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Too wet, too acid, too saline?

Temperate pastures on acid soils - Does liming pay?

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"Budgalong", Spicers Creek

Summary: Pasture decline over the past ten years has become increasingly more noticeable to farmers as their returns per hectare are struggling to keep up with rising costs. Fortunately I became aware of the acid soil issue while at Agricultural College ten years ago and have been able to pinpoint our pas ture decline problem. We have been able to address the problem with a serious liming program. Temperate pastures on acid soils work very successfully if you are prepared to lime. It's a simple solution to a serious problem. The increased production and persistence along with improved quality in crops and pastures gives good financial reward on the cost of liming.

Background

Physical Description

"Budgalong" is situated on the Central West Slopes of NSW 33 km north east of Wellington on the Mudgee Road, in the Spicers Creek district. The area is 1,660 ha of principally undulating country with approximately 75% being arable. The remainder is aerially sown. The altitude ranges from 460 to 600 metres a.s.l. The average rain fall for the past 37 years is 660 mm ranging from 300 to 1,160 mm/year.

"Budgalong" is a mixed farming operation currently cropping approximately 360 ha annually on a three year cropping phase of oats, canola and wheat undersown with pasture. We also run 2,000 Merino ewes joined to Poll Dorsets; 1,500 self replacing Merino ewes and 120 Shorthorn breeding cows turning off feedlot steers. Stocking rate is approximately 7 DSE/ha.

The soil types consist of 40% red brown loam soils derived from Devonian shales, varying in depth. The shallowest areas have exposed reefs of shale. The remaining 60% which represents the majority of the recent pasture improvement are brown grey sandy loams derived from Permian sediments, characterised by flat lying sandstone. They originated as transported soils and this characteristic contributes to their easily erodable nature. The sandy loams have a top soil depth varying from 2 - 15 cm and pH ($CaCl_2$) ranging from 4.5 to 5.4before liming. The sub soils are a sodic medium sandy clay. This duplex profile gives them a "spewy" effect in wet win ters and limited moisture storage ability for crop and pasture production in drier times. Subsoil pH($CaCl_2$) ranges from 5.1 to 5.7.

Typical of all light country, it is low in all the important nutrients. Calcium (Ca) levels are generally low while magnesium (Mg) is high in some paddocks and low in others. Phosphorus (P) levels are adequate where there has been a recent single super history. Nitrogen (N) and sulphur (S) are both generally very low.

Problems with pasture establishment and persistence

Initial pasture establishment in the 1960's (lucerne and clover) was very successful with easy establishment and good persistence. After 10 to 15 years when the pastures were being re-sown for the second time, the results were far from satisfactory with poor establishment and persistence. The cause at the time was blamed on the unsuitability of Hunter River lucerne due to aphids and the poorer performances of the new American varieties. With hindsight the problem had also been caused by regular applications of single superphosphate and lack of perennial grasses in the mix to utilise surplus N produced from the legumes. As this N was leached out it has created our acidity problem today.

I initially became aware of the acidification problem in 1986 (my first year out of Orange Agricultural College). Dad had just sown two adjoining paddocks to pasture two years running with very poor establishment of grasses and lucerne. Soil tests revealed a pH($CaCl_2$) of 4.4 and 4.6 in the two paddocks, with aluminium saturation levels of 4.6% and 1.6%, respectively. That year we did a few test strips with lime just before two other paddocks were sown to pasture. A 10 x 10 m block treated with 2.5 t/ha of lime was used. The response showed that the grasses had a better strike and were more vigorous. Even the acid tolerant cocksfoot showed a positive response producing distinctly larger crowns.

