Office Use Only

Project Code	
Project Type	

FINAL REPORT 2019

Applicants must read the *SAGIT Project Funding Guidelines 2019* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be emailed to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

PROJECT CODE :	**TC116**

PROJECT TITLE (10 words maximum)
Increasing lentil productivity on dune and swale soils

PROJECT DURATION

*These dates **must** be the same as those stated in the Funding Agreement*

Project Start date	1/7/2016					
Project End date	30/06/2019					
SAGIT Funding Request	2019/20	$	2020/21	$	2021/22	$

PROJECT SUPERVISOR CONTACT DETAILS

The project supervisor is the person responsible for the overall project

Title:	**First Name:**	**Surname:**	
Mr	Sam	Trengove	
Organisation:			
Trengove Consulting			
Mailing address:			
Telephone:	**Facsimile:**	**Mobile:**	**Email:**

ADMINISTRATION CONTACT DETAILS

The Administration Contact is the person responsible for all administrative matters relating to the project

Title:	First Name:	Surname:
Mr	Sam	Trengove

Organisation:
Trengove Consulting

Mailing address:

Telephone:	Facsimile:	Mobile:	Email:

PROJECT REPORT

Provide clear description of the following:

Executive Summary (200 words maximum)

A few paragraphs covering what was discovered, written in a manner that is easily understood and relevant to SA growers. A number of key dot points should be included which can be used in SAGIT communication programs

Project results indicate there are several constraints growers in the northern YP region can address on their sandy soils to significantly improve lentil production and profitability.

- Paddock surveys conducted in 2016 highlighted that high penetrometer resistance (soil compaction) was widespread, but more severe on the sandier soils in the survey paddocks.
- Across all trials, there was a consistent trend between increased biomass (measured as NDVI) in September and final grain yield, suggesting the crops on these sands are biomass constrained, where any treatment providing a growth response typically translates to yield.
- Addressing soil compaction with deep ripping demonstrated a 0.8t/ha (200%) yield increase in one trial. This response increased to 1.3t/ha when ripping was combined with the use of chicken litter.
- Sandy soils are particularly high risk for herbicide damage with commonly used group C and B herbicides.
- Using combinations of herbicide can cause cumulative crop damage. In some cases, two herbicides that have reasonable crop safety when applied alone can cause significant crop effect when applied in combination.
- The use of commonly used group C and B herbicides in combination reduced grain yield by 0.9t/ha (61%) in one trial.
- Generally, two nutrition trials did not show yield responses to various nutrient treatments on alkaline sandy soils. However, there was evidence of response to Molybdenum on acidic sands that requires further investigation.

Project Objectives

A concise statement of the aims of the project in outcome terms should be provided.

The aim of this project is to increase lentil productivity on dune and swale soils of the northern Yorke Peninsula and to realise their water limited yield potential, with particular focus on underperforming sandy soil types.

This project will have potential application for other regions of SA producing lentils on dune and swale soil types.

Gains will be achieved by identifying and addressing constraints limiting productive capacity of lentils on dune and swale soils of the northern Yorke Peninsula region. To overcome constraints to lentil production, a trials program will investigate and identify cost effective management options for these constraints and enable the crop to realise its water limited yield potential.

Overall Performance

A concise statement indicating the extent to which the Project objectives were achieved, a list of personnel who participated in the Research Project including co-operators, and any difficulties encountered and the reasons for these difficulties.

The objectives of this project have been achieved. Several production constraints have been identified, in particular soil compaction and herbicide safety. The trials program has quantified potential gains that growers will be able to achieve by employing management options that address those constraints, increasing lentil yields and water use efficiency.

Personnel who participated in the project

Trengove Consulting: Sam Trengove, Stuart Sherriff, Jordan Bruce and Matthew Hewett
Grains Innovation Australia: Larn McMurray, harvest equipment
Pulse Breeding Australia: Supply of lentil seed
SARDI: Nigel Wilhelm and Peter Telfer, loan of cone penetrometer and trials harvest
Ag Consulting Co: Stefan Schmitt, supply of plot seeder
Bruce Philbey: supply of tractor for plot seeding
Bill Trengove: field trials and paddock surveys
Stewart Johns: field trials and paddock surveys
David & Stefan Schmitt: field trials
James Venning: field trials
Andrew Morony: paddock surveys
Craig Ayles: paddock surveys
Nathan Hewett: paddock surveys
Kym Fidge: paddock surveys

The biggest difficulty during the project was contending with the mouse plague in 2017. One trial site located at Alford was particularly difficult, with mice not consuming baits and causing significant damage to plots, increasing site variability, potentially masking some treatment responses for the three trials that were located at that site. Fortunately, trials were located at several locations in that year.

Key Performance Indicators (KPI)

*Please indicate whether KPI's were achieved. The KPI's **must** be the same as those stated in the Application for Funding and a brief explanation provided as to how they were achieved or why they were not achieved.*		
KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
Identify 5 paddocks for survey that have 2 historical lentil yield maps and will be sown to lentils in 2016 in the northern Yorke Peninsula region. Conduct soil surveys with Veris MSP-3, access historical satellite imagery and perform spatial analysis of data layers.	Yes	
Conduct soil sampling and segmented soil analysis of 8 points per paddock (5 paddocks), at locations determined from spatial analysis of yield, NDVI and soil survey maps.	Yes	
Conduct plant nodulation, plant tissue nutrient tests and biomass measurements to identify factors restricting growth and grain yield at the same 8 locations per paddock (5 paddocks). Collect yield map data from the 5 paddocks for the current season and analyse data to diagnose yield constraints.	Yes	
Provide a progress report to SAGIT. Review of year 1 in consultation with SAGIT to assess whether constraints to lentil yield have been identified and if a targeted trials program has potential to identify cost effective solutions to. Stop/Go point.	Yes	
Identify 2 paddocks for survey that have 2 historical lentil yield maps and will be sown to lentils in 2017 in the northern Yorke Peninsula region. Conduct soil surveys with Veris MSP-3, access historical satellite imagery and perform spatial analysis of data layers. Conduct soil sampling and segmented soil analysis of 8 points per paddock, at locations determined from spatial analysis of yield, NDVI and soil survey maps. Identify locations for trial sites where constraints to lentil production will be addressed.	Yes	
Establish a trial protocol that will address issues identified and establish replicated plot trial(s) in 2 paddocks.	Yes	
Conduct plant nodulation, plant tissue nutrient tests and biomass measurements to identify factors	Yes	

restricting growth and grain yield at the same 8 locations per paddock (2 paddocks). Collect in-season crop measurements for trial treatments of plant tissue testing, plant nodulation and Greenseeker NDVI measurements. Harvest trials for grain yield and quality data from plot trials. Collection of yield maps of selected paddocks.		
Identify 2 paddocks for survey that have 2 historical lentil yield maps and will be sown to lentils in 2018 in the northern Yorke Peninsula region. Conduct soil surveys with Veris MSP-3, access historical satellite imagery and perform spatial analysis of data layers. Conduct soil sampling and segmented soil analysis of 8 points per paddock, at locations determined from spatial analysis of yield, NDVI and soil survey maps. Identify locations for trial sites where constraints to lentil production will be addressed.	Yes	
Establish a trial protocol that will address issues identified and establish replicated plot trial(s) in 2 paddocks.	Yes	
Conduct plant nodulation, plant tissue nutrient tests and biomass measurements to identify factors restricting growth and grain yield at the same 8 locations per paddock (2 paddocks). Collect in-season crop measurements for trial treatments of plant tissue testing, plant nodulation and Greenseeker NDVI measurements. Harvest trials for grain yield and quality data from plot trials. Collection of yield maps of selected paddocks.	Yes	
Submit final report.	Yes	

Technical Information (Not to exceed **three** pages)
Provide sufficient data and short clear statements of outcomes.

Summary of paddock surveys, 2016-18

Paddock surveys and transect analysis over three years implicated various constraints that could cause poor lentil performance on sandy soils of the northern YP region, however many of these were variable between paddocks and did not provide a consistent explanation for poor performance observed across the region. However, compaction (high penetrometer resistance) is one constraint that was consistent across paddocks surveyed in 2016, with a trend toward greater resistance deeper in the profile for poorer performing sandy soils (Red sand, Deep sand, Figure 1a), compared with better performing loamy sands and sandy loams. Of note is the high penetrometer resistance of up to 3600kPa, between 150 and 450mm soil depth, given root growth of cereals is said to be restricted at 2500kPa it is likely that this is restricting root growth of many lentil crops. At several locations wheel tracks of machinery passes prior to the lentil crop were obvious due to reduced crop vigor. Penetrometer resistance was measured for five paired comparisons on and off the visibly affected wheel tracks, showing greater resistance under the wheel track (Figure 1b).

Low pH was identified as a potential major constraint in two of nine paddocks surveyed, with poor performing soils ranging between 4.6 – 5.0 (1:5 CaC_2). However, in other paddocks the opposite was identified as a potential issue with high pH, greater than 8.0 (1:5 $CaCl_2$) and associated high phosphorus buffering index (PBI) identified as a potential problem.

In addition to the planned paddock surveys, another paddock was identified that had a sand hill area only under cropping for one year prior to a lentil crop being grown in 2016, as opposed to the remainder of the paddock that had been continuously cropped for many years, whereby it was possible to do paired comparisons between the areas with different cropping histories. The area with limited cropping history had 89% more dry matter in September than the adjacent continually cropped area. Factors that may have affected the increase in biomass production are increased soil organic carbon from 0.5% to 1.2% and associated increases in nutrition and compaction. The soil with short cropping history was higher in N (75%), S (100%), K (40%) and CEC (75%) than its continuously cropped comparison. Higher levels of phosphorus and zinc were found in the poor performing area and this would likely be a result of historical application during cropping and indicates that these nutrients are not limiting factors in this case. Soil penetrometer resistance was higher to a depth of 400 mm with the long continuous cropping history (Figure 1c), reaching 3000 kPa at 300 mm, this compaction likely caused by a longer history of machinery traffic on the continuously cropped area.

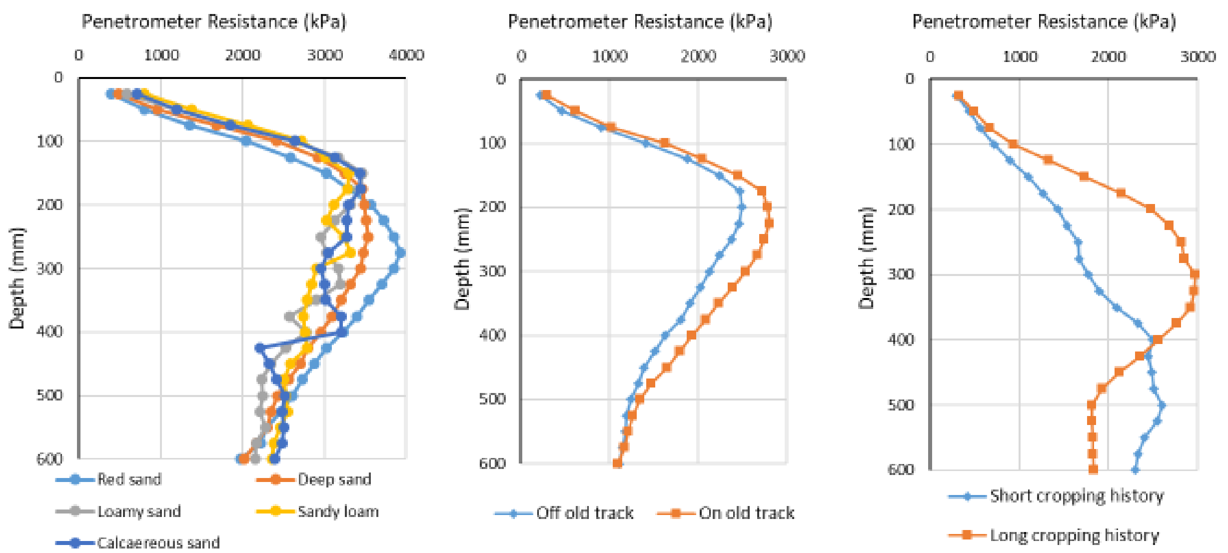

Figure 1: Penetrometer resistance measured to a depth of 600mm for a) 2016 paddock surveys grouped by soil type, b) paired comparisons for on and off machinery wheel tracks, and c) paired comparison for short and long cropping histories.

Field Trials, 2017-18

14 field trials were conducted in 2017-18, targeted to sandy soils in the northern Yorke region where issues have been identified. These trials were formulated in response to findings from paddock surveys, addressing soil compaction, nutrition and soil acidity. Paddock surveys also revealed a wide array of herbicide strategies between growers and

concerns around herbicide safety and residues in soil, as such herbicide tolerance and herbicide residue trials were established too. In 2018 trials included; lentil variety, herbicide tolerance, lentil nutrition, herbicide residues, molybdenum nutrition plot trial, molybdenum nutrition strip trial, and in 2017; lentil variety, herbicide tolerance, Jumbo2 and diflufenican tolerance, summer spray residues, soil amelioration, lentil nutrition, alternative products and low pH and lime.

A full trial report for each of the 14 field trials and results from paddock surveys has been included in a separate document.

Treatments that increase crop growth on the sandy soils of northern Yorke Peninsula increase lentil grain yield (Table 1). Using Greenseeker NDVI as a surrogate for crop biomass, shows that on average grain yield increased 0.21t/ha for each 0.1 unit increase in NDVI, with similar responses observed across a range of trials. This suggests these soils are biomass constrained, where treatments that overcome constraints increase biomass and yield. This has been observed in variety trials too, where varieties with greater NDVI produced higher grain yield, even though no other site-specific constraints were addressed.

Table 1: Linear relationship between Greenseeker NDVI measured in September and final lentil grain yield for 13 field trials, where Grain Yield (t/ha) = Slope*September NDVI + Intercept.

Year	Trial	Slope	Intercept	R Squared
2018	Variety	1.50	0.36	0.61
2018	Herbicide Tolerance	2.55	-0.12	0.67
2018	Nutrition	1.75	0.33	0.24
2018	Spading strip trial	2.08	-0.49	0.47
2017	Soil amelioration	3.32	-1.12	0.50
2017	Brodal and Jumbo2	1.93	-0.60	0.32
2017	Soil Amendments	2.65	-0.78	0.62
2017	Nutrition	2.04	-0.40	0.61
2017	Alternative products	3.24	-0.90	0.81
2017	Herbicide Residues	1.54	-0.44	0.65
2017	Herbicide Tolerance	1.80	-0.50	0.66
2017	Variety	1.46	-0.29	0.48
2015	Herbicide Tolerance	1.55	-0.25	0.58
	Average	**2.11**	**-0.40**	**0.56**

Soil amelioration 2017

A long-term trial site with treatments assessing deep ripping, spading, clay application, fertilizer nutrition, chicken litter application and chicken litter placement into the subsoil was established in 2015 in wheat. This trial was sown to barley in 2016 and lentil in 2017. Deep ripping provided the greatest benefit to lentil production. With grain yields increasing from 0.4 t/ha in the control to 1.2 t/ha in the ripping treatments without any fertiliser. When chicken litter was applied to the ripped plots at 5 or 20 t/ha lentil grain yields increased further to an average of 1.7 t/ha, a 325% yield increase over the untreated control. Grain yield response was related to an increase in soil water extraction, lowering the crop lower limit. Post-harvest measurements in 2017 show that an additional 23mm of water was extracted from the profile to 1.2m for deep rip plus chicken litter treatments, an increase in plant available water capacity of 50%.

Responses to chicken litter were observed where responses to inorganic fertiliser were not, even though in some treatments the contribution of N, P, K and S were matched for both chicken litter and fertiliser treatment. Plant tissue testing revealed higher concentrations of molybdenum in response to chicken litter compared with fertilizer treatments, indicating the chicken litter was supplying some nutrients, in particular molybdenum, that was not included in the fertilizer treatment. Subsequently, molybdenum nutrition has been investigated further.

Nutrition trials in 2017 and 2018

Nutrition trials in 2017 and 2018 were both located on alkaline sands. Reduced vigor and yield from fertiliser toxicity had a greater effect on lentil performance than improved crop nutrition. In 2017 this was primarily in response to boron. In 2018 high rate of P (MAP @ 120kg/ha) also reduced vigor (23% reduction in NDVI) due to fertiliser toxicity. This highlights that lentils are sensitive to fertiliser toxicity and high fertiliser rates should be separated from the seed.

In 2018 there was a growth response to standard P rates (MAP @ 60kg/ha). The initial survey work indicated that P supply was adequate/high in most of the poor performing sandy soils in the region, given low tie up and low P removal. Therefore, the observed P response in 2018 was a surprise and the first time in the project a positive response to P application was observed, though yield differences were not significant. Tissue testing showed that complete fertiliser treatments (full suite of nutrients applied) increased nutrient concentration in response to all applied nutrients, except copper. Chicken litter applied at 5t/ha provided similar tissue test responses in P, K, Mg, S and Mn, but not to Ca, B or Mo.

Molybdenum plots and paddock strips 2018

Molybdenum was identified as a potentially responsive nutrient on lower pH sands. A trial investigated molybdenum application and was established on a sand hill with 0 – 10 cm pH 5.3 ($CaCl_2$), treatments included three rates of foliar applied Mo applied twice post emergent and an application of chicken litter. Only the application of chicken litter produced significant increases in NDVI and crop vigor. The plots were not harvested for yield.

In addition to the plot trials the trial co-operator applied strips of molybdenum across a variety of soil types in a different lentil paddock. Significant increases in crop biomass (41%) and increases in leaf tissue nitrogen and molybdenum were observed over the sand hills. This is an area that needs further investigation, to understand the variability in responses observed. The limit of detection of Mo in leaf tissue provided by APAL is 0.4mg/kg. Findings to date suggest the critical level for Mo in lentils is less than the limit of detection.

Low pH and lime 2017

During the 2016 paddock survey several sites of low pH in the area were identified. Until then there had been little recognition of acid sands in the area with the Yorke Peninsula more typically being associated with high soil pH. A trial site was established on an acidic sand targeting lime and chicken litter application in the year of lentil (2017), this site had 0 – 10cm pH 4.5 ($CaCl_2$). The trial was established immediately prior to seeding in 2017 and lime and chicken litter was incorporated by seeding. No significant differences in NDVI were observed during the growing season or other visual differences observed. Limited incorporation and time for neutralisation is hypothesised as the reason for lack of response in the first crop post treatment. The entire trial area and surrounding sand hill has since been treated with 4 t/ha lime and deep ripped. Testing lentil response to lime treatments following appropriate time for lime to be effective needs further investigation.

