Evaluating alternative fertilisers and biological products for pastures and crops - part 1

Results of three years measurement of products at eight pasture and crop sites.

Woady Yaloak Catchment Group

CARING FOR OUR COUNTRY

WOADY YALOAK Productive Catchment Management

This report has been prepared by Cam Nicholson on behalf of the Woady Yaloak Catchment Group. It may be revised once feedback is received.

It documents the results of three years of responses to the application of a range of alternative fertilisers and biological products. Part 1 presents the results by product tested. Part 2 present the results of various products at each site. The trials were funded by the Caring for our Country Program and the Woady Yaloak Catchment Group.

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Executive summary

The Woady Yaloak Catchment Group evaluated a range of alternative nutrient sources and biological products for their effect on crop and pasture production and soil conditions. Eight replicated trials were conducted from 2009 to 2011 on pasture, lucerne and winter crops. Funding for the trials was received from the Caring for our Country program and the Woady Yaloak Catchment Group.

Twelve products were tested, some at multiple sites, some at only one or two sites, with the choice of product to test determined by local farmer interest. Eight products (called treatments) were tested at each site, with one treatment assigned no product. This was considered the Nil treatment and all other products have been compared to the response of the Nil treatment. A 'standard' fertiliser recommendation was also made for each site, based on previous soil testing.

The rate and time of application of products was determined after consultation with the product suppliers. Suppliers were offered access to the traditional soil test and biological soil test results for each site to help inform their recommendation. Rates of different products were not adjusted to apply the equivalent amount of any particular nutrient. Instead they were applied at the suppliers recommendation, to test what they would recommended to the farmer. Seasonal conditions sometimes prevented the ideal timing of product application, due to wind, rain, dry or waterlogged conditions, however this represented what a farmer would be faced with and would be capable of achieving.

Dry matter production was measured on the pasture and lucerne sites, with up to 13 cuts taken from 2009 to 2011. Pasture composition and lucerne density were measured in October 2011 across treatments. Grain yield was measured annually on the crop sites. Soil test for nutrients, other soil properties and biological activity were taken at each site before the commencement of the trial and repeated in November 2011 at one pasture, one crop and one lucerne site (due to cost constraints). This enabled some insights into the changes in 'soil health' and soil carbon through the application of different products.

Results

The growing seasons across the three years of trialing were highly variable. In 2009 a late break and a short growing season, including an unprecedented hot period in October and November, severely curtailed pasture growth and affected crop yields. In contrast 2010 was wet, with the growing season extending into the start of 2011, including a flood at one site and the loss of one crop at harvest due to lodging. The final year of the trial was more 'typical', despite a delayed autumn break and a dry spell in September, which caused the annual species in the pasture to run to head prematurely.

Dry matter production from specific products for pasture and lucerne are compared against the Nil treatment for the three years (table 1). Three other products were only tested at one pasture or lucerne site. These were:

- Munash mineral fertiliser with additional products on pasture (-3% of Nil treatment)
- Biosolids on pasture (-11% of Nil treatment)
- Guano on lucerne (+2% of Nil treatment).

Table 1: Difference in dry matter production (t/ha) compared to the Nil treatment for pasture and lucerne sites from 2009 to 2011. Numbers in brackets represents percentage difference. Asterix represents significant difference ($p<0.05$) and grey indicates product was not tested at this site.

Product	Pasture 1	Pasture 2	Pasture 3	Lucerne 1	Lucerne 2	Lucerne 3
Traditional fertiliser	5.37* (+28%)	0.81 (+5%)	2.37 (+12%)	0.04 (0%)	1.08 (+5%)	0.99 (+6%)
Twin N + trad fertiliser		0.56 (+4%)	2.95* (+15%)		1.30 (+6%)	0.69 (+4%)
TM + trad fertiliser			4.42* (+22%)			0.64 (+4%)
Pig manure	5.56* (+29%)	6.46* (+43%)		2.34* (+12%)	1.36* (+6%)	
Poultry manure		1.54 (+10%)	1.60* (+8%)		1.14* (+5%)	0.38 (+2%)
Seasol & Powerfeed	-0.60 (-3%)	2.30 (+15%)	0.53 (+3%)	-0.52 (-3%)	-0.07 (0%)	0.04 (0%)
Worm Caste & lime	1.31 (+7%)	1.72 (+11%)	2.00* (+10%)	1.25 (+6%)	0.68 (+3%)	0.44 (+3%)
Nutrisoil	-0.46 (-2%)	0.35 (+2%)	0.62 (+3%)	-0.22 (-2%)	-0.48 (-2%)	-0.11 (-1%)
Compost products				0.30 (+2%)		

Pasture composition improved significantly where traditional fertiliser was applied at one pasture site (from 23% desirable grasses and legumes to 65%) and was visually better, but did not reach statistical significance, at another pasture site where traditional fertiliser and TM were used (increase from 70% to 86%). There was no composition difference to any product at the third pasture site.

Crop results are presented from two sites for each of the three years (table 2).

Table 2: Difference in dry matter production (t/ha) compared to the Nil treatment for crop sites from 2009 to 2011. Numbers in brackets represents percentage difference. Asterix represents significant difference ($p<0.05$) and grey indicates product was not tested at this site.

	Crop 1			Crop 2		
Product	**2009 Triticale**	**2010 Triticale**	**2011 Barley**	**2009 Chickpeas**	**2010 Barley**	**2011 Canola**
Traditional fertiliser	-0.23 (-6%)	0.49* (+20%)	0.32 (+13%)	0.02 (+4%)	Crop lodged severely due to wet summer.	0.20 (+12%)
Twin N + trad fertiliser				-0.04 (-9%)		0.16 (+9%)
TM + trad fertiliser	-0.05 (-1%)	0.59* (+25%)	0.44 (+18%)			

Pig manure	0.15 (+4%)	0.34 (+14%)	0.20 (+8%)	0.04 (+9%)	Unable to harvest	0.16 (+9%)
Poultry manure				-0.01 (-2%)		0.20 (+12%)
Seasol & Powerfeed	-0.03 (-1%)	0.07 (+3%)	0.03 (+1%)	-0.01 (-2%)		0.06 (+4%)
Worm Caste & lime	0.20 (+6%)	0.24 (+10%)	0.20 (+8%)	-0.05 (-11%)		0.23 (+14%)
Nutrisoil	-0.39 (-11%)	0.09 (+4%)	-0.04 (-2%)	-0.04 (-9%)		0.00 (0%)
Compost products	0.08 (+2%)	-0.17 (-7%)	-0.11 (-4%)			

Testing of soil biology at three sites did not provide conclusive evidence that any product consistently increased soil health or soil carbon. Using six indicators of soil condition, there was no repeatable response to any product tested. The only consistent observation was that soil organic carbon appears to have increased at the pasture site, decreased at the crop site and remained similar at the lucerne site. There was also no consistent correlation between improvements in the soil indicators, such as microbial diversity and increased production (figure 1).

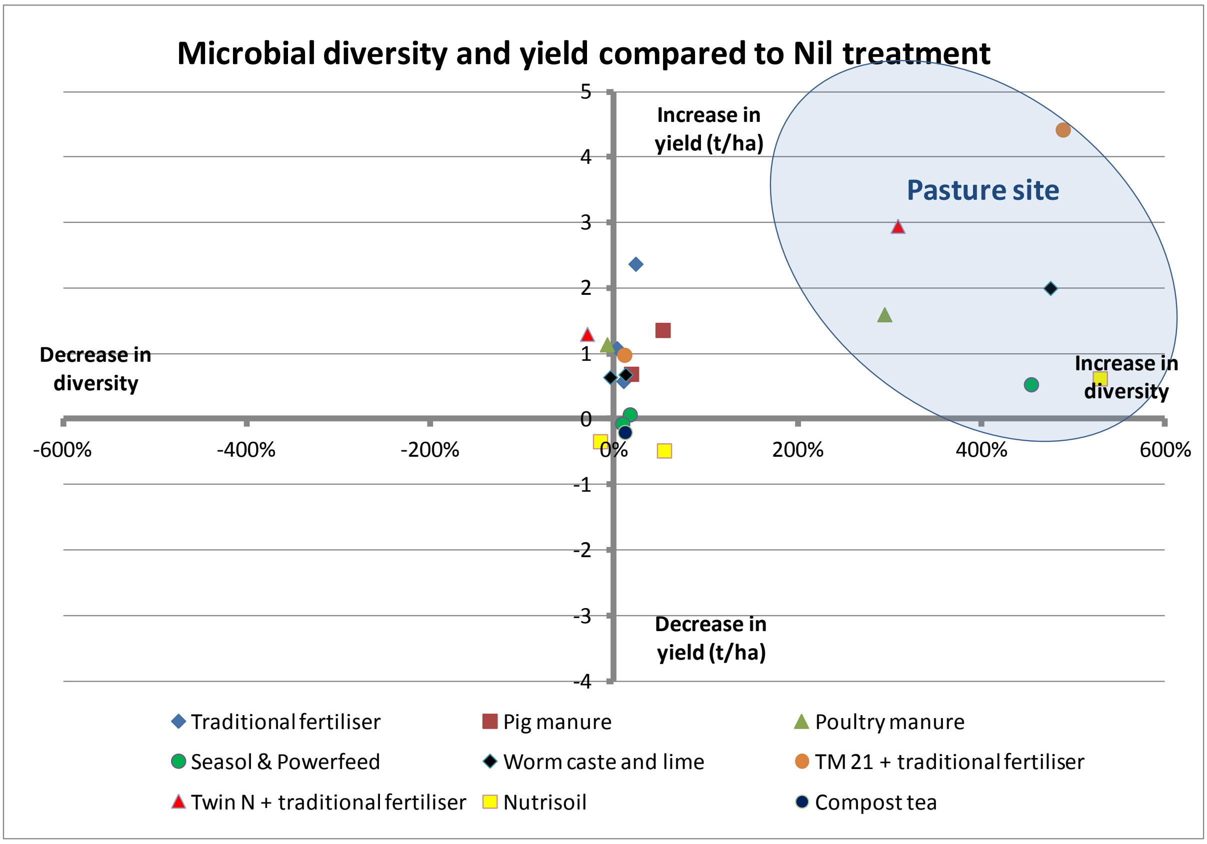

Figure 1. Changes in microbial diversity and yield compared to Nil treatment. Responses within the blue circle represents treatments at the pasture site.

A summary of other observations and soil each product tested follows.

Traditional inorganic fertiliser

- Traditional fertiliser increased yield in most cases and the responses were generally in line with predictions.
- Soil nutrient and pH levels increased or declined (where no fertiliser was applied) to levels that could be broadly anticipated.
- Where responses to applied fertiliser did not occur, there were no obvious indicators as to what might be preventing a response to the fertiliser applied.
- Glomalin levels (biological soil carbon) increased dramatically at one site where large quantities of nitrogen, phosphorus, potassium and sulphur were also applied.
- The evidence to support claims that traditional fertiliser is 'bad' for soil biology is inconclusive from these results, with some favourable responses to fertiliser and some negative results.

Traditional inorganic fertiliser with Twin N

- There was no significant response to Twin N once the yield increase attributed to the traditional fertiliser were accounted for.
- Soil nutrient and pH levels changed in a similar fashion to traditional fertiliser alone.
- The evidence to suggest increases in free living nitrogen bacteria in the soil is inconclusive.

Traditional inorganic fertiliser with TM (formerly called TM21)

- A significant response to TM with traditional fertiliser was measured at one pasture site however the increase in production was not repeated at a crop site and a lucerne site.
- The common soil test and biological tests do not consistently explain the reasons for the response (or lack of response).
- The product is easy to fit into a farming operation and given the spectacular response at one of the three sites would be worth investigating further.

Pig manure

- Pig manure applied at these rates grew more dry matter and at the price supplied is a cost effective alternative to traditional fertiliser.
- There was a small increase in crop yields although increases in canopy growth were evident.
- Increasing pasture growth in winter is a feature of the response.
- It increased microbial diversity in the soil and may increase glomalin (stable soil carbon) levels.
- Nutrient levels in November 2011 are still above 2008 levels suggesting the applied nutrients may last more than three years.

Poultry manure

- Poultry manure applied at these rates grew more dry matter, especially in the first year and at the price supplied is a cost effective alternative to traditional fertiliser.
- It did not increase crop yields.
- It increased microbial diversity in the soil when starting from a low base, but has not affected glomalin levels or dramatically increased dry matter production.
- Nutrient levels in November 2011 have returns to 2008 levels suggesting the applied nutrients have been used up over three years.

Worm caste with lime

- Dry matter responses were recorded in some years and at some sites, with the greatest response on the pasture sites.
- While the response to worm caste or lime cannot be separated, the decline in phosphorus and the small increase pH may indicate the dry matter and grain yield response is due to the lime.
- These findings bring into question the threshold levels currently used to recommend liming in Southern Victoria.
- The response worm caste and lime have on soil biology remains unclear.

Compost products

- No significant dry matter or yield responses were recorded.
- Microbial diversity did not change dramatically as a result of applications of compost and compost tea.
- Limited testing prevents any strong conclusions to be drawn however there were no spectacular results from using compost products over the three year period.

Seasol & Powerfeed

- Seasol and Powerfeed applied multiple times over three years did not significantly increase dry matter production or grain yield at any of the eight sites tested.
- Changes in available phosphorus, potassium and pH were similar to the Nil treatment.
- Apart from a positive response to soil biodiversity at one of three sites, there were no appreciable differences in key soil biological indicators.

Nutrisoil

- Nutrisoil applied multiple times over three years did not significantly increase dry matter production or grain yield at any of the eight sites tested.
- Changes in available phosphorus, potassium and pH were similar to the Nil treatment.
- Increases in microbial diversity compared to the Nil treatment were recorded at two of the three sites tested however no associated dry matter increases were recorded.

Contents

Background

There is growing farmer interest in using alternative nutrient sources and biological soil enhancers instead of traditional manufactured fertiliser to improve productivity and 'soil health'.

The reasons behind wanting to explore alternatives is understandable. This includes the spike in traditional fertiliser prices in the mid 2000's, concerns about the long term supply of rock phosphate to meet future demand and the realisation that some of the phosphorus applied in traditional fertiliser is 'locked up' by the soil and not available for plant growth. As nutrient replacement is essential for sustainable farming practices, possible alternatives need to be examined and their potential benefits and costs understood.

Interest in biological products has also increased in past years and the theory behind improved soil health is reasonably sound. Significant amounts of nutrients are stored in organic matter (nitrogen 95%, sulphur 90%, phosphorus 40%). A slow release of these nutrients through the year should provide an ongoing supply to the plants. The growth and breakdown of fungi is of particular importance. Improved biological activity also has the added benefit of enhancing soil structure, increasing water holding capacity and increasing the amount of stable soil carbon.

While the benefits of improved soil health are widely accepted, there are numerous questions around whether the products being sold to improve soil health actually change soil biological activity, if this improved biological health translates into improve production and quality and ultimately if the products are cost effective. Many of these products have only recently appeared on the market and while anecdotal stories and testimonials abound, the scientific evidence to support the suggested responses is often limited.

Farmers in the Woady Yaloak catchment were interested in investigating the response of a range of alternative products tested under local conditions. A three year screening trial funded by *Caring for our Country* was established to evaluate:

- alternative nutrient sources (animal manures and non traditional nutrient sources) that are locally available and comparing these to traditional inorganic fertilisers (common practice)
- the impact of some recently promoted biological products to change soil biological activity and in turn plant production.

Sites and products tested

Eight sites were identified by farmers in the catchment (table 1). The sites represented a range of typical pastures and crops found in the Woady Yaloak Catchment. All sites were soil tested before the trial commenced. This included a traditional soil test, as well as a test to measure biological activity in the soil. A description and results for each site are presented in part 2.

Table 1: Description of sites tested

Site	Description
Pasture 1	Recently sown tall fescue and sub clover pasture
Pasture 2	Well established Australian type phalaris pasture
Pasture 3	Well established Victoria ryegrass, old style sub clover, native pasture
Lucerne 1	Well established lucerne stand
Lucerne 2	Well established lucerne stand
Lucerne 3	Well established lucerne stand
Crop 1	Triticale in 2009, 2010, late sown barley in 2011
Crop 2	Chickpeas in 2009, barley in 2010 (not harvested), canola in 2011

Twelve products were tested, some at multiple sites, some at only one or two sites (table 2). The choice of product to test at any site was determined by local farmer interest. This means the trial was not an exhaustive testing of all possible products on the market.

Table 2: Type and number of products tested

Broad product category	Product	Sites tested
NIL – used for product comparison	Nil	8
Nutrient sources	Traditional fertiliser (inorganic)	8
	Pig manure	6
	Poultry manure	5
	Biosolids	1
	Guano	1
Nutrient source and 'biological enhancers'	TM21 & common fertiliser	3
	Twin N & common fertiliser	5
Biological 'enhancers'	Seasol & Powerfeed	8
	Nutrisoil	8
	Worm caste & lime	8
	Munash products	1
	Compost products	2

Eight products were tested at each site (commonly referred to in the report as treatments). At each site one treatment was assigned no product. This was considered the Nil treatment and all other products have been compared to the response of the Nil treatment. A 'standard' fertiliser recommendation was also made for each site based on recommendations from Jen Clarke and Cam Nicholson, based on the traditional soil test results and interpretation. This means each the traditional fertiliser application was different at each site. Other products were applied according to supplier or label recommendations. This varied for each site and are described in detail in part 2 of this report.

Treatments (products) were applied in a completely randomised block design with four replicates. Each treatment plot was 4m x 16m, with the edge of each 4m plot providing a buffer to the adjacent plot.

Solid products were applied by hand and foliar products by a 2 m boom spray (nozzles at 50 cm spacing, coarse nozzles at 2.0 bar pressure). Where higher water volumes were required, the products were diluted and repeat applications were performed.

The rate and time of application of products was determined after consultation with the product suppliers. Suppliers were offered access to the traditional soil test and biological soil test results for each site to help inform their recommendation (summary in appendix 1). This means products were not compared on equivalents of any one component of the product such as equal quantities of phosphorus, as there was no consistent component that could be used given the range of product chosen. Nor were they applied to balance nutrient removal. Instead it was decided to test what the supplier would recommended to the farmer.

Seasonal conditions sometimes prevented the ideal timing of product application, due to wind, rain, dry or waterlogged conditions. However the delay in application represented what a farmer would be faced with and would be capable of achieving.

The growing seasons across the three years of the trials were highly variable. In 2009 a late break and a short growing season, including an unprecedented hot period in October and November, severely curtailed pasture growth and affected crop yields. This is likely to have limited any treatment benefits that would normally occurred in the 'spring flush'. Visual differences in bulk and height with the crop sites did not carry through into crop yields.

In contrast 2010 was wet, with the growing season extending into the start of 2011, including a flood at one site and the loss of one crop at harvest due to lodging.

The final year of the trial was more 'typical', despite a delayed autumn break and a dry spell in September, which caused the annual species in the pasture to run to head prematurely. The opportunity to measure the full potential of the 'spring flush' was again restricted.

Measurements

Samples for traditional and biological testing were collected in October 2008.

Dry matter cuts (with a lawn mower) commenced in winter 2009. They were taken from the middle of each pasture plot and then $0.1m^2$ sub samples were cut down to ground level. The two were added to calculate the total dry matter production. Up to 13 cuts were taken from 2009 to 2011. Once cuts were taken, the area was crash grazed to remove uncut dry matter. Grazing was then excluded to allow regrowth. This effectively created a cell grazing approach across all treatments. Crop samples were harvested with a plot header. No grain quality measurements were taken.

