final report

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Barossa Improved Grazing Group – Soil borne diseases of sub-clover

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Executive Summary

Subterranean clover is the dominant pasture legume of grazing systems throughout the Barossa region in South Australia. In 2014-2017 the Barossa Improved Grazing Group conducted a MLA Producer Site Research Project to determine the effect of soil borne root diseases on sub-clover. Various small-plot field experiments were undertaken that focussed on evaluating strategies to reduce root disease impact and improve sub-clover winter productivity. These management strategies included the use of fungicides, inoculants and fertilisers.

In the fungicide experiments, fungicide application had no affect on dry matter production of the sub-clover varieties, Clare and Trikkala. This included the treatments registered for use in sub-clover, Metalaxyl (Apron®XL) seed treatment and Phosphorous acid (Agri-Fos® 600) foliar treatment. The lack of a positive response to fungicide application also suggests that Clare and Trikkala can perform well in the presence of root diseases.

In the inoculant experiments, the Group C inoculants, Nodulaid® (peat inoculant) and Alosca (granular inoculant) were applied to sub-clover plants at the cotyledon stage. This was conducted to determine their potential use in regenerated pastures, however neither were found to improve sub-clover dry matter production or plant nodulation.

In the fertiliser experiments, up to five treatments (Superphosphate, Complete Fertiliser, Superphosphate+DAP, Urea and Sulphate of Ammonia) were evaluated across four trials. Superphosphate and or Complete Fertiliser significantly improved sub-clover dry matter production in winter/early spring by 28-112% at the sites with marginal soil phosphorus levels (<21 mg/kg Colwell). **These results emphasise the importance for producers to know the soil nutrition status of their paddocks and the benefit of maintaining soil nutrients (particularly phosphorous) at adequate levels, irrespective of the presence of root diseases.**

In addition to the experiments, there was a strong focus on extension and communication activities throughout the project. This included conducting six ‘pasture walks’ and delivering 20 articles for local, state and MLA media.

The projects results indicate that the management of soil borne root diseases for sub-clover is difficult. Root diseases in pastures usually occur as complexes of two to four key pathogens (*Pythium, Phytophthora, Rhizoctonia, Aphanomyces*) with the severity of each being expressed under different environmental conditions. There are also no fungicides registered for use in sub-clover that are effective on all diseases, hence sub-clover variety selection is critical when sowing a new pasture.

Table of Contents

1 Background 5
1.1 Barossa Improved Grazing Group....................5
1.2 Issues faced by the group 5
1.3 Producer management practices 5
1.4 Motivation of the group....................5
2 Projective Objectives 6
3 Methodology 6
3.1 Experiment 1: Winter sub-clover production 8
3.2 Experiment 2: Sub-clover regeneration....................8
3.3 Experiment 3: Fertilisers and fungicides 9
3.4 Experiment 4: Inoculants....................10
3.5 Experiment 5: Fungicides....................11
3.6 Experiment 6: Fertilisers....................13
3.7 Extension and Communication....................14
4 Results....................14
4.1 Experiment 1: Winter sub-clover production 14
4.1.1 Moculta 14
4.1.2 Eden Valley....................15
4.2 Experiment 2: Sub-clover regeneration....................17
4.3 Experiment 3: Fertilisers and fungicides 17
4.3.1 Moculta 17
4.3.2 Craneford....................19
4.4 Experiment 4: Inoculants....................20
4.4.1 Moculta 20
4.4.2 Craneford....................20
4.5 Experiment 5: Fungicides....................21
4.5.1 Moculta 21
4.5.2 Craneford....................22
4.6 Experiment 6: Fertilisers....................22
4.6.1 Moculta 22
4.6.2 Craneford....................24
4.7 Extension and communication 26
5 Discussion....................27
5.1 Research objectives....................27

5.1.1 Winter sub-clover production 28
5.1.2 Sub-clover regeneration 28
5.1.3 Effect of fungicide use 29
5.1.4 Effect of fertiliser use 30
5.1.5 Effect of inoculant use 31
5.2 The value of the research results (benefits/costs)..32
5.2.1 Benefits...32
5.2.2 Costs to achieve outcomes and cost benefit analysis 32
5.2.3 Unexpected benefits 34
5.3 Promotion of research results and its effectiveness.......................................35
5.3.1 Practice changes 35
5.3.2 Changes in knowledge, attitudes and skills 35
5.3.3 Barriers and enablers for change 35
5.4 Effectiveness of the participatory research process.......................................35
6 Conclusions/ Key Messages /Recommendations...36
6.1 Conclusions...36
6.2 Key Messages..37
6.3 Recommendations 37
7 Acknowledgements...38
8 Appendix..39

1 Background

1.1 Barossa Improved Grazing Group

The Barossa Improved Grazing Group (BIGG) is a community-driven network of livestock production and farming groups from the Barossa and eastern ranges region of the Mount Lofty Ranges in South Australia. The group aims to be a trusted and valuable network supporting innovative, sustainable and resilient grazing businesses. This is achieved through delivering productivity and NRM outcomes for local producers via a range of pasture and grazing management projects. Some of BIGG's key projects since its establishment have included:

- Soil moisture monitoring in grazing systems
- Management of native pastures after local bushfires
- Determining pasture options that maximise production in a variable climate (MLA Producer Demonstration Site project).

BIGG has 280 members who share an interest in sustainable grazing systems within the local region. The Barossa and eastern ranges region of the Mount Lofty Ranges covers approximately 50,000 hectares of grazing land carrying an estimated 60,000 livestock. The local pasture systems are diverse and include perennials (mostly phalaris based), annual pastures (annual grasses or sown cereals as part of a mixed farming operation) and natives. In all these systems, sub-clover is the dominant legume type, with it playing a critical role in increasing annual pasture quantity and quality.

Further information about BIGG can be found at www.biggroup.org.au.

1.2 Issues faced by the group

A significant issue for local producers is a lack of persistence and production in their pastures. The key concern being the level of production available early in the season (late autumn/early winter), given winter pasture production is a key profit driver for their grazing businesses. Hence production needs to be optimised to fill the traditional winter-feed gap.

Lack of pasture productivity and more particularly sub-clover persistence and production may be due to a multitude of reasons. However, at the start of this MLA Producer Research Site (PRS) project, local producers did not consider the issue of soil borne root diseases as 'top of mind'.

1.3 Producer management practices

There were no specific practices that local producers have traditionally conducted to manage soil borne root diseases in their pastures prior to this project.

In the case of fungicide use, this is uncommon except when a pasture is being renovated and the newly purchased sub-clover seed may be treated with a fungicide. When selecting sub-clover varieties for a new pasture, local producers simply choose varieties that do well in their local area rather than focusing on its disease tolerance/resistance. For example, the Clare variety is considered to do well in the Moculta district and likewise Trikkala in the Eden Valley/Craneford district.

1.4 Motivation of the group

Sub-clovers are a vital component of local pasture systems and as soil borne root diseases may cause significant production losses, this PRS project was seen as a valuable opportunity to evaluate management strategies to improve sub-clover productivity. This is especially important considering the core producer group members in this project had generally addressed other limiting factors of sub-clover production, such as; low pH (through liming), grazing management and soil nutrition.

Most local producers had little knowledge about root diseases in local pasture systems. Producers who have a cropping enterprise seem to have a greater awareness of root diseases (e.g. take-all, *Rhizoctonia*) compared to those solely reliant on grazing, given the need to manage diseases leading into the cereal phase of their crop rotation (so to help maximise yield). However, irrespective of this, amongst the group there was a low understanding about which root diseases are affecting local sub-clover pastures, their affect on production and the management strategies that may reduce their impact.

2 Projective Objectives

This project forms part of MLA's PRS program that is part of the southern Feedbase Investment Plan. In particular, this project supports the MLA-funded project B.PSP.0005 – Managing soil borne root disease in sub-clover pastures.

The objectives of this PRS project were to:

1. Determine the effect of soil borne root disease on winter sub-clover production
2. Determine the effect of soil borne root disease on sub-clover regeneration
3. Determine cost-effective management strategies to reduce the impact of soil borne root disease in sub-clovers to improve their production

3 Methodology

To address the projects objectives, six small plot field experiments were initiated between 2014-2016 at several research sites. The key focus of these experiments was to evaluate management strategies that may reduce the impact of root diseases on winter sub-clover productivity. These strategies included fungicides, inoculants and fertilisers. In addition, a small plot field experiment was initiated in 2014 to assess the effect of root diseases on sub-clover regeneration. The experiments conducted throughout the project and their locations are summarised in Table 1. These locations have an annual average rainfall of 520-600mm.

Table 1: Timing and locations of the experiments conducted for this project.

Experiment	**Location/paddock of experiments**		
	2014	**2015**	**2016**
Experiment 1: Winter sub-clover production	Moculta: Long Johns Eden Valley: Rock		
Experiment 2: Sub-clover regeneration	Eden Valley: Rock		
Experiment 3: Fertilisers and fungicides		Moculta: Creek Craneford: South Phalaris	
Experiment 4: Inoculants		Moculta: Creek Craneford: South Phalaris	
Experiment 5: Fungicides			Moculta: Creek Craneford: South Phalaris
Experiment 6: Fertilisers			Moculta: Hill Craneford: South Phalaris

All trial sites were located in long-term pasture paddocks. The soil nutrient and root disease status of each site was determined after analysis of a representative soil sample to a depth of 10cm. The soil nutrient status of the research sites are summarised in Table 2, whilst the full results are in Table 39. All sites were confirmed to comprise various soil borne root diseases and at levels expected to compromise pasture production (Table 3).

Table 2: Key soil analysis results for each of the projects research sites.

Research site	Soil type	pH ($CaCl_2$)	Phosphorous (Colwell mg/Kg)	Potassium (Colwell mg/Kg)	Sulphur (mg/Kg)	Organic carbon (%)
[A]Moculta: Long Johns	Red-brown earth	5.7	38	416	4.8	2.4
[A]Eden Valley: Rock	Sandy loam	4.6	29	283	4.2	2.9
[B]Craneford: South Phalaris	Sandy loam	5.7	17	244	7.1	2.3
[B]Moculta: Creek	Loam	5.2	21	468	10.1	2.5
[C]Moculta: Hill	Loam	5.1	36	577	8.7	2.7

Soil sample collected on [A]22/03/14, [B]14/03/15 and [C]23/02/16 and assessed by CSBP.

Table 3: Soil borne root diseases present at each research site that were considered to be at adequate levels to compromise pasture production at the time of sampling.

Site location	Root diseases (in estimated order of impact)
[A]Moculta: Long Johns	*Rhizoctonia, Pythium, Phytophthora*
[A]Eden Valley: Rock	*Rhizoctonia, Pythium, Phytophthora*
[B]Craneford: South Phalaris	*Pythium, Phytophthora, Rhizoctonia*
[B]Moculta: Creek	*Pythium, Phytophthora, Rhizoctonia, Aphanomyces*
[C]Moculta: Hill	*Rhizoctonia, Aphanomyces, Pythium*

Soil sample collected on [A]22/03/14, [B]14/03/15 and [C]23/02/16 and assessed by SARDI's Predicta B test.

The research conducted for this PRS project was determined in consultation with the projects core producer group members. In addition, the projects research partner The University of Western Australia (UWA), led by Professor Martin Barbetti, and the Mackillop Farm Management Group (MFMG) in South Australia (who like BIGG conducted a similar PRS project investigating soil borne root diseases of sub-clover in south-east SA), provided feedback on the research protocols developed.

