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Project Code	
Project Type	

FINAL REPORT 2019

PROJECT CODE :	S716

PROJECT TITLE
Optimising legume inoculation for dry sowing

PROJECT DURATION

Project Start date	1 July 2016					
Project End date	30 June 2019					
SAGIT Funding Request	2019/20	$	2020/21	$	2021/22	$

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PROJECT REPORT

Executive Summary

<u>Optimising inoculation for dry sown legumes.</u>
Dry sowing legumes allows growers to better manage time demands around sowing, ensure successful early establishment of crops and reduce yield losses in dry springs.

SAGIT project S217 evaluated a range of inoculant formulations, application strategies and sowing times in order to provide industry with recommendations that optimise nodulation and nitrogen fixation for a range of pulse crops, when dry sown.

<u>Key Findings</u>
Where sowing pulses on inoculation-responsive paddocks with low or no suitable rhizobia present in the soil:

- Standard inoculation practises (peat slurry applied to seed at recommended rate) are unlikely to deliver satisfactory nodulation following dry sowing* where there are extended dry conditions (> 7 days) and/or additional stresses to rhizobia survival such as low soil pH (<5.5 Ca).

- The higher the number of rhizobia applied on seed or in the soil when dry sowing, the greater the likelihood sufficient rhizobia will be present when germinating rains occur.

    - Trials with bean, lupin and chickpea have shown products with the highest number of rhizobia generally resulted in the most nodulation and production.

    - For peat slurry applied to seed; satisfactory nodulation can be achieved when dry sowing if inoculation rate is increased. Doubling the rate of inoculation significantly improved nodulation.

- Granule formulations with high rhizobia numbers per gram or applied at higher rates to deliver 500,000 cells per seed can provide good nodulation of pulse crops when dry sown.

- Granular inoculant formulations varied in quality (rhizobia number) between products and years. This affected their performance and emphasises the need for an independent quality assurance program (e.g. like the Green Tick Logo issued for peat inoculants by AIRG) to ensure minimum rhizobia numbers are achieved, before they can be reliably recommended to growers

- Application of the seed dressing P-Pickle T significantly reduced rhizobia numbers on bean seed under simulated dry sowing conditions (moisture 2% w/w) after 7 days. It is recommended granular inoculant is used in preference to peat on seed if using a seed chemical treatment and dry sowing.

'*' Dry sowing in this project is defined as insufficient soil moisture for seed germination.

Project Objectives

This project aimed to provide South Australian pulse growers with guidelines around best inoculation practice for dry sowing legumes in inoculation responsive soils.

This was to be achieved by:

i) Assessing survival of rhizobia in different inoculant products under simulated dry sowing conditions in the greenhouse.

ii) Establishing field trials of inoculation responsive legumes (faba bean, lupin, chickpea and fieldpea) in SA on acid soils or soils with no recent history of the pulse crop to assess;
   - inoculant placement and sowing time options
   - a range of commercial strains and inoculant formulations

Trials were to be assessed for nodulation, nitrogen fixation and yield to determine which options maximize nodulation, N-fixation and crop productivity.

This project added value to the GRDC project DAS00128 (Optimising nitrogen fixation of grain legumes- southern region) 2012-2017 by addressing the knowledge gap which currently existed regarding the effectiveness and best practices for dry sowing legumes in SA.

Overall Performance

In the three years of project S716 we successfully achieved the main project objectives, along with additional outcomes such as assessing the performance of new acid tolerant rhizobia under dry sowing conditions and the effect of the seed chemical P-PickleT on rhizobia survival on seed and its potential impact if used when dry sowing.

Key SARDI staff on the project were
Liz Farquharson (PI -10%FTE)
Ross Ballard (Senior Research Scientist-5% FTE)
Lynette Schubert (Technical officer- 0.4 FTE)
Stephen Barnett (Research Scientist – 7 days)

Seven field trials were conducted in South Australia across 2017 and 2018 at four sites. Details of trials, including collaborators are listed in Table 1.