Species composition in the pasture and lucerne was measured in November 2011 across all treatments.

Three sites (one crop, one pasture and one lucerne) were retested at the treatment level for changes in soil nutrients and biological activity. An explanation of the biological interactions

the testing is endeavouring to determine is described in appendix 2. Other sites were not tested because of financial constraints.

All replicated data was analysed as a randomised complete block using the statistical package ARM 8.

Presenting and interpreting responses

As mentioned previously, rates of different products were not adjusted to apply the equivalent amount of any particular nutrient. Instead they were applied at the suppliers recommendation. Therefore the most meaningful comparison is between a specific product and the Nil treatment in any year. It logically follows that a treatment that respond similarly to the Nil treatment is not having an effect.

The results for total dry matter, crop yields and some pasture composition results have been mathematically analysed to take into account the natural variability across the site. The mathematical analysis enables a figure to be derived that provides confidence to state if the differences are *possibly* due to chance or luck and not the product or whether it is due to the product used[1].

The cost of product, transport and application costs have been calculated (appendix 3). The total cost is listed in cases where multiple applications have been used over three year. Readers need to be aware costs are a guide only as purchase price can vary markedly depending on volume purchased and transport. They should also take into account the potential carry over effects of some of these products when making a judgment about their cost benefit. Benefits may accrue in 2013 and beyond.

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[1] The mathematical calculation is called analysis of variance (ANOVA). It enables the yield and composition measurements from the products used at each site to be compared to the natural variation at the site and against other products used at the same site. If there is a 95% probability the differences between measurements is due to the products, then a yield value is calculated. This is known as the least significant difference or LSD. If the difference between two treatments is <u>less</u> than the LSD, then even though there may be difference between the numbers, this difference <u>could</u> be due to chance or luck or the product. However, if the difference is <u>greater</u> than the LSD, then the difference is considered not due to chance or luck, it is due to the product used.

Results by product

Results are presented for each product tested. The production graphs presented list all eight sites and for the three years of testing. The vertical scale (difference in dry matter or grain yield compared to Nil treatment) is the same for each product to help convey the size difference of the response. Where no bar is represented on the graph, the product was not used at this site or no measurements were completed (this is mentioned in the figure caption).

Traditional inorganic fertiliser

In a nutshell

- ***Traditional fertiliser increased yield in most cases and the responses were generally in line with predictions.***
- ***Soil nutrient and pH levels increased or declined (where no fertiliser was applied) to levels that could be broadly anticipated.***
- ***Where responses to applied fertiliser did not occur, there were no obvious indicators as to what might be preventing a response to the fertiliser applied.***
- ***Glomalin levels (biological soil carbon) increased dramatically at one site where large quantities of nitrogen, phosphorus, potassium and sulphur were also applied.***
- ***The evidence to support claims that traditional fertiliser is 'bad' for soil biology is inconclusive from these results, with some favourable responses to fertiliser and some negative results.***

Product description

The treatments comprised inorganic fertilisers that are commonly used on farms. There were four base products tested, single superphosphate, triple superphosphate, di-amonnium phosphate (DAP) and muriate of potash. Gypsum was also applied where additional sulphur was needed. Super potash blends were made from single superphosphate and muriate of potash. The nutrient levels of these fertilisers are listed (table 3).

Table 3: Percentage nutrients of various products used

Product	N	P	K	S
Single superphosphate	0	8.8	0	11
Triple superphosphate	0	20	0	1
DAP	18	20	0	1.6
MOP	0	0	50	0
Super Potash 2 & 1	0	5.9	16.5	7.4
Super Potash 3 & 1	0	6.6	12.7	8.2
Super Potash 5 & 1	0	7.4	8	9.2
Gypsum	0	0	0	19

Product application

Fertiliser was applied at all eight sites. The rates were formulated to reach target nutrient levels at the end of 2011 (table 4).

Table 4: Target nutrient levels by the end of 2011

Site	**Target nutrient levels by 2011**		
	P (Olsen)	**K (Colwell)**	**S (KCl_{40})**
Pasture 1	15	185	15
Pasture 2	15	185	15
Pasture 3	12	170	12
Lucerne 1	18	200	15
Lucerne 2	15	185	15
Lucerne 3	15	185	15
Crop 1	20	120	18
Crop 2	20	120	18

The type of crop or pasture, starting nutrient levels, cation exchange capacity and phosphorus buffering index were all taken into account in determining the rate and type of fertiliser to apply. Therefore the total quantity of nutrient applied varied at each site (table 5 - also see part 2 each individual site for rates and types of products used). Fertilisers were broadcast annually in early May, including those on the cropping sites. Crop sites received no additional fertiliser at sowing. Details of cost used are in appendix 2.

Table 5: Total quantity of nutrients applied by traditional inorganic fertilisers from 2009 to 2011.

Site	**Nutrient applied in 2009 - 2011**				**Product cost* ($/ha)**
	N (kg/ha)	**P (kg/ha)**	**K (kg/ha)**	**S (kg/ha)**	
Pasture 1	0	76	150	4	$573
Pasture 2	0	52	101	65	$457
Pasture 3	0	83	90	104	$592
Lucerne 1	0	50	139	62	$499
Lucerne 2	0	40	0	50	$200
Lucerne 3	0	70	0	3	$314
Crop 1	54	61	0	69	$471
Crop 2	54	61	90	5	$401

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 1).

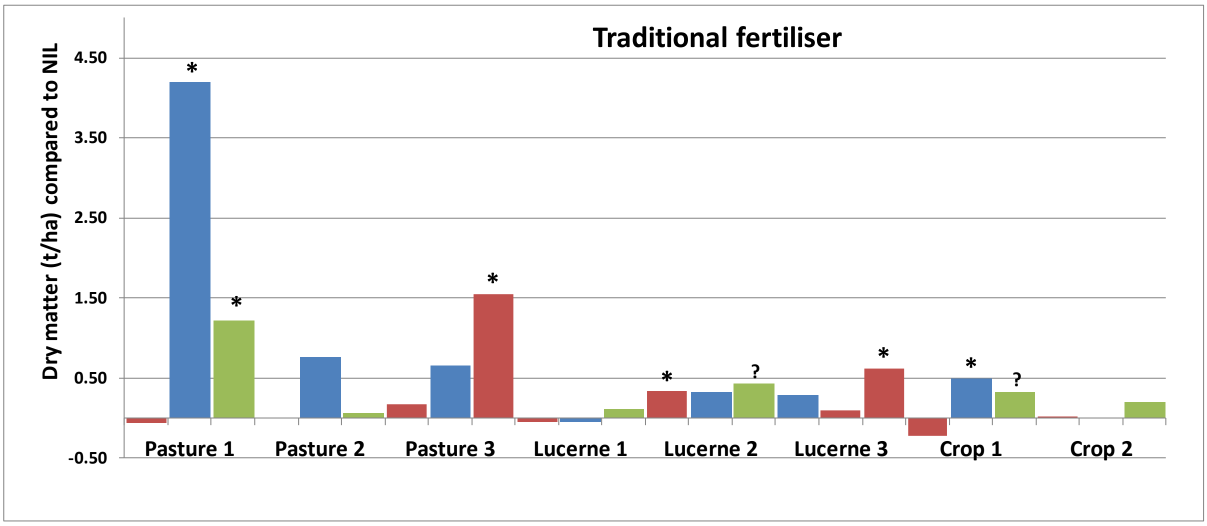

Figure 1: Annual difference in dry matter production for traditional fertilisers compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the traditional fertiliser and the Nil treatment ($p < 0.05$), ? represents just outside statistical significance.

Composition

The application of traditional fertiliser change composition at one site. All other sites were similar to the Nil treatment. At the responsive site, the legume component of the pasture increased dramatically and was visually obvious in all four replicates. The site was sown in 2008 and had a starting phosphorus level of 11.3 mg/kg (Olsen P) and a potassium level of 90 mg/kg). The composition change was in response to annual applications of triple superphosphate (125 kg/ha) and muriate of potash (100 kg/ha).

Soil conditions

Soil samples were taken in 2011 from the traditional fertiliser at one lucerne (lucerne 2), one pasture (pasture 3) and one crop site (crop 1) (table 6).

Table 6: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and November 2011.

Element	Site	2008 baseline	2011
Phosphorus (Olsen)	Lucerne 2	22.7	21.9
	Pasture 3	6.5	19.5
	Crop 1	18.5	23.6
Potassium (Colwell)	Lucerne 2	258[2]	413
	Pasture 3	123	154
	Crop 1	203	182
pH ($CaCl_2$)	Lucerne 2	5.3	5.4
	Pasture 3	4.8	4.4
	Crop 1	4.9	4.8

[2] Suspect an error in the 2008 result as all 8 treatments tested in 2011 have potassium levels around 400 mg/kg.

At all three sites phosphorus levels were higher than target level, although they may be elevated because sampling was only seven months after application. The most dramatic increase was in pasture 3, which started with an Olsen phosphorus of 6.5 mg/kg. Potassium rose on the pasture site with the application of potash, but also rose on the lucerne site, where no potassium was applied. This odd results can be explained by the Nil treatment measuring 258 mg/kg in 2008 and greater than 400 mg/kg in 2011. This would suggest the 2008 potassium value in incorrect. Potassium levels declined on the crop site where no potassium was applied. Soil pH at two of the sites did not change appreciably. However at the pasture site the decline in pH was rapid.

The biological condition of the soil also changed as a result of the fertilisers applied (table 7).

Table 7: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Traditional fertiliser 2011	Guide level
Mycorrizhal colonisation	Lucerne 2	82.7	52.1	70
	Pasture 3	48.2	65.1	70
	Crop 1	60.3	25.8	50
Glomalin	Lucerne 2	23896	23255	30,000 (kgC/ha)
	Pasture 3	24326	28586	30,000 (kgC/ha)
	Crop 1	28080	23828	30,000 (kgC/ha)
Microbial diversity	Lucerne 2	45.7	47.1	80
	Pasture 3	12.4	15.3	80
	Crop 1	50.1	55.2	80

Interpretation and discussion

There was a positive response in dry matter at five of the six pasture / lucerne sites and both of the cropping sites in at least one of the three years measurements were taken. Six of the annual responses were significant and two just below significance.

A spectacular response occurred at a pasture site that had recently been sown to tall fescue and sub clover. Dry matter increased above the Nil treatment by 60% in 2010 and 14% in 2009. Olsen phosphorus was 11.3 mg/kg and Colwell potassium was 90 mg/kg in 2008. Sub clover content was significantly greater compared to the Nil and all other treatments at the site.

The two old established pasture sites responded to the fertiliser applied but to a smaller extent. The phalaris based pasture grew 5% more than the Nil treatment over the three years and the Victorian ryegrass - native pasture, which had an Olsen phosphorus of 6.5 mg/kg in 2008 grew 5% more in 2009, 6% more in 2010 and 24% more in 2011.

Two of the three lucerne sites recorded marginal increases in dry matter production compared to the Nil treatment. At one site the increase was 5%, where the starting Olsen P was 22.7 mg/kg and 6% where the Olsen P was 12.4 mg/kg. This response is within

expectations, although a greater response may have anticipated for the site with lower phosphorus.

It is unclear why there was no response at one lucerne site where three annual applications of 280kg/ha of super potash 2:1 was applied. The soil fertility in November 2008 was only moderate (Olsen phosphorus 11.9 mg/kg, Colwell potassium 93 mg/kg and KCl sulphur 11.3 mg/kg), so additional fertiliser would have been expected to increase dry matter production, if only by the 5% seen at the other sites. Adequate levels of all trace elements except for copper, which was slightly marginal, were measured. The site had been limed and the pH ($CaCl_2$) was 5.0 with 0.7% available aluminium. However the lucerne responded to light rates of lime (250 kg/ha twice a year) when combined with worm castings, suggesting there still may be a pH / aluminium effect even though the soil test would not indicate this is the case.

Crop sites responded to the fertiliser applied in at least one year. The fertiliser was broadcast and a larger response could have been expected if the DAP was sown with the seed. Both crops were effectively 'cooked' in 2009 by a very dry and hot spring, so 2010 and 2011 were more representative years. In 2010, one crop lodged due to heavy rain so only one crop could be harvested. The harvested crop measured a 20% increase in triticale grain yield. In 2011 both crops were harvested, with yield increases over the Nil treatment of 13% for canola and 12% for late sown barley.

At all three sites phosphorus levels were higher than target levels. This may be a result of using larger assumptions than needed for maintenance, capital and phosphorus 'lock up' or the results may be elevated because sampling was undertaken only seven months after application.

Testing of the Nil treatment at three sites provided an insight into how rapidly soil conditions change without any product application. Phosphorus levels declined under pasture, lucerne and crop (table 8).

Table 8: Changes in phosphorus, potassium and pH levels for the Nil treatment from baseline measurements in November 2008 to November 2011.

Element	Site	2008 baseline	2011
Phosphorus (Olsen)	Lucerne 2	22.7	17.6
	Pasture 3	6.5	6.3
	Crop 1	18.5	15.9

While some caution needs to be applied to these results, they do provide an indication of the likely trend at each site and enable comparisons with other products that do not contain large quantities of phosphorus.

Soil biological testing provides insights into the effect large quantities of inorganic fertiliser has on microbial activity. The scientific literature indicates the infection of beneficial myccorrhizal fungi in the plant roots is affected by traditional inorganic fertiliser containing nitrogen and phosphorus. The results from two of the three sites supports this premise. However there is one site which received 1,125 kg/ha of super potash 5:1 over the three

years that *increased* the myccorrhizal colonisation of the plant roots, to amounts close to the target level.

Glomalin, a concentrated carbon compound that is relatively stable in the soil, decreased at one site compared to the Nil treatment, remained stable at another site and increased at the pasture site with high fertiliser applications. It is impossible to draw any firm conclusions about the link between glomalin and inorganic fertiliser applications based on this data. However it is accepted that to increase soil carbon requires the sequestration of soil organic matter which largely comprises carbon, nitrogen, phosphorus and sulphur. It is plausible that the large additions of P, K and S and the dramatic increase in sub clover (supplying N) has provided the building blocks for rapid biological growth and hence increases in measured carbon (from the glomalin test).

The microbial diversity did not appear to change under the different fertiliser regimes. This could be because fertiliser does not affect microbial diversity compared to not applying anything, or that the Nil treatment has not recovered from previous fertiliser applications. This comparison remains inconclusive.

Traditional inorganic fertiliser with Twin N

In a nutshell

- ***There was no significant response to Twin N once the yield increase attributed to the traditional fertiliser were accounted for.***
- ***Soil nutrient and pH levels changed in a similar fashion to traditional fertiliser alone.***
- ***The evidence to suggest increases in free living nitrogen bacteria in the soil is inconclusive.***

Product description

Twin N reports to contains a selection of nitrogen fixing microbes. A proportion of the microbes are claimed to live within the plant (roots, leaves, stem), with the rest established in the root zone very close to surface of roots and root hairs. A secondary effect is reported to be the production of growth factors and release of substances that improve nutrient solubility.

Twin N is supplied in a freeze dried form and has to be 'awoken' before application. It is applied via boom spray in addition to the standard fertiliser recommendations at the rate of 50 ml/ha. In these trials it was applied late in the afternoon with 300 l of water per hectare to avoid desiccation of the microbes. For pasture and lucerne it was applied twice per year (around May / June and late August). At the one cropping site, where nitrogen was part of the standard fertiliser application, the rate of nitrogen applied in the traditional fertiliser was reduced by 50%. It was applied at 3 to 4 tillers for cereals, with a second application at early flowering. Twin N contains no measurable amounts of nutrients.

Product application

Twin N was applied at five sites, with the same standard fertiliser as the traditional inorganic fertiliser, except for the one crop site where the nitrogen was reduced by 50% (and a corresponding reduction in P and S) (table 9).

Table 9: Total quantity of nutrients applied by traditional inorganic fertilisers with Twin N from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Pasture 2	0	52	101	65	$652
Pasture 3	0	83	90	104	$787
Lucerne 2	0	40	0	50	$395
Lucerne 3	0	70	0	3	$509
Crop 2	27	30	90	3	$478

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 2), with the response to traditional fertiliser removed showing the Twin N response only (figure 3).

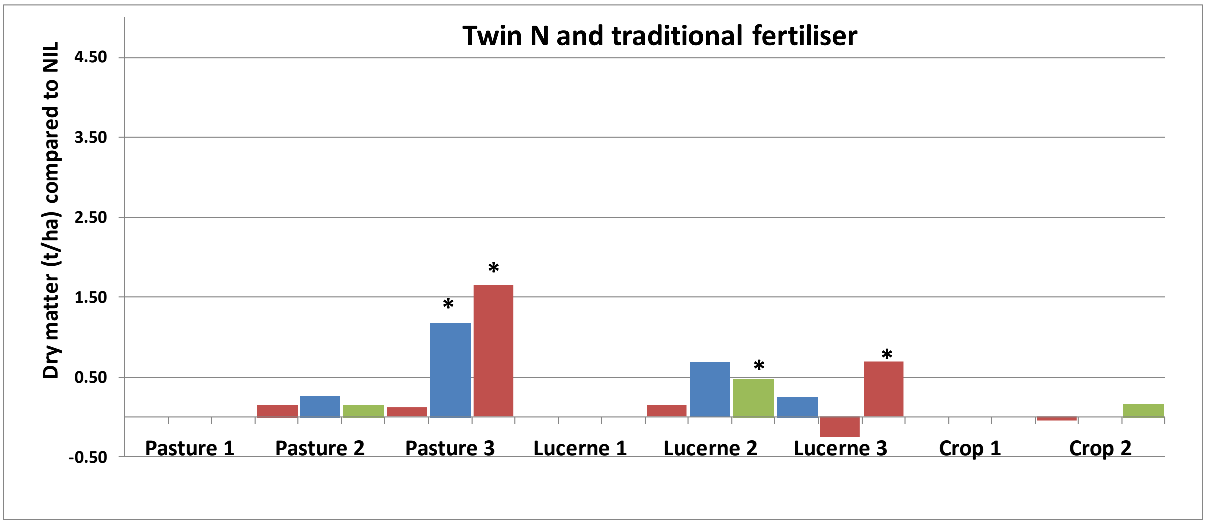

Figure 2: Annual difference in dry matter production for Twin N with traditional fertilisers compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the Twin N with traditional fertiliser and the Nil treatment ($p < 0.05$).