Variety assessment 2017 and 2018

In 2017 varietal yield differences were not significant, despite a trend toward varieties with higher NDVI in September to produce higher yield. In 2018 highest yielding varieties included PBA Ace, PBA Jumbo2, PBA Hurricane XT along with several unnamed lines. Interestingly PBA Ace has been dropped from the local NVT trial where historically (2013 – 2016) it was 16% lower yielding than PBA Jumbo2. In more recent trials conducted by PBA at Melton on Yorke Peninsula PBA Ace was 26% lower yielding than PBA Jumbo2. The result in these trials indicate that there may be some response to the increased vigor of Ace on these sands and potentially a more vigorous line may be higher yielding under these circumstances.

Herbicide tolerance 2017 and 2018

Lentils grown on sandy soils are a high risk for herbicide damage. Herbicide tolerance trials demonstrated grain yield losses up to 78 and 61% compared with the untreated control in 2017 and 2018, respectively. However, these trials were hand weeded, so these results are in a weed free scenario and the herbicide benefit for weed control was not tested. Group C herbicides have historically formed the backbone for broadleaf weed control in lentils. The introduction of XT (lentils with increased tolerance to group B herbicides) lentils has seen increased reliance on group B herbicides including chlorsulfuron and imidazolinone options. The safety of soil applied group C herbicides is variable, dependent on rainfall patterns, soil characteristics and interactions with seeding systems. In 2017 metribuzin and simazine were the most injurious group C products, whereas terbuthylazine and diuron were safer. In 2018 simazine was the most damaging group C product, followed by terbuthylazine, with metribuzin and diuron causing the least damage of the group C products. However, weed control data in 2018 shows that the group C herbicide treatments that caused the most herbicide damage also provided the greatest weed control, so there was a tradeoff between balancing weed control and crop safety.

Herbicide effects of group C and B when applied in combination are often cumulative, with the effect being additive or synergistic. In 2018 a low rate of simazine + diuron or Intervix did not significantly reduce yield, however when used in combination the yield decrease was significant (19%, Table 1). Similar additive effects were observed when simazine + diuron was used in combination with chlorsulfuron. However, when the two group B products were applied together the damage was synergistic resulting in much higher levels of crop injury, for example chlorsulfuron applied alone reduced yield by 27% and Intervix reduced yield by 8% (not significant), whereas chlorsulfuron applied in combination with Intervix caused 55% yield loss. Growers are often nervous about using diflufenican due to its visual bleaching and crop effect, however in both years diflufenican had good crop safety, even when applied in combination with other products, despite NDVI reductions in the 2018 season.

Table 1: Herbicide combination effect on lentil NDVI and grain yield in 2018.

Treatment	Group C	Group C Rate catagory	Group C Rate (g/ha)	Diflufenican (mL/ha)	Chlorsulfuron (g/ha)	Intervix (mL/ha)	NDVI 5th Sept	Grain yield (t/ha)
1	Control						0.60	1.47
10	Sim/Diu	Low	250/275				0.51	1.31
11	Sim/Diu	High	375/412.5				0.44	1.06
12					5		0.50	1.08
13						500	0.59	1.35
14	Sim/Diu	Mix	250/275		5		0.45	0.95
15	Sim/Diu	Mix	250/275			500	0.50	1.19
16		0			5	500	0.43	0.67
17	Sim/Diu	Mix	250/275		5	500	0.36	0.61
18		0		150			0.56	1.33
19	Sim/Diu	Mix	250/275	150			0.45	1.23
20	Sim/Diu	Mix	250/275	150	5		0.44	0.94
21	Sim/Diu	Mix	250/275	150		500	0.51	1.18
22	Sim/Diu	Mix	250/275	150	5	500	0.34	0.57
LSD (0.05)							*0.06*	*0.18*

Conclusions Reached &/or Discoveries Made (Not to exceed one page)

Please provide concise statement of any conclusions reached &/or discoveries made.

Project results indicate there are several constraints growers in the northern YP region can address on their sandy soils to significantly improve lentil production and profitability.

- Paddock surveys conducted in 2016 highlighted that high penetrometer resistance (soil compaction) was widespread, but more severe on the sandier soils in the survey paddocks.
- Across all trials, there was a consistent trend between increased biomass (measured as NDVI) in September and final grain yield, suggesting the crops on these sands are biomass constrained, where any treatment providing a growth response typically translates to yield.
- Addressing soil compaction with deep ripping demonstrated a 0.8t/ha (200%) yield increase in one trial. This response increased to 1.3t/ha when ripping was combined with the use of chicken litter.
- The regions soils are predominantly neutral to alkaline pH, however paddock surveys identified acidic sands that had previously gone undetected. Addressing acidity constraints may generate productivity gain, though the lime trial in this project failed to demonstrate a benefit in the year of lime application.
- Sandy soils are particularly high risk for herbicide damage with commonly used group C and B herbicides.
- Using combinations of herbicide can cause cumulative crop damage. In some cases, two herbicides that have reasonable crop safety when applied alone can cause significant crop effect when applied in combination.
- The use of commonly used group C and B herbicides in combination reduced grain yield by 0.9t/ha (61%) in one trial.
- There was often a tradeoff between weed control and crop damage, where herbicide options that caused the most crop damage also provided the highest level of broad spectrum weed control. It is important to identify which are the important weeds that need controlling and tailoring the herbicide treatment to minimise the number of herbicides used in combination.

- Generally, two nutrition trials did not show yield responses to various nutrient treatments on alkaline sandy soils. However, there was evidence of response to Molybdenum on acidic sands that requires further investigation.
- There is some evidence that more vigorous and higher biomass varieties such as PBA Ace have a better performance ranking on these sandy soils than they do in other variety evaluations on heavier textured soils in the northern YP region.

Given these findings there are several opportunities for growers to explore to improve lentil productivity on their sandy soils, improving the reliability and profitability of this important break crop on vulnerable sandy soils. Improved performance in the lentil phase is also likely to have flow on benefits for following crops, through reduced wind erosion risk and improved N fixation for the following crops to utilise.

Intellectual Property

Please provide concise statement of any intellectual property generated and potential for commercialisation.

There are no intellectual property implications as a result of this project.

Application / Communication of Results

A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*
- *A statement of potential industry impact*
- *Publications and extension articles delivered as part of the project; and,*
- *Suggested path to market for the results including barriers to adoption.*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

Results have been communicated throughout the project, including

- NSS preseason meeting - March 2017
- NSS winter and spring field days - July and Oct 2017
- Hart Field Site Group young farmers bus tour - Sept 2017
- Landmark Cummins bus tour - Oct 2017
- Independent Ag Consultants meeting - Jan 2018
- GRDC Adviser updates - Feb 2018, submitted paper attached
- Trial site visits in 2018
    - NSS crop walk
    - EP Pulse Check groups *2
    - Mallala Ag Bureau
    - Landmark client crop walk
    - SARDI agronomists

Trial responses and project activities have been posted on social media (Twitter).

Results have also been communicated through the Trengove Consulting and Hooper Consulting newsletter, NSS results booklet and EPARF compendium.

Findings from the project have been shared and discussed with researchers involved in GRDC's southern region sandy soil project.

At project initiation it was estimated that approx. 4,550ha of sandy soils are performing below potential in the northern YP region in the lentil phase of the rotation on an annual basis, yielding approx. 0.53t/ha below potential. Findings from this project demonstrate that these estimates of lost potential were conservative. Addressing compaction increased yields by 0.8t/ha, and in combination with chicken litter increased 1.3t/ha. Field survey work showed the compaction constraints are widespread and most growers will benefit from addressing compacted sandy soils. This would suggest that an additional 3,640t/annum could be produced from addressing compaction alone, worth approx. $2.2M to the region in increased gross revenue. Since the project begun a number of growers have initiated soil amelioration programs that include deep ripping. The identification of significant areas of low soil pH in the area has led to several growers taking on soil pH mapping and consequent lime application. Yield loss on sandy soils from the combined use of commonly used herbicides has been demonstrated to be up to 0.9t/ha. The benefits from these findings will depend on individual grower's current herbicide strategy and weed burdens. These findings are also applicable outside the northern YP region, as demonstrated by groups visiting from the EP and mid and lower north.

POSSIBLE FUTURE WORK

Provide possible future directions for the research arising from the project including potential for further work and partnerships.

Areas for further investigation include

1. Continued evaluation and understanding of soil compaction on crop performance and the response to amelioration through ripping, ripping depth, inclusion plates, spading and combined with the use of organic amendments such as chicken litter.
2. Assess the agronomic and economic value of new novel herbicide traits under development in lentil breeding programs, including tolerance to metribuzin and clopyralid.
3. Continued investigation of best practice herbicide strategies on sandy soils; this will include assessment of crop safety, herbicide efficacy and yield loss associated with weeds, where the latter component was not considered in TC116.
4. Continued varietal evaluations on poorer performing sandy soils.
5. Investigate lentil nutrition responses on acidic sandy soils, in particular responses to Molybdenum.
6. Lentil response to liming and increased soil pH on acidic sandy soils.
7. Assess the performance of new acid tolerant rhizobia being developed by SARDI on acidic sands.
8. Better understanding of lentil growth, development and phenology across a wider range of soil types. On the sandy soil types this project has repeatedly demonstrated a link between increasing biomass and increasing yield. These crops tend to mature before the heavier textured soils as well in dune and swale landscapes. However, on some heavier textured soils crop growth and biomass accumulation appear unconstrained during the vegetative phase, and

the link between biomass accumulation and yield appears more tenuous. The crop can take a long time to flower and set pods in this scenario, then often running into terminal drought. The environmental cues that trigger reproductive growth are poorly understood, as is the interaction with soil type or crop health. Understanding these interactions would result in improved crop management.

Many of the issues listed above are being pursued by Trengove Consulting through other/new projects. Issues 2-5 are being investigated through SAGIT project TC119, following on from this project. Issue 1 continues to be explored through the GRDC sandy soils project for the southern region (CSP00203). Three long term soil amelioration trials, two at Bute and one at Warnertown will assess lentil responses in 2020. Lentil responses to lime application and management of soil acidity will be assessed through the new GRDC soil acidity project for SA (DAS 1905-011RTX) and the sandy soil project (CSP00203). Three long term trials were established in 2019 on acidic sandy soils in the region to assess lime products and rates, lime incorporation and the uniformity of mixing. These sites will be sown to lentils in 2020, with an expectation that a response will more likely be realised in the second year after treatment, compared with our 2017 trial assessment in the year of application. In addition to that, the performance of acid tolerant rhizobia is being assessed on similar acidic soil types in the region through GRDC's N fixation and extension project. Combined, this will form a significant body of work. Questions relating to the last issue (8) are not currently being explored.

AUTHORISATION
Name: Sam Trengove
Position: Managing Director
Signature:
Date: 24/10/2019

Submit report via email to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

SAGIT Lentil Agronomy Trial Reports 2017 and 2018

Project No: TC116 **Project Title: Increasing lentil productivity on dune and swale soils**

Contents

2018 Site Descriptions and soil test results

Alford

The Alford sand hill site is located approximately 1km north west of Alford. It consists of a red/grey alkaline sand with low organic carbon (0-10cm) 0.94% and surface pH of 7.7 (CaCl2).

Latitude: -33.808346, Longitude: 137.816560

Alford site		0-10cm	10-30cm	30-60cm	Total
Ammonium Nitrogen	mg/kg	3	1	1.05	
Nitrate Nitrogen	mg/kg	16	3	4	
Available nitrogen	kg/ha	28	11	23	61
Phosphorus Colwell	mg/kg	26	3	2	Moderate
Potassium Colwell	mg/kg	208	167	89	High
Sulphur	mg/kg	3.2	1.55	2.8	
Available sulphur	kg/ha	5	5	13	22
Organic Carbon	%	0.94	0.51	0.42	Moderate
Conductivity	dS/m	0.11	0.08	0.08	
	CEc	1.54	1.12	1.12	Low
pH Level (CaCl2)	pH Level (CaCl2)	7.7	7.8	8.0	Alkaline
pH Level (H2O)	pH Level (H2O)	8.4	8.7	8.9	
DTPA Copper	mg/kg	0.4	0.5	0.5	Adequate
DTPA Iron	mg/kg	2.9	3.2	3.2	Low
DTPA Manganese	mg/kg	2.8	0.9	0.6	Adequate
DTPA Zinc	mg/kg	1.4	0.2	0.1	Adequate
Exc. Aluminium	meq/100g	0.07	0.10	0.07	
Exc. Calcium	meq/100g	10.4	10.9	9.5	
Exc. Magnesium	meq/100g	0.7	0.8	1.5	
Exc. Potassium	meq/100g	0.5	0.4	0.2	
Exc. Sodium	meq/100g	0.0	0.0	0.1	
CEC		11.7	12.2	11.3	
ESP		0.34%	0.37%	0.49%	Low
Boron Hot CaCl2	mg/kg	0.90	0.91	1.06	Adequate
PBI		50	85	125	Low

Bute

The Bute herbicide residues sandhill site is located approximately 4.5km north of the town of Bute on Workuna Rd. It consists of a deep red sand with moderate levels of non-wetting.
Latitude -33.827832, Longitude 138.022938

Bute site		**0-10cm**		**10-20cm**	
Ammonium Nitrogen	mg/kg	1		4	
Nitrate Nitrogen	mg/kg	20		15	
Available N 0 - 20cm	kg/ha	**30**			
Phosphorus Colwell	mg/kg	30	Adequate	45	Adequate
Potassium Colwell	mg/kg	180	Adequate	312	High
Sulphur	mg/kg	19.4	Adequate	21.5	Adequate
Available S	kg/ha	**41**			
Organic Carbon	%	0.55	Low	0.47	Low
Conductivity	dS/m	0.125		0.114	
Conductivity	Ece	1.75	Low	1.60	Low
pH Level (CaCl2)		5.3	Moderately acidic	5.3	Moderately acidic
pH Level (H2O)		5.9		6.4	
DTPA Copper	mg/kg	0.29	Low	0.45	
DTPA Iron	mg/kg	37.27	Moderate	57.26	
DTPA Manganese	mg/kg	6.47	Moderate	6.14	
DTPA Zinc	mg/kg	0.97	Moderate	0.39	
Exc. Aluminium	meq/100g	0.04		0.08	
Exc. Calcium	meq/100g	2.86		2.06	
Exc. Magnesium	meq/100g	0.61		0.51	
Exc. Potassium	meq/100g	0.38		0.74	
Exc. Sodium	meq/100g	0.09		0.11	
CEC		3.98	Low	3.50	
Exc. Aluminium	%	1.08		2.29	
ESP	%	2.26	Low	3.14	
Boron Hot CaCl2	mg/kg	0.37	Low	0.34	

Lentil Variety trial 2018

Sam Trengove and Stuart Sherriff, Trengove Consulting

Location – Alford

Key Messages

- PBA Ace was the highest yielding variety at 1.53t/ha, but not significantly better than PBA Jumbo 2, PBA Hurricane XT and numbered lines CIPAL1504, CIPAL 1721, CIPAL1522 and CIPAL1602.
- Grain yield was positively linked to canopy size (GreenSeeker NDVI) measured in early September, where higher NDVI was related to higher yields.

Why do the trial?

Sandy soils in the region are poorly represented in the National Variety Trial (NVT) Program. The nearest and most representative lentil variety trial run by the NVT program is located at the Willamulka site. However, this site is typically located in the swale on a heavier soil type compared with the sand hills where lentils can perform poorly. It is possible that the relative performance of lentil varieties on the weaker sands may be different compared to those on the heavier soil types represented in the NVT. The aim of this trial is to identify if any currently grown or pre-release lentil varieties perform better on these poorer soil types.

How was it done?

The trial was a randomized complete block design consisting of 12 varieties with 3 replicates.
The plots were 9.5m * 1.5m and were sown with knife points and press wheels on 250mm spacing.

Sowing date: 21st May **Fertiliser:** 60kg MAP
Herbicides: 300g/ha simazine (900g/kg) and 300g/ha diuron (900g/kg) IBS.
Varieties: PBA Ace, PBA Blitz, PBA Bolt, PBA Hallmark XT (CIPAL1422), PBA Hurricane XT, PBA Jumbo2, CIPAL1504, CIPAL1522, CIPAL1602, CIPAL1701, CIPAL1721 and the PBA breeding line LenHiBM1.

Measurements throughout the season included GreenSeeker NDVI July 16th, August 4th, August 16th and September 5th, pod drop prior to harvest and grain yield. Results were analysed with the statistical package R.

Results and Discussion

Grain yield varied from 1.22 t/ha (CIPAL 1701) to 1.53 t/ha (PBA Ace), The highest yielding varieties were PBA Ace, CIPAL1504, CPAL1721, CIPAL1522, PBA Jumbo2, PBA Hurricane XT and CIPAL 1602, averaging 1.38 t/ha (Table 1). These results contrast with NVT and PBA trial results on medium and heavier textured soils, where PBA Ace has been 16% lower yielding than PBA Jumbo 2 between 2013-16 and 21% lower yielding in 2017-18.

Varietal differences in crop growth were evident in early Spring, based on GreenSeeker NDVI measurements (Table 1). No variety reached canopy closure at this site. Grain yield was related to

NDVI, with yield increasing 277kg/ha for each 0.1 increase in NDVI (Figure 1). Interestingly, similar yield increases have been observed in response to increasing NDVI measured in early Spring for trials assessing deep ripping, nutrition and herbicide effects on similar sandy soils in both 2017 and 2018. This suggests that in general, on these soil types, any treatments that can increase crop growth will likely improve yield.

Pod drop was scored prior to harvest but variation across the trial was not significantly affected by variety.

Table 1: Predicted grain yield (t/ha) from REML analysis and GreenSeeker NDVI for the 2018 lentil variety trial at Alford.