Table 1. Details of field trials, collaborators and issues arising in S716

Year	Location	Soil	Crop	Treatment summary	Collaborators	Issues arising
2017	Wanilla (EP)	Sandy Loan (pHCa4.4)	Bean (Samira)	Trial 1-2x TOS (4wk & 2wk dry) * 6 Formulations (+ 3 controls)	Co-operator – Andrew Green	Dry Start – Not possible to sow on break
				Trial 2 – 1x TOS (4wk dry) * 7 (strain*peat rate)	SARDI – Andrew Ware, Jacob Giles	
	Farrell Flat (MN)	Loan (pHCa 5.1)	Lupin (PBA Barlock)	Trial 1-2 x TOS (7 days dry and Break) * 5 Formulations (+1 control	Cooperator – Craig Jaeschke	
				Trial 2 -1x TOS (7 days dry) * 6 peat rates	SARDI Pulse Agronomy – John Nairne, Larn McMurray	
2018	Lameroo (Mallee)	Sandy Loan (pHCa 7.8)	Chickpea (Gen090)	Trial 1-1x TOS (18 days dry) *10 Treatments (Formulations & Rate)	Co-operator – Peter Maynard SARDI Pulse Agronomy (Struan)	
	Hart (MN)	Loam (pHCa 7.7)	Chickpea (Gen090)	Trial 1-1x TOS (14 days dry) * 10 Treatments (Formulations & Rate)	Hart Field Site Group (Sarah Noack and intern – Emma Pearce) & SARDI Pulse Agronomy (Clare) – John Nairne	Site not responsive to inoculation
	Minnipa (EP)	Sandy Loam (pHCa 7.8)	Chickpea (Gen090) & Field Pea (PBA Oura)	Trial 1 (3x TOS (20 days dry, 7 days dry, Break) * (SARDI Peat vs Granule)	Co-operator – Bruce Heddles Minnipa Ag. Centre (Amanda Cook, Fiona Tomney)	Decile 1 rainfall year. Trial severely water stressed. Esp. TOS1.

<u>Difficulties encountered</u>
There were a few minor difficulties encountered in this project.
Firstly it was difficult to source ALOSCA granules. When sourcing inoculants our preferred method is directly from the manufacturers in order to avoid reductions in product quality

which can arise when obtaining inoculant via a reseller or third party. As a result Group F ALOSCA granules were only sourced from Landmark in 2017 and included in one trial. More generally, the quality of commercial granular inoculants varied with product and year in terms of both rhizobia numbers and contaminant numbers which may have resulted in additional variation within trials.

The recommended best practice for inoculation is to sow peat inoculated seed into moist soil and this was intended to be our benchmark in trials. However, the very dry starts in both trial years made predicting when to sow the first treatment exceedingly difficult, hence on some occasions we opted for a second dry sown treatment rather than a sow on break treatment. Furthermore because of the dry starts, early sown crops which were able to get a quicker start once rain came, generally did better overall than later sown treatments in terms of both growth and nodulation.

Key Performance Indicators (KPI)

KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
Year 1 – Undertake trials in the greenhouse to assess survival of rhizobia from different inoculant products under simulated dry sowing conditions.	Y 30/2/2017 30/3/19	*Details: Three greenhouse experiments were conducted to assess the survival and efficacy of rhizobia in peat and granular inoculants under various dry sowing conditions.* *In 2019 a laboratory experiment was conducted to assess the impact of inoculant rate and P-pickle t seed dressing on survival of rhizobia on seed (applied as peat slurry) over 21 days at 2% and 4% soil moisture.*
Year 1- Soils collected from potential field sites and target legumes (e.g. lupin/bean) rhizobia numbers measured using MPN bioassay. Suitable sites selected for field trials.	Y 31/3/2017	*Details: Soils were collected from 8 potential field sites in February 2017. pH was measured and MPN bioassays were undertaken to determine if target rhizobia were present.* *Field sites were selected for 2017 trials at Wanilla on Eyre Peninsula and Farrell Flat in the mid north.*
Year 1- Field trials established to evaluate a range of dry sowing inoculant formulations, inoculant placement and sowing times.	Y 30/6/2017	*Details: Two bean trials were sown at Wanilla (EP) by June 16th 2017.* • *The first assessed 6 inoculant formulations dry sown on either 28th April (4 wks dry) or 16th June (2 wks dry).* • *The second trial was to determine if increasing the rate of peat applied inoculant on seed (3 rates) improves nodulation of faba bean when*

		sown dry, and to examine if new acid tolerant Gr E-F rhizobia provide any benefit under dry sowing conditions. *Two lupin trials were sown at Farrell Flat by April 28th 2017.* • *The first assessed 5 inoculant formulations dry sown on the13th April (7 days dry) or sown into moist soil on the 28th April.* • *The second trial assessed if increasing the inoculation rate (6 rates) of peat applied on seed improves nodulation of lupin when sown dry.*
Year 2- Field trials sampled and harvested to evaluate a range of dry sowing inoculant formulations, inoculant placement and sowing times.	Y 31/12/2017	*Details:* • *All trials were assessed for nodulation (Nodule count/score and weights) approximately 10 weeks after emergence for both TOS1 and TOS2 plants.* • *All trials were sampled when the crop was at mid pod fill (10 plants per plot) and biomass measured. These samples have been processed for 15N analysis to measure N fixation.* • *All trials were harvested and grain yields recorded.*
Year 2- Sample analysis for ^{15}N completed, data analysed.	Y 31/4/2018	*Details: Herbage samples collected at mid pod fill, processed and sent to UC Davis for analysis.* *Analysis received in May 2018 and data processed to estimate nitrogen fixation and trial data from 2018 was analysed.*
Year 2 – Soils collected from potential field sites and target legumes (e.g. lupin/bean) rhizobia numbers measured using MPN bioassay. Suitable sites selected for field trials.	Y 31/3/18	*Details:* • *Soils were collected from 10 potential field sites in February 2018. pH was measured and MPN bioassays were undertaken to determine if target rhizobia were present.* • *Primary field sites were selected for 2017 trials at Lameroo in the Mallee and*