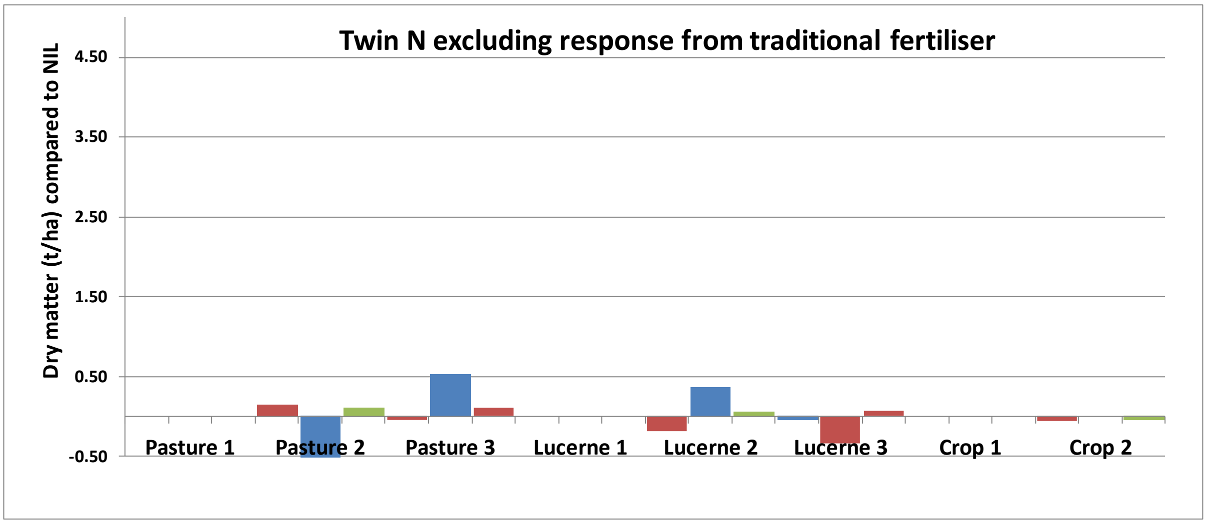

Figure 1: Annual difference in dry matter production for Twin N (traditional fertilisers excluded) compared to Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the Twin N and the traditional fertiliser treatment ($p < 0.05$). NB: Phosphorus, nitrogen and sulphur rates were less at the crop 2 site.

Composition

The application of Twin N with traditional fertiliser did not change pasture composition or lucerne density at any site.

Soil conditions

Soil samples were taken from the Twin N with traditional fertiliser at one lucerne (lucerne 2) and one pasture (pasture 3) site (table10).

Table 10: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and Twin N with traditional fertiliser and traditional fertiliser only in November 2011.

Element	Site	2008 baseline	Twin N with Traditional fertiliser 2011	Traditional fertiliser 2011
Phosphorus (Olsen)	Lucerne 2	22.7	22.3	21.9
	Pasture 3	6.5	17.5	19.5
Potassium (Colwell)	Lucerne 2	258[3]	317	413
	Pasture 3	123	176	154
pH ($CaCl_2$)	Lucerne 2	5.3	5.4	5.4
	Pasture 3	4.8	4.6	4.4

The addition of Twin N to the traditional fertiliser did not change the phosphorus, potassium and pH levels compared to traditional fertiliser.

The biological condition of the soil to the application of Twin N and traditional fertiliser was variable when compared to traditional fertiliser alone and the Nil treatment (table 11).

Table 11: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Twin N + Traditional fertiliser 2011	Traditional fertiliser 2011	Guide level
Mycorrizhal colonisation	Lucerne 2	82.7	56.3	52.1	70
	Pasture 3	48.2	65.4	65.1	70
Glomalin	Lucerne 2	23896	26375	23255	30,000 (kgC/ha)
	Pasture 3	24326	19433	28586	30,000 (kgC/ha)
Microbial diversity	Lucerne 2	45.7	32.3	47.1	80
	Pasture 3	12.4	50.7	15.3	80

Interpretation and discussion

The response to Twin N with traditional fertiliser in pasture and lucerne was similar to traditional fertiliser alone (positive response recorded at most sites). However once the yield response to traditional fertiliser was removed, there was no significant response at any of the sites to Twin N. The closest positive yield response was at pasture 3 in 2010, where an additional 0.47 t/ha of dry matter was grown compared to traditional fertiliser only (LSD 0.05 = 0.59 t/ha). This site was deficient in clover so there may be a response but the limited data does not support this conclusion.

[3] Suspect an error in the 2008 result as all 8 treatments tested in 2011 have potassium levels around 400 mg/kg.

There was no response at the only crop site in 2009 (a very dry spring) and 2011 (the 2010 crop was destroyed by heavy rain). The crop received reduced rates of nitrogen compared to the traditional fertiliser, which also reduced the phosphorus and sulphur applied. The small negative result, while not significant, may be a result of the reduced fertiliser applied.

There was no evidence to suggest nutrient levels have increased through increase nutrient solubility.

Soil biological testing was only conducted at two sites and interpretation of the responses are difficult. Mycorrihizal colonisation in the Twin N and traditional fertiliser was the same as traditional fertiliser alone, however glomalin levels were higher at one site and appreciably lower at the other site. Microbial diversity in the Twin N and traditional fertiliser treatment did not follow the was the same trends as traditional fertiliser alone. At the pasture site where there was a large shift in microbial diversity, the total diversity was similar to traditional fertiliser only, but the proportion of bacteria increased dramatically. Fungi to bacteria ratios changed from 2.7:1 with traditional fertiliser to 1.2:1 for Twin N with traditional fertiliser (data not presented in this report). A guide to the desired ratio is 2.3:1[4]. This change in bacterial numbers was not repeated at the lucerne site.

[4] Creation Innovation, Agriculture and Forestry laboratory, St Marys South Australia.

Traditional inorganic fertiliser with TM (formerly called TM21)

In a nutshell

- ***A significant response to TM with traditional fertiliser was measured at one pasture site however the increase in production was not repeated at a crop site and a lucerne site.***
- ***The common soil test and biological tests do not consistently explain the reasons for the response (or lack of response).***
- ***The product is easy to fit into a farming operation and given the spectacular response at one of the three sites would be worth investigating further.***

Product description

TM (formerly marketed as TM 21) is a bio-stimulant that claims to feed and increase the population of micro-organisms in the soil. Traditional fertiliser is still applied, with full application rates in the first year and gradually reducing rates in subsequent years[5].

Product application

TM was applied at three sites by boom spray using 250 ml/ha of product in 80L/ha of water. Two applications were made on pasture and lucerne, one in May / June and a second in August / September. For the crop site, application was post sowing, pre- emergence (bare earth) and again in late August (foliar). Traditional fertiliser was used at each site, with 80% of the prescribed rate used in 2011 (table 12).

Table 12: Total quantity of nutrients applied by traditional inorganic fertilisers with TM from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Pasture 3	0	78	84	97	$674
Lucerne 3	0	65	0	3	$414
Crop 1	50	57	0	69	$467

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 4), with the response to traditional fertiliser removed (figure 5).

[5] Exact rates and timings are presented in each site report

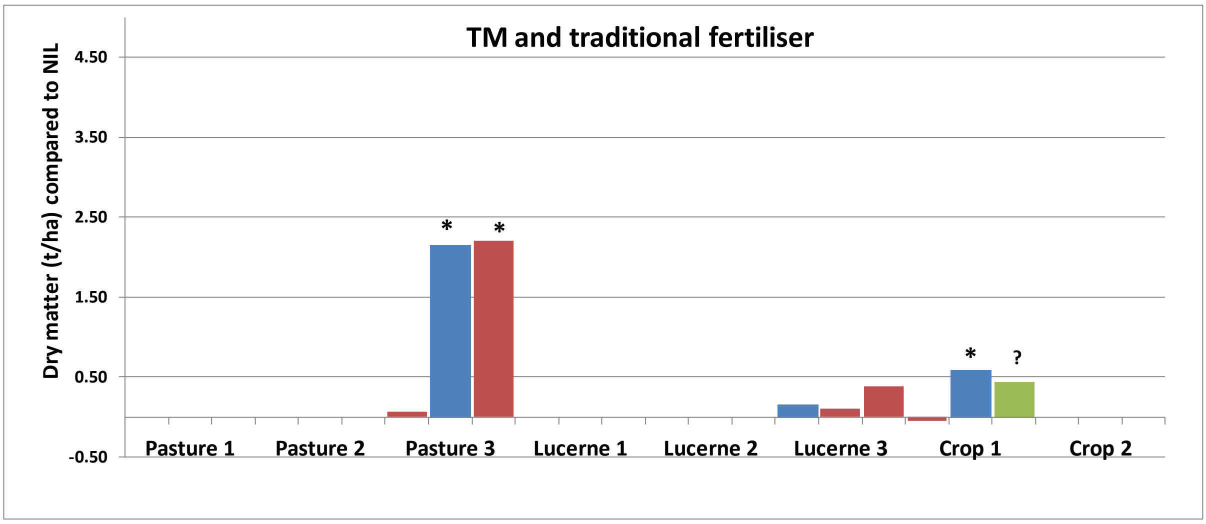

Figure 4: Annual difference in dry matter production for TM with traditional fertilisers compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the TM with traditional fertiliser and the Nil treatment ($p < 0.05$). ? represents just outside statistical significance.

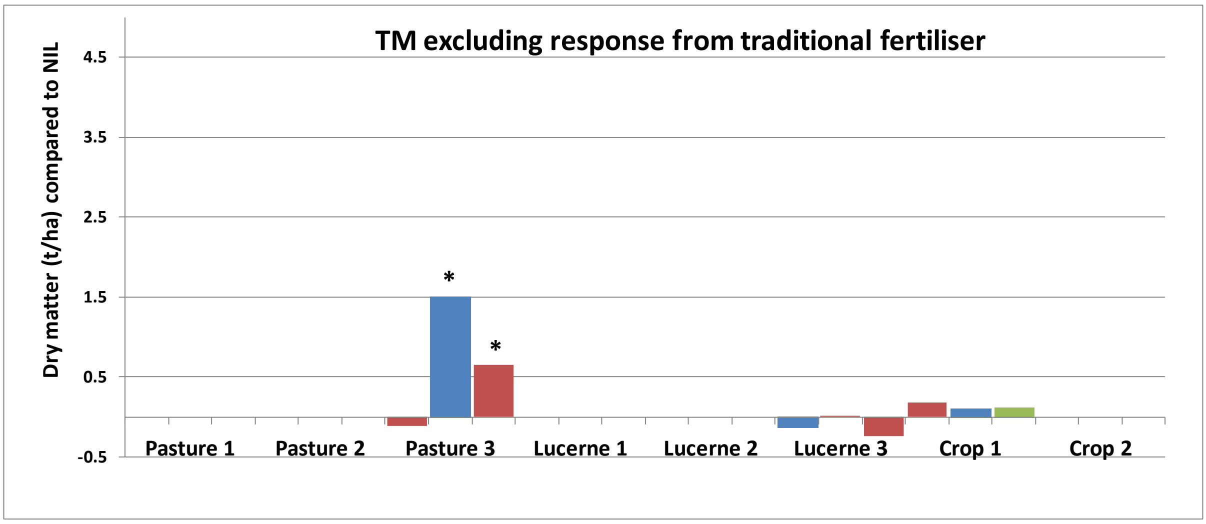

Figure 5: Annual difference in dry matter production and crop yield for TM (traditional fertilisers excluded) compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the TM and the traditional fertiliser treatment ($p < 0.05$). NB: Phosphorus, nitrogen and sulphur rates were less at the crop 2 site.

Composition

The application of Twin N increased the desirable species in the pasture to 86% compared to the Nil treatment (70%) and traditional fertiliser (69%).

Soil conditions

Soil samples were taken from the traditional fertiliser at one pasture (pasture 3) and one crop (crop 1) site (table 13).

Table 13: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and TM with traditional fertiliser and traditional fertiliser only in November 2011.

Element	Site	2008 baseline	TM with Traditional fertiliser 2011	Traditional fertiliser 2011
Phosphorus (Olsen)	Pasture 3	6.5	17.8	19.5
	Crop 1	18.5	23.8	23.6
Potassium (Colwell)	Pasture 3	123	147	154
	Crop 1	203	216	182
pH ($CaCl_2$)	Pasture 3	4.8	4.4	4.4
	Crop 1	4.9	4.7	4.8

The addition of TM to the traditional fertiliser did not change the phosphorus, potassium and pH levels compared to traditional fertiliser.

The biological condition of the soil to the application of Twin N and traditional fertiliser was variable when compared to traditional fertiliser alone and the Nil treatment (table 14).

Table 14: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	TM + Traditional fertiliser 2011	Traditional fertiliser 2011	Guide level
Mycorrizhal colonisation	Pasture 3	48.2	55.7	65.1	70
	Crop 1	60.3	33.1	25.8	50
Glomalin	Pasture 3	24326	20286	28586	30,000 (kgC/ha)
	Crop 1	28080	30189	23828	30,000 (kgC/ha)
Microbial diversity	Pasture 3	12.4	73.0	15.3	80
	Crop 1	50.1	55.7	55.2	80

Interpretation and discussion

There was a significant and spectacular response to TM at the pasture site in 2010 and 2011. This was significantly greater than traditional fertiliser alone, with the TM treated plots visually different from the other treatments in quantity of dry matter and clover content. The measured levels of soil fertility and pH were similar to traditional fertiliser alone suggesting it is not a macronutrient response.

The biological condition of the soil suggests there has been a dramatic increase in *microbial diversity*, increasing to 73 while the Nil treatment and the traditional fertiliser remained at 12.4 and 15.3 respectively. However the *total microorganism* count under the TM treatment (81,329) has reduced markedly compared to the Nil treatment (122,567) and the traditional fertiliser (105,145). In particular total fungal activity has declined to a ratio with bacteria of 1:1 (desired level 2.3:1) and is less than half of the fungi in the Nil treatment. While the TM treatment is the highest microbial diversity of any treatment at this site it has not improved mycorrizhal colonisation (but this may be due to the negative impact of the

traditional fertiliser). Of potential concern in these results is the apparent reduction in glomalin, a stable carbon rich compound formed by mycorrhiza and fungal growth.

In contrast to the pasture, the results from the crop site show a small although not significant increase in yield and no changes in microbial diversity or mycorrhizhal colonisation compared to traditional fertiliser. Glomalin levels appear to have *increased not decreased* and there were no changes in total micro-organisms or fungal populations compared to the Nil treatment or traditional fertiliser!

The third site where TM was applied with traditional fertiliser showed no dry matter response (biological measurements were not taken due to costs), despite there being a response to traditional fertiliser only.

The three somewhat conflicting results makes it impossible to draw any firm conclusions about TM. There have been five applications of TM but a statistically valid response was only measured at one of the three sites. The common soil test does not explain the responses and the biological conditions measured in the soil, while varying are not consistent.

Pig manure

In a nutshell

- ***Pig manure applied at these rates grew more dry matter and at the price supplied is a cost effective alternative to traditional fertiliser.***
- ***There was a small increase in crop yields although increases in canopy growth were evident.***
- ***Increasing pasture growth in winter is a feature of the response.***
- ***It increased microbial diversity in the soil and may increase glomalin (stable soil carbon) levels.***
- ***Nutrient levels in November 2011 are still above 2008 levels suggesting the applied nutrients may last more than three years.***

Product description

Pig manure was supplied from a local grower shed. The manure used contained 3.32% nitrogen, 1.89% phosphorus, 2.61% potassium, 0.82% sulphur and 62.8% DM[6]. It was applied after being stockpiled for six months but was in an un-composted form.

Product application

Pig manure was applied in May 2009 at six of the eight sites as a once off application. The rates were 4.2 t/ha (6.4 m^3/ha) on pasture and lucerne and 6.2 t/ha (9.6m^3/ha) on crop. The application applied the following macronutrients (table 15).

Table 15: Quantity of nutrients applied in pig manure

Site	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Product cost* ($/ha)
Crop	132	89	90	48	$164
Pasture/lucerne	88	59	60	32	$246

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 6).

[6] Tested by SWEP Analytical Laboratories

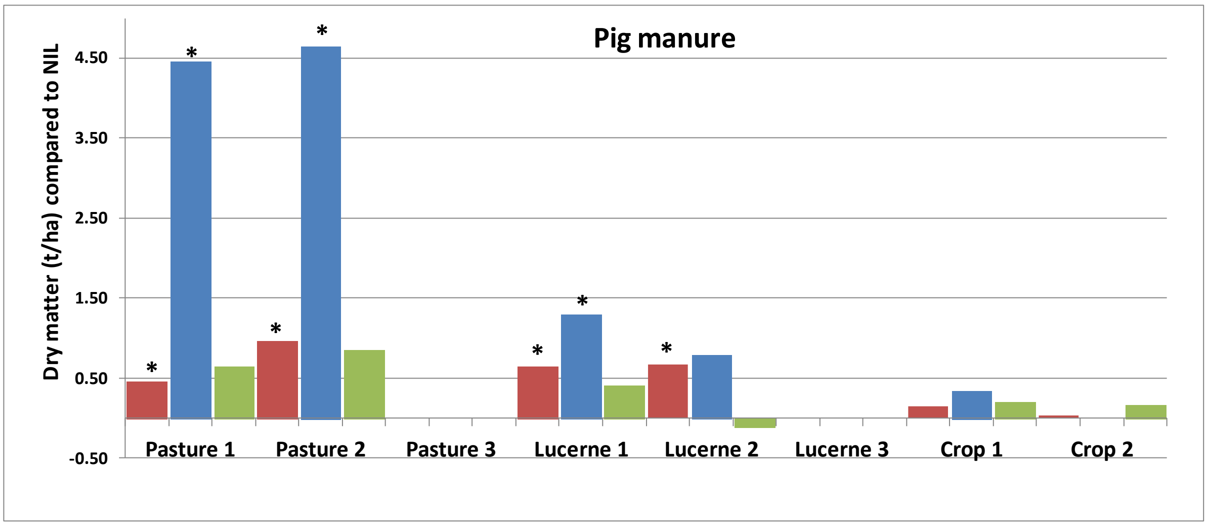

Figure 6: Annual difference in dry matter production for pig manure compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the pig manure and the NIL treatment ($p < 0.05$).

The increase in dry matter in percentage terms was most significant in the first cut after the autumn break each year (table 16). These responses, especially in 2009 and 2010 were much greater than any other treatment. Similar increases in dry matter in the crop were observed, however this did not translate into increased grain yield.

Table 16: Dry matter difference at the first cut (winter) from pig manure compared to the Nil treatment

Site	Year	Dry matter difference compared to nil of first cut (winter)
Pasture 1	2009	46%
	2010	33%
	2011	4%
Pasture 2	2009	47%
	2010	24%
	2011	27%
Lucerne 1	2009	21%
	2010	9%
	2011	3%
Lucerne 2	2009	20%
	2010	4%
	2011	-5%

Composition

The application of pig manure did not change the composition of desirable perennial species or sub clover.

Soil conditions

Soil samples were taken from the pig manure treatment at one lucerne (lucerne 2) and one crop (crop 1) site. There was a noticeably increase the phosphorus levels measured two and

a half years after the pig manure was applied. Smaller increases were seen in the potassium levels and no change in pH (table 17).

Table 17: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and November 2011.

Element	Site	2008 baseline	2011
Phosphorus (Olsen)	Lucerne 2	22.7	25.8
	Crop 1	18.5	24.6
Potassium (Colwell)	Lucerne 2	258	348
	Crop 1	203	219
pH ($CaCl_2$)	Lucerne 2	5.3	5.3
	Crop 1	4.9	4.9

The biological condition of the soil also changed as a result of the pig manure (table 18).

Table 18: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Pig manure 2011	Guide level
Mycorrizhal colonisation	Lucerne 2	82.7	67.7	70
	Crop 1	60.3	57.7	50
Glomalin	Lucerne 2	23896	25982	30,000 (kgC/ha)
	Crop 1	28080	33613	30,000 (kgC/ha)
Microbial diversity	Lucerne 2	45.7	69.9	80
	Crop 1	50.1	59.4	80

Interpretation and discussion

The application of large quantities of pig manure increased dry matter production at all pasture and lucerne sites. Similar visual responses were seen where pig manure was applied to crops, but this did not translate into any significant increase in grain yield.

The most striking response to the pig manure was in the measurements taken from the first cut each year, which roughly represents the autumn / winter period. It is speculated that the nitrogen in the manure, which become plant available over the summer period, is the primarily reason for the response as the extra dry matter. It was much greater than the traditional fertilisers, which contained no nitrogen. The extra fodder produced in winter is likely to be more highly valued as it is often a time of feed shortages. However in cropping, the extra plant size (crop canopy) may not be of benefit and may even be detrimental. Pasture composition did not change as a result of the pig manure.

