Determining the nutrient requirements of perennial pastures when grown with an annual legume companion

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Aim:

Consistent feedback from Evergreen Farming members in the Northern Agricultural Region (NAR) is that they want to know more about the nutrient requirements of perennial pastures. With their very deep roots (>3m), perennial pastures can access nutrients from deep in the soil profile, previously leached past the root zone of shallow rooted annual pasture species. However, the poor sandy soils that perennial pastures are typically grown on have a low nutrient holding capacity. And in most cases, due to low margins and cost cutting, the application of fertiliser in recent years has been sporadic at best. It is highly likely that perennial pastures will respond to additional nutrition, but which nutrients at what rate will give the best bang for buck?

A DAFWA project examined some of these issues in 2012 and 2013 and found that many perennial pastures in the NAR were responsive to fertiliser, with the largest response usually to additional nitrogen. However, the vast majority of the paddocks surveyed had nil or very low annual legume component. Legumes are able to fix nitrogen from the atmosphere, and make it available for later use by the perennial grass component.

The aim of this NACC funded project was to determine if the nitrogen requirements of subtropical perennial grass based pastures can be met by the nitrogen fixation of the annual legume component and if the nutrient requirements of the annual legumes are being adequately met.

Method:

Sites were chosen at Jurien Bay, Lancelin and Dandaragan in paddocks with a good mix of subtropical perennial grasses and annual legumes. At Jurien Bay, on a deep pale grey sand, the pasture was mostly a mix of rhodes grass, panic, giant bermuda grass, serradella, blue lupins and brome grass. At Lancelin, on a deep pale yellow sand, the pasture was mostly a mix of panic, rhodes grass, serradella, blue lupins, rose clover and brome grass. At Dandaragan, on a deep orange sand, the pasture was mostly a mix of panic grass, kikuyu, serradella, sub clover and brome grass.

Four fertiliser treatments were applied at each site, and each treatment was replicated three times. The range and amount of each nutrient applied by each fertiliser treatment is shown in Table 1. High levels of both macro and micro nutrients were applied in treatments 1 and 4 to ensure any deficiencies were overcome. This was applied once at the beginning of the trial in May 2015. Only nitrogen was applied in Treatment 2, and this was applied twice (May 2015 and September 2015). Treatment 3 was a nil fertiliser control. To deliver the range and amount of nutrients required in Treatment 4, a mix of 200kg/ha of TEK Phos 21, 100kg/ha of Big Phos Manganese, 100kg/ha of NPK Blue Special and 100kg/ha of Urea was applied.

The plots were 25 metres long and 4 metres wide with fertiliser applied via a handheld fertiliser spreader. The plots were fenced off to exclude stock.

Deep soil testing (0 to 100cm) was conducted in 2015 to determine the background soil fertility of each site. The annual and perennial components of the sward were tissue tested in September 2015 and December 2016. Botanical composition and biomass were visually assessed on a regular basis.

Table 1: Nutrients applied (kg/ha) in May 2015.

Treatment	N	P	K	S	Ca	Cu	Zn	Mo	Mn	Fe	Mg	B
1	12	31	47	26	44	0.80	0.41	0.08	5.22	0.08	1.20	0.02
2	46											
3												
4	58	31	47	26	44	0.80	0.41	0.08	5.22	0.08	1.20	0.02

Results:

Soil Analysis:

Table 2: Initial soil test data (red = low level, orange = medium level, green = high level)

	Jurien Bay			Lancelin			Dandaragan		
	0-10cm	**10-20cm**	**20-30cm**	**0-10cm**	**10-20cm**	**20-30cm**	**0-10cm**	**10-20cm**	**20-30cm**
P	4	2	2	5	4	4	31	23	20
K	30	20	16	46	39	33	50	37	27
S	2	1	1	2	1	1	3	2	2
pH	5.5	5.6	5.6	5.4	5.0	4.9	6.3	5.5	4.9
C	0.8	0.6	0.3	1.2	0.8	0.4	1.9	1.2	0.7
PBI	4	4	4	8	10	12	23	24	19

The initial soil test data (Table 2) shows that the Jurien Bay and Lancelin sites had low levels of plant available Phosphorus (P), Potassium (K) and Sulphur (S). The Dandaragan site had a high level of Phosphorus, but low levels of Potassium and Sulphur. Levels of plant available P, K and S declined with depth at all sites, with often very low levels at 50-100cm. The Phosphorus Buffering Index (PBI) mirrored the soil cores (Figure 1), with the pale grey sand at Jurien Bay having the lowest PBI and the orange sand at Dandaragan having the highest PBI. Soil Organic Carbon (C) content was highest at the surface and dropped significantly with depth at all sites. The better quality sand at the Dandaragan site had the highest soil C content. Soil pH was acceptable at all sites.