Variety	**Predicted grain yield (t/ha)**		**NDVI Sept 5th**	
PBA Ace	1.53	a	0.491	a
CIPAL1504	1.43	ab	0.465	ab
CIPAL1721	1.38	ab	0.441	bcd
CIPAL1522	1.34	ab	0.442	bcd
PBA Jumbo2	1.34	ab	0.450	bcd
PBA Hurricane XT	1.32	ab	0.453	abc
CIPAL1602	1.31	ab	0.412	de
LenHiBM1	1.28	b	0.458	abc
PBA Hallmark XT	1.27	b	0.445	bcd
PBA Bolt	1.24	b	0.398	e
PBA Blitz	1.24	b	0.422	cde
CIPAL1701	1.22	b	0.424	cde

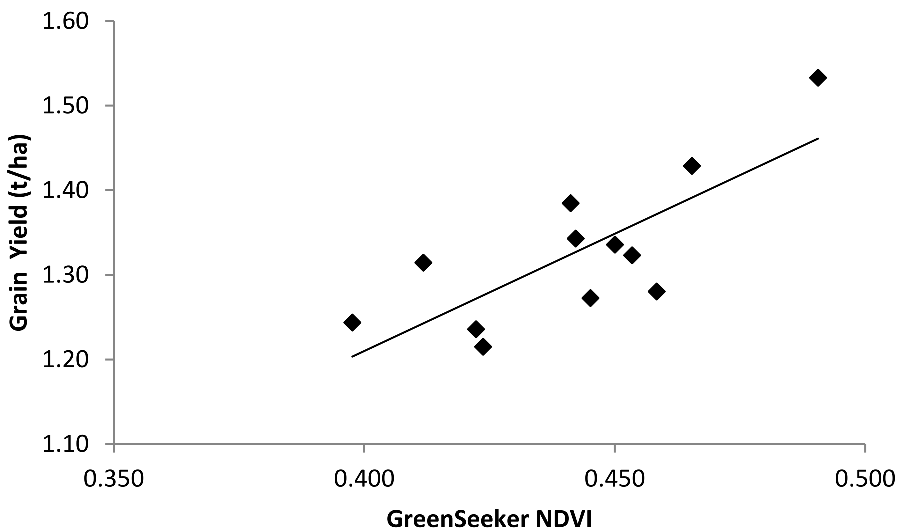

Figure 1: GreenSeeker NDVI of each variety measured 5th September and final grain yield. Y = 2.771x + 0.102, R^2 = 0.60.

Acknowledgements
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Herbicide tolerance and weed control in lentil on sandy soils

Sam Trengove and Stuart Sherriff, Trengove Consulting

Location – Alford, northern Yorke Peninsula

Key Messages

- Sandy soils can have narrow safety margins for commonly used broadleaf herbicides used in lentils. Herbicide damage from some group C and B herbicides reduced lentil growth and grain yield on a sandy soil at Alford.
- Herbicide efficacy on four weed species was variable between products. Herbicide combinations were required to provide high levels of control of all four weed species.
- Treatments that provided the highest levels of weed control also tended to have the largest negative effect on the crop.
- Optimising the herbicide strategy in lentils on sandy soils requires a balance between minimising crop effect but achieving acceptable weed control. This requires knowledge of the target weeds and their resistance status to determine which herbicides to use and in what combination. The benefit of high level weed control then needs to be weighed against the risk of herbicide damage to the crop.

Why do the trial?

Herbicide damage in lentils can occur readily on sandy soils from both pre and post emergent applications. Low clay content, low organic carbon and low cation exchange capacity of sand hills predispose these areas to increased risk from herbicide damage. It is possible that even without visible plant injury symptoms there is an underlying level of herbicide damage restricting biomass production and yield of lentils on these soil types. Previous work conducted on a similar soil type in 2015 and 2017 showed that when more than one herbicide is applied the level of damage can be greater than the sum of the damage of the single herbicides on their own.

This trial aimed to test the safety level of several commonly used herbicide options and combinations on PBA Hurricane XT lentils.

How was it done?

The trial was a randomised complete block design consisting of 22 treatments with 3 replicates. The plots were 9.5m * 1.5m and were sown with knife points and press wheels on 250mm spacing. Herbicide treatments were applied using a 2m hand boom in 100L water per ha.

Sowing date: 21 May **Fertiliser:** 60kg MAP
Variety: PBA Hurricane XT

Herbicides:

The treatments included 2 rates of Group C herbicides Simazine900 (500 and 750g/ha), Diuron900 (550 and 825g/ha), Terbyne (500 and 750g/ha) and Metribuzin (150 and 225g/ha) applied 4 days pre sowing (IBS), Group B herbicide chlorsulfuron (5g/ha) applied IBS and Intervix (500mL/ha) applied post emergent (9 July) and Group F herbicide diflufenican (150mL) applied post emergent (14 June) and combinations of Simazine + Diuron and the Group B and F herbicides as per the treatment list (Table 1 & 2).

Seven mm of rain fell between the IBS herbicide application and seeding. Plots were rolled prior to crop emergence.

Measurements throughout the season included visual herbicide damage scores, weed counts, GreenSeeker NDVI 16 July, 4 August, 16 August and 5 September, pod drop prior to harvest, grain yield and general plant growth observations throughout the season.

Weed control of Wild turnip *(Brassica tournefortii)*, Sow thistle *(Sonchus asper)*, Medic *(Medicago spp.)* and Indian hedge mustard *(Sisymbrium orietale)* was assessed by plant counts when plots were hand weeded.

Results were analysed with the statistical package R.

Not all rates and herbicides used in this trial are registered for use in lentil and the results and findings reported in this article do not constitute a recommendation of their use by the authors.

What happened?

<u>Herbicide damage</u>

Significant levels of group C herbicide damage occurred at the site in 2018, even though all group C herbicides were applied IBS to improve crop safety (Table 1).

Herbicide damage scores show that there were significant differences between treatments at early growth stages with diuron being the safest of the group C herbicides evaluated in 2018.

The highest level of damage from any single group C herbicide occurred with Simazine900 at the high rate (750 g/ha) where there was a 23% reduction in NDVI compared with the untreated control on the 16 July. This level of damage increased to 44% by early August and then remained at that level until the end of the season where a 32% reduction in grain yield compared with the untreated control was observed (Table 1). High rates of metribuzin resulted in low levels of plant damage early, as measured by NDVI but the plots recovered towards the end of the season. This contrasted with the Terbyne treatment where damage started low but increased towards the end of the season. Diuron plots were not significantly affected at either rate, producing grain yields of 1.3 t/ha and similar to the untreated control. The crop safety of the simazine and diuron mixture (250/275 g/ha) was improved over the simazine applied as a standalone treatment.

The NDVI and grain yield data shows that Terbyne provided good levels of crop safety in 2018. However, observation of necrosis around the leaf margins in September suggests that had it been a wetter and longer growing season higher levels of plant damage may have occurred.

The group F herbicide treatment, diflufenican (Brodal) applied at 150 mL/ha early post emergent had a transient visual effect on the lentils in 2018. A reduction in NDVI of 9% on 4 August and 14% on 16 August compared with untreated control was observed however no yield loss was observed. When diflufenican was applied in combination with group B or C herbicides there was no increase in the level of damage to either of these herbicides when compared with their respective standalone treatments.

Of the group B herbicides, chlorsulfuron applied at 5 g/ha prior to sowing had higher levels of plant damage and yield loss than Intervix applied at 500 mL/ha post emergent, however, both resulted in significant reductions in NDVI, of 20% and 9% respectively by the 4^{th} of August. The NDVI results on the 5^{th} of September suggest that Intervix applied as a standalone treatment had recovered completely.

When the group B products were applied in combination with the group C mixture of simazine + diuron, the level of damage was cumulative. For example, the yield loss from simazine + diuron was 11% and the yield loss from Intervix was 8% and the yield loss when applied in combination was 19%. A similar result was observed with the chlorsulfuron (27% yield loss) and simazine + diuron combination causing 35% yield loss. In contrast, when the group B herbicides Intervix and chlorsulfuron were applied in combination the effect was greater than the sum of each on their own. producing a 28% reduction in NDVI on 5^{th} September and 55% reduction in grain yield.

Weed control

Turnip control ranged from 52% with the low rate of diuron to greater than 97% for Intervix or any combination with simazine + diuron mixtures (Table 2). There was no difference between any of the other group C products at either the high or low rate. Diflufenican also provided good control (97%) Sow thistle control was poor with the use of chlorsulfuron alone with only 11% of weeds controlled. In comparison 88% control was achieved with Intervix. Of the group C herbicides metribuzin only controlled 35 and 69% of sow thistle weeds at 150 and 225 g/ha respectively, however higher levels of control were achieved with the other group C herbicides and diflufenican (83% control).

The sulphonyl urea (SU) product chlorsulfuron was the only individual treatment to provide high levels of medic control (98%), with Intervix next best at 74%. Most group C products struggled and provided suppression at best, but the combination of simazine + diuron followed by Intervix improved control to 94%.

The population of Indian hedge mustard (IHM) was sporadic across the sight so there was poor statistical separation between treatments. However, chlorsulfuron alone and the low rate of metribuzin provided limited control.

What does this mean?

Herbicide damage from some Group C herbicide products caused significant biomass reductions and yield loss. The herbicide mixture of simazine + diuron at the lower rate provided a reasonable level of safety to the lentil crop and was still able to maintain good weed control for most species. Given the results recorded it may be possible to adjust the ratios of these two herbicides to reduce the amount of simazine to further improve crop safety and maintain weed control, however these results need to be considered with respect to the seasonal conditions too, where different rainfall patterns may produce a different result.

It was necessary to include some group B chemistry to get good control of the full spectrum of weeds, particularly medic, however it is important to note the impact this has on crop NDVI and the resulting grain yield. Intervix applied post emergent was the safest group B product in this trial.

Diflufenican in combination with the Group C mixture provided excellent control of the brassica weeds and had very good crop safety but provided poor control of medic.

The variation in efficacy between herbicide products and groups means it is important to know what weeds are present in the paddock and plan the herbicide strategy accordingly. Further to this, it is also important to know the herbicide resistance status of the target weeds. For example, Intervix has provided reasonable control of milk thistle and Indian hedge mustard at this site, however resistance to this herbicide is known to be increasing in these species and weed control failures will occur where this is the case unless alternative options can be used.

Figure 1 shows that for a given level of herbicide damage visible at flowering, as measured by a reduction in NDVI, there can be a variety of grain yield responses. The NDVI or biomass reduction from the combination of group B + C herbicides in 2018 had a much greater impact on grain yield compared to the same symptoms from the group C herbicides.

It is important to note that grain yields achieved were in the absence of weed competition, with plots hand weeded in mid-August, before the weeds imposed significant competition. The aim being to measure the effect of herbicide on crop performance, rather than the effect of weeds on crop yield. However, in a real paddock scenario where yields will reflect both crop effect from herbicide damage and remaining levels of weed competition, treatments that balance both crop damage and weed control are expected to perform better than the untreated control. The compromise between optimising weed control and minimising crop effect is highlighted in Figure 2, where group C herbicides that provided the best weed control also had the largest negative effect on crop yield. Weed competition in lentils can reduce yields close to zero where weeds are left uncontrolled and in high numbers. Previous research by the University of Adelaide at Minlaton, SA using triazine canola as a surrogate brassica weed showed that 10 canola plants per sq. m reduced lentil yields by 15 to 26%.

Seasonal conditions have a large impact on weed emergence, herbicide efficacy and herbicide damage. Group C and B herbicides applied to sandy soils and incorporated by sowing (IBS) or post sowing and pre emergence (PSPE) are particularly sensitive to rainfall frequency and amounts. Therefore, results should be interpreted with this in mind. Growing season rainfall was well below average, with the six-week period post sowing being particularly dry. Results may differ in seasons with different seasonal conditions.

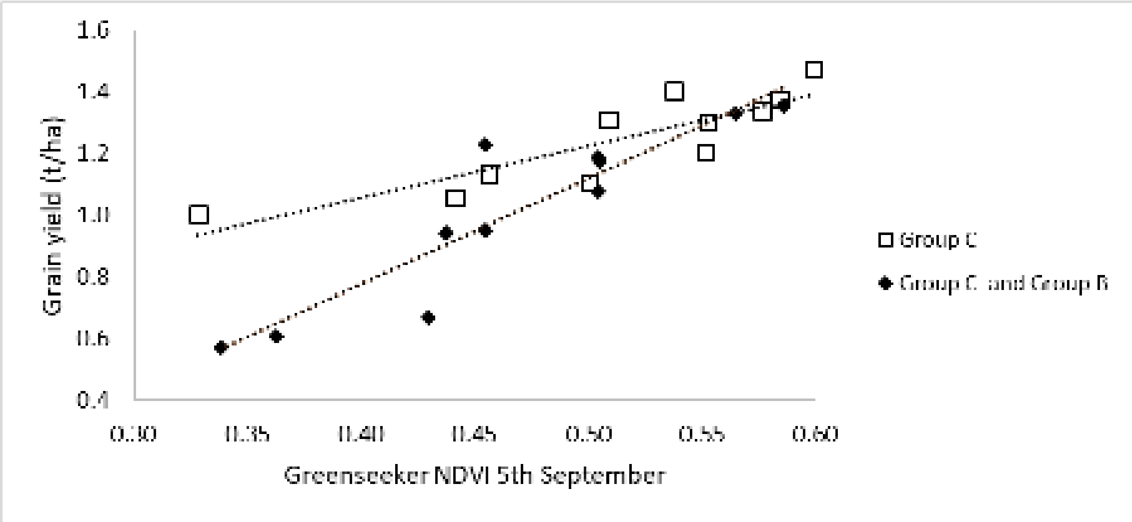

Figure 1 Grain yield (t/ha) and Greenseeker NDVI 5 September (early flowering) for group C treatments only (y = 1.668x + 0.3912 , R^2 = 0.743) and Group B / Group C combinations (y = 3.4308x – 0.5941, R^2 = 0.842)

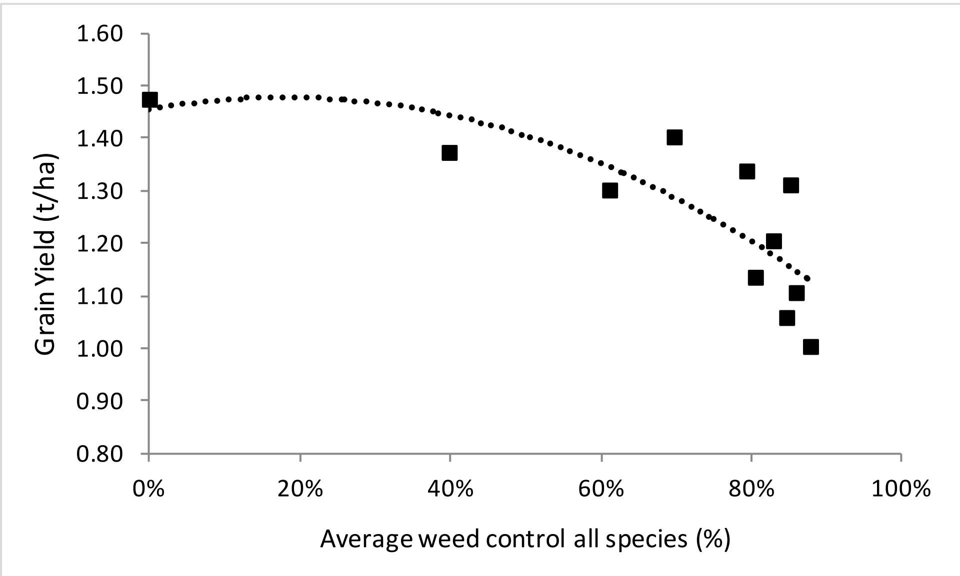

Figure 2: Effect of weed control of all species from Group C herbicides on grain yield (t/ha) of lentil at Alford, 2018. Y = $-0.72x^2 + 0.26x + 1.45$, R^2 = 0.60.

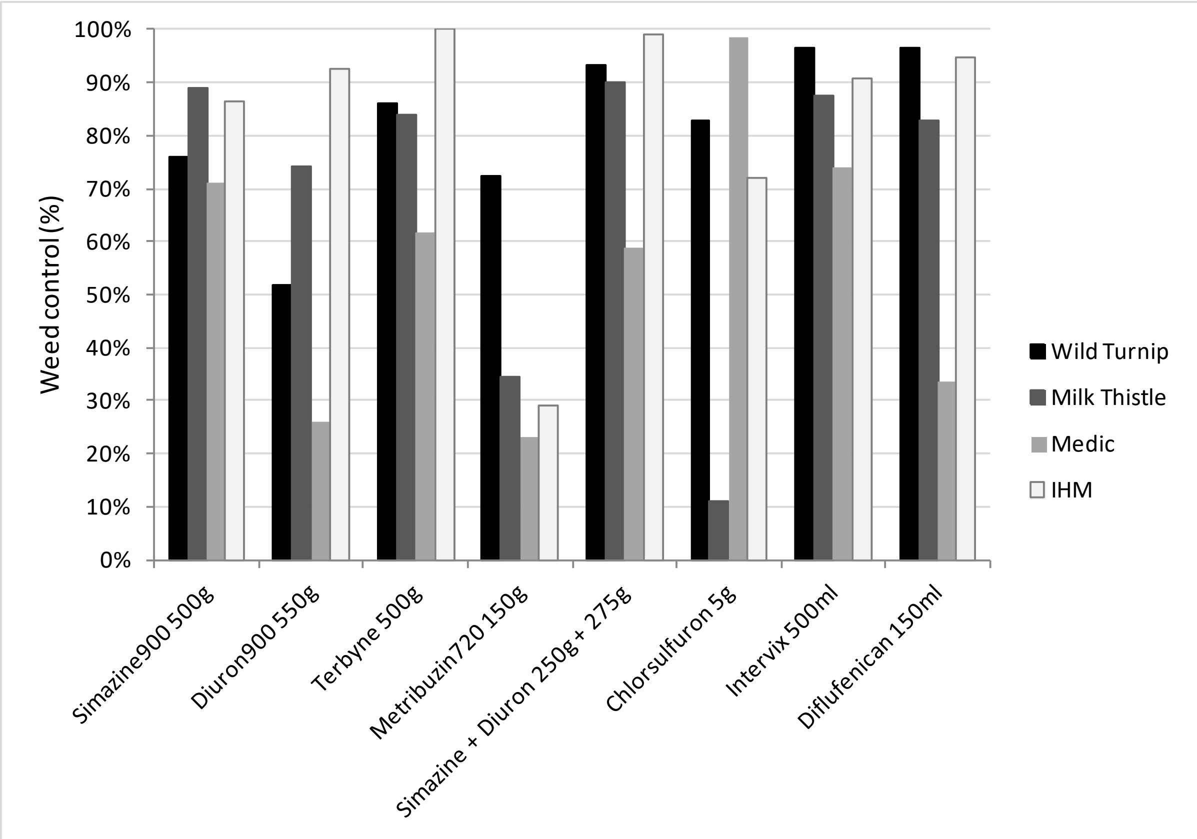

Figure 3: Weed control of four weed species with individual herbicides.

Table 1: Herbicide damage score (0= no symptoms, 6 = plot death), Green seeker NDVI 16 July, 4 August and 5 September and grain yield for 2018 lentil herbicide tolerance trial at Alford.