All data collected in the experiments were subjected to statistical analysis using GenStat (courtesy of Dr Mingpei You, UWA). Treatment comparisons were undertaken using the least significant difference (lsd) method.

The aim, background, experimental treatments and assessments conducted for each of the projects six experiments are as follows:

3.1 Experiment 1: Winter sub-clover production

Aim: Determine the effect of sub-clover variety and fungicide seed treatment on winter sub-clover production in the presence of soil borne root diseases.

Background: The fungicide seed treatment, metalaxyl (350 g/L metalaxyl-m, Apron®XL) is registered for use in sub-clover to control seedling diseases caused by *Pythium* and *Phytophthora*. However, it has not been evaluated locally in sub-clover pastures.

In 2014 field trials located at Moculta (Long Johns paddock) and Eden Valley (Rock paddock) were conducted in a Randomised Complete Block Design (RCBD) with six replications to evaluate three sub-clover varieties (Clare, Trikkala, Woogenellup) by two fungicide seed treatments (Nil, Metalaxyl-M at 5ml/1kg of seed). Treatments were:

- Clare + Nil seed treatment
- Clare + Metalaxyl seed treatment at 5ml/1kg of seed
- Trikkala + Nil seed treatment
- Trikkala + Metalaxyl seed treatment at 5ml/1kg of seed
- Woogenellup + Nil seed treatment
- Woogenellup + Metalaxyl seed treatment at 5ml/1kg of seed

In March and May 2014 both trial sites were sprayed with glyphosate to kill the emerged weeds before sowing. Each site was then pegged in 1m single row plots and any existing surface clover burrs were removed by lightly scraping them off with a spade. On 22/05/14 (Eden Valley) and 25/05/14 (Moculta), 100 un-inoculated sub-clover seeds were sown in each plot. Seeds were evenly distributed by hand in a shallow slot (0.5-1.0cm deep) and depending on the treatment, the seed was either untreated (i.e. nil treatment) or treated with metalaxyl (at fives times the label rate) prior to sowing.

At both sites there was significant pest pressure (black-headed pasture cockchafer and wireworms), particularly early in the season. This necessitated the re-sowing of the Eden Valley site on 12/06/14.

The treatments were assessed for:

- Plant emergence 14 days after sowing (DAS) by counting the number of sub-clover plants/plot
- Plant establishment 35 (Moculta) and 27 (Eden Valley) DAS by counting the number of sub-clover plants/plot
- Plant nodulation 54 (Moculta) and 43 (Eden Valley) DAS by scoring three sub-clover plants/plot for their level of nodulation (0-5 scale)
- Cotyledon yellowing of sub-clover plants 43 DAS at Eden Valley
- Dry matter production at various times throughout the season, either by scoring each plot (1-5 scale) or by cutting the plot, oven drying and weighing it

3.2 Experiment 2: Sub-clover regeneration

Aim: Determine the effect of sub-clover variety on sub-clover regeneration in the presence of soil borne root diseases.

Background: Some local sub-clover stands lack persistence and production. To help assess this, three sub-clover cultivars were sown in small plots and monitored for their persistence. The varieties were Clare and Trikkala (varieties that are considered to perform well locally) and Woogenellup (a variety considered highly susceptible to soil borne root diseases).

In 2014 a field trial was initiated at Eden Valley (Rock paddock) in a RCBD (five replications) to evaluate Clare, Trikkala, and Woogenellup for their ability to persist over a three-year period. The trials planned assessments were; sub-clover plant emergence (2014), dry matter production (2014-2016) and plant re-emergence (2015-2017).

In March and May 2014 the trial site was sprayed with glyphosate to kill the emerged weeds before sowing. On 21/05/14 the site was pegged in 1m^2 plots and any surface clover burrs were removed by lightly scraping them off with a spade. Lime was also applied at 1t/ha to each plot to help mitigate the possible impact of soil acidity.

On 22/05/14, 200 un-inoculated sub-clover seeds were sown per plot, lightly raked into the soil surface and the site sprayed with phosmet as a bare earth protectant for insect control.

On 12/06/14 the trial was re-sown as black-headed pasture cockchafer and wireworms had eaten the newly emerged seedlings. Immediately after re-sowing the site was sprayed with alpha-cypermethrin and chlorpyrifos to mitigate their impact. However, ongoing pest pressure (including slugs) and low sub-clover plant emergence necessitated the trial to be again re-sown (on 17/08/14 by scattering seeds over each plot and lightly pressing them into the soil with a trowel). By the end of the 2014 growing season (October) the trial had very low and uneven sub-clover emergence.

3.3 Experiment 3: Fertilisers and fungicides

Aim: Determine the effect of fertilisers and fungicides on winter sub-clover production in the presence of soil borne root diseases.

Background: Adequate plant nutrition and the use of fungicides are management strategies that can limit the impact of soil borne root diseases of sub-clover. In 2014 as part of this project the fungicide metalaxyl was evaluated for its effect on sub-clover productivity (experiment 1), however alternate fungicides and fertilisers require evaluation.

In 2015 field trials located at Moculta (Creek paddock) and Craneford (South Phalaris paddock) were conducted in a RCBD (ten replications) to evaluate six treatments:

- Nil (control)
- Superphosphate @ 150kg/ha
- Complete fertiliser @ 200kg/ha
- Phosphorous acid (Agri-Fos® 600) foliar treatment @ 1.7l/ha
- Metalaxyl (Apron®XL) seed treatment @ 3ml/kg
- Metalaxyl+Iprodione (Apron®XL+Rovral®) seed treatment @ 3ml/kg+6ml/kg

On 02/05/15 both trial sites were sprayed with glyphosate to kill the emerged weeds before sowing. Each site was then pegged in 1m single row plots and any existing surface clover burrs were removed by lightly scraping them off with a spade.

Given the vast majority of local pasture paddocks are regenerated (i.e. not sown), to mimic this the seed sown in the experiment was not inoculated. On 27/05/15, 100 viable un-inoculated sub-clover seeds (variety Clare at Moculta, variety Trikkala at Craneford) were sown per plot in a shallow slot (0.5-1.0cm deep). Depending on the treatment, the seed sown was either:

- Untreated (nil, Superphosphate, Complete fertiliser and Phosphorous acid treatments)
- Treated with a fungicide (Metalaxyl and Metalaxyl+Iprodione treatments).

Immediately after sowing, Superphosphate and Complete fertiliser were applied to their respective treatments (10cm either side of the 1m-row plot) at rates that were the equivalent units of phosphorous (13.2kg/ha). On 25/06/15, the Phosphorous acid treatment was applied as a foliar application. Further details about each treatment are summarised in Table 4.

Table 4: Experiment 3 treatment details.

Treatment	**Application rate/date**	**Comments**
Nil	-	No fertiliser or fungicide treatment.
Superphosphate	150kg/ha: 27/05/15	Analysis of 8.8 P, 11.0 S, 19.0 Ca.
Complete fertiliser	200kg/ha: 27/05/15	Analysis of 6.6 P, 12.7 K, 8.3 S, 1.5 Zn, 0.5 Cu, 0.025 Mo, 0.5 B (zero nitrogen).
Phosphorous acid (600 g/L)	1.7L/ha: 25/06/15	Sprayed (3.4x label rate) at the first true sub-clover leaf stage with a hand-held sprayer. Controls *Phytophthora*.
Metalaxyl-M (350 g/L)	3ml/kg: 27/05/15	Applied as a seed treatment (3x label rate) and then sown. Controls *Pythium* and *Phytophthora*.
Metalaxyl-M (350 g/L)+Iprodione (250 g/L)	3ml/kg+ 6ml/kg: 27/05/15	Fungicide mix applied to the seed as a seed treatment and then sown. Iprodione suppresses *Rhizoctonia* and is registered as a seed treatment in lupins at 1-4ml/kg (it is not registered in sub-clover). *Rhizoctonia* is the key root disease of local pastures (M. Barbetti pers. comm.) hence both fungicides were added together to ensure there was a treatment that had activity on *Rhizoctonia*.

The treatments were assessed for:

- Plant emergence 14 DAS by counting the number of sub-clover plants/plot
- Plant establishment 29 DAS by counting the number of sub-clover plants/plot
- Dry matter production at various times throughout the season, either by scoring each plot (1-5 scale) or by cutting the plot, oven drying and weighing it

3.4 Experiment 4: Inoculants

Aim: Determine the effect of post emergent inoculant application on winter sub-clover production in the presence of soil borne root diseases.

Background: When high numbers of appropriate rhizobia (Group C) aren't present in the soil, sub-clover production may be improved through inoculation. If a new pasture is sown, sub-clover seed is generally inoculated. However, given the vast majority of pasture paddocks locally are regenerated, an option in these cases could be for producers to apply an inoculant once sub-clover plants have emerged.

In 2015 field trials located at Moculta (Creek paddock) and Craneford (South Phalaris paddock) were conducted in a RCBD (six replications) to evaluate three treatments:

- Nil (control)
- Nodulaid® @ 1.25kg/ha (peat inoculant)
- Alosca @ 20kg/ha (granular inoculant)

The rates for each inoculant were determined by their similar product cost/ha (approximately $30/ha).

On 02/05/15 both trial sites were sprayed with glyphosate to kill the emerged weeds before sowing. Each site was then pegged in 1m single row plots and any existing surface clover burrs were removed by lightly scraping them off with a spade.

On 27/05/15 100 viable un-inoculated sub-clover seeds (variety Clare at Moculta, variety Trikkala at Craneford) were sown per plot in a shallow slot (0.5-1.0cm deep). On 16/06/15 Nodulaid and Alosca were applied to their respective treatments at the sub-clover cotyledon stage (first true-leaf was just starting to appear).

At both sites the treatments were applied to moist topsoil with some rain falling soon after application (At Moculta, 5mm fell on 15/06/15 and 4mm on 17-18/06/15. At Craneford, 5mm fell on 15/06/15 and 5mm on 16-18/06/15). Further details about each treatment in the experiment are summarised in Table 5.

Table 5: Experiment 4 treatment details.

Treatment	**Application rate/date**	**Comment**
Nil	-	No inoculation treatment.
Nodulaid	1.25kg/ha: 16/06/15	Group C peat inoculant mixed into a solution and sprayed on the soil surface with a hand-held sprayer. Based on an application rate of 1.25kg/ha, product cost is $30/ha.
Alosca	20kg/ha: 16/06/15	Group C dry granular inoculant evenly spread on the soil surface 10 cm either side of the plot row. Applied at 2x label rate the product cost is $31/ha.

The treatments were assessed for:

- Dry matter production at various times throughout the season, either by scoring each plot (1-5 scale) or by cutting the plot, oven drying and weighing it
- Plant nodulation 69 (Moculta) and 71 (Craneford) DAS by scoring five sub-clover plants/plot for their level of nodulation using the 'Yates scale' (see Appendix Figure 6)

3.5 Experiment 5: Fungicides

Aim: Determine the effect of key fungicides on winter sub-clover production in the presence of soil borne root diseases.

Background: The incidence of root diseases in sub-clover may be reduced by the use of fungicides. In 2014 and 2015, as part of this project several fungicides were evaluated in small-plot field trials (experiments 1 and 3), however they didn't impact sub-clover production. In contrast field trials conducted nationally by the projects research partner, UWA have largely produced positive results.