The dry matter responses measured are not surprising given the amount of nutrients applied. The soil tests reveal there is still an increased amount of phosphorus and potassium three years after application (Olsen P remains 3.1 units higher than 2009 baseline in pasture and 6.1 units higher in crop where a higher rate was applied). This may mean the pig manure applied at these rates will still give some positive response in future years.

There was one noticeable change in the soil biology. The microbial diversity increased at both sites, with the size of the change larger than typical biological variability (Dr Maria Manjarrez, *pers comm*). The microbial diversity levels were the highest or equal highest of any treatment. This is a positive result given the 2008 baseline analysis suggested both these sites were limited in microbial diversity. The glomain levels (a stable soil carbon compound) may also have increased slightly with the addition of the pig manure. Mycorrhizal infection of the plant roots were similar to the nil treatment, but were already around the desired levels.

Poultry manure

In a nutshell

- ***Poultry manure applied at these rates grew more dry matter, especially in the first year and at the price supplied is a cost effective alternative to traditional fertiliser.***
- ***It did not increase crop yields.***
- ***It increased microbial diversity in the soil when starting from a low base, but has not affected glomalin levels or dramatically increased dry matter production.***
- ***Nutrient levels in November 2011 have returns to 2008 levels suggesting the applied nutrients have been used up over three years.***

Product description

Poultry manure was supplied from a local broiler shed and contained wood shavings. The sample contained 2.74% Nitrogen, 1.52% phosphorus, 1.56% potassium, 0.43% sulphur and 73.1% DM. It was applied in a stockpiled but un-composted form.

Product application

Poultry manure was applied in May 2009 at five of the eight sites as a once off application. The rates were 2.1 t/ha (5.0 m^3/ha) on pasture and lucerne and 3.2 t/ha (7.5m^3/ha) on crop. The application applied the following macronutrients at a cost of $xx/ha for pasture/lucerne and $xx/ha for crops (table 2). This was about half the quantity of nutrients provided with the pig manure.

Table 19: Quantity of nutrients applied in poultry manure

Site	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Product cost* ($/ha)
Crop	63	35	36	11	$100
Pasture/lucerne	42	23	24	7	$150

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 7). Several measurements were only just outside the significance range.

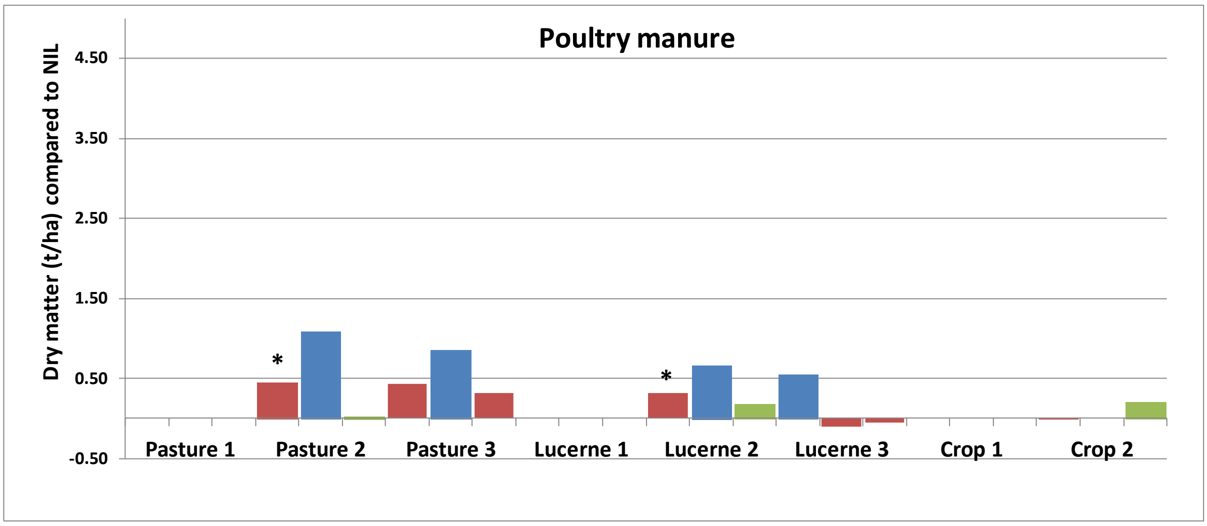

Figure 7: Annual difference in dry matter production for poultry manure compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the pig manure and the NIL treatment ($p < 0.05$).

Composition

The application of poultry manure did not change the composition of desirable perennial species or sub clover.

Soil conditions

Soil samples were taken from the poultry manure treatment at one lucerne (lucerne 2) and one pasture (pasture 3) site. Phosphorus levels were similar two and a half years after the poultry manure was applied. Increases were seen in the potassium levels and a slight positive change in pH (table 20).

Table 20: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and November 2011.

Element	Site	2008 baseline	2011
Phosphorus (Olsen)	Lucerne 2	22.7	22.0
	Pasture 3	6.5	5.8
Potassium (Colwell)	Lucerne 2	258	414
	Pasture 3	123	149
pH ($CaCl_2$)	Lucerne 2	5.3	5.5
	Pasture 3	4.8	4.5

The biological condition of the soil also changed as a result of the poultry manure (table 21).

Table 21: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Poultry manure 2011	Guide level
Mycorrizhal colonisation	Lucerne 2	82.7	68.3	70
	Pasture 3	48.2	60.0	70
Glomalin	Lucerne 2	23896	26038	30,000 (kgC/ha)
	Pasture 3	24326	23614	30,000 (kgC/ha)
Microbial diversity	Lucerne 2	45.7	42.2	80
	Pasture 3	12.4	48.9	80

Interpretation and discussion

The application of poultry manure increased dry matter production at all pasture / lucerne sites in 2009, with two site showing significant increases. In 2010 the response was only recorded at three of the four sites and by 2011 at only two sites, with one of the ongoing responsive sites having a starting Olsen P of 6.5 mg/kg. The winter dry matter response seen with the pig manure was not repeated with the poultry manure. There was no response in grain yield and pasture composition did not change.

Soil test results show the amount of available phosphorus was at similar levels to November 2008, with potassium levels increasing only slightly three years after application. It would appear the nutrients applied in the single application of poultry manure have been utilised. The soil at the pasture site appears to have acidified under the poultry manure treatment. However the Nil treatment also measured pH ($CaCl_2$) of 4.5 suggesting either the sites has acidified rapidly or the baseline measurement in 2008 was elevated. There is insufficient evidence to conclude poultry manure rapidly acidifies the soil.

Soil biological responses varied under the poultry manure treatments. In the higher fertility lucerne site, where the baseline levels of microbiology were reasonable, there was little change, except maybe a slight increase in glomalin. The pasture site, which measured virtually no biological activity in 2008 increased dramatically. Mycorrhizal infection of the plant roots increased, as did the microbial diversity. Microbial diversity rose 300% compared to the NIL treatment, albeit from an extremely low starting point (The Nil results in 2011 confirms the lack of biological activity measured in 2008). While the microbial activity is not as the desired level, it is a dramatic increase compared to the Nil treatment.

The increase in biological activity at the pasture site has not translated into changes in soil carbon (as measured by glomalin levels).

Worm caste with lime

In a nutshell

- ***Dry matter responses were recorded in some years and at some sites, with the greatest response on the pasture sites.***
- ***While the response to worm caste or lime cannot be separated, the decline in phosphorus and the small increase pH may indicate the dry matter and grain yield response is due to the lime.***
- ***These findings bring into question the threshold levels currently used to recommend liming in Southern Victoria.***
- ***The response worm caste and lime have on soil biology remains unclear.***

Product description

Worm castings are intended to act as a plant food source and soil conditioner, in a mixture of readily available nutrients, bacteria and enzymes. It is the solid product of vermiculture (worms) and was supplied by a local farmer who produces castings for sale. The castings are spread in combination with small quantities of lime. The lime is required to provide a calcium source and neutralises the environment for the microbes in the castings.

The supplier of the worm caste indicated the product contained on average 2.3% nitrogen, 0.6% phosphorus, 1.0% potassium and 0.6 % sulphur. The lime used was Kurdeez dried lime with a neutralizing value (NV) of 93.

Product application

Worm caste and lime were applied at all eight sites. The rates were 200 kg/ha of worm caste with 250 kg/ha of lime. Five applications were made, one in 2009, and two in 2010 and 2011 (table 22).

Table 22: Total quantity of nutrients applied by worm caste and lime from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Crop / pasture / lucerne	11.5	3.0	5.0	3.0	$930[7]

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 8).

[7] Lime cost were only $71.25/ha

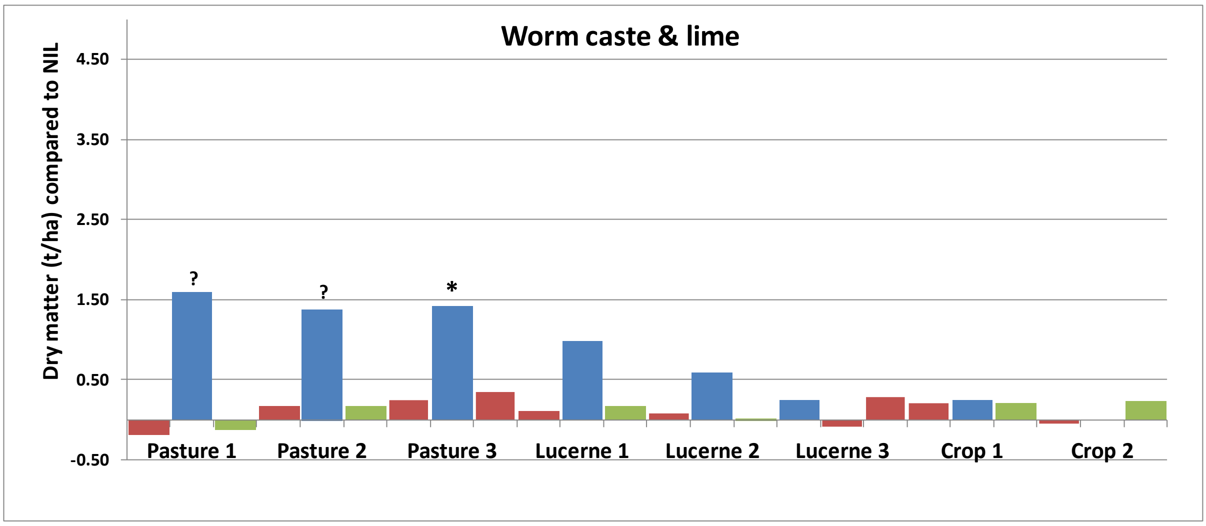

Figure 8: Annual difference in dry matter production for worm caste and lime compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the traditional fertiliser and the Nil treatment ($p < 0.05$), ? represents just outside statistical significance.

Composition

The application of worm caste and lime did not change the combined legume and perennial grass components at any of the three pasture sites compared to the NIL treatment.

Soil conditions

Soil samples were taken from the worm caste and lime at one lucerne (lucerne 2), one pasture (pasture 3) and one crop site (crop 1) (table 23).

Table 23: Phosphorus, potassium, pH and aluminium levels from baseline measurements in November 2008 and November 2011.

Element	Site	2008 baseline	2011
Phosphorus (Olsen)	Lucerne 2	22.7	18.4
	Pasture 3	6.5	5.4
	Crop 1	18.5	17.1
Potassium (Colwell)	Lucerne 2	258[8]	426
	Pasture 3	123	125
	Crop 1	203	218
pH ($CaCl_2$)	Lucerne 2	5.3	6.0
	Pasture 3	4.8	5.1
	Crop 1	4.9	5.4
Aluminium (% CEC)	Lucerne 2	0.4	<0.1
	Pasture 3	2.3	0.3
	Crop 1	1.2	0.3

[8] Suspect an error in the 2008 result as all 8 treatments tested in 2011 have potassium levels around 400 mg/kg.

At all three sites the decline in Olsen phosphorus levels presented in table 23 were similar to the Nil treatment while potassium levels remained roughly the same (table 24).

Table 24: Changes in phosphorus and potassium levels from baseline measurements in November 2008 and November 2011.

Element	Site	Change in nutrient status with worm caste and lime from baseline in 2008 to 2011	Change in nutrient status with Nil treatment from baseline in 2008 to 2011
Phosphorus (Olsen)	Lucerne 2	-4.3	-5.1
	Pasture 3	-0.9	-0.2
	Crop 1	-1.4	-2.6
Potassium (Colwell)	Lucerne 2	+29[9]	+26
	Pasture 3	+2	+19
	Crop 1	+15	-21

The pH of the soil increased with the worm caste and lime treatment, where the NIL treatment remained virtually the same (table 25).

Table 25: Changes in pH levels from baseline measurements in November 2008 and November 2011.

Element	Site	Change in pH status with worm caste and lime from baseline in 2008 to 2011	Change in pH status with Nil treatment from baseline in 2008 to 2011
pH ($CaCl_2$)	Lucerne 2	+0.7	+0.2
	Pasture 3	+0.3	-0.3
	Crop 1	+0.5	-0.1

The biological condition of the soil changed at some sites as result of the worm caste and lime applied (table 26).

Table 26: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Worm caste and lime 2011	Guide level
Mycorrizhal colonisation	Lucerne 2	82.7	77.1	70
	Pasture 3	48.2	79.9	70
	Crop 1	60.3	38.5	50
Glomalin	Lucerne 2	23896	27170	30,000 (kgC/ha)
	Pasture 3	24326	22397	30,000 (kgC/ha)
	Crop 1	28080	30964	30,000 (kgC/ha)
Microbial diversity	Lucerne 2	45.7	51.4	80
	Pasture 3	12.4	71.3	80
	Crop 1	50.1	48.0	80

[9] Suspect baseline error in 2008 result. Use Colwell K of 400 mg/kg

Interpretation and discussion

The application of worm caste and lime has resulted in an interesting response. There was only a small amount of nutrients applied (N, P, K, S) in the five applications of worm caste and the equivalent of 1.25 t/ha of a high purity lime. Only three sites were re-tested for nutrients in 2011, with all three sites recording a decline phosphorus similar to the Nil treatment, maintenance of potassium levels but a noticeable increase in pH resulting in a decline in available aluminium. The changes in these key soil measures are consistent with the level of nutrient applied and the expected response to 1.25 t/ha of lime.

Dry matter responses were largest in the pasture, with a significant yield increases compared to the Nil treatment at one site and just below significance at the other two sites in 2010. There was no response in 2009, although the spring was very dry, and a small dry matter change in 2011 at only two sites. The increase in dry matter occurred despite a decline in phosphorus similar to the Nil treatment. This would suggest the increase in pH from the lime may be influencing the result.

The three pasture sites recorded baseline soil pH ($CaCl_2$) readings in November 2008 of 4.6, 4.7 and 4.8 with a corresponding aluminium level (% CEC) of 3.0, 2.7 and 2.3. While the soil pH levels are considered highly acidic and some aluminium was present, they were not excessive and would not be considered in urgent need of liming based on current DPI recommendations[10]. However all sites responded to the worm caste and lime treatments.

All lucerne sites had previously been limed and had soil pH ($CaCl_2$) of 5.0, 5.1 and 5.3 with aluminium levels (% CEC) of 0.7%, 0.4% and 0.8%. A much smaller response, including no response, was measured at these sites. One of the two cropped sited has a baseline pH of 4.8 with an aluminium level (% CEC) of 5.1%. A modest yield increase of 6%, 10% and 8% was measured at this site compared to the Nil treatment. The other crop site had a higher pH of 4.9 and less aluminium (1.2%) but still recorded a 13% increase in yield compared to the Nil treatment in 2011.

The measured responses bring into question the aluminium 'trigger points' currently used to determine if lime is required. It would appear the removal of even small amounts of available aluminium (or some other unquantified change) leads to a increase in dry matter and crop yields. More work is required to validate this suspicion.

The biological response in the soil to the worm caste and lime is inconclusive. Microbial diversity at the pasture site increased dramatically and mycorrhizal colonisation improved, however there was no change in glomalin levels. It is unclear if this change is caused by the worm caste (which is claimed to contain bacteria and enzymes) or the change in pH improving the conditions for microbial growth. The lime increased the calcium to magnesium ratio at the pasture site to 2.6 where all other treatments remained below 2.0. It may be the additional calcium is causing the response.

There was no change in microbial diversity at the lucerne and crop sites and mycorrhizal colonisation actually declined at the crop site compared to the Nil treatment.

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[10] Pasture plants such as phalaris and lucerne are sensitive to aluminium levels of 2% to 8% (% CEC), subclover 8% to12% and ryegrass 13% to 21%. Source Acid Soil Action DPI.

Guano

In a nutshell

- ***Guano Gold Kwik start was only tested at one site and no response was recorded, however the site was also not responsive to traditional fertiliser applied at similar rates.***
- ***Given the limited data, no conclusion about the effectiveness of this product can be made.***

Product description

Supplied as Guano Gold Kwik start and claims to provide a combination of available nutrients and slow release nutrients. Guano Gold Kwik start contains 11.6% phosphorus (total P), 28.8% calcium (total Ca) and 8.8% silica. Silica is reported to increase exchange sites for nutrient storage. This product was spread in a mix of 75% Guano Gold and 25% Muriate of Potash.

Product application

Guano Gold Kwik start was only applied at one lucerne site. Annual applications of Guano Gold Kwik start were applied in May of each year at 113 kg/ha in 2009 and 150 kg/ha in 2010 and 2011. Additional potassium in the form of muriate of potash (38 kg/ha in 2009) and sulphate of potash (80 kg/ha in 2010 and 2011). The total amount of nutrient applied is presented (table 27).

Table 27: Total quantity of nutrients applied by Guano Gold Kwik start and various forms of potash from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Lucerne	0	48	85	29	Not calculated

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 9).

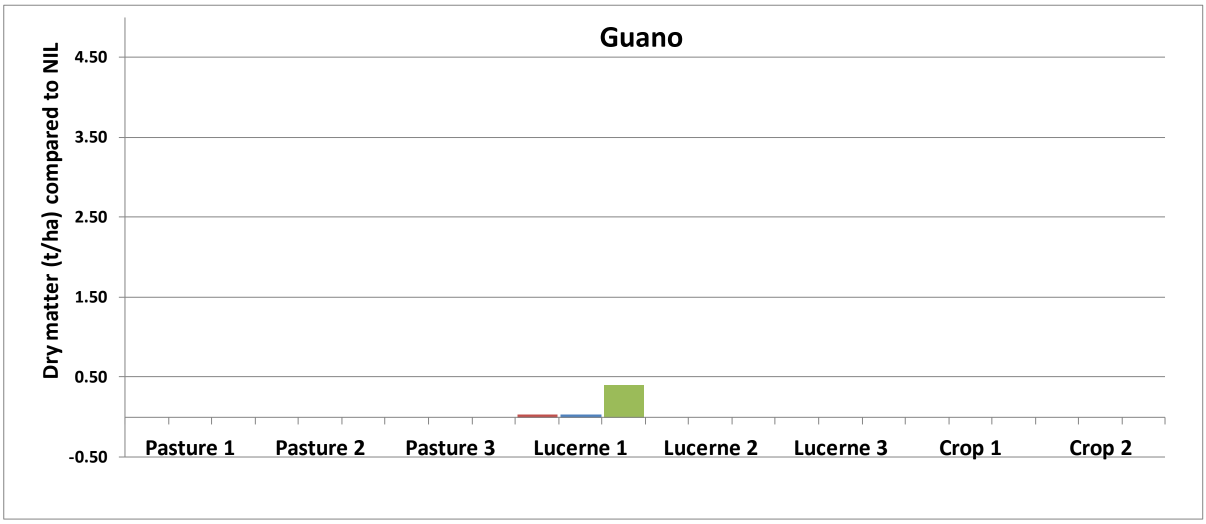

Figure 9: Annual difference in dry matter production for Guano Gold Kwik start compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the traditional fertiliser and the Nil treatment ($p < 0.05$).