		Hart in the mid north. A further trial was co-located with GRDC trials at Minnipa on the upper EP.
Year 2- Second season of field trials established in SA to evaluate a range of dry sowing inoculant formulations, inoculant placement and sowing times.	Y 30/6/2018	*Details* *A Chickpea trial was sown at Lameroo on April 16th 2018 into dry soil with 18 days before germinating rains.* • *The effect of inoculant formulation and application rate on nodulation was assessed.* *A Second Chickpea trial, with the same treatments as Lameroo was dry sown at Hart on April 20th 2018. Moisture was 8%w/w but predominately above the seed and insufficient to trigger germination. It was 14 days until a germinating rain event.* *A third trial was sown at Minnipa.* • *This trial assessed the efficacy of peat vs granule inoculant formulations (made at SARDI) for chickpea and field pea sown at three different times (13th April, 25th April, 26th June).*
Year 3 – Second season field trials sampled and harvested to evaluate a range of dry sowing inoculant formulations, inoculant placement and sowing times.	Y 31/12/2018	*Details: All trials were assessed for nodulation (Nodule count and weights) approximately 10 weeks after emergence for all sowing times.* *All trials were sampled when the crop was at mid pod fill (10 plants per plot) and biomass measured with the exception of TOS1 treatments at Minnipa (poor growth). These samples were processed for 15N analysis to measure N fixation.* *Lameroo and Hart trials were harvested and grain yields recorded. Only TOS 3 treatments were harvested at Minnipa due to the poor season*
Year 3- Sample analysis for 15N completed, data analysed.		*Details: Herbage samples collected at mid pod fill, processed and sent to UC Davis for analysis.*

		Analysis received in May 2019 and data processed to estimate nitrogen fixation and trial data from 2019 was analysed.
Year 3- Results communicated to growers: Two field days (e.g. Mid North and Murray Mallee) and the production and the eventual incorporation of the information into the Inoculation manual and Pulse Best Management Practice Manuals.		*Details:* *Results to date have been presented at the EPARF Field day February 2018, The Walpeup GRDC updates July 2018, the Hart field day September 2018.* *In 2019 Results were presented to 80 growers and agronomists as part of four GRDC workshops "Boosting on Farm Nitrogen Fixation in Pulses" held at Kimba, Cummins, Adelaide and Swan Hill. A further two workshops are scheduled for Riverton and Horsham later in 2019.* *Results were presented at the 2019 SAGIT update and will be presented at the Australian Pulse Conference in Horsham in October. Recommendations will also be included in the updated version of "Inoculating legumes a practical Guide" produced by GRDC and a fact sheet to be produced by Ag. Communicators.*
Year 3- Final Report Completed	Y	

Technical Information

Survival of rhizobia under dry sowing conditions (greenhouse experiment)

The minimum standard for rhizobia inoculation of pulses is the delivery of 100,000 rhizobia cells per seed when sowing into moist soil. Following sowing, the rhizobia proliferate in the moist soil and infect the plant root following germination. Under dry sowing conditions (insufficient moisture for seed germination) rhizobia cells are under significant moisture stress, which can lead to cell death and risk insufficient cell numbers at seed germination (following a rain event). Granular inoculant formulations are often promoted as being effective under dry sowing conditions. We assessed both commercial peat slurry on seed and a peat granular product under simulated dry sowing conditions for a range of inoculant groups, temperature and moisture regimes in order to understand the impact of dry sowing may have on inoculant performance.

Results showed when Group F (strain WSM1455) rhizobia are applied as peat slurry on bean seed and sown in to very dry soil (<2% w/w moisture) the number of rhizobia decreased on average by tenfold between 24 hours post sowing and 14 days post sowing. Despite this decline in rhizobia numbers, there were still adequate rhizobia per seed (>100,000 per seed) to nodulate faba bean under greenhouse conditions once moisture was applied. The rhizobia for chickpea (Group N, strain CC119) and lupin (Group G, strain WU425) behaved similarly. The number of rhizobia supplied using a granular bean inoculant (Novozymes Peat Granule) was initially much lower than that for peat on seed treatments. However, as is often promoted for granules, the lower rhizobia numbers remained relatively stable in dry soil over 28 days when measured using the Most Probable Number bioassay.

Impact of soil temperature and moisture (growth room experiment)

Higher soil temperature and low moisture levels at the time of sowing were detrimental to the survival of bean rhizobia and subsequent nodulation of bean. Bean rhizobia in both granules and in peat (applied to seed) survived better when sown into a dry soil (<1% w/w) maintained at 15°C (average May soil Temperature) compared to 20°C (average April soil temperature). Both inoculants also nodulated better when sown into dry soil rather than into marginal soil moisture (3% w/w) which was then allowed to dry over the next 14 days. Moisture fluctuation may be more detrimental to rhizobial survival than 'dry soil'.

