies in August 2009. These results are summarised below relative to the ranges required to optimise pasture production (achieve 97% maximum yield) in clover-based pastures (my assessment).

Source	pH	Olsen P	K	Mg	Ca	Na	Sulphate S	Organic S
Abron (mean of 3 samples)	5.8	19	14	35	11	7	Not given	5
Fertiliser company (mean of 5 samples)	6.0	13	5	26	10	8	8	6
Optimal	*5.8-6.0*	*30-35*	*8-10*	*8-10*	*> 1*	*>3-4*	*10-12*	*10-12*

Except for the K levels, the average results from the two sources are similar, For soil K, the levels reported by the fertiliser company were much lower than those from Abron. This can arise if the soil sampling is not done in accordance with the standard procedure, which specifically requires avoiding all nutrient hot-spots (e.g. urine patches).

These results suggest that the nutrients most likely to be limiting pasture production are P, K (based on the fertiliser company results) and S. No lime, Ca, Mg or Na is required.

Abron's Fertiliser Advice

Based on their soil tests, Abron advised a fertiliser blend to be applied at 266kg/ha. The composition of the blend is set out below:

Component	Comment	Amount recommended (kg/ha)	Cost ($/ha)	Agronomic Value ($/ha)
Rorisons[1] serpentine	Trials show it is an ineffective source of Mg	50	4.25	0
Rorisons[2] elemental S	Effective source of S providing it is finely ground	5	1.75	1.75
Soluble humate granules[3]	Most NZ pastoral soils already contain many tonnes (100 to 200 tonnes/ha) of organic matter, 50% of which is humate	5	23.0	0
Humated B, Co and Se[4]	B is not required on pastoral soils. Co and Se may be required depending on the current soil/pasture levels	6.0	24.6	12.68 (Co and Se only)
AgLime[5]	Soil pH levels indicate lime is not required. 200 kg/ha unlikely to have any agronomic value	200	3.9	0
Total		**266 kg/ha**	**$59.915**	**$14.436**

Notes
1) price from Rorison (May 4, 2011) $85 per tonne
2) According to Rorison they do not sell elemental S. Price assumes fine lime at $0.85/kg
3) price from Abron (May 4, 2011) at $4.6/kg
4) price from Abron (May 4, 2011) $4.10/kg (14% B. 0.5% Co, 0.125% Se).
5) As quoted on the Abron Recommendation excluding the blending and mixing fee of $0.88/ha.
6) Assuming the active ingredients were purchased elsewhere

Assuming that Co and Se are required, the value of the agronomically useful components in the Abron mix is $14.43/ha ($15,440.00 for the whole farm of 1070 ha) relative to the actual cost to the farmer of $59.91 ($64,041.00 for the whole farm). This represents a margin of about 315%. If neither Co or Se are required then the agronomic value of the components in the Abron mix is $1.75/ha ($1875.00 total farm)

Thus it appears from this example that the products recommended by Abron are very expensive relative to buying the same components from more conventional sources.

The Quality of Abron's Advice

The table below compares the nutrient inputs (in kg nutrient per hectare), if the Abron Blend was applied as recommended, with the amounts that would be required based on an objective scientific assessment of the evidence and assuming the goal was to optimise pasture production.

	Nutrient (kg/ha)					
	N	P	K	S	Mg	Ca
Abron Blend	0	0	1	5	12	74
Conventional science	0	75	150	30	0	0

It is abundantly clear that nutrient inputs recommended by Abron fall far short of the actual nutrient requirements based on current scientific knowledge. It is predictable therefore that if this advice were followed for some years the soil fertility of the farm would decrease over time.

Conclusions

The advice offered by Abron in this case is deeply flawed:

1. The soil tests results have not been correctly interpreted and as a result some nutrients are recommended although not required (e.g. Mg, Ca and B) and others have not been recommended (e.g. P, K and S). A sensible interpretation of the soil tests indicates that they are required.
2. The fertiliser blend recommended by Abron includes products that are known to be agronomically ineffective (e.g. Rorisons serpentine) and others, which would be ineffective and have little if any effect on soil production or health (e.g. humates).
3. The value of the agronomically effective ingredients in the Abron mix is estimated to be in the range $1.75/ha to $14.43/ha (depending on whether Co and Se are required) which is very much less than the cost charged to the farmer of $59.91 per hectare.
4. If a farmer chose to follow this advice from Abron he will suffer a double financial blow. Pasture production and soil productivity will decline and he would have paid more than necessary for the active ingredients.

PASTURE PERSISTENCE: A soil fertility problem?

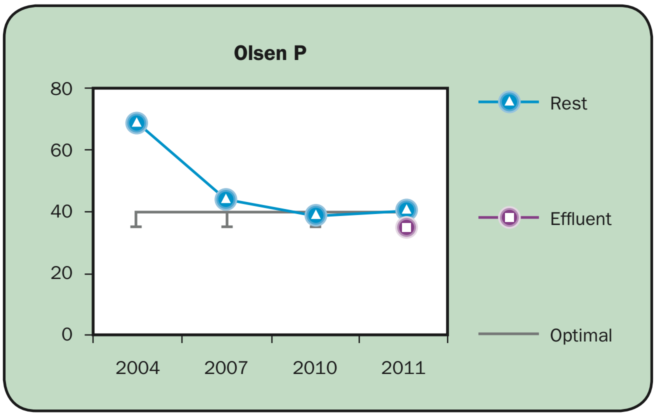
I was asked to attend a farm discussion group recently on a property out of Hamilton. The subject for discussion was pasture persistence – a hot topic at present. In addition to a handful of farmers, the seed merchants were well represented.