In 1987 we sought advice on the acidity and pasture health problems. It was suggested that Al levels

Table 1. Soil tests from areas with and without lucerne

	AFL - Berts Bush 1989		NSWA – Worobil 1988	
	With Lucerne	Without Lucerne	With Lucerne	Without Lucerne
pH H_2O	6.5	6.3	5.3	4.6
pH $CaCl_2$	5.9	5.7	N/A	N/A
Ca	6.0 (79%)	4.3 (75%)	9.9 (58%)	3.0 (44%)
Mg	0.7 (9.2%)	0.7 (12%)	5.8 (34%)	2.8 (41%)
K	0.74 (9.7%)	0.6 (10%)	0.77 (4.5%)	0.67 (10%)
Na	0.15 (1.9%)	0.1 (1.7%)	0.45 (2.6%)	0.16 (2.3%)
Al	<0.05	<0.05	<0.05	0.13 (1.9%)
CEC	7.59	5.7	17	6.7
Ca/Mg	8.57	6.14	1.7	1.0
P	22	23	6	12

at 4.6% were not a threat and the benefits of liming may not be worth the $125/ha cost. The suggestion was to sow tolerant species, lime pellet sub clover and exclude lucerne from the mix.

Realising there was a problem in the soil, I then began soil testing areas in paddocks that had lucerne and areas without to learn why lucerne wasn't persisting anymore. Table 1 shows the results of these tests which is before any lime was applied.

Although the soils without lucerne showed a lower CEC, pH and a slight Al problem, which according to the experts at the time was okay, lucerne wasn't persisting. In fact the lime recommendation for "Berts Bush – No Lucerne" was 0.24 t/ha, hardly worth worrying about. I wondered whether the tests were not showing everything.

We decided to follow the recommendations of the experts and tried lime pelleting in 1988. I only had to experience that once to never do that again, *ie.* problems with blockages. My thought at the time was that if the soil was acidic enough to require lime pelleting, then pasture establishment would only be short term as the roots grew into the acidic conditions, so why not lime the paddock and be done with it.

We considered acid tolerant species as recommended, but after seeing them perform in the lime/no lime test strips, we decided to lime the whole paddock.

An observation I have made is that pasture species can be tolerant of acid soils, but they don't grow as well as on a balanced Ca rich soil. In a balanced soil the quality and quantity will be better, so you must decide if you want to have plants just growing or plants that are productive. If the soil is in balance, the pasture will be a top quality pasture rather than "just a pasture".

Further soil testing in paddocks where we had low pasture persistence showed no acidity and no aluminium (Al). Soil pH($CaCl_2$) was 5.4 and yet pasture lasted only 2 to 3 years. Therefore, I began to conclude that the response to lime was not totally based on the exclusion of Al and raising the pH. It was more about getting Ca back into the soil.

Action Taken

As a result of all these studies we began a serious liming program. Over the past eight years we have spread some 2000 tonnes (Table 2).

Productivity changes

The response from liming was immediate. In our first year of liming we were growing much healthier looking crops of Coolabah oats (which happens to be acid sensitive). With extra N and a healthier soil we were getting visually "double" the production.

The pasture previously mentioned that failed in 1985 and 1986, was resown in 1990 after applying 2.5t/ha of agricultural lime. The results revealing an excellent stand that is still going strong today. It was interesting to get such a pasture response from the lime when it was not recommended. The lucerne in particular has persisted now for seven years, a vast improvement on the 1986 failure.

One of the most dramatic responses to lime was in the Spring A paddock (Table 3). The good shale area was okay with pastures still only persisting a few years, but the poor shale area grew virtually nothing for years. An application of 2.5 t/ha of lime over the whole paddock and an extra 2.5t/ha on the poor shale area was tried. Wheat and canola grew very successfully on the poor area without any variation to the good area. Now the paddock is sown down to pasture, the whole paddock is productive

Table 2. Yearly quantity of lime applied on Budgalong:

Year	Lime Applied (t)
1990	225
1991	Nil
1992	232
1993	214
1994	317
1995	311
1996	277
1997	498
Total	2.074

Table 3. Soil tests from Spring A paddock before liming.