Impact of inoculation rate and P-Pickle T® (growth room experiment)

Doubling the amount of peat applied to seed prior to sowing into a soil with 2% w/w moisture (insufficient for seed germination) increased the number of rhizobia surviving on seed at 14 days after sowing and maintained levels above the minimum standard threshold of 100,000 cells per seed at 21 days (Figure 1). The application of PPT significantly reduced rhizobia numbers to below the minimum threshold by 7 days after sowing at both inoculation rates (Figure 1). This result suggests PPT should not be in direct contact with the rhizobia inoculant when dry sowing, rather inoculant should be placed separate from the seed (e.g. a granule in furrow).

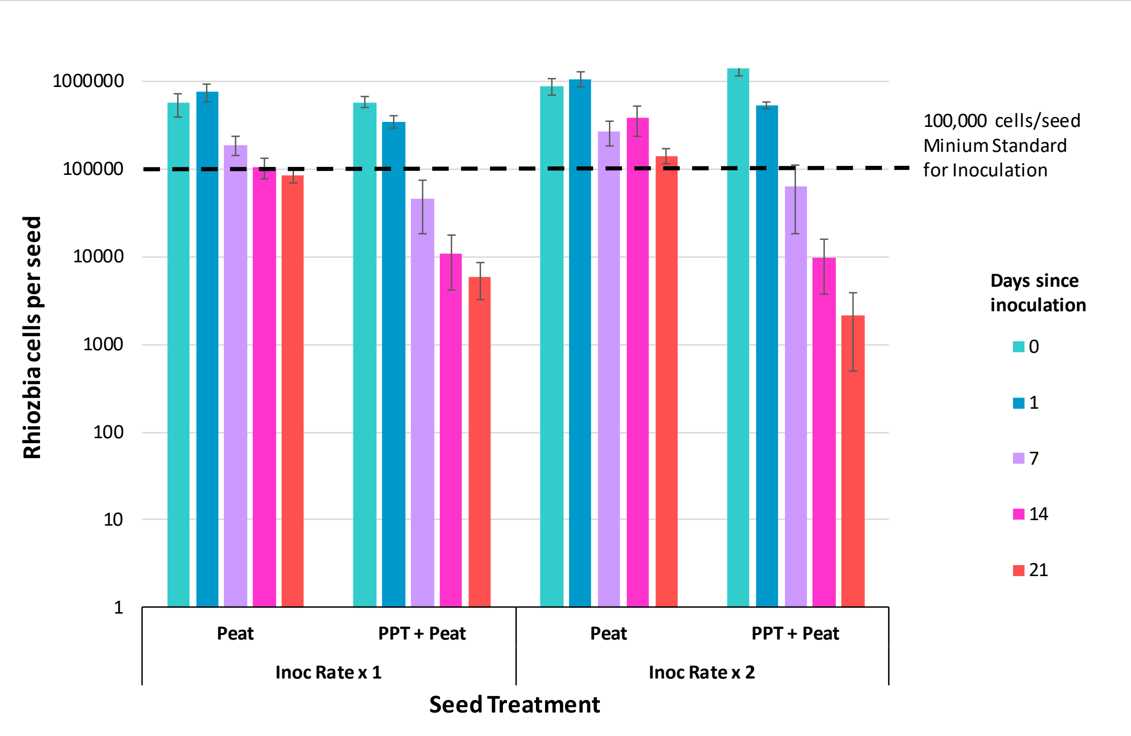

Figure 1. Survival of bean rhizobia (WSM1455) during the 21 days after application as peat slurry on Samira bean seed at either the standard inoculation rate (x1) or double the standard rate (x2).

Seed was surface sterilised before inoculation and either left untreated or treated with P-Pickle T® (2mL/kg seed) prior to inoculation. Seed was incubated at 18°C in a pastuerised sandy loam soil with a moisture content of 2% w/w.

Nodulation impacts: Peat slurry on seed inoculation (Field trials)

In 2017 and 2018 a total of seven of field trials were undertaken (Table 1, 'overall performance' section) to assess the performance of different inoculant formulations under dry sowing conditions (insufficient soil moisture for seed germination). With the exception of the Hart field site, all trial sites lacked existing populations of rhizobia for the sown legume, meaning that the crops sown were reliant inoculation for successful nodulation. In contrast, the Hart field site highlighted that where there is a history of pulses in the cropping rotation and a population of compatible rhizobia has been established in the soil, growers can dry sow with confidence as inoculation is unlikely to be necessary.

When dry sowing pulse crops into inoculation responsive soils the standard rate of peat slurry applied to seed failed to achieve a satisfactory level of nodulation, especially if dry sowing periods were extended beyond 1 week or there was an additional stress to rhizobia survival such as low soil pH. Increasing the rate of peat slurry applied to seed improved nodulation of Lupins (at Farrell Flat), Chickpea (at Lameroo) and Beans at Wanilla (data not shown), Figure 2.