In 2016 field trials located at Moculta (Creek paddock) and Craneford (South Phalaris paddock) were conducted in a RCBD to evaluate four treatments:

- Nil (control)
- Phosphorous acid (Agri-Fos® 600) foliar treatment @ 1.7l/ha
- Metalaxyl-M (Apron®XL) seed treatment @ 3ml/kg
- Difenoconazole+Metlaxyl+Sedexane (DMS) (Vibrance®) seed treatment @ 10.8ml/kg

On 12/04/16 both trial sites were sprayed with the knockdown herbicide, glyphosate to kill the emerged weeds before sowing. On 30/05/16 these sites were pegged in 1m single row plots and existing surface clover burrs were removed from the plots by lightly scraping them off with a spade.

On 31/05/16 100 viable un-inoculated sub-clover seeds (variety Clare at Moculta, variety Trikkala at Craneford) were sown per plot in a shallow slot (0.5-1.0cm deep). Depending on the treatment the seed was either:

- Untreated (Nil and Phosphorous acid treatments)
- Treated with a fungicide (Metalaxyl and DMS treatments applied on 30/05/16).

Immediately after sowing Complete fertiliser was evenly spread over each plot at 200kg/ha (10cm either side of the 1m-row plot) to ensure nutrition would not limit sub-clover productivity. The pesticides, alpha-cypermethrin and chloryrifos were also applied over the trial sites as a bare earth treatment for insect control.

On 14/06/16, the Phosphorous acid treatment was applied as a foliar application. Further details about each treatment are outlined in Table 6.

Table 6: Experiment 5 treatment details.

Treatment	**Application rate/date**	**Comments**
Nil	-	Seed sown without fungicide seed treatment
Phosphorous acid (600 g/L)	1.7l/ha: 14/06/16	Sprayed (3.4x label rate) at the first true sub-clover leaf stage with a hand-held sprayer. Controls *Phytophthora*.
Metalaxyl-M (350 g/L)	3ml/kg: 31/05/16	Applied as a seed treatment (3x label rate) and then sown. Controls *Pythium* and *Phytophthora*.
Difenoconazole (66.2 g/L), Metalaxyl-m (16.5 g/L), Sedexane (13.8 g/L)	10.8ml/kg: 31/05/16	Applied as a seed treatment (3x cereal label rate) and then sown. Registered as a seed treatment for cereals to control *Pythium* and suppress *Rhizoctonia* (it is not registered for use in sub-clover). *Rhizoctonia* is the key root disease of local pastures (M. Barbetti pers. comm.) hence the inclusion of this treatment.

The treatments were assessed for:

- Plant emergence 14 days DAS by counting the number of plants in each plot
- Plant establishment 28 DAS by counting the number of plants in each plot
- Dry matter production at various times throughout the season, either by scoring each plot at 50 and 92 DAS (1-5 scale) or by cutting the plot, oven drying and weighing it (127 DAS Moculta, 148 DAS Craneford)

3.6 Experiment 6: Fertilisers

Aim: Determine the effect of fertiliser treatment on regenerated winter sub-clover production in the presence of soil borne root diseases.

Background: Adequate plant nutrition can limit the impact of soil borne root diseases in sub-clover. In 2015 as part of this project, fertiliser application improved winter/early spring sub-clover production on marginal soil phosphorus sites (experiment 3). Additional fertiliser treatments were evaluated for their ability to help fill the winter feed gap.

In 2016 field trials located at Moculta (Hill paddock) and Craneford (South Phalaris paddock) were conducted in a RCBD (four replications) to evaluate six treatments in regenerated pasture paddocks where sub-clover was known to be present:

- Nil (control)
- Superphosphate @ 150kg/ha
- Complete fertiliser @ 200kg/ha
- Superphosphate (60%) + DAP (40%) @ 99.5 kg/ha
- Urea @ 40kg/ha
- Sulphate of Ammonia @ 87.5kg/ha

The application rates of each fertiliser treatment ensured equivalent units of either phosphorous (13.2 kg/ha) or nitrogen (18.4 kg/ha) were applied (Table 7).

Table 7: Nutrient units applied for each treatment in experiment 6.

Treatment	**Application rate (kg/ha)**	**Units applied (kg/ha)**				
		N	**P**	**K**	**S**	**Ca**
Nil	-	-	-	-	-	-
Superphosphate	150	-	13.2	-	16.5	28.5
Complete fertiliser[A]	200	-	13.2	25.4	16.6	-
Superphosphate (60%)+DAP(40%)	99.5	7.2	13.2	-	7.2	11.3
Urea	40	18.4	-	-	-	-
Sulphate of Ammonia	87.5	18.4	-	-	21.0	-

[A]Nutrients applied also included; 3.0 kg/ha zinc, 1.0 kg/ha copper, 0.05 kg/ha molybdenum, 1.0 kg/ha boron.

The Moculta trial site had adequate soil phosphorous levels (36 mg/kg) and consisted of annual grasses (barley grass and silver grass), sub-clover and some broadleaf weeds (salvation jane, capeweed) in the 2016 growing season. The Craneford trial site had marginal phosphorous levels (17 mg/kg) and consisted of phalaris, sub-clover and some broadleaf weeds (geranium, capeweed) in the 2016 growing season. The plot size for the trial at Moculta and Craneford was 8m^2 and 6m^2 respectively. Various management operations of the trial sites were conducted throughout 2016 (Table 8).

Table 8: Management operations conducted at each trial site in experiment 6.

Management operation	**Moculta**	**Craneford**
Trials pegged out and Superphosphate and Complete fertiliser spread evenly by hand on the soil surface to their respective treatments (to simulate an autumn application)	29/04/16	27/04/16
Superphosphate+DAP, Urea and Sulphate of Ammonia spread evenly by hand on the soil surface to their respective treatments (applied immediately prior to impending rainfall as they contained nitrogen)	06/05/16	06/05/16
Trial sites sprayed with MCPA and pyraflufen-ethyl to control broadleaf weeds	14/06/16	14/06/16
To encourage sub-clover production at each site, trials sprayed with haloxyfop to control barley grass (Moculta) and 'temper' phalaris growth (Craneford)	28/06/16	28/06/16
To encourage sub-clover production and manage the high proportion of silver grass (Moculta) and phalaris (Craneford), plots were mown with a lawnmower to simulate grazing	27/07/16	27/07/16
Moculta trial site sprayed with clethodim to suppress silver grass	17/08/16	-

The treatments were assessed for:

- Dry matter production either by scoring each plot (1-5 scale) or by cutting two (Craneford) or three (Moculta) 0.1m^2 quadrats/plot, oven drying and weighing them

3.7 Extension and Communication

In addition to the experiments, a strong focus for the project was delivering associated extension and communication activities. These included pasture walks for local producers and writing various media articles. These activities are outlined in 4.7.

4 Results

4.1 Experiment 1: Winter sub-clover production

4.1.1 Moculta

Metalaxyl seed treatment had no significant affect on plant emergence or plant establishment for the same sub-clover variety (i.e. a comparison between the same variety only, not between all treatments). This was except for the variety Trikkala, as Metalaxyl seed treatment significantly reduced plant numbers (compared to Trikkala without Metalaxyl) at both 14 and 35 DAS (Table 9).

Table 9: Effect of sub-clover variety and Metalaxyl seed treatment on plant emergence and establishment at Moculta.

Treatment	**Plant emergence (nos./1.0m row) 14 DAS- 05/06/14**	**Plant establishment (nos./1.0m row) 35 DAS- 26/06/14**
Clare+Nil	48.5 ab	35.7 ab
Clare+Metalaxyl	37.3 a	29.8 a
Trikkala+Nil	53.2 b	43.8 b
Trikkala+Metalaxyl	37.7 a	31.7 a
Woogenellup+Nil	44.0 ab	32.3 a
Woogenellup+Metalaxyl	44.0 ab	34.2 ab
Lsd (P<0.05)	**13.5**	**9.7**

Values in columns not followed by the same common letter differ significantly.

Differences were determined between treatments for plant nodulation (Table 10). However, Metalaxyl seed treatment had no significant affect on plant nodulation for the same sub-clover variety, except for Trikkala where it significantly increased nodulation (compared to without Metalaxyl) at 54 DAS (Table 10). There were no significant differences in dry matter production at 77 and 116 DAS for the same sub-clover variety (Table 10).

Table 10: Effect of sub-clover variety and Metalaxyl seed treatment on plant nodulation and dry matter production at Moculta.

Treatment	**Plant nodulation (0-5 rating) 54 DAS- 15/07/14**	**Dry matter (1-5 rating) 77 DAS- 07/08/14**	**[A]Dry matter (gms/plant) 116 DAS- 15/09/14**
Clare+Nil	1.0 b	3.33 ab	0.32 bc
Clare+Metalaxyl	1.0 b	3.00 ab	0.27 ab
Trikkala+Nil	0.93 a	3.33 ab	0.26 ab
Trikkala+Metalaxyl	1.0 b	2.33 a	0.18 a
Woogenellup+Nil	0.97 ab	3.00 ab	0.30 abc
Woogenellup+Metalaxyl	1.0 b	3.83 b	0.40 c
Lsd (P<0.05)	**0.06**	**1.20**	**0.12**

Values in columns not followed by the same common letter differ significantly.
[A]Sub-clover plant numbers were variable across the plots due to pest damage so data was converted to grams/plant.

4.1.2 Eden Valley

Differences were determined for plant emergence and establishment between treatments, however Metalaxyl seed treatment had no significant affect when comparing the same sub-clover variety (Table 11).

Table 11: Effect of sub-clover variety and Metalaxyl seed treatment on plant emergence and establishment at Eden Valley.

Treatment	**Plant emergence (nos./1.0 row) 14 DAS- 26/06/14**	**Plant establishment (nos./1.0 row) 27 DAS- 09/07/14**
Clare+Nil	55.2 bc	52.8 ab
Clare+Metalaxyl	49.0 ab	52.0 ab
Trikkala+Nil	49.8 abc	50.8 ab
Trikkala+Metalaxyl	59.7 c	56.8 b
Woogenellup+Nil	41.7 a	44.2 a
Woogenellup+Metalaxyl	45.2 ab	45.2 ab
Lsd (P<0.05)	**10.2**	**11.0**

Values in columns not followed by the same common letter differ significantly.

At 43 DAS, cotyledons of the sub-clover plants exhibited symptoms of yellowing (Figure 1), a possible symptom of root disease. However, Metalaxyl did not significantly affect yellowing when comparing the same sub-clover variety. At 43 DAS, plant nodulation was also measured, but there was no significant difference between any treatments (Table 12).

Figure 1: Woogenellup sub-clover plants displaying yellowing of their cotyledons at Eden Valley on 25/07/14.

Table 12: Effect of sub-clover variety and Metalaxyl seed treatment on cotyledon yellowing and plant nodulation at Eden Valley.

Treatment	**Cotyledon yellowing (% plants/row) 43 DAS- 25/07/14**	**Plant nodulation (0-5 rating) 43 DAS- 25/07/14**
Clare+Nil	4.15 a	0.78
Clare+Metalaxyl	5.74 a	0.67
Trikkala+Nil	12.75 b	0.83
Trikkala+Metalaxyl	8.53 ab	0.89
Woogenellup+Nil	10.76 ab	0.72
Woogenellup+Metalaxyl	8.55 ab	0.78
Lsd (P<0.05)	**6.97**	**ns**

Values in columns not followed by the same common letter differ significantly.

Throughout the 2014 growing season, sub-clover dry matter production was very low hence a winter production cut was not conducted as planned. In lieu of this, dry matter production was scored at the end of the growing season (141 DAS), however Metalaxyl had no significant affect on dry matter when comparing the same sub-clover variety (Table 13).

Table 13: Effect of sub-clover variety and Metalaxyl seed treatment on dry matter production at Eden Valley.