The final soil test data, collected 18 months after the initial application of fertiliser, showed that the large one-off application of nutrients did improve levels of plant available P, K and S at all sites, but only to a minor extent. As an example, at Jurien Bay, Colwell P increased from 3 to 5mg/kg and Colwell K increased from 25 to 34mg/kg.

Plant Analysis:

Table 3: Tissue test data from October 2015 for plus (+) and minus (-) fertiliser and % change.

	Jurien Bay Serradella			**Lancelin Blue Lupin**			**Dandaragan Serradella**		
	+	**-**	**%**	**+**	**-**	**%**	**+**	**-**	**%**
P	0.30	0.28	7%	0.19	0.17	15%	0.36	0.37	-4%
K	1.07	1.35	-20%	1.09	1.18	-8%	1.35	1.61	-16%
S	0.16	0.12	29%	0.23	0.18	25%	0.20	0.17	15%
Cu	8	8	5%	6	7	-6%	5	6	-14%
Zn	60	63	-3%	44	50	-12%	63	67	-6%
Mn	51	53	-4%	196	115	70%	37	33	12%

Plant nutrient analysis data (Table 3) shows a variable response to fertiliser application in annual legumes at the three different sites. At the Lancelin site, there was a very large (70%) increase in plant Manganese levels and a moderate (15 to 25%) increase in Phosphorus and Sulphur levels in response to fertiliser. Potassium, Copper and Zinc levels were either unchanged or slightly depressed in response to fertiliser. At the Jurien Bay and Dandaragan sites, there was a moderate increase (15 to 29%) in Sulphur levels in response to fertiliser, but most other nutrients were either unchanged or slightly depressed.

Table 4: Nutrient levels of Blue Lupin seeds from the plus (+) and minus (-) fertiliser treatments at the Lancelin site.

		+	**-**	**%**
P	%	0.30	0.27	11%
K	%	0.98	0.94	4%
S	%	0.26	0.25	5%
Cu	mg/kg	6	7	-6%
Zn	mg/kg	45	42	8%
Mn	mg/kg	34	25	35%
Mo	ug/kg	6584	5587	18%

Seeds from Blue Lupin plants grown with and without fertiliser were collected from the Lancelin site in November 2016 and analysed for nutrient levels. There was a large (35%) increase in seed Manganese level, a moderate (11 to 18%) increase in seed Phosphorus and Molybdenum levels, and a small (4 to 8%) increase in seed Potassium, Sulphur and Zinc levels in response to fertiliser.

Botanical composition:

At the Jurien Bay and Lancelin sites, there was a large increase in annual legume content when a combination of macro and micro nutrients (Treatments 1 and 4) were applied. This was particularly obvious in Blue Lupins which were dense and 50 to 100cm tall when fertiliser was applied compared to very sparse and only 5 to 10cm tall when no fertiliser was applied. The other annual legume species such as Serradella and Rose Clover also produced more biomass in response to fertiliser at these two sites, but not to the same extent as the Blue Lupins. Weed species such as brome grass and flat weed made up a greater proportion of the sward where no fertiliser was applied. The perennial pasture content of the sward did not change significantly when fertiliser was applied, but they were more productive and greener.

At the Dandaragan site, there was no significant change in botanical composition when fertiliser was applied.

Biomass production:

Biomass production was not measured due to considerable variation within each plot but visual assessments in both 2015 and 2016 suggest there were large increases in biomass production in response to macro and micro nutrients (Treatments 1 and 4) at the Jurien Bay and Lancelin sites, but not at the Dandaragan site. It was estimated that annual biomass production was at least doubled in response to fertiliser at Jurien Bay and Lancelin, with more than half of this increase coming from the annual legume component of the sward. Nitrogen on its own (Treatment 3) had a positive, but short lived, impact on biomass production of the perennial and annual grass components of the sward at all sites.

Discussion:

These trials have shown that large increases in pasture production can occur when nutrient deficiencies are overcome. The Jurien Bay and Lancelin sites were very responsive to the addition of macro and micro nutrients, while the Dandaragan site wasn’t. Why is that? The initial soil test data indicated that both the Jurien Bay and Lancelin sites had very low levels of both Phosphorus and Sulphur and low to moderate levels of Potassium, whereas Dandaragan had high soil Phosphorus, moderate Potassium and low Sulphur. It is well known that annual legumes such as blue lupins and serradella require adequate P, K and S in order to thrive so the responses at Jurien Bay and Lancelin should not be too much of surprise. However, the initial (basic) soil testing did not pick up the low Manganese levels at Lancelin. Only subsequent tissue and seed testing revealed this to be major limiting nutrient at this site.