	Good shale (Lucerne)	Poor shale (No pasture)
pH (Water)	5.8	5.5
pH ($CaCl_2$)	4.9	4.5
Ca	4.6 (74%)	2.2 (50%)
Mg	1.0 (16%)	1.2 (27%)
K	0.5 (8%)	0.4 (9%)
Na	<0.05	0.22 (5%)
Al	<0.05	0.42 (9.6%)
CEC	6.2	4.4
Ca/Mg	4.6	1.8
P	12	12

rather than just half of it.

As a result of the liming program we have greatly improved the productivity of our farm. We are able to grow profitable crops like canola, and wheat varieties don't have to be restricted to the acid tolerant varieties which are not always the highest yielding. The area sown to oats can be reduced due to increased productivity from the lime and replaced with cash crops to increase farm profits.

Productivity from cropping as a whole has improved dramatically. Canola grown on limed country is yielding better than some of the unlimed red country in the Wellington district, which says a lot for our light soils. Our 1996 canola crop yielded 2.7t/ha, which traditionally was not achievable on our lighter soils.

On the pasture side we are growing more productive and persistent pastures of phalaris, fescue and lucerne in particular. Variety selection doesn't have to be restricted to acid tolerant ones, if your soil is in balance.

With more productive, persistent and better quality pasture we have increased our carrying ca pacity. We were pushing to run 7 DSE/ha before we began liming, now it is done relatively easily. Rather than increasing stock numbers further, we are utilising the extra pasture production through improved lambing percentages, wool production and turn off time for lambs and steers. Starting time for hand-feeding has been delayed. Hopefully in short dry spells feeding will be avoided, as the better pasture quality produces more sustainable feed. This has signifcantly re duced the stress both on the stock and myself!

Changes in soil conditions

Our soils after liming have improved both nutritionally and physically. The sandy loam country has improved in soil structure creating better air and moisture transfer through the soil. This is a direct response from the Ca applied. The organic matter has improved because Ca improves the environment for micro-organisms which are responsible for the decomposition of living material into organic matter. The root systems of the perennial grasses look much healthier. You can even see a difference in soil flow when scarifying a paddock that has been limed. Some before and after comparisons of paddocks that have been limed are given in Table 4.

The Church paddock (Table 4) produced an interesting result. A large tree was burnt in this pad dock the year after liming. When the crop was sown the "burnt tree area" produced a spectacular response. The oats was well above my head in comparison to the rest of the paddock that was about waist height. I had been told that potash and old sheep camps under trees were respon sible for these responses. I conducted a soil test with the above results. Although N, P and S are not shown their levels were very similar to the "1 year later" test. The response is in the major increases in Ca and Mg.

Table 4. Soil tests taken before and after liming.

Parameter	Before	After	Result
a) Shamrocks		2.5 t/ha lime 2 years later	
pH (water)	5.7	6.2	
pH($CaCl_2$)	4.9	5.6	pH ↑0.7
Ca	2.7 (74%)	5.2 (81%)	Ca ↑ 2.3
Mg	0.6 (15%)	0.8 (12%)	
K	0.3 (7.7%)	0.3 (4.6)	
Na	<0.05	0.1 (1.5%)	
Al	<0.05	<0.05	Al ↓
CEC	3.9	6.4	CEC ↑2.5
Ca/Mg	4.8	6.5	
b) Tipperary		2.5 t/ha lime 1 years later	
pH (water)	5.6	6.3	
pH($CaCl_2$)	4.7	5.3	pH ↑ 0.6
Ca	3.3 (63%)	5.3 (68%)	Ca ↑ 2.0
Mg	1.3 (15%)	2.0 (25%)	
K	0.3 (7.7%)	0.2 (2.5%)	
Na	0.17 (3.3%)	0.18 (2.4%)	
Al	0.15 (2.9%)	<0.05	Al ↓
CEC	5.2	7.8	CEC ↑ 2.6
Ca/Mg	2.5	2.6	
c) Church		3 t/ha lime 1 years later	Burnt tree area
pH (water)	5.4	6.5	7.7
pH($CaCl_2$)	4.5	6.1	7.1
Ca	1.9 (57%)	7.1 (79%)	17.6 (80%)
Mg	0.9 (27%)	1.3 (14%)	3.5 (16%)
K	0.2 (6%)	0.3 (3.3%)	0.6 (2.7%)
Na	0.1 (3%)	0.14 (1.5%)	0.2 (0.9%)
Al	0.2 (6%)	<0.05	<0.05
CEC	3.3	8.9	21.8
Ca/Mg	2.1	5.5	5.1