Treatment	**Dry matter (1-5 rating) 141 DAS- 31/10/14**
Clare+Nil	2.17 ab
Clare+Metalaxyl	1.67 a
Trikkala+Nil	3.33 cd
Trikkala+Metalaxyl	2.33 abc
Woogenellup+Nil	3.00 bcd
Woogenellup+Metalaxyl	3.67 d
Lsd (P<0.05)	**1.10**

Values in columns not followed by the same common letter differ significantly.

4.2 Experiment 2: Sub-clover regeneration

The high pest pressure at the site during the 2014 growing season caused low and variable plant numbers across all plots, and although sub-clover plant emergence was measured (on 09/07/14 and 15/09/14), the results were not considered meaningful and therefore not presented. In addition, assessments for dry matter production were scheduled for winter and late spring, however neither was conducted due to insufficient plant numbers.

In 2015, sub-clover plant re-emergence was scheduled for assessment three weeks after the break of the growing season. In early January the site received over 50mm of rain resulting in sub-clover emergence at the site. Emergence counts were then conducted in late January, which revealed a significant background sub-clover population across all plots. However, this did not provide a true reflection of the varietal treatments sown in 2014.

A further assessment of plant re-emergence conducted in June 2015 (after the traditional break) re-confirmed the substantial background sub-clover population infesting the plots. These included the varieties: Mt Barker, Dwalganup, Dinninup, Eden Valley ecotype and Woogenellup. Given the presence of Woogenellup across all plots and coupled with the variable plant emergence of the varieties sown in 2014, the experimental results were considered compromised. The experiment was therefore halted, with no further assessments conducted.

4.3 Experiment 3: Fertilisers and fungicides

4.3.1 Moculta

Fertiliser or fungicide treatment had no significant affect on sub-clover plant emergence 14 DAS, however at 29 DAS Metalaxyl+Iprodione significantly reduced plant establishment compared to Superphosphate and Complete fertiliser (Table 14).

Table 14: Effect of fertiliser and fungicide treatment on Clare sub-clover plant emergence and establishment at Moculta.

Treatment	Plant emergence (nos./1.0m row) 14 DAS- 10/06/15	Plant establishment (nos./1.0m row) 29 DAS- 25/06/15
Nil	81.6	83.6 ab
Superphosphate	83.1	86.9 b
Complete Fertiliser	83.1	85.4 b
Phosphorous acid	82.9	82.9 ab
Metalaxyl	82.3	82.7 ab
Metalaxyl+Iprodione	80.9	80.9 a
Lsd (P<0.05)	**ns**	**4.24**

Values in columns not followed by the same common letter differ significantly.

Fertiliser or fungicide treatment had no significant affect on sub-clover dry matter production when evaluated 43 DAS (Table 15). In early August (69 DAS), Superphosphate produced significantly more dry matter than all other treatments except Complete fertiliser (Table 15). Both Superphosphate and Complete fertiliser produced significantly greater dry matter than the Nil treatment (39 and 31% respectively).

Table 15: Effect of fertiliser and fungicide treatment on Clare sub-clover dry matter production at Moculta.

Treatment	Dry matter	
	(1-5 rating) 43 DAS- 09/07/15	(gms/0.5m row) 69 DAS- 04/08/15
Nil	3.1	1.29 a
Superphosphate	3.6	1.79 c
Complete Fertiliser	3.2	1.69 bc
Phosphorous acid	3.3	1.38 ab
Metalaxyl	3.0	1.37 ab
Metalaxyl+Iprodione	3.5	1.34 ab
Lsd (P<0.05)	**ns**	**0.354**

Values in columns not followed by the same common letter differ significantly.

At mid September (115 DAS), Superphosphate dry production remained significantly greater than the Nil treatment, however by 127 DAS there was no significant dry matter differences between treatments (Table 16).

Table 16: Effect of fertiliser and fungicide treatment on Clare sub-clover dry matter production at Moculta.

Treatment	Dry matter	
	(1-5 rating) 115 DAS- 19/09/15	(gms/0.5m row) 127 DAS- 01/10/15
Nil	2.50 a	37.40
Superphosphate	3.44 b	45.67
Complete Fertiliser	3.33 ab	45.11
Phosphorous acid	3.20 ab	44.70
Metalaxyl	3.00 ab	41.56
Metalaxyl+Iprodione	3.30 ab	46.40
Lsd (P<0.05)	**0.90**	**ns**

Values in columns not followed by the same common letter differ significantly.

4.3.2 Craneford

Fertiliser or fungicide treatment had no significant affect on sub-clover plant emergence 14 DAS, however at 29 DAS Superphosphate, Complete fertiliser and Phosphorous acid significantly reduced plant establishment compared to Nil and Metalaxyl+Iprodione (Table 17).

Table 17: Effect of fertiliser and fungicide treatment on Trikkala sub-clover plant emergence and establishment at Craneford.

Treatment	Plant emergence (nos./1.0m row) 14 DAS- 10/06/15	Plant establishment (nos./1.0m row) 29 DAS- 25/06/15
Nil	79.3	83.1 c
Superphosphate	75.9	75.9 ab
Complete Fertiliser	75.1	77.1 ab
Phosphorous acid	75.3	75.6 a
Metalaxyl	78.4	81.1 bc
Metalaxyl+Iprodione	80.5	83.6 c
Lsd (P<0.05)	**ns**	**5.00**

Values in columns not followed by the same common letter differ significantly.

Fertiliser or fungicide treatment had no significant affect on sub-clover dry matter production 43 or 71 DAS (Table 18). For both assessments the treatments Complete fertiliser and Metalaxyl had the highest dry matter score.

Table 18: Effect of fertiliser and fungicide treatment on Trikkala sub-clover dry matter production at Craneford.

Treatment	Dry matter (1-5 rating)	
	43 DAS- 09/07/15	71 DAS- 06/08/15
Nil	3.3	2.9
Superphosphate	3.2	3.1
Complete Fertiliser	3.7	3.4
Phosphorous acid	3.2	3.0
Metalaxyl	3.8	3.2
Metalaxyl+Iprodione	3.5	2.8
Lsd (P<0.05)	**ns**	**ns**

At early September (105 DAS), Complete fertiliser produced significantly more dry matter than the Nil, Superphosphate and Phosphorous acid treatments (Table 19). At this assessment, Complete fertiliser increased dry matter production by 28% compared to Nil. By late October (152 DAS) there were no significant dry matter differences between treatments (Table 19).

Table 19: Effect of fertiliser and fungicide treatment on Trikkala sub-clover dry matter production at Craneford.

Treatment	**Dry matter (gms/0.5m row)**	
	105 DAS- 09/09/15	**152 DAS- 26/10/15**
Nil	1.87 ab	19.46
Superphosphate	1.81 ab	19.72
Complete Fertiliser	2.39 c	15.96
Phosphorous acid	1.56 a	18.84
Metalaxyl	2.11 bc	20.46
Metalaxyl+Iprodione	1.93 abc	15.54
Lsd (P<0.05)	**0.513**	**ns**

Values in columns not followed by the same common letter differ significantly.

4.4 Experiment 4: Inoculants

4.4.1 Moculta

Inoculant treatment had no significant effect on sub-clover dry matter production at 43, 69, 115 (Table 20) or 127 DAS (Table 21). It also had no significant effect on plant nodulation at 69 DAS (Table 21).

Table 20: Effect of inoculant treatment on Clare sub-clover dry matter production at Moculta.

Treatment	**Dry matter (1-5 rating)**		
	43 DAS- 09/07/15	**69 DAS- 04/08/15**	**115 DAS- 19/09/15**
Nil	3.17	3.00	2.67
Nodulaid	3.67	3.60	3.80
Alosca	3.00	3.00	3.33
Lsd (P<0.05)	**ns**	**ns**	**ns**

Table 21: Effect of inoculant treatment on Clare sub-clover dry matter production and plant nodulation at Moculta.

Treatment	**Dry matter (gms/1.0m row) 127 DAS- 01/10/15**	**Plant nodulation (0-8 rating) 69 DAS- 04/08/15**
Nil	49.67	3.13
Nodulaid	56.20	3.07
Alosca	51.33	3.30
Lsd (P<0.05)	**ns**	**ns**

4.4.2 Craneford

The Nil treatment produced significantly greater dry matter than Nodulaid at 43 DAS, however there were no differences between treatments at 71, 105 (Table 22) and 152 DAS (Table 23). Inoculant treatment had no significant effect on plant nodulation 71 DAS (Table 23).

Table 22: Effect of inoculant treatment on Trikkala sub-clover dry matter production at Craneford.

Treatment	Dry matter (1-5 rating)		
	43 DAS- 09/07/15	**71 DAS- 06/08/15**	**105 DAS- 09/09/15**
Nil	3.82 b	3.18	3.27
Nodulaid	2.62 a	2.77	2.95
Alosca	2.82 ab	2.35	2.44
Lsd (P<0.05)	**1.166**	**ns**	**ns**

Values in columns not followed by the same common letter differ significantly.

Table 23: Effect of inoculant treatment on Trikkala sub-clover dry matter production and plant nodulation at Craneford.

Treatment	Dry matter (gms/1.0m row) 152 DAS- 26/10/15	Plant nodulation (0-8 rating) 71 DAS- 06/08/15
Nil	22.98	3.17
Nodulaid	22.29	3.07
Alosca	20.69	3.10
Lsd (P<0.05)	**ns**	**ns**

4.5 Experiment 5: Fungicides

4.5.1 Moculta

Phosphorous acid (foliar treatment), Metalaxyl and DMS (seed treatments) had no significant affect on sub-clover plant emergence or establishment (Table 24). They also had no significant affect on sub-clover dry matter production at 50, 92 and 127 DAS (Table 25).

Table 24: Effect of fungicide treatment on Clare sub-clover plant emergence and establishment at Moculta.

Treatment	Plant emergence (nos./1.0m row) 14 DAS- 14/06/16	Plant establishment (nos./1.0m row) 28 DAS- 28/06/16
Nil	89.3	83.7
Phosphorous acid	87.2	81.8
Metalaxyl	89.9	85.1
DMS	86.9	80.9
Lsd (P<0.05)	**ns**	**ns**

Table 25: Effect of fungicide treatment on Clare sub-clover dry matter production at Moculta.

Treatment	Dry matter		
	(1-5 rating) 50 DAS- 20/07/16	**(1-5 rating) 92 DAS- 31/08/16**	**(gms/1.0m row) 127 DAS- 05/10/16**
Nil	3.3	3.1	159.5
Phosphorous acid	2.9	2.5	157.0
Metalaxyl	3.2	3.0	160.6
DMS	3.1	3.3	173.3
Lsd (P<0.05)	**ns**	**ns**	**ns**

4.5.2 Craneford

Fungicide treatment had no significant affect on sub-clover plant emergence or establishment (Table 26). The fungicides also had no significant affect on sub-clover dry matter production at 50, 92 and 148 DAS (Table 27).

Table 26: Effect of fungicide treatment on Trikkala sub-clover plant emergence and establishment at Craneford.

Treatment	**Plant emergence (nos./1.0m row) 14 DAS- 14/06/16**	**Plant establishment (nos./1.0m row) 28 DAS- 28/06/16**
Nil	76.5	79.5
Phosphorous acid	73.7	78.9
Metalaxyl	74.5	79.9
DMS	73.0	79.8
Lsd (P<0.05)	**ns**	**ns**

Table 27: Effect of fungicide treatment on Trikkala sub-clover dry matter production at Craneford.