Composition

The application of Guano Gold Kwik start did not change the lucerne density at the pasture site compared to the NIL treatment.

Soil conditions

No soil samples were taken due to cost constraints.

Interpretation and discussion

Guano Gold Kwik start was only applied at one lucerne site. There was no significant increase in dry matter production compared to the Nil treatment, with the Guano Gold Kwik start producing 20.2 t/ha over the three years compared to the Nil treatment of 19.7 t/ha. However the site did not respond to similar quantities of traditional fertiliser (280 kg/ha super potash 2:1 suppling 50 kg/ha of P, 139 kg/ha of K and 62 kg/ha of S in three years). The only responsive treatment at this site was the pig manure and is through to be due to the available nitrogen (refer to comments about the pig manure).

Given the limited number of sites where Guano Gold Kwik start was tested, the unresponsive nature of the site where the product was tested and the absence of soil data, no conclusion about the effectiveness of this product can be drawn.

Biosolids

In a nutshell

- ***Biosolids did not increase pasture production at the one pasture site where it was tested.***
- ***The product could not be sourced in 2010 and twice the rate was applied in 2011.***
- ***The product has not been adequately tested to draw any conclusions about its suitability as an alternative nutrient source.***

Product description

Biosolids are the treated residual from sewerage treatment. The product used contains 1.3% to 1.4% total phosphorus, very little of which is readily available and 1.4% to 1.6% total nitrogen, most of which is immediately available. The product has almost neutral pH and contains about 50% organic matter.

Product application

Biosolids were applied in 2009 and in 2011. Difficulty in obtaining the product prevented application in 2010. To compensate twice the rate was applied in 2011, using product supplied by Barwon Water. The product was broadcast in May 2009 at 250 kg/ha and 510 kg/ha in April 2011. The total amount of nutrient applied is presented (table 28).

Table 28: Total quantity of nutrients applied by biosolids from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Pasture	11	10	0	0	Not calculated

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 10).

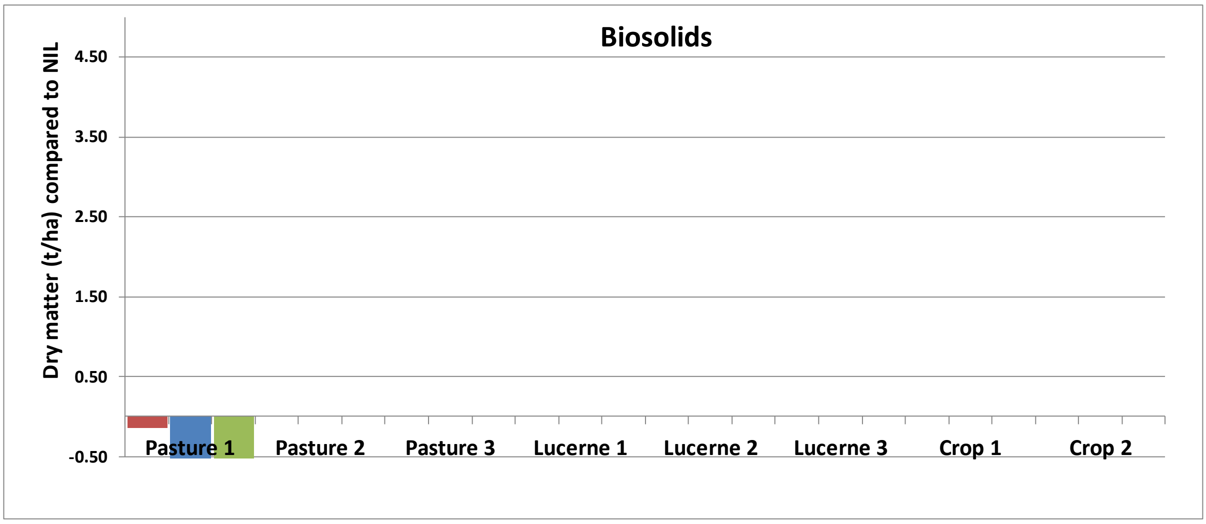

Figure 10: Annual difference in dry matter production for biosolids compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the traditional fertiliser and the NIL treatment ($p < 0.05$).

Composition

The application of biosolids did not change the combined legume and perennial grass components at this site compared to the NIL treatment.

Soil conditions

No soil samples were taken due to cost constraints.

Interpretation and discussion

Problems were encountered using biosolids in the trials. The recommended rate of 250 kg/ha/yr limited the amount of nutrients that could be applied (due to EPA constraints) and these were much less than the amount of phosphorus applied with the traditional fertiliser (10 kg/ha of P with the biosolids most of this is not immediately available compared with 76 kg/ha of P in the traditional fertiliser). Results from the 2008 soil test indicated the site was also potassium deficient and the biosolids did not contain potassium. As expected there was no dry matter response compared to the control, even though there was a significant response to traditional fertiliser.

A surprising observation was the apparent suppression in pasture growth from application of biolsolids at this site. This may be simply due to natural variation at the site and sampling error rather than undesirable contents in the product.

Given the difficulties with supply and the obvious limited with potassium deficiency that was not rectified with the application of the biosolids, it would be unwise to draw any conclusions about the suitability of the product as an alternative nutrient source.

Compost products

In a nutshell

- ***No significant dry matter or yield responses were recorded.***
- ***Microbial diversity did not change dramatically as a result of applications of compost and compost tea.***
- ***Limited testing prevents any strong conclusions to be drawn however there were no spectacular results from using compost products over the three year period***

Product description

Solid and liquid compost products (teas) were used. It is claimed these products supply organic matter, available nutrients and organisms. Compost tea is a liquid produced by extracting bacteria, fungi, protozoa and nematodes from compost. The solid compost used Sampi fish oil emulsion was also used with the spring application to provide available nutrients and discourage insect and fungal attack. The products were supplied by Camperdown Compost.

Product application

Treatments were applied at two sites, one lucerne and one crop site. Both sites received an initial application of solid compost with the crop receiving 780 kg/ha and the pasture treatment 1.7 t/ha. This was followed by two applications of compost tea (40 l/ha) in June and August - September. The Spring application also include 10 l/ha of Scampi fish oil (table 29).

Table 29: Total quantity of nutrients applied by compost, compost tea and Scampi fish oil from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Lucerne	6.6	3.5	3.5	6.6	$486
Crop	12.6	6.5	6.5	12.6	$435

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 11).

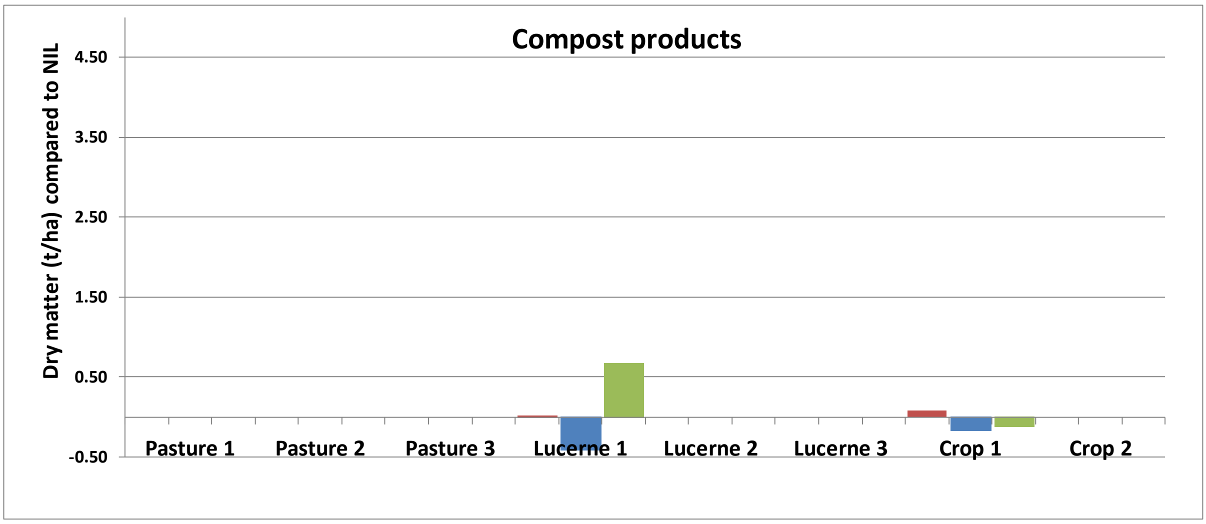

Figure 11: Annual difference in dry matter production for compost, compost tea and Scampi fish oil compared to the NIL treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between compost products and the NIL treatment ($p < 0.05$).

Composition

Compost products were not applied on any pasture sites.

Soil conditions

Soil samples were taken from the compost products at one crop site only (crop 1) (table 30).

Table 30: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and November 2011.

Element	Site	2008 baseline	2011
Phosphorus (Olsen)	Crop 1	18.5	17.9
Potassium (Colwell)	Crop 1	203	192
pH ($CaCl_2$)	Crop 1	4.9	5.0

The biological condition of the soil did not change appreciably as result of the compost products applied, except with possibly an increase in glomalin (table 31).

Table 31: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Compost products	Guide level
Mycorrizhal colonisation	Crop 1	60.3	58.6	50
Glomalin	Crop 1	28080	33943	30,000 (kgC/ha)
Microbial diversity	Crop 1	50.1	56.0	80

Interpretation and discussion

Compost products were only applied at two sites and detailed soil analysis was only conducted at the crop site. This limits the data from which to interpret the results so the interim conclusions may change if more data becomes available.

Lucerne production and crop yields were not increased by the application of compost products. The lucerne site where the compost products were used was unresponsive to most treatments (except for the pig manure) despite an Olsen P of 11.3 mg/kg and an initial microbial soil test suggesting the soil had low biological activity and very low levels of nematodes and protazoa. No pesticides, herbicides or inorganic fertiliser were used on these treatments in the three years of the trials, eliminating the chances of an external treatments killing the active soil biota (unless the soil was already affected by previous applications of herbicides and fertiliser). The amount of compost products applied should have 'drench' the soil with the deficient species. If this has occurred and the microbial activity at this site is improved, it has not translated into increased lucerne production.

More extensive soil testing was conducted at the crop site. There was no appreciable change in available phosphorus, potassium and soil pH (taking into account the accepted variability in soil testing). The biological condition of the soil does not seem to have changed with the application of the compost products. The only possible exception to this is the glomalin levels, which were slightly higher than the Nil treatment. When compared to the traditional fertiliser treatment (DAP at sowing), the microbial diversity is similar (compost products 56.0, traditional fertiliser 55.2), as was the ratio of fungi to bacterial (compost products 1.8:1, traditional fertiliser 2.1:1 with the desired ration of 2.3:1). There was a large difference in mycorrhizhal colonisation caused by the traditional fertiliser, but the mycorrhizhal levels measured where compost products had been applied was no greater than the Nil treatment. This finding does not support the proposition that synthetic fertilisers kill a range of the beneficial micro-organisms that encourage plant growth.

Seasol & Powerfeed

In a nutshell

- ***Seasol and Powerfeed applied multiple times over three years did not significantly increase dry matter production or grain yield at any of the eight sites tested.***
- ***Changes in available phosphorus, potassium and pH were similar to the Nil treatment.***
- ***Apart from a positive response to soil biodiversity at one of three sites, there were no appreciable differences in key soil biological indicators***

Product description

Seasol is an organic seaweed plant conditioner. It claims to contains naturally occurring growth regulators, trace elements, alginates, carbohydrate and vitamins derived from kelp. Powerfeed is an organic fish fertiliser (12:1.4:7:0). It is advertised as a source of amino acids, proteins, beneficial bacteria, trace elements and vitamins. Powerfeed is fortified with extra nitrogen, potassium, a small amount of phosphorus and humates. The two products were recommended to be used together.

Product application

Seasol and Powerfeed were applied at all eight sites, reflecting widespread farmer interest. It was applied either two or three times per year, depending on the condition of the crop, lucerne or pasture, but usually in mid June, late August and possibly early November. Five applications were applied to the crops, eight applications to the pasture and nine applications to the lucerne. The rate used was 5 l/ha of each product applied with a boom spray at 200 l/ha of water (table 32).

Table 32: Total quantity of nutrients applied by Seasol and Powerfeed from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Pasture 1, 2, 3	5.3	0.6	4.6	0.2	$754
Lucerne 1, 2, 3	5.9	0.7	5.2	0.2	$848
Crop 1, 2	3.3	0.4	2.9	0.1	$471

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 12).

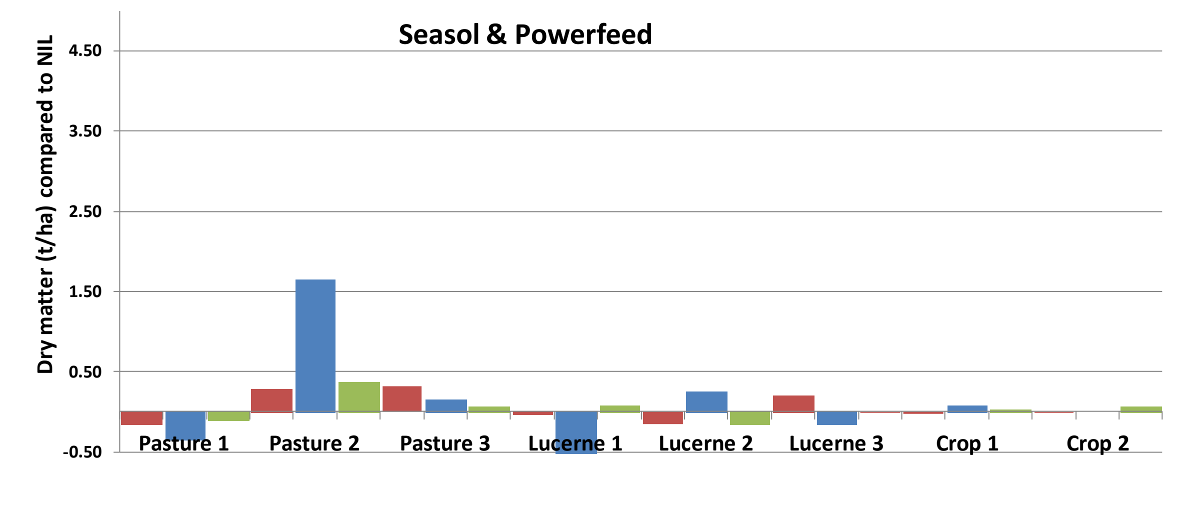

Figure 12: Annual difference in dry matter production for Seasol and Powerfeed compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between Seasol and Powerfeed and the Nil treatment ($p < 0.05$).

Composition

There was no significant difference in pasture composition from applying Seasol and Powerfeed compared to the Nil treatment at any site.

Soil conditions

Soil samples were taken from the Seasol and Powerfeed treatment at one lucerne (lucerne 2), one pasture (pasture 3) and one crop site (crop 1) (table 33).

Table 33: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and November 2011.

Element	Site	2008 baseline	Seasol & Powerfeed - 2011	Nil - 2011
Phosphorus (Olsen)	Lucerne 2	22.7	17.1	17.6
	Pasture 3	6.5	6.7	6.3
	Crop 1	18.5	17.8	15.9
Potassium (Colwell)	Lucerne 2	258[11]	406	429
	Pasture 3	123	136	142
	Crop 1	203	176	182
pH ($CaCl_2$)	Lucerne 2	5.3	5.2	5.5
	Pasture 3	4.8	4.6	4.5
	Crop 1	4.9	4.9	4.8

[11] Suspect an error in the 2008 result as all 8 treatments tested in 2011 have potassium levels around 400 mg/kg.

Phosphorus levels followed a similar trend to the Nil treatment at all three sites, with a decline at the lucerne site (highest fertility) and no appreciable change at the pasture site (lower fertility). Potassium levels and soil pH were also similar to the Nil treatment.

Some change were measured in key biological indicators (table 34).

Table 34: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Seasol & Powerfeed 2011	Guide level
Mycorrizhal colonisation	Lucerne 2	82.7	67	70
	Pasture 3	48.2	60.0	70
	Crop 1	60.3	39.3	50
Glomalin	Lucerne 2	23896	26601	30,000 (kgC/ha)
	Pasture 3	24326	21326	30,000 (kgC/ha)
	Crop 1	28080	29284	30,000 (kgC/ha)
Microbial diversity	Lucerne 2	45.7	49.8	80
	Pasture 3	12.4	68.7	80
	Crop 1	50.1	58.7	80

Interpretation and discussion

The response to multiple applications of Seasol and Powerfeed was disappointing. The products were tested at all eight sites because farmers had either tried the product before and were unable to quantify the response or had an interest in using it on a large scale. Multiple applications of the product were applied at the rate and timing recommended on the label.

Apart from one result on pasture 2 in 2010, all other responses were similar to the Nil treatment. The one apparent response was recorded from a pasture site which had a more variable pasture composition than other sites. The required dry matter difference to reach statistical significance in 2010 at this site was 2.0 t/ha and this response was 1.5 t/ha. Statistically significance yield increases compared to the control were not reached at any other site or in any year. These results do not indicate an increase in dry matter from the use of Seasol and Powerfeed when used at the rate and timing currently recommended. These comments cannot be extended to the use or value of Seasol and Powerfeed in horticulture, turf and other more intensive applications.

The total amount of nutrient applied was small compared to other treatments and the soil testing conducted in 2011 suggests the changes to phosphorus, potassium and the soil pH under this treatment was similar to the Nil treatment. The key soil biological indicators did not show any dramatic differences compared to the Nil treatment (although the product did not claim this would occur) except for one site where microbial diversity increased substantially. However this did not translate into increased dry matter production after three years.

Nutrisoil

In a nutshell

- ***Nutrisoil applied multiple times over three years did not significantly increase dry matter production or grain yield at any of the eight sites tested.***
- ***Changes in available phosphorus, potassium and pH were similar to the Nil treatment.***
- ***Increases in microbial diversity compared to the Nil treatment were recorded at two of the three sites tested however no associated dry matter increases were recorded.***

Product description

Nutrisoil is advertised as a broad spectrum liquid plant food. It is the liquid product of vermiculture (worms). Food sources used in the production of Nutrisoil include blends from organic animal, plant and ocean sources with crushed minerals, seaweed, fishmeal, dolomite lime, rock phosphate, humic acid and other natural nutrients. Typical analysis of Nutrisoil contains: 492 mg/kg nitrogen, 130 mg/kg phosphorus, 700 mg/kg potassium.

Nutrisoil was applied at all eight sites, reflecting widespread farmer interest similar to that of Seasol and Powerfeed. It was applied either two or three times per year, depending on the condition of the crop, lucerne or pasture, but usually in mid June, late August and possibly early November. Five applications were applied to the crops, eight applications for the pasture and nine applications for the lucerne. The rate used was 5 l/ha applied with a boom spray at 95 l/ha of water (table 35).