Treatment	Group C	Group C Rate (g/ha)	Diflufenican (mL/ha)	Chlorsulfuron (g/ha)	Intervix (mL/ha)	Damage score 14th June	Damage Score 2nd July	NDVI 16th July	NDVI 4th Aug	NDVI 16th Aug	NDVI 5th Sept	Grain yield (t/ha)
1	Control					1.0	1.0	0.20	0.32	0.44	0.60	1.47
2	Simazine900	500				1.7	3.3	0.18	0.23	0.33	0.46	1.14
3	Simazine900	750				1.7	4.2	0.15	0.18	0.24	0.33	1.00
4	Diuron900	550				1.3	1.3	0.19	0.30	0.43	0.55	1.30
5	Diuron900	825				1.0	1.5	0.19	0.31	0.45	0.58	1.34
6	Terbyne	500				1.7	1.3	0.19	0.28	0.39	0.55	1.20
7	Terbyne	750				2.3	1.8	0.19	0.28	0.36	0.50	1.11
8	Metribuzin720	150				1.7	1.2	0.19	0.29	0.39	0.58	1.37
9	Metribuzin720	225				1.7	1.5	0.18	0.27	0.39	0.54	1.40
10	Sim/Diu	250/275				1.3	2.5	0.19	0.25	0.33	0.51	1.31
11	Sim/Diu	375/412.5				1.7	2.7	0.17	0.23	0.32	0.44	1.06
12				5		1.0	1.8	0.18	0.26	0.36	0.50	1.08
13					500	1.0	1.8	0.20	0.29	0.39	0.59	1.35
14	Sim/Diu	250/275		5		1.7	2.2	0.17	0.22	0.30	0.45	0.95
15	Sim/Diu	250/275			500	1.7	2.5	0.18	0.24	0.34	0.50	1.19
16				5	500	1.0	2.2	0.17	0.23	0.31	0.43	0.67
17	Sim/Diu	250/275		5	500	2.0	2.7	0.16	0.19	0.26	0.36	0.61
18			150			1.0	1.0	0.20	0.30	0.38	0.56	1.33
19	Sim/Diu	250/275	150			1.0	2.8	0.18	0.24	0.31	0.45	1.23
20	Sim/Diu	250/275	150	5		1.7	2.3	0.17	0.22	0.30	0.44	0.94
21	Sim/Diu	250/275	150		500	1.3	2.7	0.18	0.23	0.30	0.51	1.18
22	Sim/Diu	250/275	150	5	500	1.3	2.5	0.17	0.19	0.24	0.34	0.57
LSD (0.05)						*0.72*	*0.77*	*0.01*	*0.03*	*0.05*	*0.06*	*0.18*

Table 2: Weed control of Wild turnip (Brassica tournefortii), Sow thistle (Sonchus asper), Medic (Medicago spp.) and Indian hedge mustard (Sisymbrium orientale) presented as percent control, the same letters denote statistically similar results as analysed as log(weeds per plot +1) at the 5% level.

Treatment	Group C	Group C Rate (g/ha)	Diflufenican (mL/ha)	Chlorsulfuron (g/ha)	Intervix (mL/ha)	Wild turnip (% control)		Sow thistle (% control)		Medic (% control)		IHM (% control)	
1	Control					0.0	a	0.0	a	0.0	ab	0.0	a
2	Simazine900	500				76%	bc	89%	de	71%	bcde	86%	bc
3	Simazine900	750				79%	bcd	99%	gh	74%	cde	99%	c
4	Diuron900	550				52%	ab	74%	bc	26%	abc	93%	bc
5	Diuron900	825				72%	bc	94%	ef	54%	abcde	97%	bc
6	Terbyne	500				86%	cd	84%	cd	62%	abcde	100%	c
7	Terbyne	750				79%	cd	96%	fg	68%	abcde	100%	c
8	Metribuzin720	150				72%	bc	35%	a	23%	a	29%	ab
9	Metribuzin720	225				83%	bc	69%	b	45%	abcd	82%	bc
10	Sim/Diu	250/275				93%	cd	90%	de	59%	cde	99%	c
11	Sim/Diu	375/412.5				86%	cd	93%	ef	69%	cde	91%	bc
12				5		83%	bcd	11%	a	98%	fgh	72%	ab
13					500	97%	cd	88%	de	74%	e	91%	bc
14	Sim/Diu	250/275		5		97%	cd	98%	gh	98%	fg	99%	c
15	Sim/Diu	250/275			500	100%	d	96%	fg	94%	f	97%	bc
16				5	500	97%	cd	96%	fg	100%	h	97%	bc
17	Sim/Diu	250/275		5	500	100%	d	100%	h	100%	h	97%	bc
18			150			97%	cd	83%	bcd	34%	abc	95%	bc
19	Sim/Diu	250/275	150			100%	d	100%	h	74%	de	100%	c
20	Sim/Diu	250/275	150	5		100%	d	99%	gh	99%	gh	100%	c
21	Sim/Diu	250/275	150		500	100%	d	100%	h	96%	fgh	100%	c
22	Sim/Diu	250/275	150	5	500	100%	d	100%	h	100%	h	100%	c

Acknowledgements

This research was proudly funded by the South Australian Grains Industry Trust (SAGIT) as part of project TC116 'Increasing lentil productivity on dune and swale soils' and is gratefully acknowledged.

Lentil Nutrition 2018

Sam Trengove and Stuart Sherriff, Trengove Consulting

Location – Alford

Key Messages

- Nutrition did not influence grain yield.
- GreenSeeker NDVI measured 5th September increased for treatments of complete nutrition or 5t/ha chicken litter treatment. Omission treatments indicate P, N or Mn may be driving this response, but this is not clear cut.
- MAP applied at 60 and 120kg/ha with the seed caused fertiliser toxicity, with the high rate significantly reducing crop growth all season. The low rate recovered.

Why do the trial?

Sand hills on the northern YP have reduced nutrient supply due to low organic carbon and cation exchange capacity of these soils. Therefore, there is a greater likelihood that a response to macro and/or micronutrient application could be achieved. Crop growth and yield responses to chicken litter have been measured in lentils at other trials and demonstration sites, where fertiliser applications were not responsive. Investigation of these responses indicated the lentils may be responsive to nutrients in the chicken litter that were not applied as part of the fertiliser program, including Molybdenum.

This trial aims to identify what key nutrients lentils are responsive to and therefore restricting lentil production on these soil types.

How was it done?

The trial was a randomised complete block design of 22 treatments. Treatments 2 – 10 were in the form of an omission trial, where each plot had commercial rates of all but one of the following nutrients applied, P, Mg, B, K, S, N, Mn, Cu and Mo. Treatments 12 – 20 were in the form of an addition trial where each plot had only one of those nutrients previously listed applied. The remaining treatments in the trial consisted of a control (treatment 1), complete (treatment 11), chicken litter (treatment 21) and double rate of P (treatment 22) (Table 1).

Nutrient responses are assessed differently in the two components of the trial. In the omission component a positive nutrient response occurs when the omission of a nutrient causes a reduction in growth or yield relative to the complete nutrient package. In the addition component of the trial a positive nutrient response occurs when the addition of a nutrient causes an increase in growth or yield relative to the untreated control. When a given nutrient produces a response in both components of the trial there is more confidence that the nutrient is limiting crop growth.

Sowing date: 21st May **Fertiliser:** as per treatment list

Herbicides: 300g/ha simazine and 300g/ha diuron IBS, 450 mL/ha Intervix late post emergent.

Variety: PBA Hurricane XT

The plots were 9.5 * 1.5m and were sown with knife points and press wheels on 250mm spacing.

<u>Nutrient application</u>
Mg, B, K, S + Ca and the chicken litter were applied pre seeding by broadcasting on the soil surface and then incorporated by sowing.
Mn, Cu and Mo were applied to the soil as a spray solution prior to seeding and then 2 foliar applications were made 9th July and 6th September.
P applications were made with the seed at seeding.
Nitrogen treatments were applied post emergent in front of rain 14th June

See Table 1 for treatment application rates and products.

Measurements throughout the season included recording early vigour and plot visual greenness, GreenSeeker NDVI July 16th, August 4th, August 16th and September 5th, leaf nutrient concentration for selected treatments, pod drop prior to harvest and grain yield.
Results were analysed with the statistical package R.

Table 1: Treatment nutrient application rates for the lentil nutrition trial at Alford in 2018.

Treatment		P	K	S & Ca	N	Mg	Mn	Cu	Mo	B	Chicken litter
	Product	MAP (22%)	MoP (50%)	Gypsum (15%S 16%Ca)	Urea (46%)	Magnesium oxide (54%)	Manganese sulphate (17%)	Copper sulphate (25%)	Sodium Molybdate (34%)	Borax (14%)	
	Units	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	L/ha	kg/ha	g/ha	kg/ha	t/ha
1	Control										
2	P omission		70	500	100	80	30 + 4.5 + 4.5	5 + 0.4 + 0.4	750 + 300 + 300	20	
3	K omision	60		500	100	80	30 + 4.5 + 4.5	5 + 0.4 + 0.4	750 + 300 + 300	20	
4	S omision	60	70		100	80	30 + 4.5 + 4.5	5 + 0.4 + 0.4	750 + 300 + 300	20	
5	N omision	60	70	500		80	30 + 4.5 + 4.5	5 + 0.4 + 0.4	750 + 300 + 300	20	
6	Mg Omision	60	70	500	100		30 + 4.5 + 4.5	5 + 0.4 + 0.4	750 + 300 + 300	20	
7	Mn Omision	60	70	500	100	80		5 + 0.4 + 0.4	750 + 300 + 300	20	
8	Cu Omision	60	70	500	100	80	30 + 4.5 + 4.5		750 + 300 + 300	20	
9	Mo Omision	60	70	500	100	80	30 + 4.5 + 4.5	5 + 0.4 + 0.4		20	
10	B Omision	60	70	500	100	80	30 + 4.5 + 4.5	5 + 0.4 + 0.4	750 + 300 + 300		
11	Complete	60	70	500	100	80	30 + 4.5 + 4.5	5 + 0.4 + 0.4	750 + 300 + 300	20	
12	P only	60									
13	K only		70								
14	S only			500							
15	N only				100						
16	Mg only					80					
17	Mn only						30 + 4.5 + 4.5				
18	Cu only							5 + 0.4 + 0.4			
19	Mo only								750 + 300 + 300		
20	B only									20	
21	Chicken litter										5
22	Double P	120									

Results and Discussion
Scores on 14th June and 2nd July indicate that the double rate of P (120 kg/ha) caused significant reduction in early vigour and this effect is identified in the NDVI measurements throughout the season (Table 2). The standard rate of P caused a reduction in early vigour at both assessment timings, but as the season progressed GreenSeeker NDVI measured a positive response to the standard P rate late in the season.

Canopy greenness scored on 2nd July indicates that the application of 100kg Urea on 14th June had made the canopy greener and that Copper applications had the opposite effect.

On the 4th August the NDVI values indicate a general trend where most of the omission treatments were lower than the addition treatments, indicating some low level of nutrient toxicity occurring when eight or more nutrients are applied in combination, however it is not clear what is causing it (Table 2). The double rate of P reduced growth with an 19% reduction in NDVI at this timing compared to the untreated control, with a similar effect observed on 16th August. However, at this timing it was observed that when P was omitted, it had a negative effect in the presence of other nutrients, with a 15% reduction in NDVI from the complete treatment. NDVI measured 5th September shows a 10% reduction in NDVI for the double P treatment compared with untreated. The complete nutrient treatment and chicken litter treatment have greater NDVI (12 and 9%, respectively) at this late timing, the first time an advantage was observed in these treatments over the untreated control for the growing season. Removing P, N or Mn from the complete treatment reduced NDVI, yet when applied individually neither of these nutrients showed a response (Table 2).

Lentil whole top nutrient analysis shows the complete treatment and the application of chicken litter at 5 t/ha increased plant concentrations of P, K, Ca, Mg, Na, S, B, Mn and Mo above the untreated control (Table 3). The results from this testing, the plot scoring and NDVI data collected throughout the growing season indicate that there are several nutrients or products that need further investigation, these include, P (MAP), Cu (copper sulphate), Mn (manganese sulphate), N (urea) and S + Ca (gypsum). Large increases were measured in tissue Mo, yet no growth or yield responses observed indicating the supply of Mo from the soil was sufficient for this crop. Given this site was an alkaline sand this is not surprising, however lower pH sands in the region may differ, with responses more likely on acidic soils.

GreenSeeker NDVI measurements over the growing season (Figure 1) shows how the double P treatment was significantly poorer performing than the control and complete treatments throughout the season. It also highlights the increase in performance from the complete treatment compared to the control.

The differences in crop canopy throughout the season did not result in significant effects on grain yield or pod drop, with an average trial yield of 1.03 t/ha.

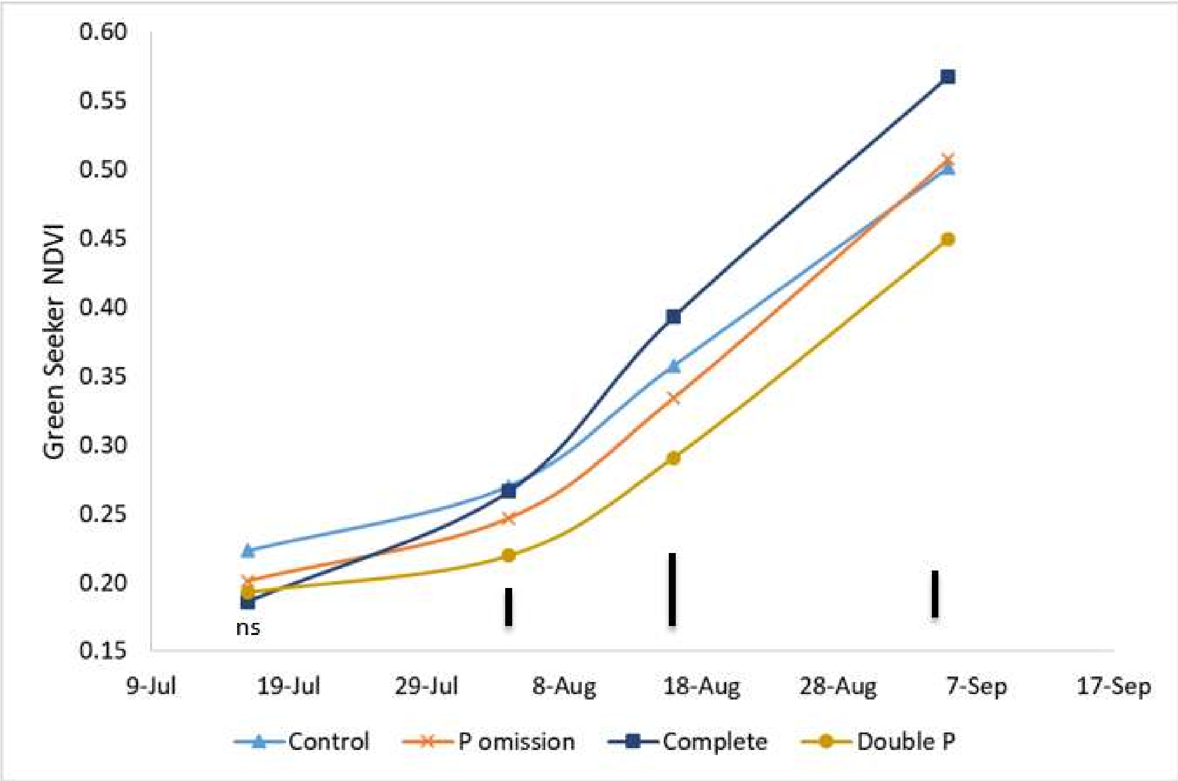

Figure1: GreenSeeker NDVI accumulation from 2nd July to 5th September for selected treatments, Control, P omission, Complete and double P. Vertical bars indicate LSD (0.05), ns = not significant.

Table 2. Vigour score 14th June and 2nd July (1 = low, 9 = high, greenness score 2nd July (1 = pale green, 3 = dark green) and GreenSeeker NDVI 4th August, 16th August and 5th September for the Alford nutrition trial 2018.

Treatment	Vigour score 14th June		Vigour score 2nd July		Greenness 2nd July		NDVI 4th Aug		NDVI 16th Aug		NDVI 5th Sep		Grain yield (t/ha)
Control	8.3	a	5.0	a	1.3	de	0.270	abcd	0.357	abc	0.501	e	0.94
P omission	7.3	abcd	4.7	ab	2.3	abc	0.247	d	0.334	cd	0.507	e	0.99
K omision	5.7	fg	4.0	bc	2.7	ab	0.269	abcd	0.382	abc	0.556	abc	1.08
S omision	6.0	efg	4.7	ab	2.7	ab	0.267	abcd	0.383	abc	0.550	abcd	1.02
N omision	5.7	fg	3.7	c	1.3	de	0.251	cd	0.361	abc	0.516	cde	0.99
Mg Omision	5.7	fg	3.7	c	2.7	ab	0.265	abcd	0.385	abc	0.564	ab	1.16
Mn Omision	5.7	fg	4.0	bc	2.7	ab	0.254	cd	0.345	bc	0.525	bcde	1.07
Cu Omision	5.7	fg	4.0	bc	3.0	a	0.258	bcd	0.372	abc	0.531	abcde	1.10
Mo Omision	5.7	fg	4.0	bc	2.7	ab	0.260	bcd	0.392	ab	0.550	abcd	1.16
B Omision	5.3	g	4.0	bc	2.7	ab	0.251	cd	0.363	abc	0.527	abcde	1.03
Complete	6.0	efg	3.7	c	2.7	ab	0.266	abcd	0.393	a	0.568	a	1.08
P only	6.3	defg	3.7	c	1.7	cde	0.273	abc	0.369	abc	0.535	abcde	1.03
K only	7.0	bcde	4.7	ab	1.3	de	0.286	ab	0.388	ab	0.520	cde	1.00
S only	6.7	cdef	4.0	bc	2.0	bcd	0.281	ab	0.392	ab	0.521	cde	0.93
N only	7.7	abc	4.0	bc	2.3	abc	0.266	abcd	0.367	abc	0.514	cde	0.95
Mg only	7.3	abcd	5.0	a	1.3	de	0.288	a	0.381	abc	0.532	abcde	1.04
Mn only	6.7	cdef	4.7	ab	1.7	cde	0.271	abcd	0.378	abc	0.522	bcde	1.06
Cu only	7.3	abcd	4.7	ab	1.0	e	0.284	ab	0.408	a	0.527	abcde	1.03
Mo only	7.3	abcd	4.0	bc	1.7	cde	0.274	abc	0.368	abc	0.526	abcde	1.03
B only	8.0	ab	4.0	bc	1.3	de	0.271	abcd	0.379	abc	0.510	de	0.96
Chicken litter	7.0	bcde	3.7	c	1.7	cde	0.264	abcd	0.362	abc	0.551	abcd	1.08
Double P	3.3	h	2.3	d	1.7	cde	0.219	e	0.291	d	0.449	f	1.00
LSD 0.05	*1.17*		*0.929*		*0.75*		*0.025*		*0.052*		*0.043*		*ns*

Table 3. Lentil whole top nutrient concentrations for Alford lentil nutrition trial sampled 5th September 2018.