Treatment	**Dry matter**		
	(1-5 rating) 50 DAS- 20/07/16	**(1-5 rating) 92 DAS- 31/08/16**	**(gms/1.0m row) 148 DAS- 26/10/16**
Nil	3.2	3.1	46.1
Phosphorous acid	2.9	3.2	49.9
Metalaxyl	3.0	3.3	50.8
DMS	3.0	3.0	46.0
Lsd (P<0.05)	**ns**	**ns**	**ns**

4.6 Experiment 6: Fertilisers

4.6.1 Moculta

Fertiliser treatment had no significant affect on total pasture (i.e. sub-clover+grass) dry matter production as assessed in late June and mid July (Table 28).

Table 28: Effect of fertiliser treatment on total pasture (sub-clover+grass) dry matter production at Moculta

Treatment	Dry matter[A]	
	(1-5 rating) 28/06/16	($gms/0.3m^2$) 20/07/16
Nil	3.0	48.0
Superphosphate	2.5	43.8
Complete fertiliser	3.0	45.3
Superphosphate+DAP	3.0	48.3
Urea	3.8	43.5
Sulphate of Ammonia	3.0	47.8
Lsd (P<0.05)	**ns**	**ns**

[A]In June-July 2017 the trial site was dominated by barley grass and silver grass. On average the plots contained approximately 5% sub-clover.

In late August a dry matter cut was undertaken with the contents being sorted into sub-clover and grass before being oven-dried and weighed. Fertiliser treatment had no significant affect on sub-clover, grass, or total pasture production (Table 29, Figure 2).

Table 29: Effect of fertiliser treatment on sub-clover, grass and total pasture (i.e. sub-clover+grass) dry matter production at Moculta.

Treatment	Dry matter ($gms/0.3m^2$) 31/08/16		
	Sub-clover	Grass	Sub-clover+grass
Nil	6.67	24.67	31.3
Superphosphate	6.0	29.0	35.0
Complete fertiliser	11.3	28.7	40.0
Superphosphate+DAP	7.3	23.7	31.0
Urea	10.3	28.7	39.0
Sulphate of Ammonia	7.0	26.0	33.0
Lsd (P<0.05)[A]	**ns**	**ns**	**ns**

[A]Statistical analysis conducted across three reps (instead of four) as the plots in rep four had insufficient sub-clover to sample.

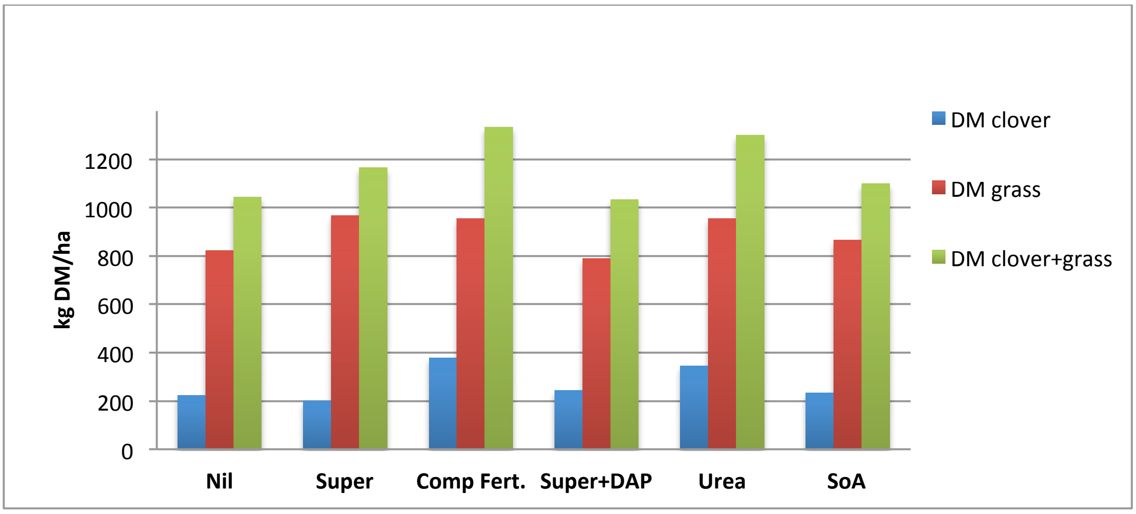

Figure 2: Effect of fertiliser treatment on sub-clover, grass and total pasture (i.e. sub-clover+grass) dry matter production on 31/08/16 at Moculta.

4.6.2 Craneford

The Superphosphate and Complete fertiliser treatments produced significantly more total (i.e. sub-clover+grass) dry matter than the Nil treatment when assessed in late June (Table 30). An assessment in mid July determined these two treatments and Superphosphate+DAP produced significantly more dry matter than the Nil treatment (Table 30).

Table 30: Effect of fertiliser treatment on total pasture (sub-clover+grass) dry matter production at Craneford.

Treatment	**Dry matter[A]**	
	(1-5 rating) 28/06/16	**(gms/0.2m^2) 20/07/16**
Nil	1.75 a	12.0 a
Superphosphate	3.50 b	22.5 b
Complete fertiliser	3.50 b	22.5 b
Superphosphate+DAP	3.00 ab	19.3 b
Urea	2.50 ab	16.5 ab
Sulphate of Ammonia	2.25 ab	16.0 ab
Lsd (P<0.05)	**1.44**	**7.17**

Values in columns not followed by the same common letter differ significantly.
[A]In June and July 2017 the trial plots were dominated by phalaris and to a lesser extent annual grasses. On average the plots contained approximately 5-10% sub-clover.

In late August a dry matter cut was undertaken with the contents sorted into sub-clover and grass before being dried and weighed. Compared to the Nil treatment, Superphosphate significantly increased the sub-clover component of the pasture by 112% (Table 31, Figure 3), while the Superphosphate+DAP treatment significantly increased the grass component (Table 31, Figure 4). The three phosphorous based fertiliser treatments; Superphosphate, Complete fertiliser and Superphosphate+DAP increased total pasture (i.e. sub-clover+grass) production by 116, 108 and 92% respectively (Table 31, Figure 5).

Table 31: Effect of fertiliser treatment on sub-clover, grass and total pasture (i.e. sub-clover+grass) dry matter production at Craneford.

Treatment	**Dry matter (gms/0.2m^2) 31/08/16**		
	Sub-clover	Grass	Sub-clover+grass
Nil	4.25 a	2.0 a	6.25 a
Superphosphate	9.00 b	4.5 ab	13.50 b
Complete fertiliser	8.00 ab	5.0 ab	13.00 b
Superphosphate+DAP	5.00 ab	7.0 b	12.00 b
Urea	3.75 a	6.5 ab	10.25 ab
Sulphate of Ammonia	6.75 ab	5.00 ab	11.75 ab
Lsd (P<0.05)	**4.32**	**4.74**	**5.52**

Values in columns not followed by the same common letter differ significantly.

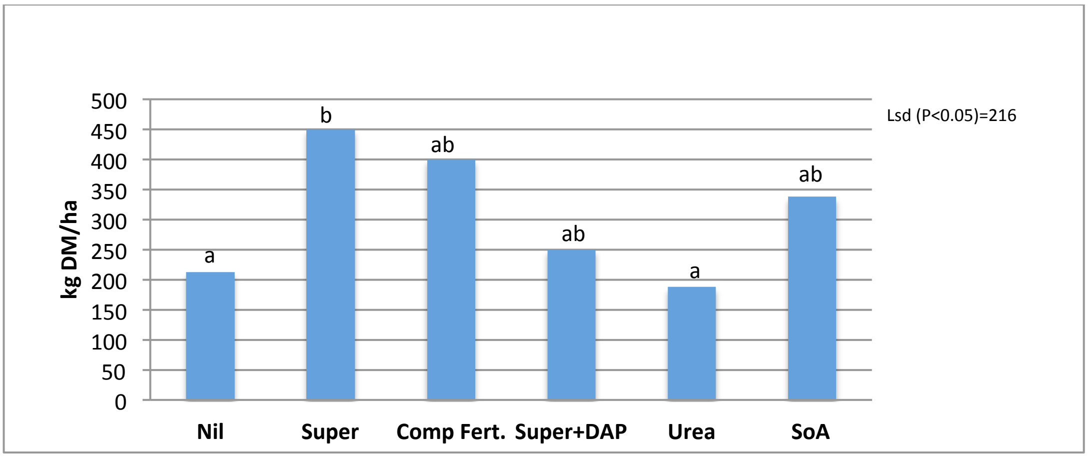

Figure 3: Effect of fertiliser treatment on the sub-clover dry matter component of the pasture (kg/ha) on 31/08/16 at Craneford.

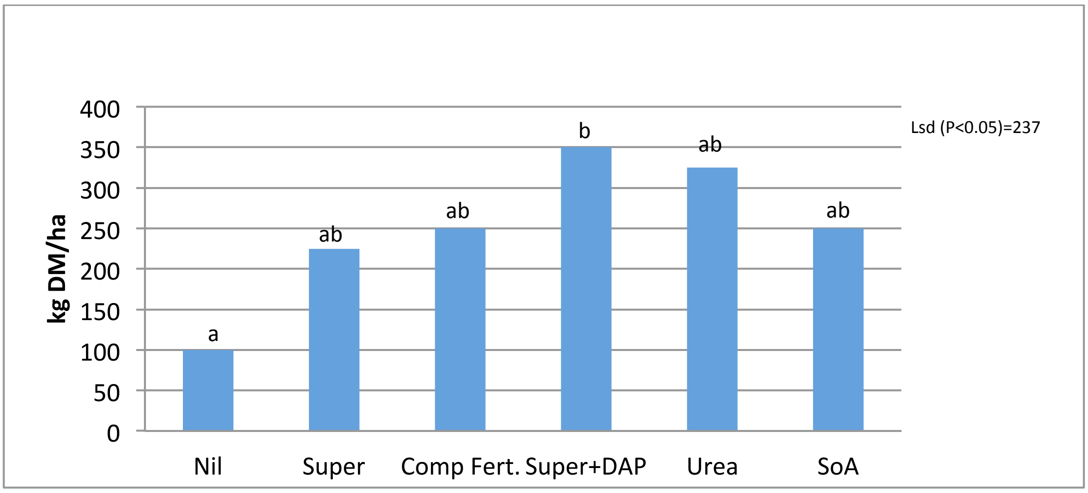

Figure 4: Effect of fertiliser treatment on the grass dry matter component of the pasture (kg/ha) on 31/08/16 at Craneford.

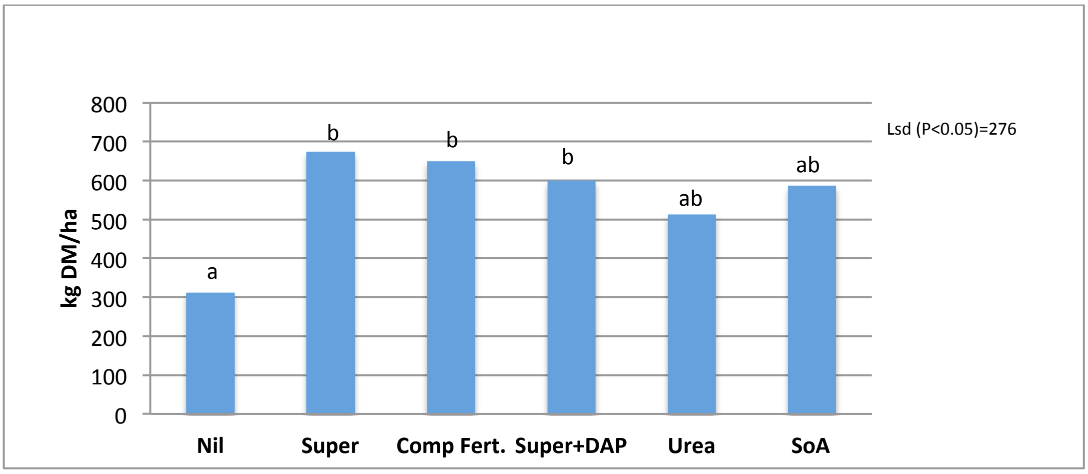

Figure 5: Effect of fertiliser treatment on total pasture (i.e. sub-clover+grass) dry matter production (kg/ha) on 31/08/16 at Craneford.