Table 35: Total quantity of nutrients applied by Nutrisoil from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Pasture 1, 2, 3	0.2	0.1	0.3	0.0	$254
Lucerne 1, 2, 3	0.2	0.1	0.3	0.0	$286
Crop 1, 2	0.1	0.0	0.2	0.0	$159

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 13).

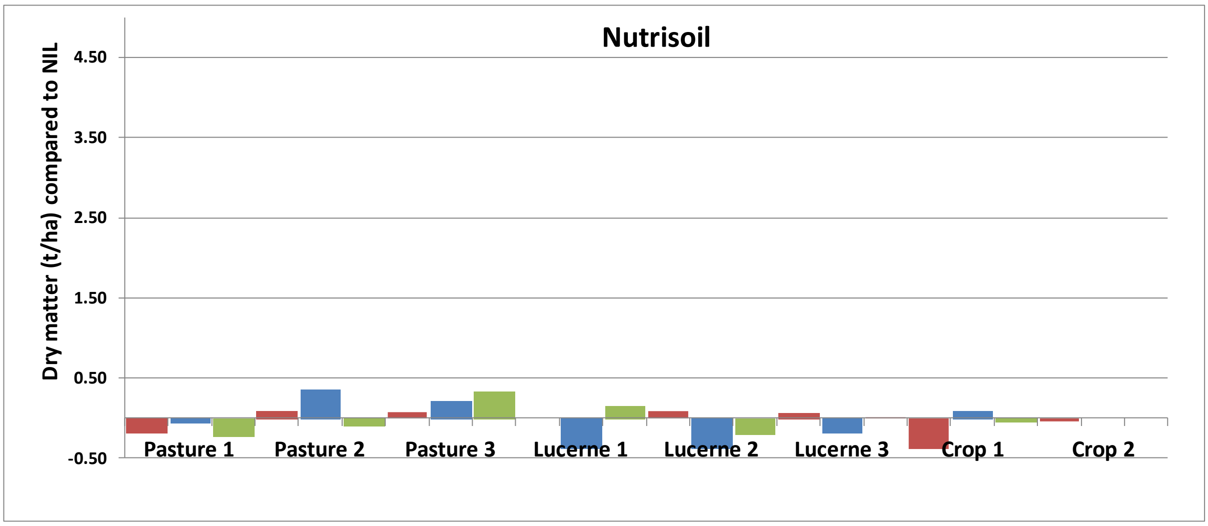

Figure 13: Annual difference in dry matter production for Nutrisoil compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between Nutrisoil and the Nil treatment ($p < 0.05$).

Composition

There was no significant difference in pasture composition from applying Nutrisoil compared to the Nil treatment at any site.

Soil conditions

Soil samples were taken from the Nutrisoil treatment at one lucerne (lucerne 2), one pasture (pasture 3) and one crop site (crop 1) (table 36).

Table 36: Phosphorus, potassium and pH levels from baseline measurements in November 2008 and November 2011.

Element	Site	2008 baseline	Nutrisoil - 2011	Nil - 2011
Phosphorus (Olsen)	Lucerne 2	22.7	17.9	17.6
	Pasture 3	6.5	6.4	6.3
	Crop 1	18.5	17.3	15.9
Potassium (Colwell)	Lucerne 2	258[12]	376	429
	Pasture 3	123	153	142
	Crop 1	203	179	182
pH ($CaCl_2$)	Lucerne 2	5.3	5.5	5.5
	Pasture 3	4.8	4.5	4.5
	Crop 1	4.9	5.0	4.8

There were no appreciable changes in any soil conditions compared to the Nil treatment. Phosphorus levels declined at the higher fertility sites (lucerne 3 and crop 1) and remained static at the low fertility site (pasture 3).

[12] Suspect an error in the 2008 result as all 8 treatments tested in 2011 have potassium levels around 400 mg/kg.

Changes in microbial diversity were recorded at two sites but there were no distinct changes in mycorrizhal colonisation or glomalin at any of the 3 sites (table 37).

Table 37: Mycorrizhal colonisation, glomalin and microbial diversity in November 2011.

Element	Site	NIL 2011	Nutrisoil 2011	Guide level
Mycorrizhal colonisation	Lucerne 2	82.7	70.4	70
	Pasture 3	48.2	67.9	70
	Crop 1	60.3	58.6	50
Glomalin	Lucerne 2	23896	26432	30,000 (kgC/ha)
	Pasture 3	24326	23497	30,000 (kgC/ha)
	Crop 1	28080	33942	30,000 (kgC/ha)
Microbial diversity	Lucerne 2	45.7	70.6	80
	Pasture 3	12.4	73.0	80
	Crop 1	50.1	56.0	80

Interpretation and discussion

There was no dry matter, pasture composition or yield response to multiple applications of Nutrisoil. This is despite multiple applications (which is recommended by the supplier). Soil nutrient levels were similar to the Nil treatment which is not unexpected given the minuet amount of nutrients in the product applied. Apart from increases in microbial diversity at two of the three sites tested and glomalin at one site, other soil biological indicators did not deviate dramatically from the Nil treatment.

Mineral based products (Munash)

In a nutshell

- ***Munash products were only tested at one location and due to difficulties at the site two suggested Spring foliar products were not applied.***
- ***There was no dry matter response compared to the Nil treatment at this site.***
- ***With limited testing and a slightly compromised treatment program, no definitive conclusion can be drawn about these products.***

Product description

The Munash treatment was a combination of three products *Ecomin Balance*, a natural mineral fertiliser containing 2.4% phosphorus, 5% potassium, 1.5% sulphur, 10% calcium, 5% magnesium, plus trace elements. Two foliar products were also applied: *Bio N, a* product which supplies bacteria and enzymes, with the ability to fix atmospheric nitrogen and *Omniboost K,* a product containing 6% nitrogen, 13% phosphorus, 3.1% potassium, 3.3% sulphur, plus magnesium, trace elements, amino acids, fulvic acid and uptake enhancers.

Product application

The combination of Munash products were applied each year. This included an annual application of 250 kg/ha of *Ecomin balance*, and foliar applications of 2 l/ha of *Bio N* and 2 l/ha of *Ominboost K*. In 2009 the solid products were followed by foliar applications in mid June and mid August. In 2010 and 2011, foliar products were only applied once due to issue with the site. Therefore products were not applied in complete accordance with the suppliers direction (recommended to apply 2 foliar applications per year).

The total amount of nutrient applied is presented (table 38).

Table 38: Total quantity of nutrients applied by Munash products from 2009 to 2011.

Site	Nutrient applied in 2009 - 2011				Product cost* ($/ha)
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	
Pasture	0.5	19	37.7	11.5	Not calculated

* Includes transport, spreading and product costs

Results

The annual dry matter and yield response are presented (figure 14).

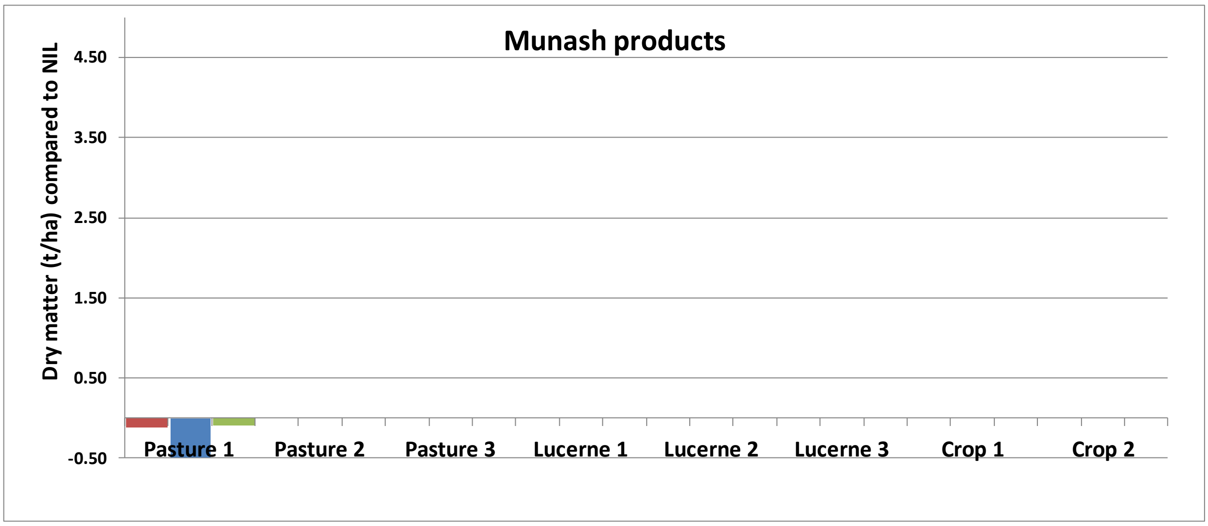

Figure 14: Annual difference in dry matter production for Munash products compared to the Nil treatment for 2009 (red), 2010 (blue) and 2011 (green). Asterix indicates significant difference between the Munash products and the Nil treatment ($p < 0.05$).

Composition

The application of Munash products did not change the combined legume and perennial grass components (27%) at this site compared to the NIL treatment (23%).

Soil conditions

No soil samples were taken due to cost constraints.

Interpretation and discussion

Munash products were only applied at one site and in 2010 and 2011 the second recommended foliar application in Spring was not completed due to management issues at the site. Therefore the product has not been tested as recommended by the supplier. Given the limited and less than idea testing regime, conclusions about this product need to be viewed with caution.

The site where the Munash product were tested was very low in potassium (Colwell K in 2009 of 90 mg/kg and Olsen P of 11.3 mg/kg). Large applications of potassium (150 kg/ha) and phosphorus (76 kg/ha) with traditional fertiliser resulted in a very significant dry matter response and a dramatic improvement in pasture composition (65% desirable species). While the Munash products resulted in much less nutrient being applied (19 kg/ha P and 37.7 kg/ha of K), it would be fair to expect some response to the products. No response occurred. Although figure 14 is negative, in percentage terms the response is only 3%, 7% and 1% less than the Nil treatments in 2009, 2010 and 2011 respectively. This response is within natural variation suggesting the product has performed similar to the Nil treatment.

Soil biology, soil carbon and soil health

Additional testing in November 2011 provided an opportunity to examine the impact different treatments had on soil biology, soil carbon accumulation through microbial activity and the corresponding plant and crop response over the three years.

Three sites were retested and included all products that were tested multiple times. Although the testing is un-replicated and was only conducted on one pasture, one crop and one lucerne site, the data does provide some preliminary insights, especially when compared to the Nil treatment at each site.

Six indicators have been chosen to represent soil biology and soil carbon accumulation (from a multitude of results provided). These indicators are:

- **Total microbial population**, indicating the total number of micro-organism in the soil, irrespective of the type of micro-organism present.
- **Microbial diversity** representing the numbers of active fungi, bacteria, protazoa and nematodes.
- **Mycorrhizal colonisation** indicating the extent to which this beneficial fungi had infected the plant roots. Mycorrhiza reside naturally in the soil.
- **Glomalin**, a by-product of hyphal (fungal) growth and sporulation from mycorrhizal growth. It is a highly carbonaceous compound that does not change quickly in the soil, so represents a possible measure of the carbon build up from increased soil biological activity.
- **Total soil organic carbon**, routinely measured on common soil tests
- **Active carbon**, a readily available energy source for the soil microbial community and is considered a 'leading indicator' of changes in soil health[13].

Total microbial population and diversity

The total microbial population under the Nil treatment at two of the three sites was close to or exceeded the guide level suggested by the testing laboratory[14]. The exception was the cropping site where the Nil treatment was approximately half the desired level. Given the results in 2008 from the biological soil test suggested these sites were less than ideal (low in total microbial population), it would appear the soil has improved without any inputs. It also means measuring no change in total microbial activity would be an understandable result at the pasture and lucerne sites because the suggested optimum level has already been reached.

The total microbial population at the pasture site declined for the traditional fertiliser alone, traditional fertiliser with Twin N or TM, Nutrisoil and Worm caste and lime compared to the Nil treatment. However these levels were still close to the desirable range, with the Nil treatment above this guide level. The one exception was the pig manure where a 46% decline in total microbial population was measured. No product increased total microbial populations at the pasture site.

[13] DPI Victoria - Quick reference guide: Potassium permanganate test for active carbon

[14] Creation Innovation Agriculture and Forestry, South Australia

There were no large declines in total microbial population for any treatments on the lucerne site. Nutrisoil was the only product on the lucerne site to show a appreciable increase (27%) in total microbial population compared to the Nil treatment, but this only raised levels above the suggested guide level.

Larger responses were measured at the crop site. Total microbial levels on the Nil treatment were less than 60% of the guide level. Only the worm caste and lime decreased this further. Substantial increases were measured under the Seasol and Powerfeed, compost tea and to a lesser extent the pig manure.

There was no increase in dry matter production or crop yield where increases in total microbial diversity were measured (under the Nutrisoil, Seasol and Powerfeed and the compost tea treatments). Yield increased under the pig manure and traditional fertiliser treatment when total microbial populations declined.

Examination of microbial diversity *within* the total microbial population suggests differences between sites rather than between treatments. The microbial diversity at all three sites was below the guide level, especially on the crop and lucerne sites. This implies that although the total population was adequate, there is an imbalance of fungi, bacteria, nematodes and protozoa.

Microbial diversity only increased at the pasture site. There was no change at the crop or lucerne sites. The dramatic increase on the pasture site occurred with six treatments. These were the pig and poultry manures, worm caste and lime, Seasol and Powerfeed, Nutrisoil and Twin N with traditional fertiliser. The only treatment where diversity did not increase dramatically was with traditional fertiliser even though the Twin N with the same fertiliser did increase.

The greatest change in microbial diversity compared to the Nil treatment at the pasture site was in the dramatic increase in protazoa. Protazoa are organisms that feed on bacteria and are critical in nutrient cycling. The number of protazoa in the Nil treatment was below detectible levels, however these number rose above the guide level under the Seasol and Powerfeed, Nutrisoil, Worm caste and lime and the Twin N with traditional fertiliser. Poultry manure and traditional fertiliser with TM were close to the guide level.

The treatments where diversity increased in the pasture also resulted in an increase in bacteria and a decrease in fungi, to levels below what is considered desirable (fungi to bacteria ratios ranged from 1:1 to 1.7:1, with guide level of 2.3:1). Nematodes which feed on fungi were not measured due to cost, so it is unclear if the decline in fungi was a result of increased nematode activity.

If it is assumed that increased nematode populations have occurred under these treatments and increase protazoa was measured, then this should lead to increased nutrient cycling. Examination of the corresponding soil test showed no increase in available nutrients, especially phosphorus and sulphur using common testing methods. If additional nutrients are being released, then the soil testing used was unable to detect these changes.

There appears no product correlation with increases in microbial diversity and increases in dry matter or crop production (figure 15). At the pasture site where microbial diversity increased under a number of treatments, the yield increase over three years compared to the Nil treatment was nothing (Nutrisoil, Seasol and Powerfeed) or less than 1.5 t/ha (pig manure, poultry manure, worm caste and lime and Twin N with traditional fertiliser). However at other sites where microbial diversity did not change, some significant yield responses were recorded.

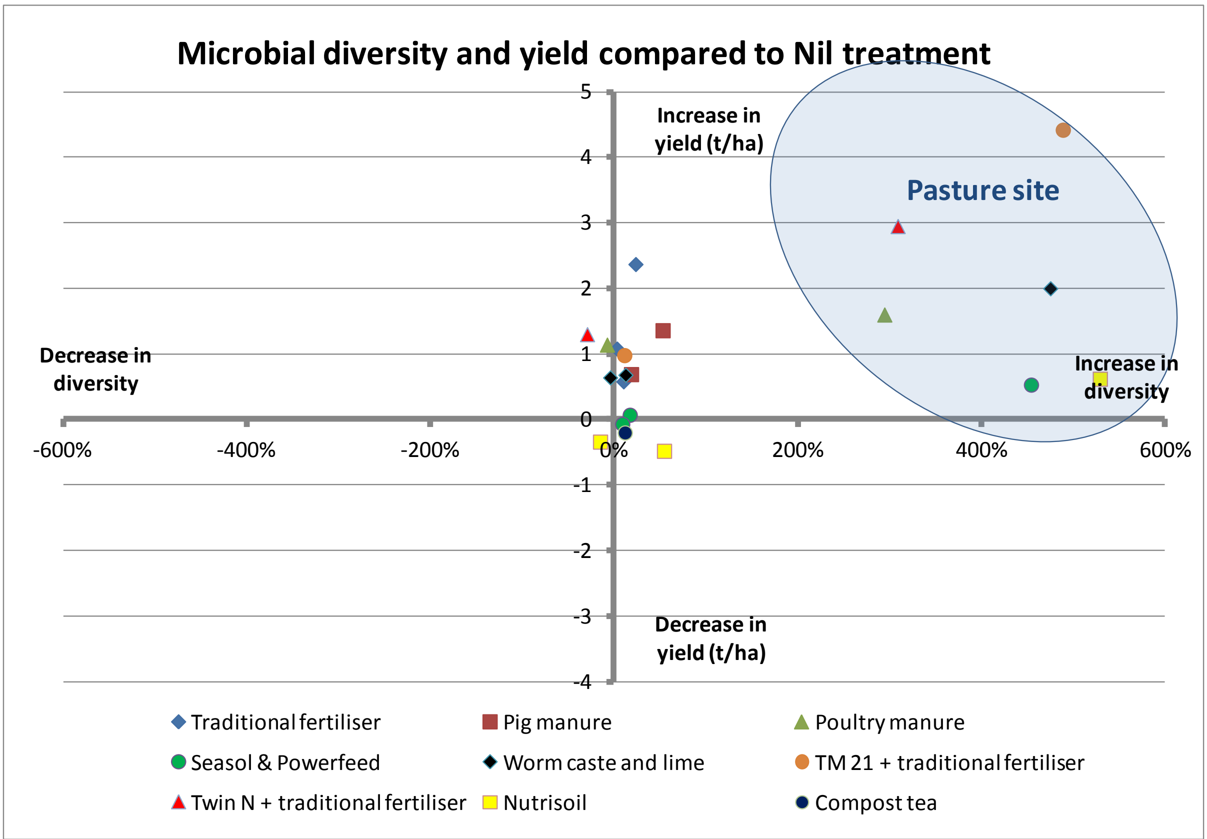

Figure 15. Changes in microbial diversity and yield compared to Nil treatment. Responses within the blue circle represents treatments at the pasture site.

Mycorrhizhal colonisation

Changes to mycorrhizhal colonisation were measured between and within sites. Increases under all treatments were recorded at the pasture site, with the results close to the guide level. Declines in mycorrhizal colonisation resulted from most treatments at the crop and to a lesser extent at the lucerne site.

Mycorrhizhal colonisation is thought to be reduced by the application of traditional inorganic fertilisers. The results from these trials do not support this premise, with only four of the seven treatments where traditional fertiliser or traditional fertiliser with Twin N or TM were applied showing a decline (crop and lucerne sites). Under two traditional fertiliser treatments on the pasture site, mycorrhizhal colonisation increased. It remained static under one traditional fertiliser treatment at the lucerne site. There was no consistent response to mycorrhizhal colonisation across sites for any other product. Both positive and negative responses were recorded for all products.

There appears to be no correlation between the amount of mycorrhizal colonisation and the dry matter production or crop yield (figure 16). The highest production responses occurred where there was a decline in mycorrhizal colonisation using products that contained traditional fertiliser. Products that did not contain large quantities of nutrients (Nutrisoil, Seaslol and Powerfeed, compost tea) did not increase production but resulted in both increases and decreases in mycorrhizal colonisation.