Treatment	Phosphorus	Potassium	Calcium	Magnesium	Sodium	Sulfur	Boron	Copper	Zinc	Manganese	Iron	Aluminium	Cobalt	Molybdenum
	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Nil	0.22	2.01	1.22	0.19	0.049	0.15	24	5.8	26.3	27.3	157	177	<0.16	0.6
Complete	0.25	2.27	1.36	0.23	0.054	0.22	36	5.4	26.0	33.3	160	177	<0.16	32.3
ChickenLitter	0.25	2.32	1.23	0.22	0.064	0.18	22	6.1	26.0	31.3	160	177	<0.16	3.3
LSD (0.05)	*0.02*	*0.17*		*0.02*	*0.009*	*0.02*	*10*	*ns*	*ns*	*2.6*	*ns*	*ns*	*ns*	*14.6*
LSD (0.1)			*0.11*											

Acknowledgements

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Herbicide Residues 2018

Location – Bute

Why do the trial?

Plant back periods for different herbicides are variable and are often affected by soil type. The effect that they can have on lentil crops, particularly on soils with low organic matter can be very severe. For this reason, a trial was set up in the 2017 season to assess the effect of several herbicides on lentil production in the following season.

How was it done?

The trial was established in August 2017 and was a randomised complete block design consisting of 14 treatments and three replicates. The herbicides tested include, two rates of Ally (600g/kg metsulfuron-methyl), Glean (750g/kg chlorsulfuron), Intervix (33 g/L imazamox + 15g/L imazapyr), Onduty (525g/kg imazapic + 175g/kg imazapyr), Velocity (210g/L bromoxynil + 37.5g/L pyrasulfotole) and three rates of Lontrel (300g/L clopyralid). Herbicide treatments were applied using a 2m hand boom to a Scope CL barley crop 8th August 2017. The site was then harvested using conventional harvesting equipment. The trial was sown to PBA Jumbo2 lentils in 2018 with a concord seeder running ag master knife points with a 50mm spread and press wheels on 300mm spacing.

The trial area had already been treated with Onduty at 40g/ha in 2017 prior to hand boom treatments being imposed.

Crop vigour assessments and Green seeker NDVI were measured during the 2018 season to assess the effect of the herbicides applied in the previous year. Results were analysed with the statistical package R. Soil samples from 0 – 10cm and 10 – 20cm showed soil pH which was 5.3 (1:5 $CaCl_2$), this has a significant influence on the minimum re-cropping interval for several herbicides (Table 7). For other soil type information see the site description section of this document (pg 3). Herbicides rates were selected based on standard label rates and a 3X rate to see the extent of the damage.

Table 2. Minimum re-cropping intervals for herbicides used in the herbicide residue trial 2017 – 2018.

<table>
<tr><th>Herbicide</th><th>Label rate (g or mL/ha</th><th>Soil pH (H2O)</th><th>Minimum re-cropping interval for lentil or similar species</th><th>Minimum rainfall requirement (mm)</th></tr>
<tr><td rowspan="2">Ally</td><td rowspan="2">7</td><td>5.6 - 8.5</td><td>9 months</td><td>-</td></tr>
<tr><td>8.6 or above</td><td>test required</td><td>-</td></tr>
<tr><td rowspan="4">Glean</td><td rowspan="4">20</td><td>6.5 or less</td><td>other pulses* - 12 months</td><td>-</td></tr>
<tr><td>6.6 - 7.5</td><td>other pulses* - 22 months</td><td>700</td></tr>
<tr><td>7.6 - 8.5</td><td>test required</td><td>700</td></tr>
<tr><td>8.6 or above</td><td>not recommended for use above pH 8.6</td><td>-</td></tr>
<tr><td>Intervix</td><td>750</td><td>-</td><td>other pulses* - 10 months</td><td>-</td></tr>
<tr><td>Onduty</td><td>40</td><td>-</td><td>other pulses* - 8 months</td><td></td></tr>
<tr><td rowspan="2">Velocity</td><td rowspan="2">1000</td><td>6.4 or less</td><td>9 months</td><td>250</td></tr>
<tr><td>6.5 or greater</td><td>21 months</td><td>500</td></tr>
<tr><td>Lontrel</td><td>300</td><td>-</td><td>9 months</td><td>25 over summer</td></tr>
</table>

-*Lentils not specifically mentioned on the label.

Sowing date: 18th May **Fertiliser:** 70kg MAP

Herbicides: 200g/ha simazine and 100g/ha diuron IBS + 100g/ha simazine and 100g/ha diuron PSPE.
Variety: PBA Jumbo2 **Plot size:** 12m * 2.5m

Results

The application of Ally at 5 or 15 g/ha or Velocity at 1000 or 3000 mL/ha did not significantly reduce early crop vigour or NDVI of PBA Jumbo2 lentil in the following season. The minimum re-cropping interval for these two herbicides was met prior to seeding.

The application of Glean at 15 g/ha reduced the vigour score 19th June however by July there was no longer a significant difference between this treatment and the untreated control. However, the high rate of Glean (45 g/ha) reduced vigour at both timings and reduced NDVI by 30% in September. The lentils were sown inside the re-cropping interval for this herbicide so it was expected that some damage would be observed.

The Intervix and Onduty treatments caused significant reductions in early vigour and approximately 30% reduction in NDVI in September. It is important to note that the trial area was treated with 40g of Onduty prior to the treatments being imposed. This means that the re-cropping interval for the standard rate is not applicable. The high rate of Onduty (120 g/ha) caused a 45% reduction in NDVI.

The re-cropping interval for the low and middle rate of Lontrel was met prior to sowing lentil in 2018. Despite this, significant reductions in early vigour were observed and a 15 – 19% reduction in NDVI in September was recorded. The high rate of Lontrel 300 (600mL/ha), caused significantly more damage with a 46% reduction in NDVI from the untreated control. If the soil background is considered in the NDVI (soil NDVI = approximately 0.15), then the reduction in NDVI increase to 87%.

Table 3. Vigour scores (1 = poor vigour, 9 = high vigour) and Green Seeker NDVI of Lentil for the herbicide residue trial at Bute in 2018. Treatments with matching letters are statistically similar.

Herbicide	**Rate (mL g/ha)**	**Vigour 180709**		**NDVI 180905**	
Nil	0	4.7	abc	0.314	ab
Ally	5	3.7	abcde	0.270	bcde
Ally	15	4.0	abcd	0.284	abcd
Glean	15	4.3	abc	0.292	abc
Glean	45	3.0	cde	0.220	efg
Intervix	500	3.3	bcde	0.235	def
Intervix	1500	3.0	cde	0.204	fg
Onduty	40	5.0	ab	0.211	fg
Onduty	120	2.2	de	0.171	g
Velocity	1000	3.7	abcde	0.304	abc
Velocity	3000	5.3	a	0.325	a
Lontrel (300)	100	3.0	cde	0.255	cdef
Lontrel (300)	300	3.3	bcde	0.266	bcde
Lontrel (300)	600	2.0	e	0.171	g
LSD (0.05)		*1.9*		*0.051*	

Molybdenum nutrition 2018

Location – Bute site + paddock tests

Why do the trial?

Molybdenum is a component of nitrogenase, which has an important role in the fixation of nitrogen in legumes by Rhizobium sp. Because of this important function specific to legumes it is possible that molybdenum deficiencies could be causing poor performance of lentils on soils with low nutrition such as sands. Molybdenum availability in soil decreases with pH and becomes limiting below pH 5.0. Recent pH mapping of sands in the upper Yorke area indicate that soil acidification is becoming more of a problem and therefore nutrition, particularly on acidic sands could be part of the reason why lentils are performing poorly in these areas. Chicken litter treatments in previous trials have also shown elevated leaf tissue molybdenum and increased lentil performance.

These trials aim to assess the effect of molybdenum application on the growth of lentil in the upper Yorke area.

How was it done?

A plot trial was established on a moderately acidic sand hill (0 – 20 cm pH 5.3 1:5 $CaCl_2$) north of Bute in a PBA Jumbo2 lentil crop. The trial consisted of five treatments and three replicates. Treatments included an untreated control, chicken litter applied at 5 t/ha and three rates of sodium molybdate (NaMo), 50 g/ha, 250 g/ha and 750 g/ha. The NaMo treatments were applied twice over the same plots.

The chicken litter and first application of molybdenum were applied 1st June and the second application of Molybdenum occurred 9th July.

Measurements of the small plot trial included vigour scores in June and July and Green Seeker NDVI in September.

Sowing date: 11th May
Fertiliser: 70kg MAP/ha + Molybdenum treatments
Variety: PBA Jumbo 2 @ 55 kg/ha

A second large scale trial was established in a paddock of PBA Jumbo2 lentils, sown 9th May @ 55 kg/ha. In this trial 200 g/ha sodium molybdate was applied 18th July using a conventional boom spray in strips across the paddock. The trial strips covered a range of soil types.

Three replicates of side by side comparisons were made. Measurements included dry matter, whole top leaf nutrient concentration and new growth (top 5cm) leaf nutrient concentrations.

Results for both experiments were analysed using the statistical package R.

Results

<u>Plot experiment</u>

No differences were observed by eye in the form of vigour scores Table 9. The GreenSeeker detected a 25% increase in NDVI from the application of chicken litter at 5 t/ha, indicating increased biomass. There appears to be a marginal increase in NDVI from the application of 750 g/ha sodium molybdate although this was not significant. The conventional rate of molybdenum application did not result in any differences.

Table 4: Vigour scores from 28th June and 9th July (1 = poor vigour, 9 = high vigour) and Greenseeker NDVI for the Molybdenum plot trial 2018, letters adjacent to NDVI values indicate statistical levels of significance.

Treatment applied twice	Vigour_180628	Vigour_180709	NDVI_180905	
Control	5.3	4.3	0.441	b
Chicken Litter 5t/ha	5.7	4.7	0.550	a
NaMo 50 g/ha	6.0	5.3	0.467	b
NaMo 250 g/ha	5.0	4.3	0.454	b
NaMo 750 g/ha	5.3	5.3	0.491	ab
LSD (0.05)	*ns*	*ns*	*0.064*	

Paddock trial

Visual observations during the season indicated that there was a response to the molybdenum that was applied by the grower. Whole top leaf tissue samples were analysed for nutrient concentrations and it was found that there was a significant increase in shoot nitrogen (Table 10). There was also a 41% increase in shoot dry matter resulting in a 47% increase in nitrogen uptake (kg/ha).

The molybdenum levels in the control areas were below the detectable limit of 0.4 mg/kg and the treated samples ranged from 0.58 mg/kg to 3.1 mg/kg. The high level of variation in the treated concentrations meant that the averages were not significantly different. Had the limit of detection been lower this may have been different.

Interestingly the application of molybdenum resulted in a significant reduction in the concentration of cobalt, another important nutrient for nitrogen fixation.

For leaf tissue analysis of the new growth, the only significant differences were an increase in nitrogen, similar to the whole top measurements and a decrease in chloride concentration (Table 11).

Table 5: Nutrient and dry matter analysis results of lentil whole tops from paddock scale molybdenum trial.

Treatment	Nitrogen (%)	Cobalt (mg/kg)	Molybdenum (mg/kg)	Dry matter (g/m2)	Nitrogen (kg/ha)
Molybdenum	3.0	0.3	1.5	213	64
Control	2.3	0.4	<0.4	151	34
LSD (0.05)	*0.6*	*ns*	*ns*	53	*6*
LSD (0.10)		*0.1*	*ns*		

Table 6: Nutrient and dry matter analysis results of new growth, top 5cm, from paddock scale molybdenum trial.

Treatment	Nitrogen (%)	Chloride (%)
Molybdenum	3.9	0.5
Control	3.0	0.8
LSD (0.05)	*0.6*	*0.3*

Spading demo Pattingale Rd Port Broughton

Co-operator – Stefan Schmitt

Why was it done?

Poor performing sands are a part of the landscape in the upper Yorke and Broughton areas. When the trial was established, Spading was a new technology to the area with only limited areas being treated prior to the establishment of this trial. Chicken litter is a readily available nutrient source in the area and many growers see it as a "fix all" product. It is regularly used to treat poor performing soil types with the expectation that the addition of an organic amendment will improve performance. This trial seeks to investigate the effects of spading alone and in combination with application of chicken litter on sand hill performance.

How was it done?

In 2016 a trial to investigate the effects of spading and chicken litter was established. Treatments were a factorial of spading and an application of chicken litter at 5 t/ha. The trial has two replicates.

GreenSeeker NDVI data was captured 17th September 2018 and grain yield data was measured using a commercial harvester and yield monitoring software. Results were analysed using the software package R.

Results & Discussion

Spading reduced lentil NDVI in September and grain yield by 0.21t/ha. Chicken litter had little impact.

Spading	**NDVI Sept 17th**	**Grain yield (t/ha)**
Yes	0.588	0.68
No	0.638	0.89
LSD (0.05)	*ns*	*0.05*
LSD (0.10)	*0.051*	-

Chicken Litter (t/ha)	NDVI Sept 17th	Grain yield (t/ha)
0	0.593	0.78
5	0.633	0.79
LSD (0.05)	*ns*	*ns*
LSD (0.10)	*0.037*	*ns*

Lentil paddock survey / Transect analysis 2018

How was it done?

Transects across sand hills in two paddocks, one at Alford and one at Bute were selected as transitional areas of soil type and grain yield. Points were marked at 15m or 17m intervals from the top of the sand hill down to the heavier textured flat for the Alford and Bute sites, respectively.

Soil sample analysis at depths 0-10cm, 10-30cm and 30-90cm at Alford and 0-10cm, 10-30cm and 30-90cm were taken during the season. Root nodulation scores and lentil leaf tissue analysis were undertaken in early September. Data from these samples was used to identify potential yield limiting factor.

Results

Alford

Soil sample analysis did not indicate any obvious issues associated with lower yield on the sand hill. Table 12 shows that pH values at the site are moderate – strongly alkaline on the surface and are strongly alkaline at depth. Colwell P at most points is marginal. Phosphorus buffering index (PBI) is highest on the flat. Organic carbon is low – adequate on the sand and increases towards the flat. Cation exchange capacity (CEC) is high, where these values are influenced heavily by high level of exchangeable calcium. Other soil issues at depth include high exchangeable sodium and boron towards the flat (points 6 – 8). Issues that were identified in the soil do not correlate well to reduced yield on the sand hill.

Results from root nodulation scores did not indicate any poor nodulation at any point, with average scores from 6.1 to 6.5 out of 10.

Leaf nutrient analysis (Table 14) showed that the copper uptake was lower at the top of the sand hill. Other nutrients did not show consistent patterns with location.

Bute

As for the Alford site, the soil samples did not show a lot of consistency with poorer yield on the sand hill. Table 13 shows that the pH values were lower than Alford but only getting as low as 5.9 (1:5 $CaCl_2$). PH values increased towards the flat to strongly alkaline (8.4 1:5 $CaCl_2$). Subsoil pH was also high at almost every point.

Some root nodulation scores were slightly lower at Bute compared to Alford, with scores between 5.9 and 6.6 out of 10.

Leaf nutrient analysis also didn't show consistent trends with poor performance of lentils on the sand hill. However manganese was lower on the sandier soil types and could be worth pursuing.