These trials also show that with the appropriate fertiliser strategy significant amounts of nitrogen can be fixed from the atmosphere by annual legumes to be subsequently be used by perennial grasses. It is generally accepted that for every ton of above ground biomass produced by annual legumes, 20 to 25 kg/ha of nitrogen is fixed. So, if serradella or blue lupins produced 4 to 5 ton/ha of biomass in a year, approximately 100kg/ha of nitrogen would be fixed. This amount of nitrogen is likely to satisfy the vast majority of the perennial grass’s annual requirements for nitrogen, understanding that this requirement will vary from year to year in accordance with the amount and timing of rainfall (e.g. less nitrogen is needed in a very dry year when there is significantly less perennial pasture growth).

It is important to note that the incorporation of a vigorous annual legume component in perennial grass pastures will not only supply the nitrogen requirements of the perennial grass component but also improve animal nutrition in a couple of other ways. The first way is by directly providing the animals with a high quality feed source (such as serradella) in winter and spring. And if there is little or no summer rain, the dry serradella residue can have reasonable feed quality over summer. The second way is more indirect, as access to more nitrogen will improve the feed quality of the perennial grasses by making them leafier and less fibrous.

While these trials did not put a dollar value on the benefits of applying fertiliser, they do provide some clues. An excellent return on investment is highly likely on sites with low nutrient levels, especially when the appropriate fertiliser is applied. By contrast, on sites with higher nutrient levels (such as the Dandaragan site), the return on investment from additional fertiliser is likely to be much smaller or possibly even negative. They key on all sites is to determine which nutrients are deficient, and only apply those nutrients. In the case of the Dandaragan site, the only major limiting nutrient is likely to be Sulphur, so a low rate of Gypsum could be applied as a very cost effective way to supply this nutrient on its own. In terms of nitrogen fertiliser, even though it did improve biomass production, the return on investment is likely to be low to moderate at best because the response was only modest and relatively short lived. But if a good annual legume component does not exist, nitrogen may be needed to sustain production in the short to medium term until a legume base can be established.

One of the biggest returns on investment is likely to come from regular soil and tissue testing. Without knowing the nutrient status of your soils and plants, you are flying blind and potentially losing a lot of money. If the nutrient levels are low and you aren't applying fertiliser, the opportunity cost of forgone production could be substantial. And conversely, if your nutrient levels are high and you are applying fertiliser, your return on that investment in fertiliser could be very low. When you combine soil and tissue testing with your own DIY fertiliser trials (see below), you have a very powerful set of diagnostic tools.

Take Home Messages:

1) Very big improvements in pasture production can occur when nutrient deficiencies are overcome.
2) Soil test. Soil test. Soil test. You can usually predict what type of response to fertiliser you will get just by testing your soil.
3) Do your own fertiliser trials. Apply nutrients (either singularly or in mixtures) that you suspect are lacking.
4) Tissue test. Especially your own trials that have + and – fertiliser. Just to help narrow down what the plants are responding to.

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How to conduct DIY fertiliser trials:

1) Soil test to determine which nutrients might be deficient
2) Purchase a hand held fertiliser spreader ($25 from Scotts)
3) Measure out 25m long x 4m wide plots (each plot is $100m^2$)
4) Apply a range of fertilisers containing nutrients that might be deficient (1kg = 100kg/ha)
5) Fence the trial off from stock during peak pasture growth periods to assess the fertiliser response
6) Tissue test pasture that has and hasn't received fertiliser to tease out the subtleties

Figure 1: Soil Cores (0-100cm) from each site

Jurien Bay | Lancelin | Dandaragan

Jurien Bay - No fertiliser

May 2015

September 2015

November 2015

December 2016

Jurien Bay – Fertiliser

May 2015

September 2015

November 2015

December 2016

Lancelin – No fertiliser

May 2015 | September 2015 | November 2015 | November 2016

Lancelin - Fertiliser

May 2015 | September 2015 | November 2015 | November 2015

Dandaragan – No fertiliser

May 2015

September 2015

November 2015

December 2016

Dandaragan – Fertiliser

May 2015

September 2015

November 2015

December 2016