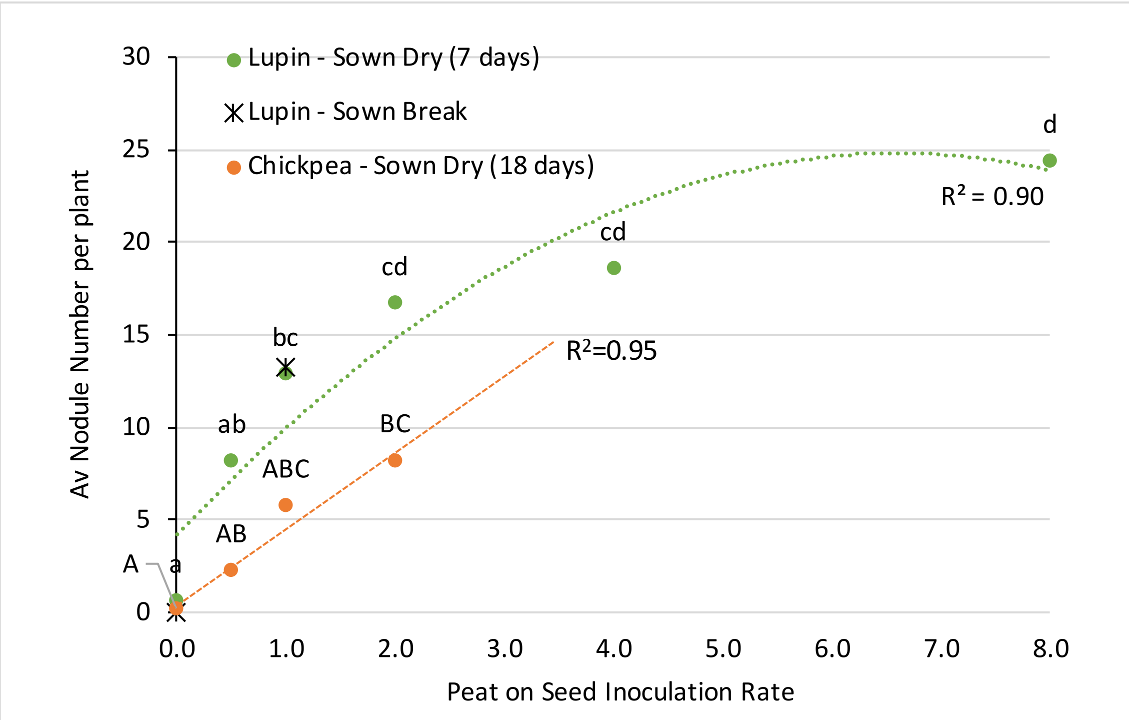

Figure 2. Effect of inoculation rate (peat slurry inoculant applied to seed) on the nodulation of dry sown and break sown lupin (Farrell Flat 2017) and dry sown chickpea (Lameroo 2018) assessed ten weeks after crop emergence.

Nodulation impacts: Efficacy of inoculant formulations under dry sowing conditions

Granular formulations of inoculant are promoted as being suitable for use under dry sowing scenarios. Prior to this project we were not aware of evidence to support these claims. There are three granular formulations currently available in Australia, a peat based granule produced by Monsanto (Novozymes), an attapulgite granule (BASF) and a bentonite clay granule (ALOSCA). In this project Novozymes/Monsanto and BASF provided granular product for testing in both 2017 and 2018. Group F ALSOCA granules was sourced from Landmark and included in the 2017trials.

Of the granular inoculants tested we found the quality of products to vary between products and years (batches). Figure 3 shows the level of variation expressed as nodule dry weight (as a % of site mean) for standard peat application and the three granular formulations assessed for dry sown field trials. Despite this variation we found that when granules had a high titre of rhizobia per gram and delivered more than 500,000 cells per seed (applied in furrow at recommend rate) then they provided the best nodulation under dry sowing conditions (Figure 4).

A peat based granule produced in the lab at SARDI (SG) for chickpea (GrN) and Field pea (Gr F) was also used in three trials in 2018 applied in furrow at 4.75 kg/ha and compared to a SARDI made peat slurry (SP) applied to seed. The Gr N SARDI granule performed similarly to the two commercial granules in the Chickpea trial at Lameroo and resulted in more than double the nodule number per plant than for the standard SP treatment.

At Minnipa (2018) the SG and SP treatments for Chickpea and Pea were compared at three different sowing times (20 days dry, 7 days dry, on Break). Although the site was extremely moisture stressed resulting low nodulation, the results for field pea showed the granule performed as well or better than the peat at the second and third sowing times (data not shown).