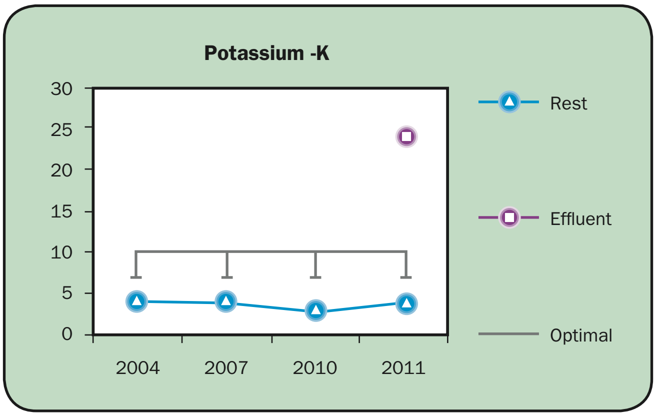
The farmer outlined his problem. He had invested considerable time, effort and money over several years trying to introduce new ryegrass cultivars. He was earnest – he genuinely believed that this was the way ahead for him – "out with the old in with the new." But his efforts were in vain. The pastures by and large were very poor – very open, very little clover and the grasses lacked vigor. He was keen to find answers.

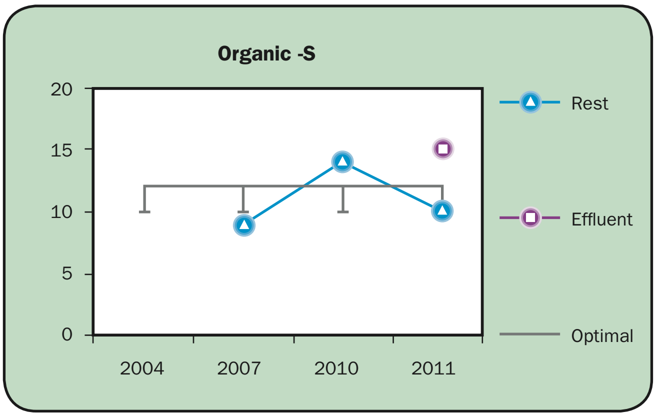
And he got "answers" from the seed merchants. Was the cultivation and seed-bed preparation appropriate? What about timing? Was enough fertiliser N being applied because these new species have a high demand for N? What about grazing – these new pastures are very palatable and easily over-grazed? What about insect pressure – where they high or low endophyte? And of course there was the drought. On and on it went. According to the seed merchants there were many reasons why these new cultivars did not persist and all of them were beyond the control of the seed merchants. It appeared that the cultivars themselves could not be faulted nor could the advice offered by the seed companies!

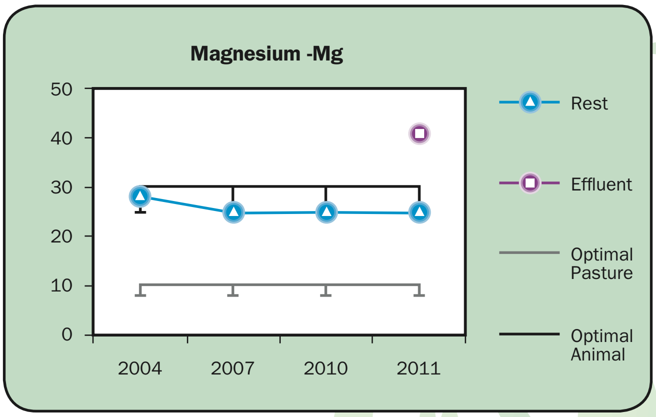
I listened intently – much of it I had heard before. I then raised the question of soil fertility. What did we know about the fertility of the soils we were standing on? It turned out that the paddock we were standing in had a soil K level of about 4. We inspected some other paddocks on the farm and sure enough most showed all the classic visual symptoms of K deficiency: the pastures were very patchy with prominent urine patches. The over-all clover content was low (< 5%) and what clover there was, was growing in the K-rich urine patches. The pasture growing between the urine patches lacked vigor (yellowish-brown colour) with a high flat-weed loading.