By putting Ca back into the soil I believe we have released Mo and P that had been tied up. This alone gives subclover a real boost; production increases up to 100% have been observed. In one paddock we sowed to pasture after liming the subclover actually choked out the wire weed.

With a soil more in balance the pasture is able to utilise all the important nutrients for successful production in crops and pastures. I have more confidence in applying N, for example, knowing the plant will make use of it. It is no good spending money on fertiliser if the plants cannot use it.

We had P levels of 50 mg/kg in some paddocks with good super history, and yet the sub clover and phalaris didn't show the result. Once we applied lime, through the cropping phase this P be came available to plants and the response was incredible. We were throwing money into the soil only for it to be locked up and not available to the pasture. Calcium actually improves the effi ciency of nutrient

uptake into the plant, so this alone should be a good incentive for liming as less N is needed to do the same job.

A good pH reading doesn't necessarily mean a soil does not need lime. The pH of a soil can be high due to Mg, but still be deficient in Ca. Calcium deficient soils do not have efficient nutrient utilisation. There are many factors besides pH that must be examined in balancing a soil.

The seriousness of acidity and soil imbalance today is such that if your not aware of the problem and take action your production levels will continue to slowly decline making it more difficult to satisfy today's narrow margins in agriculture.

Managing acid soils - Our acid management systems

We began applying lime two months before pasture sowings, but after the response of oats and canola to lime, we have gradually managed to apply it before the first crop. As well as thorough lime incorporation, three years of crop will reap the benefits of a well balanced soil via better nutrient utilisation (including applied crop fertilisers) and leave a soil that is ready to support a persistent, high quality, balanced pasture. With crops being more productive and profitable the re turn on the lime investment is good.

For first time applications of lime, we have always applied 2.5 t/ha, nothing less. Putting this amount on lighter textured soils would be considered excessive by some, but I suspected my soils needed a lot more lime then was recommended. As it has turned out this amount has not been too excessive and in some paddocks still more lime is required.

In the third year of the cropping phase the paddock is sown with wheat and pasture. To prevent any further acidity problem a good mix of grasses and legumes are selected. Selection of pasture species should be based on local NSW Agriculture trial work. In our district we have pasture variety trials on farms with production and persistence measured yearly. With these trials you can compare within each subclover variety or phalaris variety. Subclovers are selected on improved root rot resistance, which along with acidity is the major reason for sub clover decline in recent years.

My current pasture mix is;

- 2 kg/ha Aurora lucerne
- 2 kg/ha Goulburn subclover
- 2 kg/ha Seaton Park LF subclover
- 0.25 kg/ha Balansa clover
- 1.1 kg/ha Holdfast/Sirolan phalaris
- 1.9 kg/ha Triumph fescue
- 0.4 kg/ha Currie cocksfoot
- A total of 9.65 lbs/acre or 10.8 kg/ha

The heavy seeding rate is to produce an instant dense pasture capable of high stocking rates and good weed competition. The grass proportion of the mix contains equal seeds per hectare of cocksfoot and fescue and phalaris is 10% higher as this is the weakest seedling but the most persistent adult plant. Should the others disappear the phalaris density should be sufficient.

Applying lime has opened up a new avenue of pasture establishment. Previously we were glad to just get something established and maybe persist. Now with these two problems sorted out I began trying different varieties and rates. The rainfall still remains a big influence but with a properly balanced soil the plants are at least able to fully utilise any available moisture.