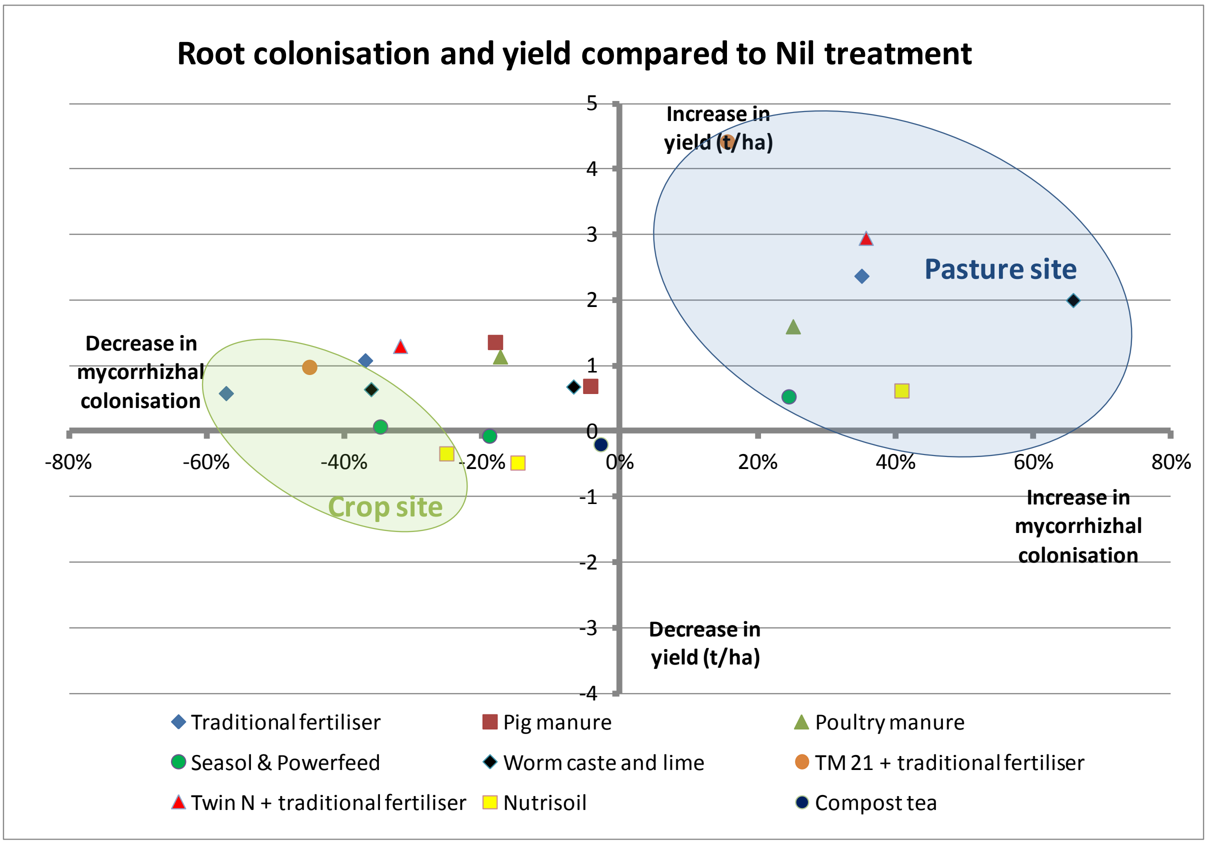

Figure 16. Changes in mychorrizhal colonisation and yield compared to Nil treatment. Responses within the blue circle represents treatments at the pasture site, responses in the green circle represent five treatments at the crop site.

Figure 16 would indicate that site effects have a much greater influence on mycorrhizal colonisation that the products applied.

Glomalin and soil carbon

There was no consistent change to glomalin levels compared to the Nil treatment from the products applied. The largest increases compared to the Nil treatment occurred with traditional fertiliser, pig manure and compost tea. The traditional fertiliser and pig manure also resulted in decline of glomalin at other sites (compost tea was only tested at one site so no comparison could be made). Other products also resulted in increases and decreases in glomalin levels. On the basis of these result no product can be shown to consistently increase glomalin levels in the soil.

There was no obvious correlation between additional dry matter production or crop yield and glomalin levels. Increases in production occurred when glomalin levels both increased and declined (figure 17). There was no obvious site influence to glomalin changes, unlike the effect seem with mycorrhizhal colonisation.

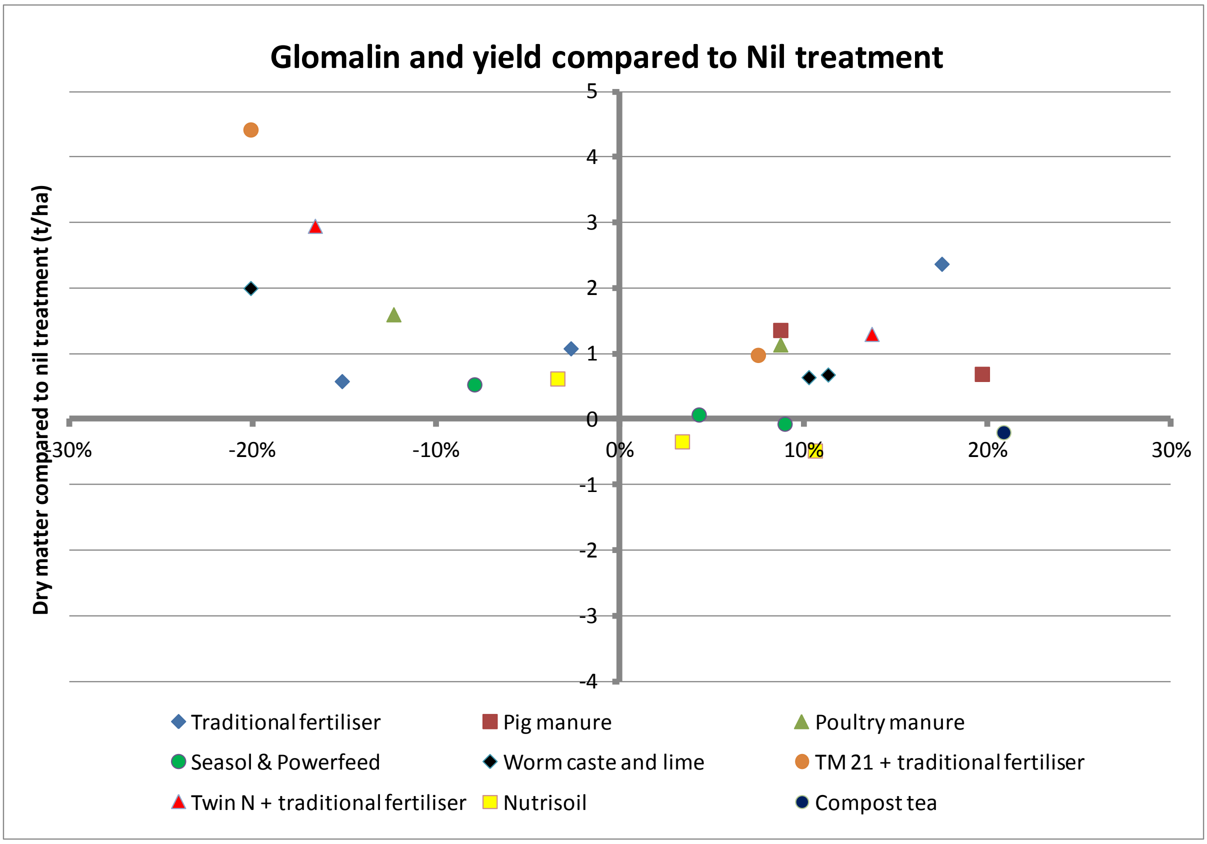

Figure 17. Changes in glomalin and yield compared to Nil treatment.

Other measurements of soil carbon were taken in 2008 and 2011. This included the common soil organic test and a labile carbon test. The common organic soil test measures total organic carbon, irrespective of whether it is dormant or actively decaying. The labile carbon test indicates the active portion of the carbon, a readily available source energy source for the soil microbial community.

The 2008 testing shows a correlation between the amount of soil organic carbon and labile carbon (figure 18). Increased soil organic matter results in increased active carbon. However even the higher levels of active carbon measured are considered marginal by United States standards[15].

[15] Cornell Soil Health Manual. USDA. No Australian values were available.

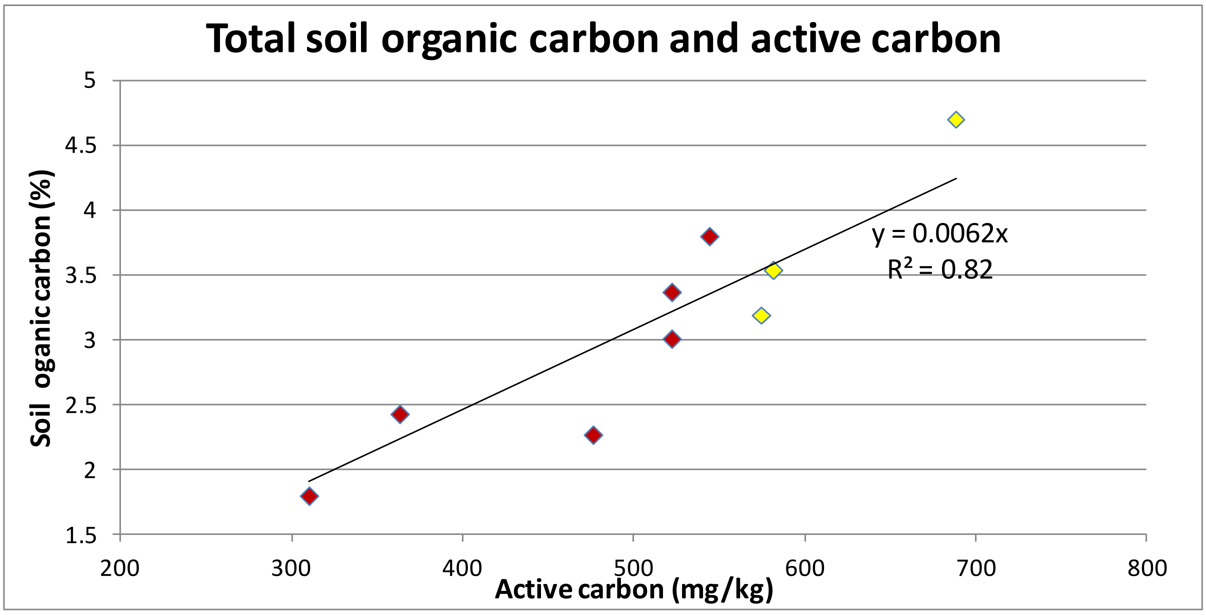

Figure 18: Relationship between total soil organic carbon and active carbon. Red indicates poor active carbon rating for the soil type, yellow indicates marginal activity.

Baseline soil organic matter varied across the three sites. Highest soil organic carbon was recorded at the pasture site and lowest at the lucerne site. Organic carbon in 2011 appears to have declined at the crop site, with no products recording an increase above the 2008 level (figure 19). However the active carbon has increased, especially for the pig manure, compost tea and Nutrisoil and are rated as having 'good' activity.

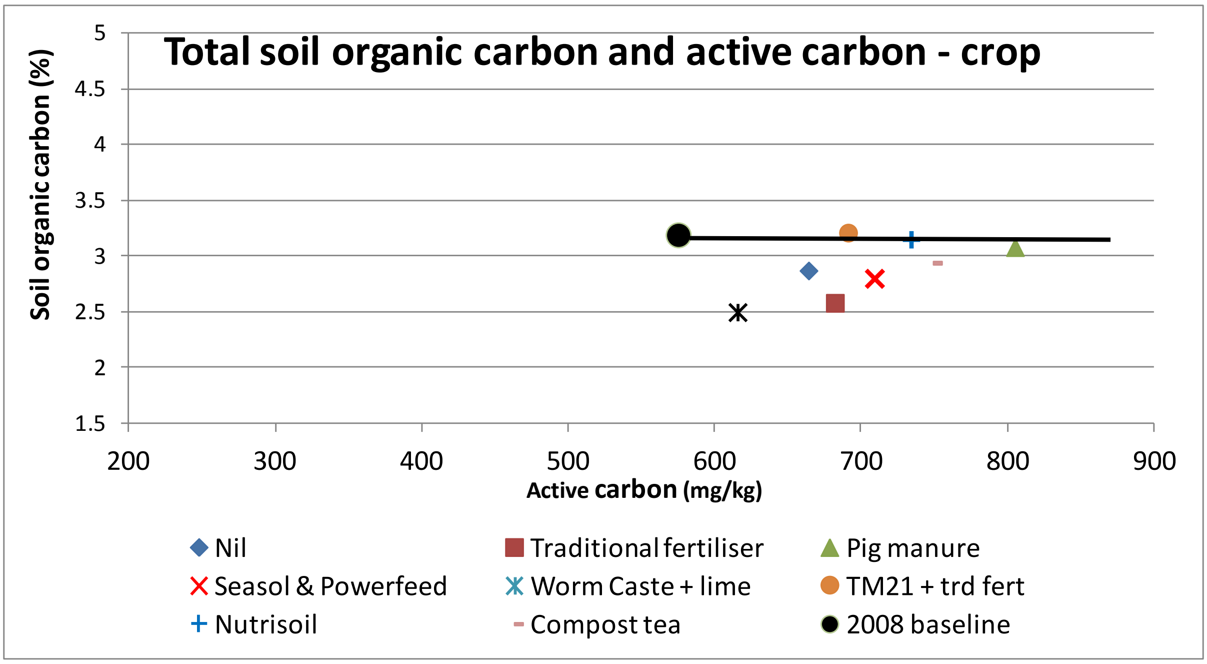

Figure 19. Change in soil organic carbon and active carbon under cropping for various products.

In contrast to the crop site, total organic carbon in 2011 has increased at the pasture site (figure 20). Active soil carbon also increased, with the traditional fertiliser and TM with traditional fertiliser treatments showing the greatest level of activity.

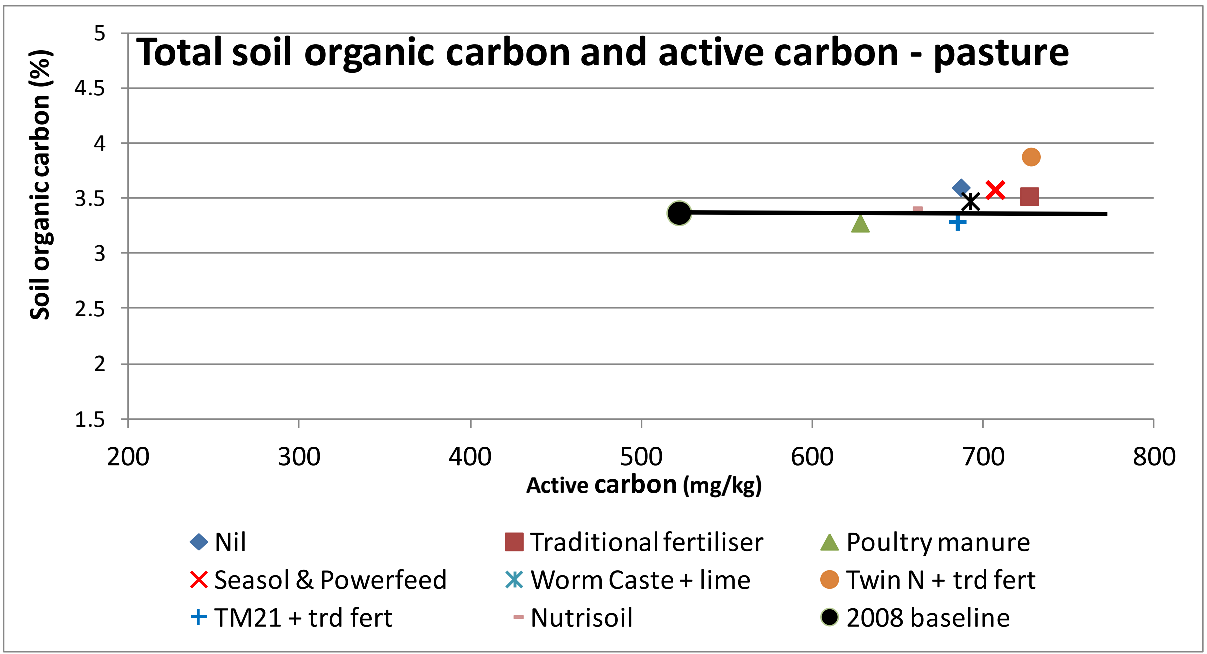

Figure 20. Change in soil organic carbon and active carbon under pasture for various products.

The lucerne site recorded both an increase and decrease in total soil organic carbon in 2001 compared to 2008 but a consistent increase in active carbon (figure 21). At this site the Nil treatment was one of the highest activity sites.

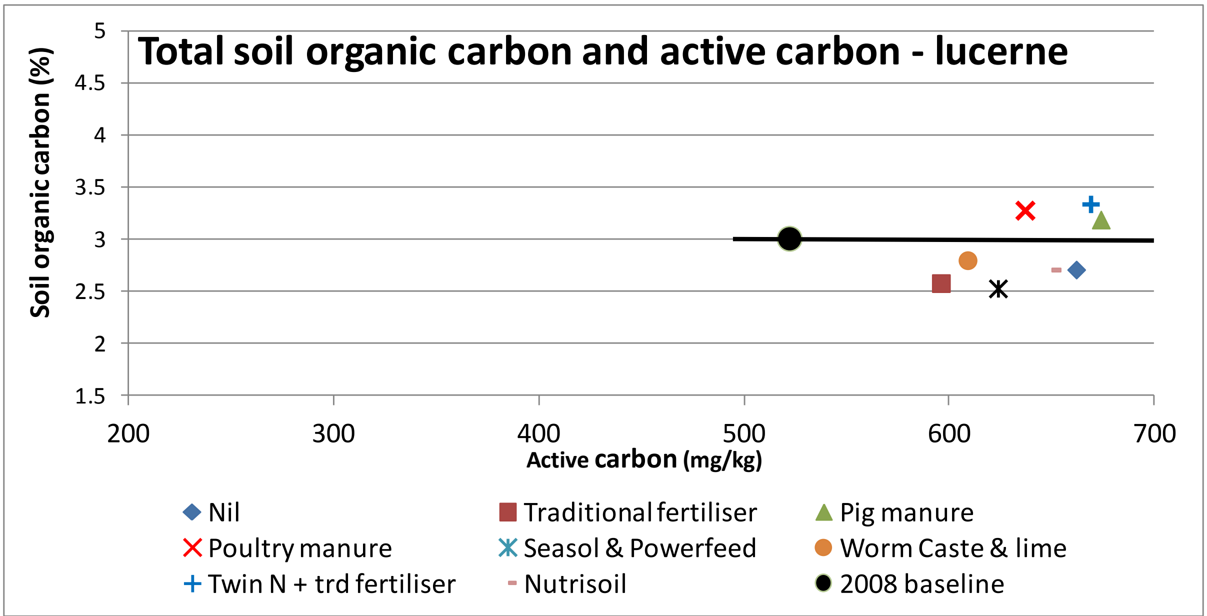

Figure 21. Change in soil organic carbon and active carbon under lucerne for various products.