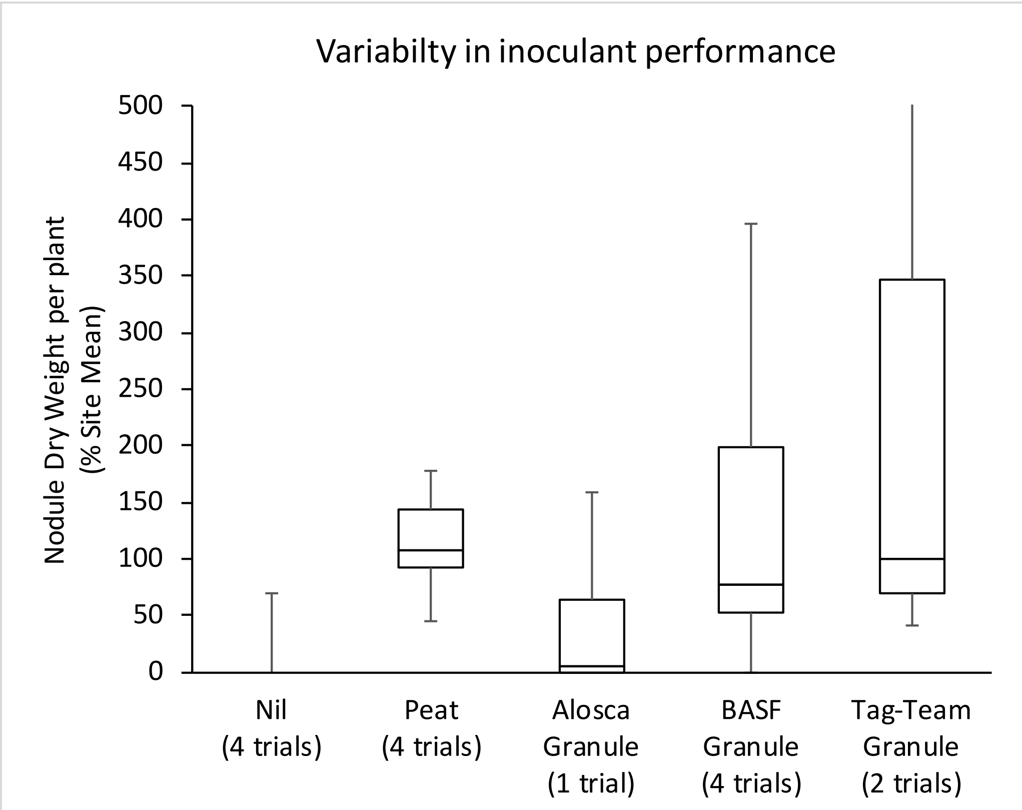

Figure 3 – Variability of inoculant performance under dry sowing conditions expressed as nodule dry weight per plant (standardized as % of site mean). The number of trials each formulation was included in for presented data is shown in brackets.