4.7 Extension and communication

Numerous planning, extension and communication activities were undertaken throughout the project. An initial planning meeting was held with the projects research partner, UWA's Professor Martin Barbetti on 23/01/14, while annual review meetings were held on 29/01/15 and 01/02/16 with UWA and the MFMG. All these meetings included a core group of BIGG producers. A final review meeting was held on 09/11/16 to discuss the projects results and involved representatives from MLA, UWA, MFMG and BIGG.

A total of six 'pasture walks' engaged 127 participants (producers and industry representatives) throughout the project. Twenty articles were published (including articles published in MLA's Friday Feedback and Feedback magazine) and a dedicated project webpage was set up and actively maintained on the BIGG website. The projects extension and communication activities are summarised in Table 32.

Table 32: The extension and communication activities delivered during the project.

Date	Activity	Number of people
May 2014	Article in BIGG monthly newsletter	Circulation 200
July 2014	Trial site visit by producer group members	6
August 2014	Article in BIGG monthly newsletter	Circulation 220
September 2014	Pasture walk (Eden Valley trial site)	22
February 2015	Article in BIGG monthly newsletter	Circulation 240
June 2015	Article in BIGG monthly newsletter	Circulation 250
September 2015	Article in BIGG monthly newsletter	Circulation 250
September 2015	Article in The Leader (local newspaper)	Circulation 8,000
September 2015	Article in The Stock Journal (state rural paper)	Circulation 12,000
September 2015	Pasture walk (Moculta trial site)	40
October 2015	Pasture walk (Craneford trial site)	14
October 2015	Article in BIGG monthly newsletter	Circulation 260
October 2015	Article in The Leader	Circulation 8,000
November 2015	Article in The Stock Journal	Circulation 12,000
November 2015	Article in MLA's Friday Feedback	Circulation 23,000
July 2016	Article in BIGG monthly newsletter	Circulation 280
September 2016	Article in BIGG monthly newsletter	Circulation 280
September 2016	Article in The Leader (x2)	Circulation 8,000
September 2016	Pasture walk (Moculta trial site)	29
October 2016	Pasture walk (Craneford trial site)	16
October 2016	Article in BIGG monthly newsletter	Circulation 280
November 2016	Article in BIGG monthly newsletter	Circulation 280
November 2016	Article in The Leader (x2)	Circulation 8,000
March 2017	Article in MLA's Feedback Magazine	Circulation 44,000

BIGG was also a co-author on a scientific paper published in February 2017 by UWA on the extent and severity of soil borne root diseases in southern Australia sub-clover pastures.

5 Discussion

5.1 Research objectives

The projects research objectives were addressed through conducting small plot field experiments that focussed on evaluating management strategies that may reduce the impact of root diseases in sub-clover to improve their winter productivity. The key outcomes against the projects objectives are summarised in Table 33.

Table 33: The objectives and key outcomes of the project.

PRS Objective	Outcome
1. Determine the effect of soil borne root disease on winter sub-clover production	This objective was specifically addressed by conducting an experiment (1) to determine the winter production of three sub-clover varieties, with and without Metalaxyl fungicide seed treatment. The results from this experiment, including others where fungicides were also assessed (experiments 3, 5) suggest that soil borne diseases did not affect winter sub-clover production of the test varieties evaluated (Clare, Trikkala, Woogenellup).
2. Determine the effect of soil borne root disease on sub-clover regeneration	This objective was not fulfilled, as the relevant experiment (2) was discontinued due to the high background sub-clover population infesting the Eden Valley research site. This highlighted the importance of controlling sub-clover seed set in the year(s) prior to conducting a multi-year sub-clover regeneration experiment.
3. Determine cost-effective management strategies to reduce the impact of soil borne root disease in sub-clovers to improve their production	This objective was addressed by evaluating fungicides (experiment 1, 3, 5), fertilisers (experiments 3, 6) and inoculants (experiment 4) as potential management options. Fungicide (seed and foliar) treatment did not improve sub-clover production and as such its use would not be currently recommended locally, particularly if Clare or Trikkala were being sown or predominate. Likewise, Group C inoculant application (at the sub-clover cotyledon stage) had no affect on sub-clover production. Application of the two phosphorous-based fertilisers, Superphosphate and or Complete Fertiliser significantly improved winter/early spring sub-clover production by 28-112% at sites with marginal soil phosphorus levels (<21 mg/kg Colwell). These results highlighted the importance of producers knowing the soil nutrition status of their paddocks and the benefit of maintaining soil nutrients (particularly phosphorous) at adequate levels.

Objectives 1 and 2 of the project directly align with experiments 1 and 2 respectively and in this section are discussed under the headings:

- Winter sub-clover production
- Sub-clover regeneration

Objective 3 cuts across several experiments (1, 3-6) and is discussed under the headings:

- Effect of fungicide use
- Effect of fertiliser use
- Effect of inoculant use

5.1.1 Winter sub-clover production

Experiment 1 was undertaken at two sites (Moculta, Eden, Valley) to determine the effect of the fungicide seed treatment, Metalaxyl on winter production of the sub-clover varieties Clare, Trikkala and Woogenellup.

At both sites, dry matter production was very low throughout the growing season meaning assessments were only undertaken later in the season (August and September at Moculta, October at Eden Valley). For all assessments, none of the varieties showed a positive production response to Metalaxyl seed treatment (Table 10, Table 13). Therefore it may be assumed that soil borne diseases did not affect sub-clover production. However, the diseases *Pythium, Phytophthora* and *Rhizoctonia* were present at levels expected to compromise pasture production at both trial sites (Table 3) and given that Metalaxyl has activity only on *Pythium and Phytophthora*, the pathogen *Rhizoctonia* may have impacted sub-clover productivity.

The poor dry matter production at both sites was caused by the initial high pest pressure (black-headed pasture cockchafer and wireworms), that resulted in low and variable sub-clover plant numbers. In addition, both sites received well below average rainfall in late winter/spring, therefore significantly reducing the potential for pasture production in spring.

Apart from dry matter production, Metalaxyl had no affect on plant emergence or plant establishment for any varieties, except Trikkala where plant numbers were reduced at the Moculta site (Table 9).

Apart from experiment 1, alternative fungicide experiments (3, 5) were conducted that align with project objective 1. The results of these experiments are discussed in 5.1.3.

5.1.2 Sub-clover regeneration

Experiment 2 was undertaken at Eden Valley to determine the effect of sub-clover variety (Clare, Trikkala, Woogenellup) on sub-clover regeneration. This experiment was to be undertaken over a three-year period, however as a large background sub-clover population infested the trial site in 2015, it was discontinued after consultation with UWA and MLA. This variation is reflected in the variation deed for the project signed off by MLA in November 2015.

Given experiment 2 was terminated, the related project objective (2) was not fulfilled. At the start of the experiment the expected findings were that Woogenellup, being highly susceptible to soil borne root diseases would not perform as well as Clare and Trikkala over the three-year period. Clare and Trikkala are varieties that are considered to do well in the local area and anecdotal evidence during the project found that in-particular Clare performed particularly well. Clare was the test sub-clover variety used at the Moculta research site in 2015 and 2016 (experiments 3, 4, 5) and relative to other varieties evaluated in separate UWA trials at the same site; its productivity was considered very good (M. Barbetti pers.

comm.). In addition, Trikkala is a variety that is thought to have some resistance to soil borne root diseases.

Although experiment 2 was not completed, it did highlight the need to control any background sub-clover population in the year(s) prior to conducting sub-clover regeneration experiments. Alternatively the experiment could have been conducted on a site that had no existing sub-clover population.

5.1.3 Effect of fungicide use

Three experiments were conducted at various sites during the project to determine the effect of fungicide management on winter production of sub-clover in the presence of soil borne root diseases. The fungicide treatments evaluated in 2014-16 are listed in Table 34 and in all experiments no fungicide improved Clare or Trikkala sub-clover production (compared to the Nil treatment) (4.1, 4.3, 4.5). These results were consistent across research sites and years. For example, Metalaxyl was assessed as a seed treatment at four sites between 2014-16 and Phosphorus acid as a foliar application at two sites in 2015 and 2016.

Table 34: Fungicides evaluated during the projects experiments.

Experiment	Research site/paddock	Fungicides evaluated
1 (2014)	Moculta: Long Johns Eden Valley: Rock	- Metalaxyl (Apron®XL) seed treatment
3 (2015)	Moculta: Creek Craneford: South Phalaris	- Phosphorus acid (Agri-Fos® 600) foliar treatment - Metalaxyl seed treatment - Metalaxyl+Iprodione (Apron®XL+Rovral®) seed treatment
5 (2016)	Moculta: Creek Craneford: South Phalaris	- Phosphorus acid foliar treatment - Metalaxyl seed treatment - Difenoconazole+Metlaxyl+Sedexane seed treatment (Vibrance®)

While the fungicides evaluated in these experiments did not improve sub-clover production, this highlights that fungicide management is difficult. Soil borne root diseases in pastures usually occur as complexes of two to four key pathogens (*Pythium, Phytophthora, Rhizoctonia, Aphanomyces*) and there are no fungicides registered for use in sub-clover that are effective on all four diseases.

Each of the projects research sites comprised at least three diseases at levels expected to compromise pasture production (Table 3) hence this may explain why none of the fungicides improved sub-clover production, even in the presence of soil borne root diseases. Alternatively, the test varieties used in most experiments; Clare and Trikkala may have exhibited some tolerance/resistance to root diseases, therefore mitigating their impact. This also highlights the importance of knowing the disease status of varieties.

Fungicide use is considered to have variable success, however the lack of a response to fungicide application for these experiments contrasts with research conducted by UWA, which has found that seed or foliar treatment can increase sub-clover germination and survival by up to 30% (M. Barbetti pers. comm.).

Apart from measuring dry matter production, the fungicide treatments were assessed for sub-clover plant emergence (approximately two weeks after sowing) and plant establishment (approximately four weeks after sowing). Across all experiments, fungicide treatment rarely affected either (see 4.1, 4.3, 4.5).

5.1.4 Effect of fertiliser use

Two experiments (experiments 3 and 6) were undertaken at several sites to determine the effect of fertiliser treatment on winter sub-clover production in the presence of soil borne root diseases. The results from these experiments demonstrated that the two phosphorous-based fertilisers, Superphosphate and Complete Fertiliser generally improved winter/early spring sub-clover production at sites with marginal soil phosphorus (Moculta's Creek paddock, 21 mg/kg Colwell P and Craneford's South Phalaris paddock, 17 mg/kg Colwell P). In addition to these treatments, Superphosphate+DAP (the other phosphorous-based fertiliser evaluated in experiment 6) was found to also increase total pasture (i.e. sub-clover+grass) dry matter production at the Craneford site.

In **experiment 3**, two fertilisers were evaluated for their effect on winter sub-clover production. At Moculta, Superphosphate increased sub-clover production by 39% and Complete fertiliser by 31% (compared to the Nil treatment) in early August (69 DAS) (Table 15). At Craneford, Complete fertiliser increased production by 28% in early September (105 DAS) while Superphosphate did not improve production (Table 19).