Table 7: soil test results for Alford transect, points 1 – 8, cells highlighted in orange indicate marginal or high values, sampled March 2018

Point	Depth	Available Nitrogen	Phosphorus Colwell	Potassium Colwell	Available Sulfur	Organic Carbon	Conductivity	pH (CaCl2)	pH (H2O)	DTPA Copper	DTPA Iron	DTPA Manganese	DTPA Zinc	CEC	ESP	Boron Hot CaCl2	PBI
		kg/ha	mg/kg	mg/kg	kg/ha	%	Ece			mg/kg	mg/kg	mg/kg	mg/kg		%	mg/kg	
1	0-10	23	25	200	4	0.8	1.4	7.5	8.3	0.29	2.77	2.41	0.98	11.1	0.4%	0.71	42
2	0-10	30	28	262	5	1.59	1.666	7.5	8.3	0.4	3.16	2.99	1.13	12.8	0.4%	1.03	51
3	0-10	33	32	325	5	1.21	1.624	7.5	8.3	0.47	3.51	3.21	1.01	14.0	0.4%	1.38	58
4	0-10	32	34	308	5	1.3	1.778	7.6	8.3	0.61	3.98	3.9	1.1	14.7	0.5%	1.78	80
5	0-10	30	30	276	6	1.37	1.736	7.6	8.3	0.7	4.68	4.38	1.12	16.9	0.5%	2.03	79
6	0-10	33	26	297	6	1.46	1.23	7.6	8.4	0.75	5.37	4.5	0.86	18.2	0.7%	2.38	96
7	0-10	29	30	336	6	1.69	1.2	7.9	8.6	0.93	5.99	5.23	1.51	19.2	0.6%	2.81	100
8	0-10	36	26	500	7	1.82	1.66	7.8	8.6	0.91	6.18	6.08	1.49	22.5	0.8%	3.2	130
1	10-30	9	< 2	146	5	0.47	0.98	7.8	8.7	0.38	2.7	0.85	0.33	10.9	0.3%	0.57	58
2	10-30	12	7	189	4	0.51	0.896	7.7	8.6	0.39	2.87	1.06	0.32	11.5	0.3%	0.79	67
3	10-30	18	4	255	5	0.66	1.372	7.8	8.7	0.6	4.13	1.25	0.22	13.7	0.3%	1.31	100
4	10-30	15	5	216	7	0.75	1.428	7.8	8.7	0.62	5.24	1.41	0.2	15.5	0.4%	1.99	126
5	10-30	18	7	165	14	0.87	1.414	7.8	8.7	0.78	6.34	1.53	0.34	18.0	0.5%	2.37	151
6	10-30	18	8	169	10	1.07	1.04	7.8	8.6	1.03	7.18	1.86	0.34	19.2	0.6%	2.84	154
7	10-30	21	8	205	9	1.35	1.08	7.8	8.6	1	8.7	1.86	0.32	21.0	0.7%	3.15	173
8	10-30	21	6	231	12	1.24	1.33	7.8	8.7	1.04	12.08	2.19	0.28	24.8	1.7%	4.34	203
1	30-90	19	< 2	78	13	0.38	0.63	8	8.9	0.32	3.35	0.61	0.61	9.8	0.4%	0.65	60
2	30-90	27	2	100	17	0.4	0.77	8	8.9	0.46	3.58	0.67	0.32	10.7	0.4%	1.03	81
3	30-90	27	2	109	37	0.5	0.96	8	9	0.65	4.16	0.79	0.31	14.1	0.8%	1.98	150
4	30-90	36	2	109	56	0.49	1.1	8.1	9	0.76	4.13	0.87	0.28	14.3	1.5%	4.01	182
5	30-90	54	4	130	80	0.56	1.43	8.1	9.1	0.73	22.68	6.11	0.21	14.0	2.6%	3.56	187
6	30-90	54	3	119	64	0.5	1.5	8.2	9.3	1.13	4.9	0.88	0.15	16.3	4.8%	7.36	209
7	30-90	45	4	126	98	0.62	1.7	8.2	9.3	1.15	6.59	1.13	0.24	18.4	6.8%	9.59	196
8	30-90	45	4	178	462	0.69	5.39	8.4	9.7	1.23	7.88	1.45	0.17	22.5	23.9%	23.49	217

Table 8: soil test results for Bute transect, points 1 – 8, cells highlighted in orange indicate marginal or high values, sampled November 2018

Point	Depth	Available Nitrogen	Phosphorus Colwell	Potassium Colwell	Available Sulfur	Organic Carbon	Conductivity	pH Level (CaCl2)	pH Level (H2O)	DTPA Copper	DTPA Iron	DTPA Manganese	DTPA Zinc	CEC	ESP	Boron Hot CaCl2
		kg/ha	mg/kg	mg/kg	kg/ha	%	Ece			mg/kg	mg/kg	mg/kg	mg/kg		%	mg/kg
1	0-10	14	29	193	3	0.58	1.2	7.6	8.3	0.22	4.18	1.82	0.88	8.9	0.8%	0.62
2	0-10	15	27	211	3	0.58	0.7	5.9	6.6	0.34	13.03	3.28	1.39	5.0	1.4%	0.45
3	0-10	21	34	262	3	0.7	0.9	6	6.7	0.28	12.57	3.45	1.59	5.5	1.1%	0.5
4	0-10	21	32	252	4	0.72	0.9	6	6.8	0.46	14.09	4	1.08	6.0	1.2%	0.53
5	0-10	17	31	263	3	0.69	0.8	6.3	7.1	0.33	13.06	3.79	1.46	5.9	1.0%	0.58
6	0-10	17	34	281	3	0.88	0.7	6.6	7.4	0.4	9.67	4	1.62	7.7	1.3%	0.87
7	0-10	11	29	503	2	1.17	1.1	7.6	8.4	0.48	6.65	4.85	1.9	15.4	0.9%	1.69
8	0-10	12	32	555	2	1.51	1.3	7.6	8.4	0.6	8.07	5.87	1.96	18.6	0.9%	1.97
1	10-30	6	3	161	4	0.17	1.0	8	8.9	0.37	4.85	0.87	0.15	9.8	0.5%	0.43
2	10-30	9	9	122	3	0.16	0.6	7.2	8.1	0.27	5.42	0.78	0.1	4.9	1.0%	0.37
3	10-30	6	15	150	9	0.17	0.9	7.8	8.6	0.41	3.8	0.86	0.24	6.0	0.7%	0.45
4	10-30	12	16	158	3	0.27	1.0	7.8	8.6	0.39	4.74	1.23	0.17	6.2	0.8%	0.53
5	10-30	6	16	196	4	0.28	1.1	7.9	8.7	0.44	3.77	1.21	0.74	8.7	0.7%	0.59
6	10-30	18	10	259	9	0.46	1.0	7.6	8.3	0.75	7.04	1.31	0.38	13.5	0.7%	1.24
7	10-30	12	6	329	9	1.02	1.2	7.9	8.6	0.91	9.69	2.49	0.33	24.7	1.3%	3.3
8	10-30	27	3	413	11	0.75	1.2	7.8	8.6	1.06	13.11	2.58	0.34	22.4	1.1%	2.91
1	30-60	9			23		0.7	7.9	8.3							0.53
2	30-60	9			10		0.6	7.7	8.6							0.57
3	30-60	5			6		0.6	7.8	8.6							0.55
4	30-60	14			10		0.7	7.9	8.7							0.69
5	30-60	18			23		0.9	7.9	8.7							1.06
6	30-60	59			39		1.5	7.9	8.5							2.06
7	30-60	23			21		1.7	8.2	9.1							5.42
8	30-60	18			9		1.3	8	9							3.86

Table 9: Alford transect lentil whole top nutrient analysis, sampled 5th September

Point	P	K	Ca	Mg	Na	S	B	Cu	Zn	Mn	Fe	Al	Co	Mo	Dry matter
	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	t/ha
1	0.2	1.18	0.97	0.18	0.057	0.11	17	2.2	17	19	170	200	<0.16	<0.40	1.1
2	0.17	1.34	1.22	0.16	0.035	0.11	20	2.9	19	22	120	130	<0.16	<0.40	1.9
3	0.17	1.66	1.2	0.17	0.035	0.12	22	4.9	20	25	120	140	<0.16	<0.40	2.5
4	0.14	1.58	1.39	0.18	0.037	0.12	26	6	16	26	150	180	<0.16	<0.40	2.1
5	0.13	1.37	1.11	0.17	0.034	0.1	21	5.8	17	20	120	140	<0.16	<0.40	2.3
6	0.15	1.57	1.1	0.16	0.04	0.11	21	6	17	20	160	210	<0.16	<0.40	2.0
7	0.15	1.54	1.12	0.18	0.039	0.11	22	6.2	18	21	120	150	<0.16	0.44	1.8
8	0.19	1.83	1.45	0.18	0.058	0.15	25	7	21	31	210	270	<0.16	0.69	1.9

Table 10: Bute transect lentil whole top nutrient analysis, sampled 7th September

Point	P	K	Ca	Mg	Na	S	B	Cu	Zn	Mn	Fe	Al	Co	Mo	Dry matter
	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	t/ha
1	0.29	1.57	1.05	0.22	0.042	0.15	18	3.8	22	45	170	210	<0.16	<0.40	2.0
2	0.35	1.81	0.99	0.25	0.035	0.18	23	5.2	24	69	200	220	0.22	<0.40	2.0
3	0.38	1.91	1.01	0.27	0.042	0.18	23	4.1	27	91	170	190	<0.16	<0.40	1.8
4	0.33	1.89	0.93	0.24	0.036	0.16	21	4.1	22	69	150	170	<0.16	<0.40	2.2
5	0.35	1.84	0.78	0.25	0.047	0.14	19	3.6	27	81	160	190	<0.16	<0.40	1.5
6	0.35	1.85	0.75	0.22	0.058	0.13	19	3.6	21	60	150	170	<0.16	<0.40	2.0
7	0.25	2.25	1.23	0.21	0.051	0.15	21	5.3	21	53	170	190	<0.16	<0.40	0.1
8	0.23	2.17	1.13	0.19	0.041	0.15	19	7.1	22	47	150	180	<0.16	0.41	2.1

2017 trials

2017 Site Description

Alford
The Alford sandhill site is located approximately 3km nth of Alford. It consists of a red/grey alkaline sand with low organic carbon (0-10cm) 0.69% and surface pH of 7.4 (CaCl2)
Latitude: -33.790, Longitude: 137.824

Pattingale Rd
The Pattingale Rd sandhill site is located approximately 8km south east of Port Broughton. It consists of a red sand with low to moderate organic carbon (0-10cm) 0.88%, slightly acidic on the surface with pH 5.4 (CaCl2) and low cation exchange capacity.
Latitude: -33.637, Longitude: 138.007

Bute
The Bute sandhill site is located approximately 3km north of the town of Bute. It consists of a deep red sand with moderate levels of non-wetting, low organic carbon (0-10cm) 0.45%, pH 5.8 (CaCl2) and low cation exchange capacity.
Latitude -33.837, Longitude 137.991

Bute low pH
The Bute low pH site is located on a sandhill approximately 6km north of Bute. It is a pale red to brown sand with topsoil (0-10cm) pH 4.5 (CaCl2) and subsoil pH (10-20cm) ranging from 4.8 – 7.2 (CaCl2).

Lentil Variety trial 2017

Location – Pattingale Rd

Why do the trial?

The nearest and most representative lentil variety trial run by the National Variety Trial (NVT) program is located at the Willamulka site. However, this site is typically located in the swale on a heavier soil type than that what is found on sandhills where lentils are performing poorly. It is possible that the performance of lentils on the weaker sands may be different compared to those on the heavier soil types such is presented in the NVT.

The aim of this trial is to identify if there are any of the currently grown lentil varieties that perform better on these poorer soil types.

How was it done?

The trial was a randomized complete block design consisting of 8 varieties with 3 replicates.

The plots were 10m * 1.5m and were sown with knifepoints and press wheels on 250mm spacing.

Sowing date: 18th May **Fertiliser:** 70kg MAP

Herbicides: 200g/ha simazine and 100g/ha diuron IBS + 100g/ha simazine and 100g/ha diuron PSPE.

Varieties: PBA Ace, PBA Blitz, PBA Bolt, PBA Greenfield, PBA Hurricane XT, PBA Jumbo2, Nipper and a breading line SP1333.

Plots were sown with knife points and press wheels on 250mm spacing. The plots were 10 * 1.5m.

Measurements throughout the season include recording Green seeker NDVI Aug 22nd and Sep 12th and grain yield. Pod drop was also scored pre harvest.

Results were analysed with the statistical package R.

Results

Green seeker NDVI varied between variety with PBA Hurricane XT producing the highest value in both late-August and mid-September (Table 16). The older variety Nipper which typically has lower vigour produced the lowest value at both timings. The amount of grain lost to pod drop varied significantly with variety and was loosely related to yield, with the highest yielding varieties generally having more grain on the ground prior to harvest. However, grain yield across the 8 varieties did not differ significantly with an average grain yield of 0.41 t/ha.

Table 11: Green seeker NDVI, pre harvest pod drop and grain yield for the 2017 variety trial at Pattingale Rd. Pod drop score: 1 = 0-5 seeds per m of row 2 = 5-10, 3 = 10-20, 4 = 20-40, 5 = 40-80, 5=80-200.

Variety	NDVI 170822	NDVI 170912	Pod drop score	Grain yield (t/ha)
Ace	0.359	0.485	2.0	0.52
Blitz	0.329	0.422	2.7	0.41
Bolt	0.309	0.422	3.0	0.41
Greenfield	0.323	0.463	2.7	0.21
Hurricane XT	0.412	0.546	4.0	0.52
Jumbo2	0.346	0.492	2.3	0.57
Nipper	0.262	0.362	1.0	0.28
SP1333	0.379	0.518	1.7	0.34
LSD (0.05)	*0.069*	*0.089*	*0.1*	*ns*

Herbicide Tolerance 2017

Location – Pattingale Rd

Why do the trial?

Given the low clay content, low organic carbon and low cation exchange capacity of these poor performing sand hills, it is not uncommon to see significant herbicide damage from both pre-emergent and post emergent herbicide applications in lentils. It is possible that even when no visible symptoms appear there is an underlying level of herbicide damage that is restricting the performance of the lentils on these soil types. Previous work that was conducted on a similar soil type in 2015 showed that when more than one herbicide is applied the level of damage can be greater than the cumulative sum damage of the single herbicides on their own.
This trial seeks to test the level of safety of several herbicide options and combinations on PBA Hurricane XT lentils.

How was it done?

The trial was a randomized complete block design consisting of 22 treatments with 3 replicates. The plots were 10m * 1.5m and were sown with knife points and press wheels on 250mm spacing. Herbicide treatments were applied using a 2m hand boom in 100L water per ha.

Sowing date: 18th May **Fertiliser:** 70kg MAP
Variety: PBA Hurricane XT
Herbicides: As per treatment below
Herbicide treatments included 2 rates of Group C herbicides Simazine900 (500g and 750g), Diuron900 (550g and 825g), Terbyne (500g and 750g) and Metribuzin (180g and 270g) applied 2/3 IBS and 1/3 PSPE, Group B herbicides Glean (5g) applied IBS and Intervix (500mL) applied post emergent (8th August) and Group F herbicide Brodal (80mL) applied PSPE or (150mL) post emergent (28th July) and combinations of Metribuzin and the Group B and F herbicides as per the treatment list.

Plots were sown with knife points and press wheels on 250mm spacing. The plots were 10 * 1.5m.

Measurements throughout the season include herbicide damage score Jul 27th, Green seeker NDVI Aug 22nd and Sep 12th and grain yield.
Results were analysed with the statistical package R.

Not all rates and herbicides used in this trial are on label for lentils and are not recommended for these use patterns.

Results
Due to a lack of rainfall post seeding, emergence of the lentil trials at Pattingale Rd was slow and staggered. Despite the lack of rainfall, when the limited rain did fall on to the dry non wetting sand of the site it washed some of the group C herbicides into the crop row causing significant damage.

The greatest level of damage was produced by the metribuzin treatments with 180 g/ha and 270 g/ha producing an average score of 4.5 and 5.2 respectively (0 = no damage and 6 = complete plant death). The Diuron and Terbyne treatments were the safest Group C herbicides in this trial, however it should be noted that Terbyne is commonly responsible for significant damage in lentils and caution should be used before using this product on these soil types. It should also be noted that Terbyne is not recommended for soils with less than 40% clay. The low rate of simazine produced a damage score equal to the nil, 2.3, compared to 4.2 for the 750g treatment, however the grain yield results show that even at the low rate yield was reduced by 57% compared to the nil.

The high level of damage that was caused by the metribuzin is likely to have masked any additive effects that may have occurred from the addition of a Group B or F herbicide applied IBS or PSPE producing two distinct groups of data, those not treated with metribuzin (excluding Simazine900 750g/ha) with an average score of 2.0 and those treated with metribuzin with an average score of 4.3. It should be noted that even the nil plots were scored blind and produced a damage result of 2.2. This score was conducted prior to the application of post emergent herbicides Intervix and Brodal.

The results of Green seeker NDVI at both timings and the grain yield data show similar responses to the treatments as the damage score in July. This indicates that there was little recovery from the initial herbicide damage. Treatments that did not receive any metribuzin or simazine produced 0.48 t/ha of lentil grain yield and those treated with these herbicides averaged 0.21 t/ha. The high rate of metribuzin (270g/ha) only yielded 0.11 t/ha although this was not significantly different to the other metribuzin treatment combinations.

Table 12: Herbicide damage score (0= no symptoms, 6 = plot death), Green seeker NDVI Aug 22nd and Sept 12th and grain yield for 2017 lentil herbicide tolerance trial at Pattingale Rd.

Herbicide Treatment	Damage score	NDVI 170822	NDVI 170912	Grain yield (t/ha)
Nil	2.2	0.35	0.50	0.49
Glean 5g IBS	1.8	0.39	0.59	0.42
Simazine 500g IBS/PSPE	2.3	0.33	0.48	0.21
Simazine 750g IBS/PSPE	4.2	0.29	0.41	0.25
Diuron 550g IBS/PSPE	2.0	0.36	0.54	0.44
Diuron 825g IBS/PSPE	2.2	0.38	0.56	0.59
Terbyne 500g IBS/PSPE	1.7	0.44	0.59	0.48
Terbyne 750g IBS/PSPE	2.7	0.37	0.51	0.41
Metribuzin 180g IBS/PSPE	4.5	0.26	0.38	0.22
Glean 5g IBS + Metribuzin 180g IBS/PSPE	4.5	0.26	0.39	0.23
Metribuzin 270g IBS/PSPE	5.2	0.23	0.32	0.11
Brodal 80mL PSPE	1.3	0.44	0.58	0.63
Metribuzin 180g IBS/PSPE + Brodal 80mL PSPE	4.2	0.25	0.37	0.18
Brodal 150mL Post	2.5	0.35	0.45	0.41
Metribuzin 180g IBS/PSPE + Brodal 150mL EPost	4.2	0.27	0.40	0.20
Intervix 500mL Post	1.7	0.40	0.55	0.50
Glean 5g IBS + Intervix 500mL Post	1.8	0.40	0.54	0.43
Metribuzin 180g IBS/PSPE + Intervix 500mL Post	4.5	0.23	0.35	0.20
Glean 5g IBS + Metribuzin 180g IBS/PSPE + Intervix 500mL Post	4.0	0.29	0.44	0.26
Glean 5g IBS + Metribuzin 180g IBS/PSPE + Brodal 150mL EPost	4.0	0.27	0.43	0.22
Metribuzin 180g IBS/PSPE + Brodal 180mL Epost + Intervix 500mL Post	4.7	0.27	0.40	0.23
Glean 5g IBS + Metribuzin 180g IBS/PSPE + Brodal 150mL EPost + Intervix 500mL Post	3.7	0.29	0.40	0.25
LSD 0.05	*1.3*	*0.11*	*0.12*	*0.24*

PBA Jumbo2 and diflufenican tolerance 2017

Location – Pattingale road

Why do the trial?

Over the last few seasons Trengove Consulting has received comments from lentil growers on the Yorke Peninsula that the lentil variety PBA Jumbo2 has been showing more severe herbicide damage symptoms as a result of diflufenican applications compared to other varieties.

This trial aims to test the sensitivity of PBA Jumbo2 to applications of post emergent applications of diflufenican compared to another commonly grown variety.

How was it done?

The trial was a randomized complete block design consisting of two varieties (PBA Jumbo2 and PBA Hurricane XT) and three diflufenican rates (0, 120 and 200 mL/ha Brodal) with three replicates. The plots were 10m * 1.5m and were sown with knife points and press wheels on 250mm spacing.

Sowing date: 18th May **Fertiliser:** 70kg MAP
Herbicides: 200g/ha simazine and 100g/ha diuron IBS + 100g/ha simazine and 100g/ha diuron PSPE + post emergent diflufenican as per treatment.
Varieties: PBA Jumbo2 and PBA Hurricane XT

Plots were sown with knife points and press wheels on 250mm spacing. The plots were 10 * 1.5m.