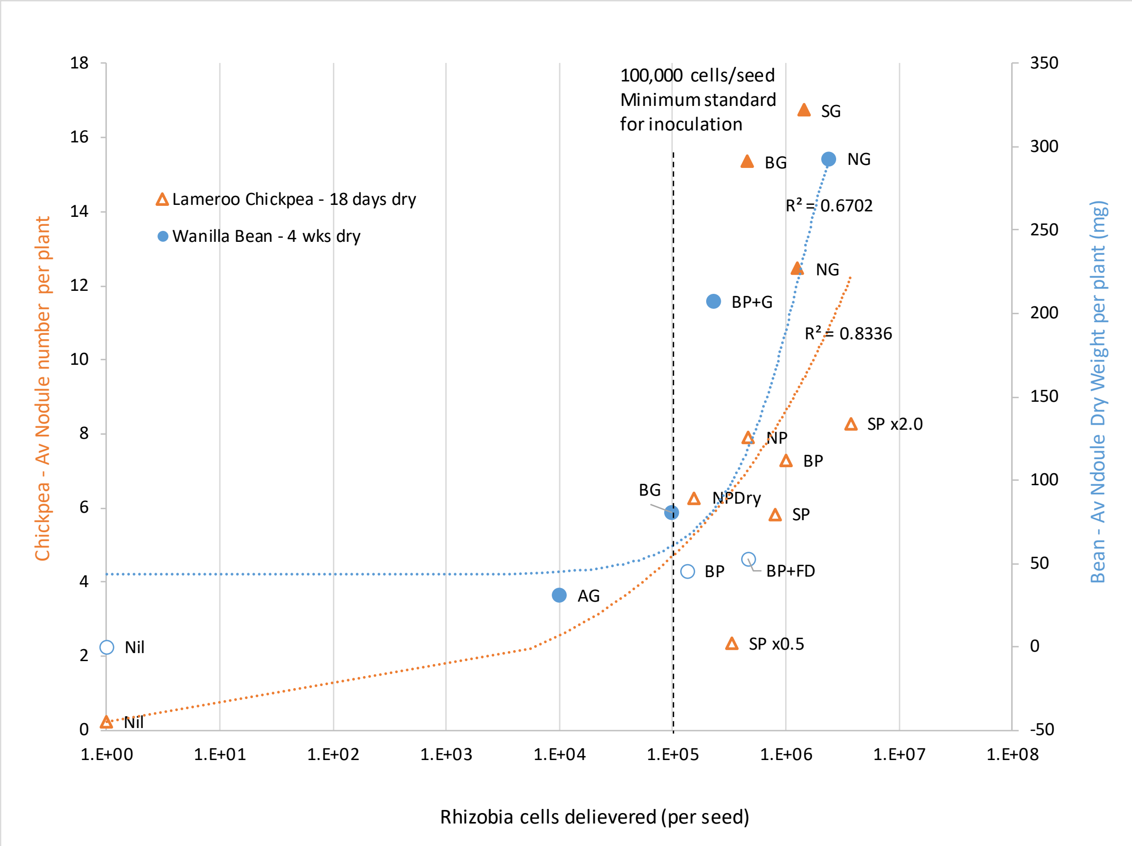

Figure 4 Relationship between rhizobia cells delivered and nodulation of dry sown bean (○) and chickpea (△). Closed symbols indicate granule formulations (SG= SARDI made peat based granule, NG=Novozymes tag-team granule, BG = BASF nodulator granule, AG = Alosca granule, BP+G = BASF peat on seed + nodulator granule), open symbols indicate uninoculated (Nil) and seed applied peat formulations (SP = SARDI made peat, BP= BASF Peat, BP + FD = BASF peat + NewEdge Freeze dried, NP = Novozymes TagTeam peat applied moist slurry and NPDry (dry powder). Samira beans were grown at Wanilla in 2017, soil pH 4.4 and in the ground dry for 4 weeks prior to germinating rain, inoculated with Gr F bean inoculant. Genesis 090 chickpea were grown at Lameroo in 2018, soil pH 7.8 and in the ground dry for 18 days prior to germinating rain, inoculated with Gr N chickpea inoculant.

Nitrogen Fixation and Yield

Nitrogen fixation and yield were positively correlated with nodulation (either nodule number or dry weight per plant) for dry sown chickpea, faba bean and lupin (Table 2). Nitrogen fixation for the best performing inoculated treatment was at least double that of the worst performing inoculation treatment (not including uninoculated treatments) across trials and yield increases varied from 16% to three times between the worst and best inoculated treatments. Given several sites were affected by both early and late season water stress this is a significant result, highlighting the importance of achieving good crop nodulation early in the season.

Table 2 R^2 and P-values for correlations between nodulation (number per plant or nodule dry weight) measured at 10 weeks post emergence and either N fixation (measured at peak biomass) or grain yield of dry sown bean, chickpea, lupin and field pea (combined data from 2017 and 2018 trials)

Nfix Ha	vs Total Nodules PP		vs. Nodule Dry Weight PP	
	R^2	p-value	R^2	p-value
Bean	na	na	0.74	<0.001
Chickpea	0.53	<0.001	0.63	<0.001
Lupin	0.46	<0.001	0.34	0.003
Pea	0.22	0.004	0.25	0.002

Yield Ha	vs Total Nodules PP		vs. Nodule Dry Weight PP	
	R^2	p-value	R^2	p-value
Bean	na	na	0.77	<0.001
Chickpea	0.66	<0.001	0.17	<0.001
Lupin	0.25	0.01	0.45	<0.001
Pea	0.36	<0.001	0.45	<0.001

Performance of new "acid tolerant" rhizobia strains.

Two new SARDI strains for bean with putative acid tolerance were beneficial when dry sown at Wanilla in 2017 (pH 4.3). Acid strains were compared to the current group F bean strain (WSM1455) at three inoculation rates. They were applied as peat slurry on seed and remained in the ground dry for four weeks before rain. The current commercial bean strain, WSM1455, was unable to nodulate faba bean at the recommended inoculation rate. In comparison the two new rhizobia strains were even able to nodulate bean at half the recommended application rate. Nitrogen Fixation (R^2=0.6, $p<0.001$) and grain yield (R^2=0.74, $p<0.001$) were significantly and positively correlated with nodulation.

Conclusions Reached &/or Discoveries Made

Where sowing pulses on inoculation responsive paddocks:

- Standard inoculation practices are unlikely to deliver satisfactory nodulation following dry sowing where there are extended dry* conditions (> 7 days), particularly where there are additional stresses to rhizobia survival such as low soil pH (<5.0 Ca).

- Rhizobia mortality is likely to be greater where some moisture is present and where soil temperatures are greater than 15^{o}C.

- The higher the number of rhizobia applied on or with seed when dry sowing the greater the likelihood sufficient rhizobia will be present when germinating rains occur.
    - Trials with bean, lupin and chickpea have shown products with the highest number of rhizobia generally resulted in the most nodulation and production.

    - For peat slurry applied to seed; satisfactory nodulation can be achieved when dry sowing if inoculation rate is increased. Doubling the rate of inoculation significantly improved nodulation.

- Granule formulations with high rhizobia numbers per gram or applied at higher rates to deliver 500,000 cells per seed can provide good nodulation of pulse crops when dry sown.