Future management plans

When a pasture paddock becomes run down in the next ten years the soil will be sampled and assessed for re-liming. If the soil is still in balance when the pasture needs upgrading and does not need physical incorporation of nutrients then perhaps pasture renovation with a suitable direct drill/sod seeder machine will be used. Particularly so if wheat and canola prices do not allow for enough profit margin or the paddock is particularly prone to erosion. The pH and Ca after eight years since liming still appear stable so the grass/legume mix is obviously working well together. Paddocks now only really become run down due to severe drought and or poor grazing management which is a lot less frequent than when acidity was a problem.

I only have 2 out of 20 pasture paddocks after eight years of liming that are run down enough to put back into crop. Both lost their grass component in the 1994 drought caused by overgrazing in one and lack of moisture in the other. Clover levels are still very good in both but I thought I would capitalise on the N build up before any leaching and acidity occurs with the legume dominant pasture.

These changes that I have been observing has encouraged me to learn more about our soil re source. If you want to achieve a nutritionally balanced soil you need to use a soil test that tests all the major and minor elements including H to get a correct indication of the saturation percentages. The testing service I have recently changed to is Eric Kawabe & Associates at Tamworth. He uses the principles developed by Dr William Albrecht, which is known as "The Albrecht system". This technique has been working very successfully in the USA for over forty years. Understanding this system has answered a lot of questions regarding the influence of lime on crop and pasture production. I have always

known that lime raised the pH and corrected Al, how ever I knew there was a lot more to it as every year after the initial application the paddocks seemed to get better. The traditional soil tests that I have been using don't show Ca as deficient unless it is very low.

The basic principles of the Albrecht system are to achieve a total nutrient balance in the soil. You feed the soil first which then feeds the plant rather then attempting to directly feed the plant with fertilisers. This can be summarised in a quote from Neil Kinsey's book "Hands on Agronomy". Neil is another consultant from the US who uses the system:

> "True soil balance means determining and adding the proper amount of each nutrient. Fertlity is the balance between elements. Not only is each element necessary individually, but a balance of all soil elements is necessary collectively. Every one works on every other one in an independent way".

The total nutrient balance that the system is based upon looks mainly at the relative saturation percentages of all the cations in the soil. The desired percentages can be seen in Table 5.

You cannot use these saturation percentages as a guide from soil testing systems that do not measure hydrogen (H). In my soils I have found that the H level is significant in determining the amount of Ca and Mg to apply. The following (Table 6) is an example from my 1997 soil tests of a paddock that had 2.5t/ha of lime ap plied in 1995.

As can be seen from the table, when you include only Ca, Mg, K and Na, the Ca saturation is over 80%, which is considered more than adequate on traditional guidelines of 65-80%. However, when hydrogen is included in this test the Ca saturation is considerably lower than ideal and more lime is required. The Albrecht system promotes what I have been trying to achieve since spreading lime; to put Ca and Mg back into the soil in the correct balance. Rather than using pH and Al saturation as guides to liming, the Albrecht system uses Ca and Mg as a priority and is guided by their base saturation percentage. As shown in Table 6 above, paddocks that are already limed may still need more Ca and Mg.

Some key points for pasture establishment

My successful pasture program is a combination

Table 5. Optimal base saturation percentages of cations in the Albrecht System.

Cation	%
Ca	60 - 70
Mg	10 - 15
K	3 - 5
Na	0
H	10 -15
Other bases	2 - 4

Table 6. Effect of hydrogen on saturation percentages.