As a consequence of these revelations the farmer invited me back and I collected 8 soil samples from representative areas on the farm. As it turned out the soil fertility across the farm was quite uniform (clearly no advantage in All Paddock Soil Testing on this farm!) and could be treated as two blocks; Rest and Effluent. The average results for the main soil nutrients over time are summarised relative to the optimal range required for near maximum production:



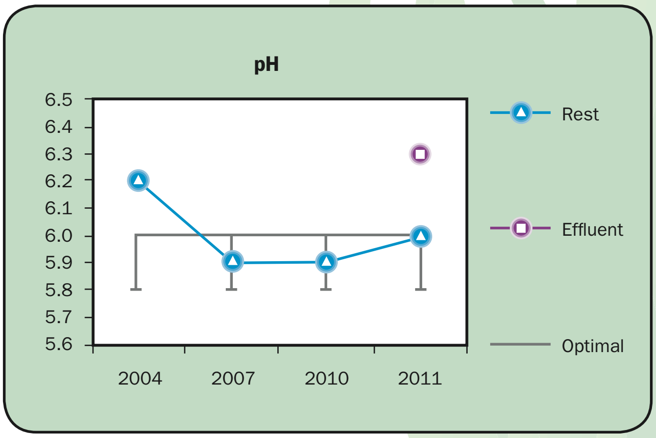






It is obvious from this data that potassium (K) was deficient across the whole farm and all the other nutrient levels, and including the soil pH, were in the appropriate optimal ranges. This problem would have been apparent about 6 years ago to anyone who looked at the pastures and knew a little about interpreting soil tests. I estimate that this 'mistake' would have cost the farmer about 10% to 20% in lost production annually for about 6 years! In my experience this example is by no means unique – I see it every week!

The Effluent block was the exception. Effluent is K rich and not surprising the soil K levels on this block were above optimal AND guess where the best pasture were? Yes, on the Effluent block! How this evidence was missed or ignored is beyond me.



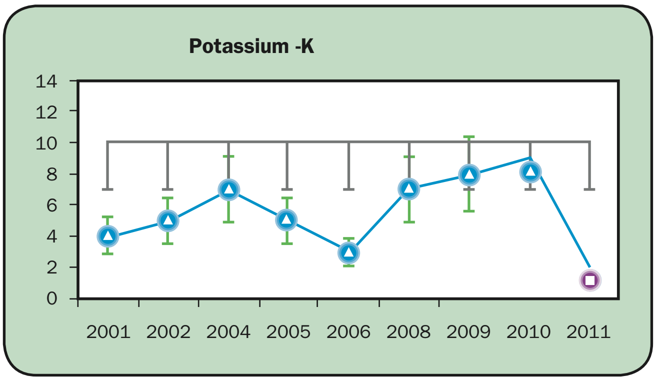
So this is my take on the lack of pasture persistence on this farm. It had little to do with the droughts, the insects, over-grazing or cultivation technique. It was due to soil K deficiency. As a consequence clover growth was poor and hence there was little return of clover N to the soil. The soils became N deficient and hence the ryegrasses did not persist.

Multiple costs arise when clover is not doing its job. First the pastures (ryegrass) has to be fed with fertiliser N, which is about 5 times more expensive than clover N. To this the cost of continually re-grassing paddocks must be added, and to top it all off, clover produces more MS/kg DM consumed that grasses.

PROFESSIONAL INCOMPETENCE OR POOR TRAINING?

A farmer asked me to audit his fertiliser program. I went through my normal routine – I visited the farm and inspected the pastures. I collected some clover-only samples for analysis and 6 soil tests from representative areas on the farm.

This farm had a long history of soil testing done by the fertiliser company. I plotted up the historical data, adding in my own results. The really interesting results were the historical soil K levels. The average soil K levels over time are shown below (blue line) with the optimal range shown as the grey scale band from 7-10. The green bars represent the typical variability associated with soil K measurements. My recent results (average of 6 samples) are shown in red.



How could it be, I asked, that the average soil K level I measured was about 3 (i.e. very K deficient) and in the previous 3 years the levels measured by the fertiliser company were in the range 7-9, which is optimal? Who to believe? What other evidence could be brought to bear on this situation?

First, from my inspection of the pastures it was clear that there was a soil fertility problem. The pastures lacked vigor, apart from those recently receiving fertiliser N. The excreta patches, and in particular the K-rich urine patches, stood out like the proverbial and the clover leaves showed the classic symptoms of K deficiency. But the clincher was that the K levels in the clover-only samples were less than 2% – an unequivocal evidence of K deficiency. So in all, the three pieces of evidence – the soil, the clover and the visual symptoms – were consistent and screamed out K deficiency!

But this begs a few questions: how is it that the soil K levels measured by the fertiliser company in the previous three years suggested adequate levels of K? How is it that the fertiliser representative did not notice that the pasture was in poor shape and why was there no further investigation? I do not know – it beggars belief that this sort of thing is happening so frequently.

I do know that it is very easy if you are not careful, to get inflated high soil K readings. A normal soil sample consists of 15-20 soil cores (0-75 cm). It only requires one core from a K-rich area of soil (e.g. urine patches, stock camping areas, gateway and troughs) to greatly inflate the soil K reading. I also know that I was lucky back in my science career to learn the art of 'reading pastures' by watching out for those clues that reflect the underlying soil fertility. And I learned the GOLDEN RULE of soil testing: **Never believe a soil test until you have seen and inspected the pasture.** To do this of course you need to put the computer away and get out of your car, and it goes without saying that it helps if you know what you are doing!!!!

Dr Doug Edmeades