As both Superphosphate and Complete fertiliser were applied at the same phosphorous rate (13.2 kg/ha), Complete fertiliser may have addressed a particular nutrient deficiency given it comprises several micronutrients (Table 4).

At both Moculta and Craneford there were no sub-clover production differences between the fertiliser treatments and the Nil treatment later in the season (early October for Moculta, late October for Craneford) (Table 16, Table 19). This may be attributed to the particularly dry finish in 2015, as both sites received well below average rainfall in September and October.

In **experiment 6**, five fertiliser treatments were evaluated for their effect on regenerated winter sub-clover production. Three fertilisers were phosphorous based (Superphosphate, Complete fertiliser, Superphosphate+DAP) and two-nitrogen based (Urea, Sulphate of Ammonia). Their application rates ensured either equivalent phosphorous or nitrogen units were applied (Table 7).

At Moculta (Hill paddock, 36 mg/kg Colwell P), fertiliser treatment had no affect on total pasture (i.e. sub-clover+grass) dry matter production in late June, mid July (Table 28) and late August (Table 29, Figure 2). In addition, fertiliser application had no production impact on the sub-clover component of the pasture when assessed in late August (Table 29).

The lack of a statistically significant response to fertiliser application at Moculta during winter may be due to the site's adequate phosphorous levels. In addition, the uneven sub-clover and grass plant numbers across the research site caused a high variability within treatments, which reduced the prospect for any statistically significant results. This was exacerbated in the late August assessment as production data could only be collected from three of the four trial replicates (replicate four had a lack of sub-clover plant numbers).

At Craneford (South Phalaris paddock, 17 mg/kg Colwell P), a positive production response to fertiliser treatment was demonstrated. Total pasture (i.e. sub-clover+grass) dry matter production assessments in late June and mid July demonstrated that the three phosphorus-based fertilisers: Superphosphate, Complete fertiliser and Superphosphate+DAP were the best performing (Table 30). In mid July, Superphosphate, Complete fertiliser and Superphosphate+DAP significantly increased total pasture dry matter production by 87, 87 and 61% respectively (compared to the Nil treatment) (Table 30).

At the next assessment (late August), Superphosphate was the only fertiliser treatment to significantly increase sub-clover production (by 112%) (Table 31, Figure 3). At the same assessment timing, the Superphosphate, Complete fertiliser and Superphosphate+DAP treatments approximately doubled total pasture (i.e. sub-clover+grass) production (Table 31, Figure 5). The positive responses to fertiliser application in experiment 6 at Craneford may be attributed to the sites marginal phosphorus level (17 mg/kg Colwell P).

The results from the experiments conducted on the marginal phosphorous sites (experiment 3: Moculta and Cranford, experiment 6: Cranford) highlights the importance of producers knowing the soil nutrition status of their paddocks and the benefit of maintaining soil nutrients at adequate levels (particularly phosphorus); irrespective of the presence of root diseases.

Adequate soil nutrition is considered to help limit the impact of root disease as sub-clover shoot productivity can be increased by up to 1.5 fold (M. Barbetti pers. comm.). This is not unexpected as healthy plants can better tolerate stresses such as root diseases. However, from these experiments it is unable to be substantiated if the positive fertiliser response on marginal phosphorous sites is solely due to improved soil fertility or if the additional nutrition also helped reduce the impact of the root diseases.

5.1.5 Effect of inoculant use

Experiment 4 was undertaken at two sites (Moculta, Craneford) to determine the effect of post emergent inoculant application on winter sub-clover production in the presence of soil borne root diseases. The two-inoculant treatments, Nodulaid (peat inoculant sprayed on the soil surface) and Alosca (granular inoculant spread on the soil surface) were applied to sub-clover plants at the cotyledon stage in mid June. At both sites, neither inoculant improved sub-clover dry matter production (assessed July-October) or sub-clover plant nodulation (assessed early August), compared to the Nil treatment (see 4.4).

The lack of a response to inoculant application at both sites may be due to their marginal soil phosphorous levels (21 and 17 mg/kg at Moculta and Craneford respectively), which could have limited the potential for a positive response to inoculation. Alternatively, it may be due to the existing presence of Group C bacteria at both sites. This is based on an Australia wide survey conducted by Murdoch University (Dr Sofie De Meyer), which in August 2015 tested the quality and strain of rhizobia sub-clover nodules from the Nil treatment of both sites.

This rhizobia study found that the nodules from the Moculta sub-clover plants had medium-good quality bacteria and were categorised as the 'Group C inoculant' group (i.e. identified as closely related to the currently used sub-clover commercial inoculant). The nodules collected from Craneford had good quality bacteria and were categorised as the 'Group C inoculant' and 'Old inoculant' group (i.e. identified as closely related to previously used sub-clover inoculants).

Given that there was no response to post emergent inoculation at the cotyledon stage, its application is not recommended for use in local regenerated pastures. However, prior to sowing a new pasture it is highly recommended that producers apply a Group C peat inoculant to sub-clover seed (if it has not already been pre-coated already).

5.2 The value of the research results (benefits/costs)

Of the three management strategies (fungicides, inoculants and fertilisers) evaluated in this project, fertiliser application was the only option that improved sub-clover production. Hence economic analysis in this section is based only on the research findings from the fertiliser experiments.

5.2.1 Benefits

Phosphorous fertiliser application significantly increased sub-clover production in winter/early spring in three of the four-fertiliser trials conducted for this project. The treatments from these trials are summarised in Table 35.

Table 35: Fertiliser treatments that significantly improved winter/early spring sub-clover production in experiments 3 and 6.

Experiment	Research site/ paddock	Treatment	Sub-clover production increase (%)[A]	Assessment timing
3	Moculta: Creek	Superphosphate Complete Fertiliser	39 31	04/08/15 (69 DAS) 04/08/15 (69 DAS)
3	Craneford: South Phalaris	Complete Fertiliser	28	09/09/15 (105 DAS)
6	Moculta: Hill	-	-	-
6	Craneford: South Phalaris	Superphosphate	112	31/08/16 (regenerated pasture)

[A]Statistically significant compared to the Nil treatment.

Filling the winter feed gap is a universal issue across southern Australian grazing systems and these trials demonstrate that phosphorous fertiliser application can help fill this feed gap in local grazing systems. Other benefits of increasing sub-clover production include; better quality feed with higher digestibility, increased ground cover and increased nitrogen fixation (which benefits both the growth of other pasture species and subsequent crops if in a mixed farming system). In addition, increased quantity and quality of pasture translates into increased condition score of livestock and potentially increased stock carrying capacity.

5.2.2 Costs to achieve outcomes and cost benefit analysis

Experiment 6 at Craneford was conducted in regenerated pasture and determined that fertiliser application (Superphosphate) significantly improved sub-clover dry matter production. Using the production results from the late August assessment (Table 31, Figure

3) and the input costs of the fertilisers (Table 36), economic analysis can be conducted comparing the profitability of each fertiliser treatment.

Table 36: Input costs of the fertilisers evaluated in experiment 6.

Fertiliser[A]	Product cost ($/ha)	Freight ($/ha)[C]	Spreading ($/ha)	Total input costs ($/ha)
Superphosphate - 150kg/ha @ $330/t	49.50	3.00	12.00	64.50
Complete fertiliser - 200kg/ha @ $650/t	130.00	4.00	12.00	146.00
Superphosphate+DAP - 99.5kg/ha @ $438/t[B]	43.58	1.99	12.00	57.57
Urea - 40kg/ha @ $400/t	16.00	0.80	12.00	28.80
Sulphate of Ammonia - 87.5kg/ha @ $380/t	33.25	1.75	12.00	47.00

[A]Fertiliser prices are bulk ex-works (ex GST) and current at July 2017.
[B]Based on a 60/40 mix of Superphosphate ($330/t) and DAP ($600/t).
[C]Freight based on a cost of $20/t.

Economic analysis determined that although Superphosphate achieved the highest sub-clover dry matter production, its cost to produce a kg of dry matter (14.3 cents) was similar to the Urea and Sulphate of Ammonia treatments (Table 37). This is largely due to the lower input costs of these treatments, particularly Urea. However, it needs to be considered that Superphosphate was the only fertiliser treatment to statistically improve sub-clover production. In addition, this analysis was conducted on the production results for a single season. Given superphosphate is a product that is phosphorous based it is likely to provide a residual fertility affect and improve production in subsequent years compared to the nitrogen based fertilisers.

Table 37: Fertiliser cost effectiveness based on sub-clover dry matter production data measured on 31/08/16 for experiment 6 at Craneford.

Fertiliser	Total input costs ($/ha)	Sub-clover dry matter (kg/ha)	Cost effectiveness (c/kg DM/ha)
Nil	-	212.5 ab	-
Superphosphate @ 150kg/ha	64.50	450.0 b	14.3
Complete fertiliser @ 200kg/ha	146.00	400.0 ab	36.5
Superphosphate+DAP @ 99.5kg/ha	57.57	250.0 ab	23.0
Urea @ 40kg/ha	28.80	187.5 a	15.4
Sulphate of Ammonia @ 87.5kg/ha	47.00	337.5 ab	13.0
Lsd (P<0.05)	-	**216.0**	-

Values in columns not followed by the same common letter differ significantly.

In experiment 6 at Craneford, total pasture (i.e. sub-clover+grass) dry matter production was also determined in late August, with the three phosphorous based fertiliser treatments; Superphosphate, Complete fertiliser and Superphosphate+DAP approximately doubling production (Table 31, Figure 5). However, apart from Complete fertiliser all treatments demonstrated a similar cost effectiveness (Table 38).

Complete fertiliser is very expensive when applied at 200kg/ha ($130/ha). It is a product that is generally used when soil micronutrient levels are deficient or low, with the expectation that there will be a four to seven year pasture production benefit (and potentially livestock health benefits). Therefore its cost would normally be spread over this time frame, rather than a single year.

Table 38: Fertiliser cost effectiveness based on total pasture (i.e. sub-clover+grass) dry matter production data measured on 31/8/16 for experiment 6 at Craneford.

Fertiliser	**Total input costs ($/ha)**	**Total pasture dry matter (kg/ha)**	**Cost effectiveness (c/kg DM/ha)**
Nil	-	312.5 a	-
Superphosphate @ 150kg/ha	64.50	675.0 b	9.6
Complete fertiliser @ 200kg/ha	146.00	650.0 b	22.5
Superphosphate+DAP @ 99.5kg/ha	57.57	600.0 b	9.6
Urea @ 40kg/ha	28.80	512.5 ab	5.6
Sulphate of Ammonia @ 87.5kg/ha	47.00	587.5 ab	8.0
Lsd (P<0.05)	-	**276.0**	-

Values in columns not followed by the same common letter differ significantly.

The economics of pasture fertiliser application are dependent on the relative price of supplementary feed (e.g. grain, hay) compared to fertiliser input costs, as well as the predicted production response (both in the current and subsequent years). However, it is generally recognised that the most profitable livestock producers grow (and utilise) as much pasture as they can, and they do this through fertiliser application.

5.2.3 Unexpected benefits

1. The experiments in this project were not specifically conducted to compare the performance of sub-clover varieties. However, Clare and Trikkala as the two test varieties used in most experiments were considered to perform well in the presence of root diseases. In particular Clare, which at Moculta was observed to have very good productivity compared with varieties being evaluated in separate UWA trials at the same site (M. Barbetti pers. comm.). Even though Clare and Trikkala are older varieties, this anecdotal evidence suggests they are ‘good local performers’. As such local producers should consider including these as part of a ‘sub-clover mix’ when pastures are re-sown, especially as they are cheaper than new varieties.