- Granular inoculant formulations varied in quality (rhizobia number) between products and years. This affected their performance and emphasises the need for an independent quality assurance program (e.g. like the Green Tick Logo issued for peat inoculants by AIRG) to ensure minimum rhizobia numbers are achieved, before they can be reliably recommended to growers
    - Some aspects of granule performance may come down to an interaction between granule formulation and soil type/conditions at sowing, however further research is needed in this area.

Application of the seed dressing P-Pickle T significantly reduced rhizobia numbers on bean seed under simulated dry sowing conditions (moisture 2% w/w) after 7 days. Where pulse disease risk is high and pesticide application necessary, dry sowing is best avoided.
Where growers have a regular cropping history of well nodulated pulse crops and inoculation is not necessary then dry sowing will not compromise nodulation of the crop.

'*' Dry sowing in this project is defined as insufficient soil moisture for seed germination.

Intellectual Property

None.

Application / Communication of Results

Main Findings – As per conclusions sections above.

Industry significance

In the last 18 years the area sown to pulses in SA has increased by 50% to around 400,000 ha, making up 14% of the cropped area (ABARES 2019- 5 year Average). Farmers are looking to dry sow some legumes where possible to better manage time demands around sowing and ensure successful early establishment of crops and maximum use of autumn rains. Dry sowing can also reduce the risks associated with dry springs.

This research has demonstrated that when good nodulation is achieved for dry sown crops, providing weed and disease management are in check, then early sown crops can outperform later sown crops in terms of both nitrogen fixation and yield. In our trials; sowing lupins early at Farrell Flat in 2017 resulted in an N fixation gain of 20kg/ha and a yield gain of 11% (0.28t/ha) which was equivalent to $155/ha^. Similarly faba bean sown early at Wanilla in 2017 resulted in an extra 46 kg N/ha and 0.4t/ha of yield, equivalent to $236/ha^.

Prior to this project one of the most commonly asked questions at field days with regard to inoculation practice was “How do we successfully inoculate dry sown pulses?”

This project has made significant progress in addressing this question.

Although granular inoculants have potential to perform well under dry sowing conditions, their variability in quality remains a significant barrier to their adoption and reliability. Until granular inoculant quality can be assured through a quality testing service we recommend applying peat on seed at higher rates (at least double) or increasing the rate of granules applied.

Achieving good nodulation by increasing the rate of peat inoculant applied or using a high quality granule provided an average increase in nitrogen fixation of 30 kg/ha and yield increase of 107%, a financial gain in the order of $560/ha^# compared to standard inoculation practice (peat slurry on seed at standard rate). With this magnitude of improvement possible, an additional investment of $10-20 per ha to increase inoculation rates makes economic sense.

(^ based on Urea price of $365/t and grain price $500/t, # Average of five trials, assuming yield of 1t/ha for standard inoculated crop and harvest index of 0.4)

Publications and Extension

Results to date have been presented at the EPARF Field day February 2018, The Walpeup GRDC updates July 2018, the Hart field day September 2018.

In 2019 Results were presented to 80 growers and agronomists as part of four GRDC workshops “Boosting on Farm Nitrogen Fixation in Pulses” held at Kimba, Cummins, Adelaide and Swan Hill. A further two workshops are scheduled for Riverton and Horsham later in 2019.

Results were presented at the 2019 SAGIT Update and will be presented at the Australian Pulse Conference in Horsham in October. Recommendations will also be included in the updated version of “Inoculating legumes a practical Guide” produced by GRDC and a fact sheet to be produced by Ag. Communicators.

Barriers to Adoption of Guidelines

Choosing a quality granule formulation

Granular inoculant formulations varied in quality between products and years. Ideally they need to be included in an independent quality assurance program (e.g. like the Green Tick Logo issued for peat inoculants by the Australian Inoculants Research Group at NSW DPI) we recommend both growers, industry bodies and researchers lobby for this to effectively occur.

Knowing if inoculation is necessary

Growers can follow the GRDC inoculating legumes back pocket guide to ascertain if they should be inoculating their crop. Further to this, GRDC are currently investing in a DNA test (to be part of PREDICTA-B) which will test for compatible rhizobia numbers in soil prior to sowing.

POSSIBLE FUTURE WORK

- Suitability of the DNA Diagnostic tool being developed at SARDI to quantify rhizobia numbers in granular inoculant products. If found to be suitable it could be used to help deliver a quality standard for granular inoculants.
- Further research into granule type by soil type interactions. Does it all come down to numbers or are there additional interactions between granule formulation and soil type (e.g. soil pH or texture).
- Determine if granules can be used to successfully overcome issues associated with seed applied chemicals.
- Development or assessment of a high count granule.
- Overcoming inoculation failures. Although rare when a high value crop fails to nodulate there are currently no known methods to overcome this other than the application of N fertiliser. Determining if top dressing inoculants prior to rain or injecting inoculant post sowing could overcome a nodulation failure would be helpful to industry.

AUTHORISATION	
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Date:	30 August 2019