Soil Test Results Excluding H		%
Ca	6.7[a]	82
Mg	0.9	11
K	0.4	4.9
Na	0.1	1.2
Including H		
Ca		52
Mg		7
K		3.3
Na		0.7
H		30
Other bases		6

[a] cations measured in meq/100 g soil

of several procedures:

- Weed control prior to cropping - pasture cleaning with MCPA 2 to 3 years before crops. Then begin cropping phase with a chemical fallow in the previous spring. These meas ures will reduce the seed burden of problem weeds.
- Complete soil test to determine all the nutrient imbalances so a plan can be made.
- Ag Lime or Cal Mag application prior to cropping.
- Three years of cropping to clean up winter weeds and Bathurst burrs in the summer and recoup lime and pasture establishment costs.
- Reduced seeding rate of cover crop to minimise the chance of smothering. Rate of 25 kg/ha for wheat is good.
- "Apron" seed dressing on legumes and sodium molybdate applied through the spray tank simply as a good management practice due to the low cost per hectare.
- Good seed/soil contact and depth control of pasture seed achieved via good seed bed preparation. Depth control is essential for good grass establishment. Pay particular attention to the suitability of the keel on the bandseeder tube to your soil type.
- Level seedbed behind combine and before the bandseeder to ensure even seed depth. Harrows or levelling bar.
- Weed and insect control during pasture establishment is critical, in particular red legged earth mite and wireweed. Even in the first year or so after pasture establishment, weeds, if dense enough, will have a detrimental effect on long term pasture density and persistence.

When sowing a bulky mix containing light fluffy grasses it is important not to have the flow of pasture seed restricted due to the lack of fall in the

bandseeder tube because plant density will not be evenly spaced, creating overcrowding and unevenness particularly with the grasses which allows weeds to re-establish again.

My cropping plan is mapped out on a ten year cycle, priority paddocks based on weed (summer and winter) and pasture density. Your pasture improvement programme needs to be on a scale large enough to get around your property before you have to start again. So if you have 1,200 ha to improve, then 120 ha needs to be sown down each year just to get around in ten years. Without lime we had no chance of following this schedule as our pastures were only lasting two years before they became rundown again.

Profitability - Does liming pay?

This section is probably the most important of my address. Whilst most people know there are benefits from liming, many believe that it is not profitable. The biggest deterrent in using lime has been cost. One of the first things that prompted the use of lime and overcoming the cost was realising the cost of pasture establishment was very similar to that of lime and if spending an extra $125/ha on lime made the pasture persist for more than the 2 - 3 years then it appeared to be a sound investment. As the pastures are per sisting up to 7 years so far and still going strong, the lime investment has actually saved me money, not that anyone could afford resowing the same paddock every 2 - 3 years. Realising this had the biggest influence on the degree and commitment of my liming p rogramme today. I believe the cost can be recouped in both grazing only and cropping/grazing situations. However, costs of applying lime are recouped more easily in a crop/pasture system. Crops like canola can successfully recover the $125/ha spent on lime in the one year, on top of what would have been made if grazing sheep and cattle. Our net livestock returns based on 7 DSE/ha are approximately $150/ha profit averaging sheep and cattle together while canola returns approximately $275/ha plus. These figures are what we actually achieved in the past few years.

The grazing only situation does cause difficulties initially because it is difficult to incorpo rate the lime. However, with adequate incorporation, I believe you will recoup the costs of lime because pasture will persist longer, be much more productive and you can grow more palatable and nutritious varieties eg-phalaris, and fescue.

Ewes joined on limed pasture improved country compared to unlimed improved country are producing a higher lambing percentage. Results from scanning are showing 12% extra twins and a reduct-ion in dry ewes from 2.0% to 1.0%. The difference in the pastures at the time of joining in March 1996 was the reason for the result. The limed pastures were of better quality (improved grasses and lucerne) which had the ewes increasing in b odyweight at joining.

The initial expenses of lime is high but, if you grow a few successful profitable crops be fore you sow pasture down then you have more than recouped costs and your soil chemistry is ready to support a long term productive pasture. Before liming we only got a few years out of our pasture, particularly lucerne, so we were not making any progress in pasture improvement. If you are to get around all your arable ground before the first pad docks are run down then you need persistence in your pasture. The cost of pasture establishment is not expensive if you do it right the first time.