Herbicide treatments were applied with a hand boom in 100L water per ha 28th July.

Measurements throughout the season include recording diflufenican damage score 8th Aug, Flower score 28th Aug, Green seeker NDVI Aug 22nd and Sep 12th and grain yield. Pod drop was also scored pre harvest.
Results were analysed with the statistical package R.

Results

The initial damage score conducted 8 days after application (DAA) showed that the visual symptoms appeared more severe in PBA Jumbo 2 compared to PBA Hurricane XT, with the 200 mL/ha rate in PBA Hurricane XT being equivalent to the 120 mL/ha rate in PBA Jumbo2 (Table 18). However, the more objective measurement, flower score did not support the initial observations with PBA Hurricane XT being more greatly affected than the PBA Jumbo 2 plots. The number of PBA Hurricane XT plants flowering on 28th August was reduced by 66% when treated with diflufenican post emergent compared to no change in the PBA Jumbo2. Green seeker NDVI and grain yield also did not support the initial observations, where there was no variety and rate interaction. This indicates that the post emergent application of diflufenican had the same effect on both varieties.
No grain yield difference was identified between variety or rate.

Table 13: Brodal herbicide damage Aug 22nd (0 = no damage, 10 = plant death), Flower score Aug 22nd (0 = no plants flowering, 10 = 100% plants flowering), Greenseeker NDVI Aug 22nd and 12th Sept, Pod drop score (1 = 0-5 seeds per m of row 2 = 5-10, 3 = 10-20, 4 = 20-40, 5 = 40-80, 5=80-200) and grain yield (t/ha) for PBA Jumbo2 diflufenican tolerance trial 2017.

Variety	Rate	Brodal Damage	Flower Score	NDVI 170822	NDVI 170912	PodDrop Score	Grain yield (t/ha)
Hurricane	0	0.0	8.3	0.44	0.59	4.33	0.57
Hurricane	120	2.7	2.3	0.45	0.62	4.67	0.44
Hurricane	200	4.3	3.7	0.44	0.60	5.00	0.37
Jumbo2	0	0.0	4.3	0.42	0.59	2.67	0.61
Jumbo2	120	4.3	4.7	0.39	0.52	3.00	0.40
Jumbo2	200	6.0	3.3	0.40	0.56	2.33	0.71
LSD (0.05)	*Var*	*0.4*	*ns*	*0.02*	*0.04*	*0.44*	*ns*
	Rate	*0.5*	*2.3*	*ns*	*ns*	*ns*	*ns*
	*Var*Rate*	*0.7*	*2.5*	*ns*	*ns*	*Fpr 0.095, LSD 0.60*	*ns*

Summer Spray Herbicide Residues 2017

Location – Pattingale Road

Why do the trial?

With the increase in summer spraying to conserve soil moisture, the number of herbicide applications in the fallow period has increased over the last decade. Although herbicide labels and plant back recommendations are generally followed, on occasion the residues from these herbicides have been blamed for poor performance of pulses, particularly lentils, on sandy soils. It is thought that the low clay content and organic matter increases the time it takes for these herbicides to break down.

This trial seeks to identify if herbicides applied in the fallow period are having adverse effects on the following lentil crop.

How was it done?

The trial was a randomised complete block design consisting of 11 herbicide treatments and three replicates. The herbicides tested included two rates of, glyphosate, 2,4D amine, 2,4D ester, triclopyr and two combinations of all four (Table 19). The herbicide treatments were applied 1st May 2017 using a hand boom in 100L water per ha. The entire site was also treated with an additional 540g ai / ha glyphosate on 1st May to ensure there were no differences in soil moisture at the time of sowing.

Due to the lack of rainfall in May 2017 (Figure 3) and the requirement for 15mm of rainfall before the commencement of plant back times (Table 20) the lentils were sown within the plant back timings for 2,4D amine and ester. It should also be noted that the high rates of each herbicide are above the maximum allowable label rate.

Sowing date: 18th May **Fertiliser:** 70kg MAP
Herbicides: 200g/ha simazine and 100g/ha diuron IBS + 100g/ha simazine and 100g/ha diuron PSPE.
Variety: PBA Hurricane XT

Plots were sown with knife points and press wheels on 250mm spacing. The plots were 10 * 1.5m.

Measurements throughout the season include recording herbicide damage score 28th Aug, Green seeker NDVI Aug 22nd and Sep 12th and grain yield. Pod drop was also scored pre harvest.
Results were analysed with the statistical package R.

Table 14: Herbicide treatments for the Summer Spray Herbicide Residues lentil agronomy trial at Pattingale Road 2017.

Treatment	Herbicide	Active concentration (g/L)	Rate (L/ha)	Rate ai (g/ha)
1	Nil		0	
2	glyphosate	540	2	1080
3			10	5400
4	2,4D amine	700	0.5	350
5			2.5	1750
6	2,4D ester	680	0.5	340
7			2.5	1700
8	triclopyr	600	0.1	60
9			0.5	300
10	glyphosate + 2,4D amine + 2,4D ester + triclopyr	540 + 700 + 680 + 600	10.0 + 2.5 + 2.5 + 0.5	5400 + 1750 + 1700 + 300
11			2.0 + 0.5 + 0.5 + 0.1	1080 + 350 + 340 + 60

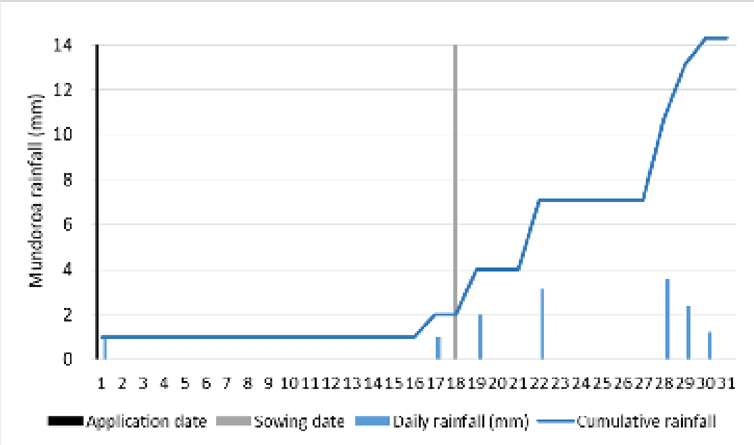

Figure 2: May 2017 daily and cumulative rainfall for Mundoora, also showing trial herbicide application and sowing date.

Table 15: Herbicide label plant back requirements for products tested in Summer Spray Herbicide Residues lentil agronomy trial at Pattingale Road 2017.

Product	Crop	Plant back requirement (days)
triclopyr	wheat, barley	7
	chickpeas	7
	cotton	14
2,4D ester and 2,4D amine <1.0L/ha	wheat	3
	lentil	7
2,4D ester and 2,4D amine >1.0L/ha	wheat	7
	lentil	10
glyphosate	not required	

Notes: 2,4D ester, when applied to dry soil, at least 15mm of rainfall must fall prior to the commencement of the plant back period.

Results

There was no significant effect to lentil growth as recorded by an herbicide damage score on the 28th July, from any of the standard herbicide rates when they were applied alone or in combination. However, at the first NDVI timing a 26% reduction was observed between the control plot and the combination of standard rates of herbicides (treatment 8, Table 21). By the second timing (12th September) the difference had reduced to 19% and there was no significant difference in grain yield between these two treatments. This shows that the application of standard rates of these herbicides, when applied alone, did not cause damage to the lentils. However, when they are applied in combination caution is required, as the cumulative herbicide effects caused significant reductions in crop growth.

The higher rates of each herbicide were included to demonstrate what the effects could be in a severe case. For the three group I herbicides, 2,4D amine, 2,4D ester and triclopyr applied at the high rates there was a significant visible effect on 17th July. The NDVI measurements support this score with a reduction in NDVI of 0.11 and 0.14 for the two timings for each of the herbicides. Grain yield was reduced by 0.3t/ha (63%) when the high rates were applied.

The combination of high rates of all herbicides created very significant damage with some plots being completely bare.

Table 16: Herbicide damage score July 28th, Green seeker NDVI Aug 22nd and Sept 12th and grain yield for Summer Spray Herbicide Residue lentil agronomy trial 2017. (Damage score = 0 = no effect, 6 = complete death)

Herbicide	Treatment	Rate (L/ha)	Damage Score 170728	NDVI 170822	NDVI 170912	Grain yield (t/ha)
Nil	1	0	2.3	0.411	0.575	0.33
2,4D amine	2	0.5	2.3	0.392	0.584	0.52
	3	2.5	5.0	0.260	0.394	0.17
2,4D ester	4	0.5	3.0	0.382	0.536	0.41
	5	2.5	5.0	0.256	0.385	0.14
triclopyr	6	0.1	2.3	0.398	0.568	0.37
	7	0.5	4.0	0.325	0.471	0.20
glyphosate + 2,4D amine + 2,4D ester + triclopyr	8	2.0 + 0.5 + 0.5 + 0.1	3.7	0.306	0.463	0.30
	9	10.0 + 2.5 + 2.5 + 0.5	6.0	0.153	0.237	0.03
glyphosate	10	2	1.7	0.399	0.512	0.33
	11	10	2.3	0.365	0.516	0.38
LSD 0.05			*1.4*	*0.071*	*0.074*	*0.22*

Soil amelioration 2017

Location – Alford

Why do the trial?

The dune swale soil type is a significant part of the landscape in the northern Yorke area. The sand hills in these areas have been historically poor performing. Recent measurements in the area have highlighted the fact that there is often moisture remaining in the soil after crop maturity. Penetrometer resistance measurements indicate that this moisture is likely to remain because of soil compaction restricting root exploration. Poor fertility is also blamed for poor performance on these soil types given that the soils have low clay content, low organic matter and low cation exchange capacity. For this reason, chicken litter, which is readily available from nearby broiler sheds has been seen by growers a "fix all" for these problems.
This trial investigates the effect of deep ripping and the application of chicken litter on the production of lentil on a sand hill north of Alford.

How was it done?
The trial was a randomised block design with three replicates. The treatments were a factorial of three depths of ripping (0, 250mm and 500mm) and four rates of nutrition (nil, chicken litter at 5t/ha, chicken litter at 10t/ha and synthetic nutrition), the trial was blocked by ripping.

Chicken litter was applied to plots and then the ripping treatments were implemented prior to sowing (28th April 2017) using a three tyne ripper on 600mm spacing. The synthetic nutrition treatments were applied to the plots pre seeding, at seeding or post emergent depending on the nutrient and product used. Table 22 shows the list of nutrients applied and the application method for these treatments. See Table 23 for a nutrient analysis of chicken litter applied to treatments.

Table 17: products and total nutrients applied in synthetic fertiliser treatment for Soil amelioration trial, lentil agronomy 2017 (IBS = incorporated by sowing).

Nutrient	**Product**	**Concentration**	**Timing**	**Rate (kg or L/ha)**	**Total nutrient applied (kg/ha)**
Potassium	Muriate of Potash	50%	Pre sowing IBS	100 20	60
Sulphur Calcium	Gypsum	15% 19%	Pre sowing Pre sowing	500	75 95
Nitrogen	Urea	46%	Post emergent	100	46
Magnesium	Magnesium oxide	54%	IBS	100	54
Manganese	Manganese sulphate	16%	Pre sowing Post emergent	30 4.5	21
Copper	Copper sulphate	25%	Pre sowing Post emergent	5 0.35	1.3
Molybdenum	Sodium molybdate	39%	Pre sowing Post emergent	1 0.3	0.5
Boron	Borax	14%	IBS	30	4.2

Table 18: Typical nutrient analysis of chicken litter sourced from Port Wakefield broiler sheds. Test from 2015.

Nutrient		Nutrient concentration dry weight	Moisture content	Nutrient concentration fresh weight	Kg nutrient per tonne fresh weight	Kg nutrient per 5 tonnes fresh weight
N	Nitrogen	3.8%	8%	3.50%	35.0	175
P	Phosphorus	1.72%		1.58%	15.8	79
K	Potassium	2.31		2.13%	21.3	106
S	Sulphur	0.55%		0.51%	5.1	25
Ca	Calcium	3.48%		3.20%	32.0	160
Mg	Magnesium	0.73%		0.67%	6.7	34
Zn	Zinc	0.46g/kg	8%	0.42g/kg	0.4	2.1
Mn	Manganese	0.51g/kg		0.47g/kg	0.5	2.3
Cu	Copper	0.13g/kg		0.12g/kg	0.1	0.6
B	Boron	0.05g/kg		0.05g/kg	0.05	0.2
Fe	Iron	4.33g/kg		3.98g/kg	4.0	19.9

The trial was rolled with a stone roller prior to seeding to create a more even seed bed.
A large mouse population caused emergence issues and the trial was baited many times to reduce the population.

Sowing date: 19th May **Fertiliser:** 70kg MAP applied to all plots
Herbicides: 200g/ha simazine and 100g/ha diuron IBS + 100g/ha simazine and 100g/ha diuron PSPE.
Variety: PBA Jumbo2

Plots were sown with knife points and press wheels on 250mm spacing. The plots were 10 * 1.5m.

Measurements throughout the season include recording early vigour score Aug 22nd, Green seeker NDVI Sep 26th and grain yield. Pod drop was also scored pre harvest.
Results were analysed with the statistical package R.

Results
The process of deep ripping reduced emergence (data not recorded) and the plots ripped to 50cm reduced the vigour of the lentils significantly. This meant that the damage from the mice was more of a problem in these plots. This is shown in Table 24 where there is a 16% reduction in vigour score and a 12% reduction of Green seeker NDVI on 26th September.

Grain yield was highest in the 25 cm ripping treatments (0.59t/ha) but this was not significantly different to the non-ripped treatments.

The synthetic fertiliser treatment had a negative impact on vigour, NDVI and grain yield. In a separate trial it was found that the boron application in this treatment caused fertiliser toxicity and reduced crop growth. There was no significant difference between the untreated plots and those treated with chicken litter.

Table 19: Vigour score (22nd August), Green seeker NDVI (26th September), pre harvest pod drop and lentil grain yield, lentil agronomy soil amelioration 2017. Vigour score, 0 = very poor vigour, 10 = very good vigour.

Treatment	Product	Rate (t/ha)	Ripping depth (cm)	Vigour score 170822	NDVI 170926	Pod Drop Score	Grain yield (t/ha)
1	Nil	0	0	7.7	0.54	3.7	0.78
2	Nil	0	25	7.3	0.54	3.0	0.72
3	Nil	0	50	5.7	0.46	2.7	0.37
4	Chicken Litter	5	0	7.0	0.53	3.0	0.50
5	Chicken Litter	5	25	6.7	0.53	3.0	0.70
6	Chicken Litter	5	50	6.3	0.46	2.3	0.51
7	Chicken Litter	10	0	6.7	0.53	2.3	0.54
8	Chicken Litter	10	25	7.3	0.53	2.3	0.62
9	Chicken Litter	10	50	5.3	0.49	3.0	0.51
10	Synthetic	NA	0	4.0	0.41	3.0	0.31
11	Synthetic	NA	25	4.3	0.41	2.7	0.34
12	Synthetic	NA	50	3.7	0.36	2.3	0.21
LSD (0.05)	*Product*			0.2	*0.05*	*Fpr 0.098, LSD (0.1) 0.378*	*0.15*
	Depth			0.1	*0.05*	*ns*	*0.15*
	*Product * Depth*			ns	*ns*	*ns*	*ns*

Nutrition omission 2017

Location – Alford

Why do the trial?

The sand hills of the dune swale system in the upper Yorke area have inherent poor fertility. It is often observed that the application of chicken litter to these soils can improve biomass production and in other amelioration trials this has been shown to be closely related to yield in lentil. The question remains, what is in the chicken litter that is producing the increased biomass.

This trial aims to identify what key nutrients lentils are responsive to and therefore restricting lentil production on these soil types.

How was it done?

The trial was a randomised complete block design of 11 treatments and three replicates. The treatments were made up of a nil (no fertiliser), chicken litter at 5t/ha, and the following nutrients in an omission format, potassium, sulphur, nitrogen, magnesium, manganese, copper, molybdenum and boron. The final treatment was "complete" and was made up of all of the nutrients listed above, Table 25 shows the products applied for each nutrient and the application rates and methods.

Take note that as this trial is an omission trial, when the treatment is listed as potassium omitted, it means that the treatment received all nutrients in the table except for potassium.

Table 20: products and total nutrient applied in synthetic fertiliser treatments for nutrient omission trial, lentil agronomy 2017 (IBS = incorporated by sowing).

Nutrient	Product	Concentration	Timing	Rate (kg or L/ha)	Total nutrient applied (kg/ha)
Potassium	Muraiate of Potash	50%	Pre sowing IBS	100 20	60
Sulphur Calcium	Gypsum	15% 19%	Pre sowing Pre sowing	500	75 95
Nitrogen	Urea	46%	Post emergent	100	46
Magnesium	Magnesium oxide	54%	IBS	100	54
Manganese	Manganese sulphate	16%	Pre sowing Post emergent	30 4.5	21
Copper	Copper sulphate	25%	Pre sowing Post emergent	5 0.35	1.3
Molybdenum	Sodium molybdate	39%	Pre sowing Post emergent	1 0.3	0.5
Boron	Borax	14%	IBS	30	4.2

The plots were ripped to 25cm and rolled to level them prior to sowing.

Sowing date: 19th May
Fertiliser: 70kg MAP applied to all plots in addition to treatments in table 10.
Herbicides: 200g/ha simazine and 100g/ha diuron IBS + 100g/ha simazine and 100g/ha diuron PSPE.
Variety: PBA Jumbo2

Plots were sown with knife points and press wheels on 250mm spacing. The plots were 10 * 1.5m.

Measurements throughout the season include recording early vigour score Aug 22nd, Green seeker NDVI Sep 26th and grain yield. Pod drop was also scored pre harvest.
Results were analysed with the statistical package R.

Results
The application of 30kg of Borax with the seed significantly reduced the vigour of emerging lentil seedlings and this effect shows clearly in Table 26 where the vigour score on 22nd August averages 6.4 for plots with no boron applied (treatments 1, 2 and 10) compared to 3.3 for the remaining treatments. Although not significant, it also appears that the potassium treatment may have had some additional negative impact on the lentils.

The grain yield results show that the B omitted treatment (treatment 10) was the highest yielding in the trial although it was not significantly higher than the chicken litter treatment (treatment 2). This indicates that there is some benefit to a combination of the nutrients applied. Unfortunately, the antagonism caused by the Borax application may have masked effects of any particular deficiencies of other nutrients in the trial.