2. Several pasture walks were held throughout the project at the research sites. At two of these sites, oestrogenic sub-clover species were identified in the immediate pasture paddocks, sparking local producer interest about this issue. This culminated in one of the pasture walks having a field presentation about oestrogenic sub-clover identification and its management (presented by clover experts David Woodard, Rural Solutions SA and Kevin Foster, UWA). This was very well received and highlighted the need for producers to be able to identify clover varieties given oestrogenic types can substantially affect sheep production through reduced ewe fertility.

5.3 Promotion of research results and its effectiveness

5.3.1 Practice changes

Fungicides, inoculants and fertilisers were evaluated as management strategies in this project, however only fertiliser application increased sub-clover productivity. Judicious fertiliser application to ensure good plant nutrition is universally accepted as part of good pasture management practice, irrespective of the presence of soil borne root diseases. Rather than leading to any definitive change in local management practice, the projects results validated the importance of maintaining good soil nutrition.

On a more general note, if the project had identified additional management strategies that improved sub-clover production, this would have helped been a catalyst for practice change as well as increasing producer interest in the project.

5.3.2 Changes in knowledge, attitudes and skills

At the start of this project, local producers generally had little knowledge about soil borne root diseases in local pasture systems. Amongst the core project group members there was considered a low understanding about the affect of root diseases on production and the management strategies to mitigate their impact. This was improved through communicating the projects learning's at pasture walks, review meetings and via media articles and project group emails (4.7).

General feedback from producers at the end of the project highlighted a knowledge improvement in: the key root diseases affecting local pastures (*Rhizoctonia, Pythium, Phytophthora)*, management of root diseases (although it is difficult) and growing locally performing sub-clover varieties (even it they are older types). A byproduct of the project was improved knowledge of oestrogenic sub-clovers and skills in sub-clover variety identification (5.2.3).

5.3.3 Barriers and enablers for change

A key barrier for change is that root disease management is difficult. This is because diseases generally occur as complexes of two to four pathogens, with the severity of each being expressed under different environmental conditions (e.g. *Rhizoctonia* favours cold conditions and dry soils, and *Phytophthora* warm wet soils). In addition, producers may not readily attribute low sub-clover productivity to soil borne root diseases and given that fungicide application was ineffective in this project (including no single fungicide controls all diseases), its local uptake will be limited. As described by one producer group member, 'root disease management in pastures is a moving feast'!

Winter pasture production is a key profit driver for local grazing businesses and as such is a strong enabler for producing productive pastures. This coupled with current meat and wool returns, enhances the likelihood that producers will apply fertiliser to their pastures.

5.4 Effectiveness of the participatory research process

Throughout the projects duration, a core group of producers (approximately ten) were directly involved in the projects research direction. After discussion amongst producers, research protocols were developed for the current years experiments, which were then refined after feedback from the projects research partner, UWA (particularly experimental methodology).

Apart from discontinuing experiment 2 (sub-clover regeneration experiment, 5.1.2), the general research content changed little throughout the project. However, at the beginning of the project it was planned that in the final (third) year of experiments, larger farm scale trials would be conducted. This was essentially to prove the results from the small plot experiments in years one and two, but on a larger scale. However, given the project results were inconclusive in 2014 and 2015 (and exacerbated by the short springs in these years), the producer group thought it best to continue with small plot experiments in year three.

In 2015 and 2016 the projects experiments at the Moculta site were co-located with separate sub-clover root disease experiments being conducted by UWA. This provided significant benefits for both parties as the research being conducted complemented each other and UWA project staff (Martin Barbetti, Mingpei You, Kevin Foster) were key presenters at the Moculta pasture walks conducted in September 2015 and 2016. This included communicating the importance of cultivation prior to sowing a new pasture for increased root disease control (a strategy that was not investigated in this project but was by UWA).

UWA also added value to the project through a separate study that determined the extent and severity of soil borne root diseases in pastures nationally. In this study, local producers submitted sub-clover seedlings for testing. The results revealed that root diseases were indeed present in local pastures with many samples displaying a severe level of disease. This information helped generate interest in the project and also informed the fungicide treatments evaluated in the 2015 and 2016 experiments.

6 Conclusions/ Key Messages/ Recommendations

6.1 Conclusions

The key focus of the projects experiments was to evaluate management strategies (fungicides, fertilisers and inoculants) that may reduce the impact of root diseases and improve winter sub-clover productivity. Of these, only fertiliser application increased sub-clover production.

In the fungicide experiments, neither of the fungicides evaluated; Metalaxyl (Apron®XL), Phosphorous acid (Agri-Fos® 600), Metalaxyl+Iprodione (Apron®XL+Rovral®) or DMS (Vibrance®) improved Clare or Trikkala sub-clover dry matter production. Of these, Metalaxyl (as a seed treatment) and Phosphorous acid (as a foliar treatment) are registered for use in sub-clover, however based on the projects results their use would not be currently recommended locally, particularly if Clare or Trikkala were being sown or predominate in existing local pastures. The lack of a positive response to fungicide application suggests that both these varieties may also perform well in the presence of root diseases.

In the inoculant experiments, neither of the Group C inoculants, Nodulaid® (peat inoculant) and Alosca (granular inoculant) improved sub-clover dry matter production or plant nodulation when applied to plants at the cotyledon stage. As such, its application at this timing in regenerated sub-clover pastures is not recommended.

In the fertiliser experiments, up to five treatments (Superphosphate, Complete Fertiliser, Superphosphate+DAP, Urea and Sulphate of Ammonia) were evaluated across four trials. Superphosphate and or Complete Fertiliser significantly improved sub-clover production in winter/early spring by 28-112% at the sites with marginal soil phosphorus levels (<21 mg/kg Colwell). These results highlighted the importance of producers knowing the soil nutrition status of their paddocks and the benefit of maintaining soil nutrients (particularly phosphorous) at adequate levels.

6.2 Key Messages

Based on the outcomes of this project, the key messages are:

- Soil borne root are present in local pasture systems, with these generally occurring as complexes of two to four pathogens.
- There is no ‘silver bullet’ for managing root diseases in local pasture systems. This is not unexpected as several diseases usually occur together, with their type and severity changing due to various environmental factors (e.g. temperature, soil moisture).
- Fungicide application in local pasture systems will not guarantee a positive production response.
- Phosphorous fertiliser application generally improved winter/early spring sub-clover winter production at trial sites with marginal soil phosphorus. This practice makes good agronomic sense, irrespective of the presence of root diseases.
- Observations of the sub-clover varieties, Clare and Trikkala suggest they performed well in the presence soil borne root diseases.

6.3 Recommendations

The key producer and research recommendations from this project are:

- Producers need to maintain good soil nutrient levels (particularly phosphorous) to enhance sub-clover winter production.
- If producers were considering applying a fungicide treatment on regenerated pastures (e.g. Phosphorous acid), rather than spraying the whole paddock first spray a test strip to determine the level of response.
- When sowing a new pasture, producers should use a mix of sub-clover varieties and choose varieties that perform well locally to help mitigate the effects of root diseases.
- Improved knowledge on the root disease tolerance/resistant status of sub-clover varieties will significantly help inform variety choice.
- Before conducting any multi-year sub-clover regeneration experiment, control sub-clover seed set at least two years prior to the experiment or select a ‘sub-clover free’ site.

7 Acknowledgements

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- John Squires and Dee Heinjus, Rural Directions as state coordinators for the PRS program

8 Appendix

Table 39: Full soil analysis results for each of the projects research sites.

	[A]Moculta: Long Johns	[A]Eden Valley: Rock	[B]Craneford: South Phalaris	[B]Moculta: Creek	[C]Moculta: Hill
Ammonium Nitrogen (mg/Kg)	2	12	6	13	10
Nitrate Nitrogen (mg/Kg)	36	43	30	32	53
Phosphorus Colwell (mg/Kg)	38	29	17	21	36
Potassium Colwell (mg/Kg)	416	283	244	468	577
Sulphur (mg/Kg)	4.8	4.2	7.1	10.1	8.7
Organic Carbon (%)	2.4	2.91	2.3	2.47	2.7
Conductivity (dS/m)	0.11	0.099	0.136	0.116	0.098
pH Level ($CaCl_2$)	5.7	4.6	5.7	5.2	5.1
pH Level (H_2O)	6.5	5.2	6.4	6.2	6.0
DTPA Copper (mg/Kg)	1.17	0.54	0.32	1.40	1.41
DTPA Iron (mg/Kg)	87.97	297.82	182.13	387.02	166.72
DTPA Manganese (mg/Kg)	7.04	20.04	16.11	27.94	47.90
DTPA Zinc (mg/Kg)	8.05	1.39	2.06	1.79	3.55
Exc. Aluminium (meq/100g)	0.07	0.271	0.096	0.078	0.038
Exc. Calcium (meq/100g)	8.52	3.22	5.07	5.39	5.85
Exc. Magnesium (meq/100g)	0.92	0.99	1.1	0.96	0.97
Exc. Potassium (meq/100g)	0.81	0.48	0.51	1.17	1.42
Exc. Sodium (meq/100g)	0.19	0.15	0.27	0.43	0.21
Boron Hot $CaCl_2$ (mg/Kg)	0.83	0.44	0.54	0.68	0.88

Soil sample collected on [A]22/03/14, [B]14/03/15 and [C]23/02/16 and assessed by CSBP.

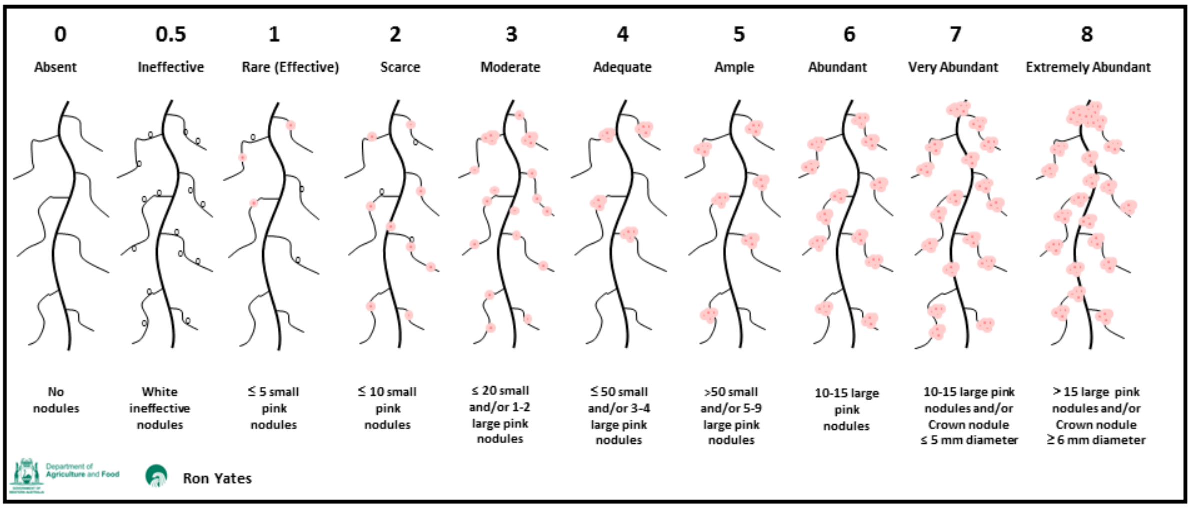

Figure 6: Yates scale (0-8) used to assess plant nodulation in Experiment 4.