This data does not show any clear evidence that treatments having a consistent effect on soil organic carbon or active carbon. At all three sites the Nil treatment increased in active soil carbon. This may be a result of more favourable growing conditions in 2010 and 2011. The response of other products was highly variable, with no product consistently measuring the highest active carbon across all three sites. The only trends from this data that supports accepted thinking is that cropping decreases and perennial pasture increases total organic carbon in the soil.

Discussion and conclusion about soil health

The results from three years of trialling a range of alternative fertilisers and biological products has not led to a clear and consistent response in soil health from any of the treatments tested. If the premise is that a healthier soil will be more productive and sustainable, then the selective use of data from these trials would enable a positive case to be constructed for most of the products used. There are examples where the use of 'biological' products corresponds with measured improvement in active carbon, increased microbial populations and diversity and increased soil carbon. However these cases have not led to increases in dry matter production or grain yield. Maybe more time is required? The only consistent measurement across the biological products tested is that available phosphorus, a widely accepted indicator of likely levels of production, declines under these treatments in a similar fashion to the Nil treatment. It is difficult to fathom how an approach that does not apply at least equivalent amounts of nutrient to match what is being taken off in animal and plant products can be sustainable in the long run (unless something is about to happen in the near future). From this data there is no evidence to suggest the biological approach is 'unlocking' locked up nutrients.

A positive case could also be constructed to show traditional fertiliser improves soil health (with or without other biological treatments). While there are examples of lower levels of mycorrhizal colonisation and diversity where traditional fertiliser has been used, some of the most positive responses were on treatments that received more than 1.1 t/ha of super potash 5:1 over a three year period. In cases where improvements in the biological indicators were measured, dry matter production and grain yield also increased.

From the data produced in this three year trial, it cannot be concluded that improving soil biology will necessarily lead to improved plant production.

It is likely that the sampling and testing procedures, while the best available at the time, are not adequate to detect the subtle differences in biological activity and soil carbon from the natural variability within the soil and the unavoidable 'errors' through sampling and the sensitivity of the laboratory analysis. In particular biological testing is relatively new and the sampling procedure, number of components tested, guide levels and equipment variability means the results and indicators used could be lead to an incorrect conclusion. Interpretation must be viewed with a great deal of caution.

Soil biology and nutrient cycling occurs within a complex biological system. Many factors influence the result, including some key drivers that are beyond the farmers control such as rainfall and temperature. The evidence from these trials shows the differences between sites, and the corresponding enterprise is more influential than the products used.

Appendix 1: Initial soil conditions - 2008

Table A1: Key soil test results (traditional soil test) – tested Spring 2008

Site	P (Olsen)	K (Colwell)	S (KCl 40)	pH ($CaCl_2$)	Al (%CEC)	PBI	CEC
Pasture 1	11.3	90	13.6	4.6	3.0	115	14.51
Lucerne 1	11.9	93	11.3	5.0	0.7	33	4.12
Crop site 1	18.5	203	8.9	4.9	1.2	58	6.80
Pasture 2	12.1	132	11.0	4.7	2.7	61	6.71
Lucerne 2	22.7	258	15.2	5.3	0.4	37	7.31
Crop site 2	19.2	61	9.3	4.8	5.1	40	4.15
Pasture 3	6.5	123	9.0	4.8	2.3	126	13.10
Lucerne 3	12.4	295	20.5	5.1	0.8	102	10.30

Table A2: Summary of key biological test results for all eight sites – tested Spring 2008 (warm, moist conditions)[16]

Test	Comment on combined 8 sites
Total and active soil fungi	Total fungi high, especially in older pastures. Active fungi very low to nil at all sites. Severely out of balance, needs additional active fungi (recommend compost or compost tea). Minimal beneficial (mycorrhizal) fungal infection.
Total & active soil bacteria	Total bacteria high, but active bacteria low at all sites. Severely out of balance, needs additional food source to stimulate bacterial activity (sugars or amino sugars)
Type of fungi	Good balance of disease suppressive and normal fungi at all sites
Balance of active fungi to active bacteria	Bacterial dominant. Apply additional fungal foods to address these imbalances
Protozoa	Low in all but one site. Suggested this will limit natural nutrient cycling. Needs additional protozoa from compost or compost tea.
Nematodes	Nematode levels low to very low. Suggested this will limit natural nutrient cycling.

[16] Analysed by Soil Foodweb Institute. Results of individual sites will be compared again in 2011, to examine changes both over time and between treatments

Appendix 2: The basics of soil biology

'Healthy soils' has become a catch phrase for those wanting to improve the productivity and resilience in their farming system. Healthy soils are seen as balanced and biologically active, with an appropriate mix of microbes that interact with each other to cycle nutrients and carbon, stabilising soil structure and help moisture infiltration and storage. A healthy soil is widely assumed to enhance farm production and there is sound scientific theory to supports the concept of the soil food web. This has led to an explosion in products that claim to improve soil health by stimulating or adding appropriate soil biology. Whether products that claim to improve soil biology actually achieve this result is less clear and further scientifically credible examination is urgently required.

A consequence of the interest in soil health is the demand to test for microbial balance and activity in the soil. Several laboratories now offer microbial soil testing, producing numerous result that are unfamiliar to most farmers and advisors and with thresholds or desirable ranges that have not be proven for Australian conditions.

The laboratory analysis looks for and measures four main groups in soil biology. A brief description of each microbial group, their purpose and interactions are briefly described.

Fungi

Soil fungi perform many useful purposes in a soil. They break down the carbon in plant residues, releasing some nutrients for plant growth but also storing some of these nutrient in long thread like structures they grow called hyphae. When these hyphae break down they release trapped nutrients. Fungi are the most important biological way of storing and releasing nutrients in a soil.

One very useful type of fungi is called arbuscular mycorrhizal fungi or AM. AM infects plant roots and removes energy from the plant. In return this fungi extends its hyphae through the soil, effectively increasing the roots of the plants. The fungi absorb water and phosphorus. The colonisation of plant roots with this fungi is a critical association for plants growing on low phosphorus soils. It is thought increased mycorrhizal colonisation should increase plant production. Mycorrhizal fungi also help protect the plant roots from root feeding nematodes and pathogens (see later).

Soils naturally contain AM that infect plant roots when conditions are right. It is thought most traditional inorganic fertiliser discourage AM infection of plant roots.

The growth of fungal hyphae also creates a net like structure that helps bind soil particles together. During growth of the fungal hyphae a glue like substance called *glomalin* is produced. Glomalin is a highly carbonaceous compound that does not change quickly in the soil. The combination of the hyphae 'net' and the *glomalin* 'glue' improves the soils ability to store water and encourages root growth.

Fungi and *glomalin* contain a lot of carbon. However the growth of fungi also requires the 'capture' of nutrients. These nutrients are release when the fungi is broken down, but if

carbon accumulation is desired (so not broken down), then additional nutrients will also be required.

Just measuring total fungi only tells part of the story. The active portion of the total fungi is also measured, to determine how much 'turnover' of fungi is occurring. The level of activity is influenced by having an adequate feed source (mainly carbon from organic matter) but also by heat and moisture. Testing under warm moist conditions (eg Spring) is the best time to determine the activity of fungi in the soil. Samples taken during dry conditions may be interpreted incorrectly.

There are many different types of fungi, some are highly beneficial to plant growth and some damaging. The accepted way to classify fungi is by the thickness of the hyphae they grow. Beneficial fungi generally have thicker hyphae.

Not surprisingly cultivation and soil disturbance physically breaks the hyphae 'net' and reduces the total amount of fungi in the soil.

Bacteria
Bacteria are smaller than fungi but perform some similar functions. Bacteria breaks down organic matter, releasing some for plant growth and storing some inside themselves. When the bacteria die or are eaten, these nutrients are released. Bacteria also help bind small soil particles together.

Because bacteria don't grow hyphae like fungi, they require less carbon. Instead they require a lot of nitrogen.

Like fungi, there are good and bad bacteria. The most recognised good bacteria is *rhyzobia* that infect the roots of legumes and allow them to fix nitrogen. Also like fungi, the total amount of bacteria only tells part of the story. Therefore the amount of active bacteria is measured.

Fungi to Bacteria ratios
Soil biological life is dominated by fungi and bacteria and both are important. Ratios that compare the amount of total and active fungi or bacteria provides some information, as does the ratio of fungi to bacteria.

The ratio of fungi and bacteria changes depending on the management practices and climatic conditions. It is claimed soils with greater fertility and higher organic matter generally have higher levels of fungi and bacteria (although the data from 9 sites in the Woady Yaloak Catchment do not support this). Cultivation and soil disturbance breaks fungal hyphae and therefore has greater impact on fungi than bacteria. Organic matter high in carbon compared to nitrogen, such as stubbles and dry pasture residues provides an ideal source of food for fungi. In contrast organic matter containing nitrogen or legume residues favour bacteria. Soil pH is also believed to make a difference, with fungi favoured by low pH (acidic) soils and bacteria by higher pH (alkaline) soils. Wet warm conditions favour growth of both bacteria and fungi.

As rule, soils with more active fungi are considered 'better' than soils dominated by active bacteria.

Protazoa
Protozoa feed on bacteria. The byproduct of this feeding are nutrients that the plants can take up. Protozoa are important to get a sense of the amount of potential nutrient cycling. There are three main types of protozoa with one type, *ciliates* that thrive in compacted or poorly aerated soils. High numbers of *cilliates* can indicate a soil structure problem.

Nematodes
Nematodes feed on bacteria, fungi, plant roots and disease causing organisms. The byproduct of this feeding are nutrients that are available for the plants. Like protozoa, nematodes give an indication of the amount of nutrient cycling in a soil.

There are specific nematodes that only eat fungi, or bacteria or roots. Some nematodes also eat other nematodes. Nematodes are also important because they are a food source for other larger organisms in the soil.

The soil test will provide an indication of the type and proportion of nematodes that feed on bacteria, fungi, roots and other nematodes. It is suggested high levels of root feeding nematodes indicates poor soil health.

Beneficial nematodes (that eat bacteria and fungi) can be added to the soil but generally these are increased by improving their food source of bacteria and fungi.

Appendix 3: Product, transport and application costs

NB: Prices are as accurate as possible but should be used as a guide only because of large variations in price depending on quantity purchased and transport

					Product cost (ex GST)			Transport (ex GST)			Spreading (ex GST)				
Site	**Treatment**	**Rate**	**Units**	**Apps**	**($/unit)**	**unit**	**($/ha)**	**Distance (km)**	**Rate ($ /km / unit)**	**($/ha)**	**($/unit)**	**unit**	**($/ha)**	**Sub total**	**TOTAL**
Pasture 1	MOP	100	kg	3	$ 680.00	tonne	$ 204.00	100	$ 0.10	$ 30.00	$ 8.00	ha	$ 24.00	$ 258.00	**$ 573**
	Triple SP	125	kg	3	$ 740.00	tonne	$ 277.50	100	$ 0.10	$ 37.50	$ -	ha	$ -	$ 315.00	
Pasture 2	SP 3 & 1	265	kg	3	$ 445.00	tonne	$ 353.78	100	$ 0.10	$ 79.50	$ 8.00	ha	$ 24.00	$ 457.28	**$ 457**
Pasture 3	SP 5 & 1	375	kg	3	$ 405.00	tonne	$ 455.63	100	$ 0.10	$ 112.50	$ 8.00	ha	$ 24.00	$ 592.13	**$ 592**
Lucerne 1	SP 2 & 1	280	kg	3	$ 465.00	tonne	$ 390.60	100	$ 0.10	$ 84.00	$ 8.00	ha	$ 24.00	$ 498.60	**$ 499**
Lucerne 2	SP	150	kg	3	$ 290.00	tonne	$ 130.50	100	$ 0.10	$ 45.00	$ 8.00	ha	$ 24.00	$ 199.50	**$ 200**
Lucerne 3	Triple SP	115	kg	3	$ 740.00	tonne	$ 255.30	100	$ 0.10	$ 34.50	$ 8.00	ha	$ 24.00	$ 313.80	**$ 314**
Crop 1	DAP	100	kg	3	$ 690.00	tonne	$ 207.00	100	$ 0.10	$ 30.00	$ 8.00	ha	$ 24.00	$ 261.00	**$ 471**
	Gypsum	185	kg	3	$ 35.00	tonne	$ 19.43	300	$ 0.10	$ 166.50	$ 8.00	ha	$ 24.00	$ 209.93	
Crop 2	DAP	100	kg	3	$ 690.00	tonne	$ 207.00	100	$ 0.10	$ 30.00	$ 8.00	ha	$ 24.00	$ 261.00	**$ 401**
	MOP	60	kg	3	$ 680.00	tonne	$ 122.40	100	$ 0.10	$ 18.00	$ -	ha	$ -	$ 140.40	
Pasture 2	Twin N	1	ha	6	$ 25.00	ha	$ 150.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 195.00	**$ 652**
	SP 3 & 1	265	kg	3	$ 445.00	tonne	$ 353.78	100	$ 0.10	$ 79.50	$ 8.00	ha	$ 24.00	$ 457.28	
Pasture 3	Twin N	1	ha	6	$ 25.00	ha	$ 150.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 195.00	**$ 787**
	SP 5 & 1	375	kg	3	$ 405.00	tonne	$ 455.63	100	$ 0.10	$ 112.50	$ 8.00	ha	$ 24.00	$ 592.13	
Lucerne 2	Twin N	1	ha	6	$ 25.00	ha	$ 150.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 195.00	**$ 395**
	SP	150	kg	3	$ 290.00	tonne	$ 130.50	100	$ 0.10	$ 45.00	$ 8.00	ha	$ 24.00	$ 199.50	
Lucerne 3	Twin N	1	ha	6	$ 25.00	ha	$ 150.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 195.00	**$ 509**
	Triple SP	115	kg	3	$ 740.00	tonne	$ 255.30	100	$ 0.10	$ 34.50	$ 8.00	ha	$ 24.00	$ 313.80	
Crop 2	Twin N	1	ha	6	$ 25.00	ha	$ 150.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 195.00	**$ 478**

	DAP	50	kg	3	$ 690.00	tonne	$ 103.50	100	$ 0.10	$ 15.00	$ 8.00	ha	$ 24.00	$ 142.50	
	MOP	60	kg	3	$ 680.00	tonne	$ 122.40	100	$ 0.10	$ 18.00	$ -	ha	$ -	$ 140.40	
Pasture 3	TM	250	ml	6	$ 50.00	l	$ 75.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 120.00	**$ 674**
	SP 5 & 1	375	kg	2	$ 405.00	tonne	$ 303.75	100	$ 0.10	$ 75.00	$ 8.00	ha	$ 16.00	$ 394.75	
	SP 5 & 1	300	kg	1	$ 405.00	tonne	$ 121.50	100	$ 0.10	$ 30.00	$ 8.00	ha	$ 8.00	$ 159.50	
Lucerne 3	TM	250	ml	6	$ 50.00	l	$ 75.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 120.00	**$ 414**
	Triple SP	115	kg	2	$ 740.00	tonne	$ 170.20	100	$ 0.10	$ 23.00	$ 8.00	ha	$ 16.00	$ 209.20	
	Triple SP	92	kg	1	$ 740.00	tonne	$ 68.08	100	$ 0.10	$ 9.20	$ 8.00	ha	$ 8.00	$ 85.28	
Crop 1	TM	250	ml	6	$ 50.00	l	$ 75.00	0	0	$ -	$ 7.50	ha	$ 45.00	$ 120.00	**$ 467**
	DAP	100	kg	2	$ 690.00	tonne	$ 138.00	100	$ 0.10	$ 20.00	$ 8.00	ha	$ 16.00	$ 174.00	
	DAP	80	kg	1	$ 690.00	tonne	$ 55.20	100	$ 0.10	$ 8.00	$ 8.00	ha	$ 8.00	$ 71.20	
	Gypsum	185	kg	3	$ 40.00	tonne	$ 22.20	100	$ 0.10	$ 55.50	$ 8.00	ha	$ 24.00	$ 101.70	
Pasture	Pig manure	6.2	m3	1	$ 15.00	m3	$ 93.00	50	$ 0.12	$ 37.20	$ 5.50	m3	$ 34.10	$ 164.30	**$ 164**
Crop	Pig manure	9.3	m3	1	$ 15.00	m3	$ 139.50	50	$ 0.12	$ 55.80	$ 5.50	m3	$ 51.15	$ 246.45	**$ 246**
Pasture	Poultry manure	5	m3	1	$ 8.50	m3	$ 42.50	50	$ 0.12	$ 30.00	$ 5.50	m3	$ 27.50	$ 100.00	**$ 100**
Crop	Poultry manure	7.5	m3	1	$ 8.50	m3	$ 63.75	50	$ 0.12	$ 45.00	$ 5.50	m3	$ 41.25	$ 150.00	**$ 150**
Pasture / crop	Worme caste	200	kg	5	$ 0.80	kg	$ 800.00	25	$ 0.15	$ 18.75	$ 8.00	ha	$ 40.00	$ 858.75	**$ 930**
	Lime	250	kg	5	$ 17.00	tonne	$ 21.25	80	$ 0.10	$ 10.00	$ 8.00	ha	$ 40.00	$ 71.25	
Lucerne	Compost	1700	kg	1	$ 50.00	tonne	$ 85.00	0	$ -	$ -	$ 5.50	t	$ 9.35	$ 94.35	**$ 486**
	Compost tea	40	l	6	$ 0.35	l	$ 84.00	0	$ -	$ -	$ 7.50	ha	$ 45.00	$ 129.00	
	Fish oil	10	l	3	$ 8.00	l	$ 240.00	0	$ -	$ -	$ 7.50	ha	$ 22.50	$ 262.50	

Crop	Compost	780	kg	1	$ 50.00	tonne	$ 39.00	0	$ -	$ -	$ 5.50	t	$ 4.29	$ 43.29	**$ 435**
	Compost tea	40	l	6	$ 0.35	l	$ 84.00	0	$ -	$ -	$ 7.50	ha	$ 45.00	$ 129.00	
	Fish oil	10	l	3	$ 8.00	l	$ 240.00	0	$ -	$ -	$ 7.50	ha	$ 22.50	$ 262.50	
Pasture	Seasol	5	l	8	$ 7.55	l	$ 302.00	0	$ -	$ -	$ 9.50	ha	$ 76.00	$ 378.00	**$ 754**
	Powerfeed	5	l	8	$ 9.40	l	$ 376.00	0	$ -	$ -	$ -	ha	$ -	$ 376.00	
Lucerne	Seasol	5	l	9	$ 7.55	l	$ 339.75	0	$ -	$ -	$ 9.50	ha	$ 85.50	$ 425.25	**$ 848**
	Powerfeed	5	l	9	$ 9.40	l	$ 423.00	0	$ -	$ -	$ -	ha	$ -	$ 423.00	
Crop	Seasol	5	l	5	$ 7.55	l	$ 188.75	0	$ -	$ -	$ 9.50	ha	$ 47.50	$ 236.25	**$ 471**
	Powerfeed	5	l	5	$ 9.40	l	$ 235.00	0	$ -	$ -	$ -	ha	$ -	$ 235.00	
Pasture	Nutrisoil	5	l	8	$ 4.86	l	$ 194.40	0	$ -	$ -	$ 7.50	ha	$ 60.00	$ 254.40	**$ 254**
Lucerne	Nutrisoil	5	l	9	$ 4.86	l	$ 218.70	0	$ -	$ -	$ 7.50	ha	$ 67.50	$ 286.20	**$ 286**
Crop	Nutrisoil	5	l	5	$ 4.86	l	$ 121.50	0	$ -	$ -	$ 7.50	ha	$ 37.50	$ 159.00	**$ 159**