Table 21: vigour score 22nd August, NDVI 26th September and grain yield for nutrient omission trial, lentil agronomy 2017. Vigour score, 0 = very poor vigour, 10 = very good vigour.

Treatment	Vigour score 170822	NDVI 170926	Grain yield (t/ha)
Nil	6.7	0.50	0.60
5t/ha Chicken Litter	6.3	0.49	0.70
N omitted	3.3	0.39	0.36
S omitted	3.3	0.33	0.32
K omitted	4.0	0.41	0.40
Mg omitted	2.7	0.36	0.33
Mn omitted	3.0	0.38	0.29
Cu omitted	3.7	0.43	0.41
Mo omitted	3.3	0.33	0.21
B omitted	6.3	0.48	0.89
Complete*	3.3	0.36	0.31
LSD (0.05)	*1.9*	*0.10*	*0.23*

Alternative products 2017

Location – Alford

Why do the trial?

There are many different products available on the market that claim to increase the performance of lentils, particularly on poor soil types. These include several seed treatments including several fungicides, nutrient coatings and normal rhizobium inoculants.
This trial aims to identify if there is any biomass or grain yield response to these products at this site.

How was it done?

The trial was a randomised complete block design with nine treatments and three replicates. Treatments included chicken litter, fungicides applied to the seed or fertiliser (Apron, Uniform and Azoxystrobin), a nutrient seed coat and rhizobium inoculant applied to the seed. See Table 27 for a complete list of treatments.

Sowing date: 19th May
Fertiliser: 70kg MAP applied to all plots in addition to treatments in table 26.
Herbicides: 200g/ha simazine and 100g/ha diuron IBS
Variety: PBA Jumbo2

Plots were sown with knife points and press wheels on 250mm spacing. The plots were 10 * 1.5m. Measurements throughout the season include recording early vigour score Aug 22nd, Green seeker NDVI Sep 26th and grain yield. Pod drop was also scored pre harvest.
Results were analysed with the statistical package R.

Results

There was no significant treatment effect on the vigour score conducted 22nd August at the 5% confidence level. However, at the 10% level of significance the results show that the inoculant + chicken litter treatment was the most vigorous, it should be noted that treatment 9 (all treatments combined) also received the chicken litter prior to seeding. The grain yield results suggest that there is some response to the chicken litter with treatment 3 producing the highest yield in the trial (1.15t/ha) although this is not significantly different from treatment 9, it is greater than the nil at the 10% confidence level.

There was no significant difference between any of the other treatments for any measurement, even at the 10% level.

Table 22: vigour score 22nd August, Green seeker NDVI 26th September and grain yield for the alternative product trial, lentil agronomy 2017. Vigour score, 0 = very poor vigour, 10 = very good vigour.

	Treatment	**Vigour score 170822**	**NDVI 170926**	**Grain yield (t/ha)**
1	Nil	7.7	0.58	0.79
2	Inoculant	7.7	0.52	0.82
3	Inoculant + 5t chicken litter	8.7	0.60	1.15
4	Inoculant + Apron	6.7	0.53	0.74
5	Inoculant + Azoxystrobin	7.3	0.54	0.84
6	Inoculant + Gibberellic Acid	6.7	0.51	0.69
7	Inoculant + Seed Coat	7.3	0.52	0.88
8	Inoculant + Uniform	7.0	0.53	0.75
9	All treatments combined	7.7	0.57	1.02
	LSD (0.05)	*ns*	*0.04*	*ns*
	LSD (0.1)	*1.0*	*0.04*	*0.24*

Low pH and lime 2017

Location – Bute low pH

Why do the trial?

Low soil pH is emerging as an issue in the upper Yorke area, mostly on the sands of the dune swale landscapes. Given that sands have a lower pH buffering capacity than the swale soils in between, and productivity on these soil types has increased through greater adoption of nitrogen and sulphur applications, the pH of these soil types is beginning to drop significantly. Lentils have less tolerance to acid soils than many other crops grown in the region including wheat, barley and lupin. However there remains many sands that although not acidic, they are still poor performing particularly when sown to lentil. Many growers attempt to improve these poor performing soil types with the “fix all” chicken litter which is locally available in significant quantity. This trial combines lime treatments to resolve the acidity issue and chicken litter to help with low organic matter and nutrition.
Through the application of lime and chicken litter, this trial aims to increase the soil pH and improve lentil productivity.

How was it done?

The trial was a randomised complete block design with a factorial of three rates of lime (0, 3t/ha and 6t/ha) and two rates of chicken litter (0 and 5t/ha) and three replicates. The lime was sourced from Kulpara Quarry, it has a total neutralising value (TNV) of 90% and an effective neutralising value (ENV) 59%. It was spread on May 1st prior to seeding in 2017. The chicken litter was spread at the same time, see Table 28 for a typical analysis of the chicken litter used in the trial.

Sowing date: 11th May 2017
Variety: PBA Jumbo2

Fertiliser: 70kg MAP
Plot size: 2.5m * 10m

The plots were sown using a commercial Concord seeder on 12 inch row spacing with a five inch ribbon. Greenseeker NDVI was recorded during the growing season but no differences were observed. The site was not harvested due to the lack of response during the growing season.

The location of the plots is accurately recorded for future reference. However, the entire site has since been treated with 4t/ha lime and deep ripped.

Table 23: Typical nutrient analysis of chicken litter sourced from Port Wakefield broiler sheds. Test from 2015.

Nutrient		Nutrient concentration dry weight	Moisture content	Nutrient concentration fresh weight	Kg nutrient per tonne fresh weight	Kg nutrient per 5 tonne fresh weight
N	Nitrogen	3.8%	8%	3.50%	35.0	175
P	Phosphorus	1.72%		1.58%	15.8	79
K	Potassium	2.31		2.13%	21.3	106
S	Sulphur	0.55%		0.51%	5.1	25
Ca	Calcium	3.48%		3.20%	32.0	160
Mg	Magnesium	0.73%		0.67%	6.7	34
Zn	Zinc	0.46g/kg	8%	0.42g/kg	0.4	2.1
Mn	Manganese	0.51g/kg		0.47g/kg	0.5	2.3
Cu	Copper	0.13g/kg		0.12g/kg	0.1	0.6
B	Boron	0.05g/kg		0.05g/kg	0.05	0.2
Fe	Iron	4.33g/kg		3.98g/kg	4.0	19.9

Spatial analysis of survey paddock Shed 2017

Co-operator – Stewart Johns

How was it done?

A paddock north of Alford to be sown to lentil in 2017 was analysed for historical yield, NDVI and Veris soil pH and EC data. The spatial variability was used to identify eight points with varying yield potential. Soil testing was conducted to try and identify causes for variation in lentil performance.

A Pearson's correlation matrix was generated with the data listed below in tables 30 - 34.
Grain yield, NDVI, leaf tissue tests and nodulation scores from 2017 were not captured due to severe mouse infestation and damage and parts of the paddock being re-sown up to three times.

Results

The pearsons correlation matrix identified that of the measurements taken there was little that was correlated to historical grain yield or NDVI. The best relationships with crop NDVI and grain yield are shown in Table 29. The relationship with grain yield was not always consistent across years and that is why the average relationship is below 0.5. In the dryer years the lighter textured sands tend to be better yielding compared to the rest of the paddock compared to wetter years. The most consistent measurement with lentil and wheat grain yield was clay and silt content from 30 to 90cm. Clay content produces the equation $y = 0.0389x + 0.7252$ and silt producing the equation $y = 0.0239x + 0.8247$.

Unfortunately, it is difficult and expensive to manipulate the clay content of soil, particularly the subsoil.

Table 24: results from Pearson's correlation matrix analysis showing the best relationships with grain yield from two years of lentils and one year of wheat (2012, 2014 and 2015 respectively).

Depth	Measurement	Average relationship with yield - lentil 2012, lentil 2014 and wheat 2015
0 – 10cm	Organic carbon	0.54
0 – 10cm	Colwell K,	0.31
0 – 10cm	Exchangeable K	0.40
10 – 30cm	Cation exchange capacity	0.20
0 – 90cm	Available Sulphur	0.49
0 – 10cm	MIR Sand %	0.45
30 – 90cm	MIR Clay %	0.75
30 – 90cm	MIR Silt %	0.62

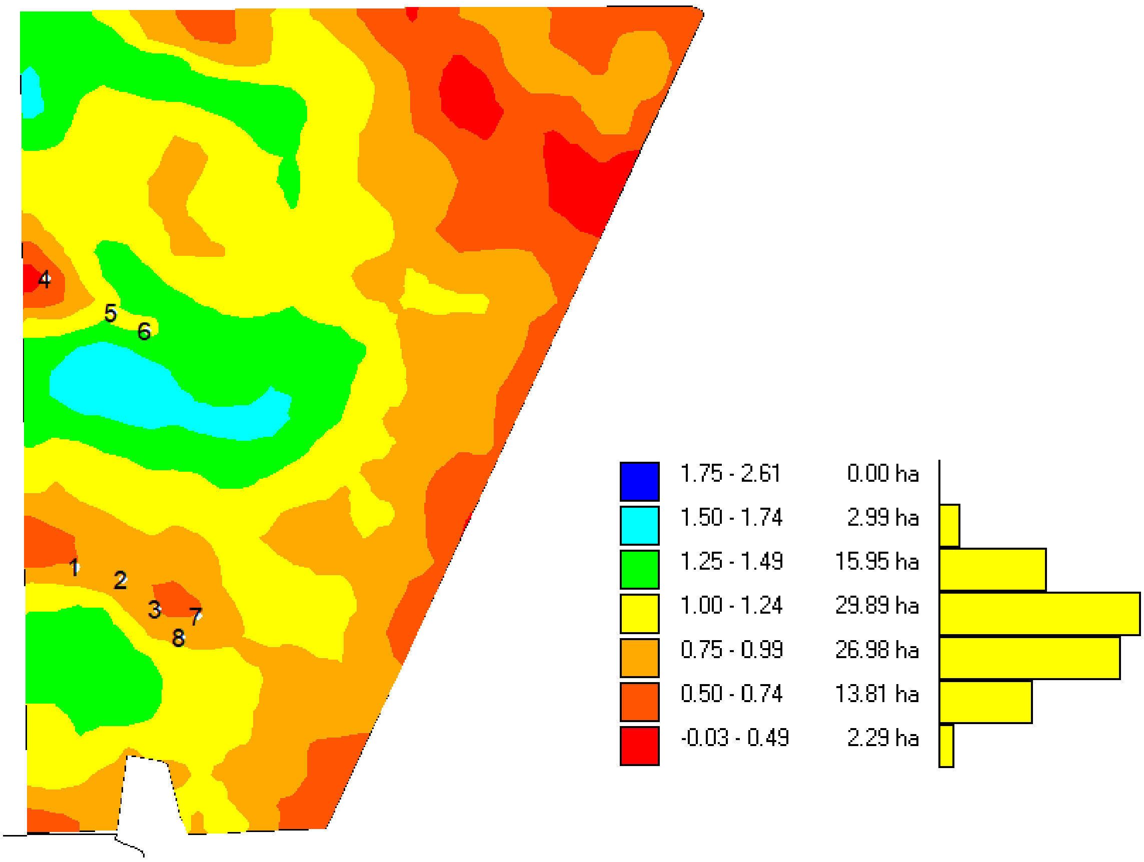

Figure 3: Lentil grain yield (t/ha) 2012 for survey paddock Shed near Alford and location of eight survey points.

Table 25: Historical yield and NDVI data for 8 points in Shed paddock near Alford

Point	Lentil NDVI 121009	Lentil Yld 2012	Lentil NDVI 140921	Lentil Yld 2014	Wheat NDVI 151002	Wheat Yld 2015
1	0.397	0.74	0.665	1.16	0.716	4.46
2	0.373	0.52	0.619	0.93	0.679	3.82
3	0.404	0.8	0.685	1.09	0.711	4.14
4	0.296	0.21	0.623	0.64	0.640	3.59
5	0.446	1.08	0.743	1.43	0.714	4.5
6	0.441	0.41	0.679	1.07	0.710	3.55
7	0.399	0.3	0.605	0.89	0.681	2.92
8	0.448	0.95	0.711	1.16	0.705	4.19

Table 26: 0 – 10 soil test data for points 1 – 8 Shed paddock at Alford

Point	P Colwell	K Colwell	S	OC	EC	pH Level (CaCl2)	pH Level (H2O)	DTPA Cu	DTPA Fe	DTPA Mn	DTPA Zn	CEC	Exc. Al	Exc. Ca	Exc. Mg	Exc. K	Exc. Na	Ca:Mg Ratio	B Hot CaCl2
	mg/Kg	mg/Kg	mg/Kg	%	dS/m	pH	pH	mg/Kg	mg/Kg	mg/Kg	mg/Kg		%	%	%	%	%		mg/Kg
1	52	239	3.9	0.69	0.07	7.3	8.4	0.33	3.31	3.27	2.58	11.056	0.51	86.11	8.23	4.70	0.45	10.5	0.81
2	47	202	3.9	0.56	0.068	7.5	8.7	0.32	2.87	3.02	5.11	10.18	0.49	87.92	7.07	4.22	0.29	12.4	0.51
3	48	230	3.9	0.74	0.085	7.5	8.6	0.28	2.75	2.69	1.73	11.461	0.44	86.99	7.59	4.45	0.52	11.5	0.93
4	64	200	3.1	0.44	0.054	7.6	8.8	0.31	2.66	2.05	2.3	8.786	1.09	84.79	9.33	4.44	0.34	9.1	0.48
5	51	221	2.6	0.6	0.06	7.6	8.7	0.27	3.22	2.61	2.05	9.619	0.82	83.27	9.98	5.51	0.42	8.3	0.63
6	49	253	3	0.62	0.064	7.6	8.8	0.31	2.54	1.99	2.36	9.594	0.56	84.32	9.07	5.73	0.31	9.3	0.53
7	26	266	3.2	0.74	0.059	7.5	8.4	0.42	4.73	4.07	1.92	10.295	0.44	81.88	10.98	6.22	0.49	7.5	0.81
8	30	225	6	0.78	0.07	7.6	8.5	0.36	4.05	3.41	1.08	9.214	0.37	85.96	8.03	5.32	0.33	10.7	0.82

Table 27: 10 – 30cm soil test data for points 1 – 8 Shed paddock at Alford

Point	Phosphorus Colwell	Potassium Colwell	Sulphur	Conductivity	pH Level (CaCl2)	pH Level (H2O)
	mg/Kg	mg/Kg	mg/Kg	dS/m	pH	pH
1	16	212	1.7	0.069	7.5	8.5
2	11	170	2.4	0.064	7.9	9.1
3	8	202	3.8	0.093	7.7	8.8
4	3	113	1.5	0.054	8.0	9.1
5	2	196	2.2	0.061	7.8	9.1
6	6	212	1.5	0.056	8.0	9.2
7	4	270	2.1	0.078	7.9	9.0
8	9	293	3.7	0.107	7.9	8.9

Table 28: 0 – 90 cm available soil nitrogen and sulphur (kg/ha) soil test results for points 1-8 Shed paddock near Alford

Point	Available soil N kg/ha	Available soil S kg/ha
1	62	48
2	41	28
3	54	56
4	28	22
5	33	32
6	50	27
7	53	34
8	51	63

Table 29: MIR soil texture analysis for Shed paddock points 1 – 8 for three depths, 0 – 10cm, 10 – 30cm and 30 – 90cm

	0-10cm Segment 1				**10-30 cm Segment 2**				**30-90 cm Segment 3**			
Point	**MIR Sand %**	**MIR Clay %**	**MIR Silt %**	**MIR Texture**	**MIR Sand %**	**MIR Clay %**	**MIR Silt %**	**MIR Texture**	**MIR Sand %**	**MIR Clay %**	**MIR Silt %**	**MIR Texture**
1	86	7	7	loamy sand	91	5	5	sand	77	11	12	sandy loam
2	91	4	5	sand	90	5	5	sand	94	1	4	sand
3	92	4	5	sand	79	11	10	sandy loam	79	10	12	sandy loam
4	86	9	5	loamy sand	91	5	4	sand	95	2	3	sand
5	90	5	5	sand	89	7	5	sand	81	11	8	loamy sand
6	89	6	5	sand	93	3	3	sand	84	8	8	loamy sand
7	89	5	6	sand	83	10	7	loamy sand	83	9	8	loamy sand
8	96	0	4	sand	73	15	12	sandy loam	67	14	19	sandy loam

Spatial analysis of survey paddock Fogdens Dam 2017

Co-operator – Bill Trengove

How was it done?

A paddock north of Bute to be sown to lentil in 2017 was analysed for historical yield, NDVI and Veris soil pH and EC data. The spatial data identified significant variability, however, for this paddock 10 points were selected along a transect where soil type, crop growth and yield transitioned from poor performing dune to better performing swale. This was to try and understand the difference in soil type at a smaller scale. Soil tests, leaf tissue tests and nodulation scoring were conducted to try and identify causes for variation in lentil performance.

A Pearson's correlation matrix was generated with the data listed below in Table 36.

Results

Figures 6 and 7 show the level of variation across the transect area.

Data from the three different grain crops, lupin, wheat and lentil, shows that lentil had the greatest level of yield variation within the transect area (0.87t/ha – 2.53t/ha) (Table 35).

The yield variation in lentil and wheat has a good correlation with many attributes measured, as shown in Table 36. Some of the standout correlations include phosphorus, potassium and sulphur and some trace elements. These nutrients are generally associated with clay content and this measurement is also highly correlated with the grain yields and NDVI.

Analysis of the data has indicated that the pH at this site is very low and is likely to be causing yield reductions in lentil with 0 – 10cm pH $CaCl_2$ ranging from 4.4 – 5.0. This has produced an unexpected result whereby this has a strong but negative relationship (-0.81) with lentil yield. This may be explained by the narrow range of the data and the fact that there are many other factors changing at the same time. Almost all the other strong relationships are positive, whereby increasing nutrition, for example, organic carbon, exchangeable cations, micronutrients and clay content, has resulted in increased NDVI and Grain yield. The correlation for subsoil pH is more what would be expected for lentil where increasing pH $CaCl_2$ from 4.5 – 7.2 resulted in increased NDVI and grain yields. The correlations for the other soil attributes are shown in Table 36 to Table 40.

As a result of identifying low soil pH a lime trial has been established in the area adjacent to the transect points. Chicken litter treatments have been included to address any nutritional issues not rectified by the adjustment of pH.

Lentil nodulation scores for 2017 lentils were not very well correlated with soil pH or yield (data not presented).

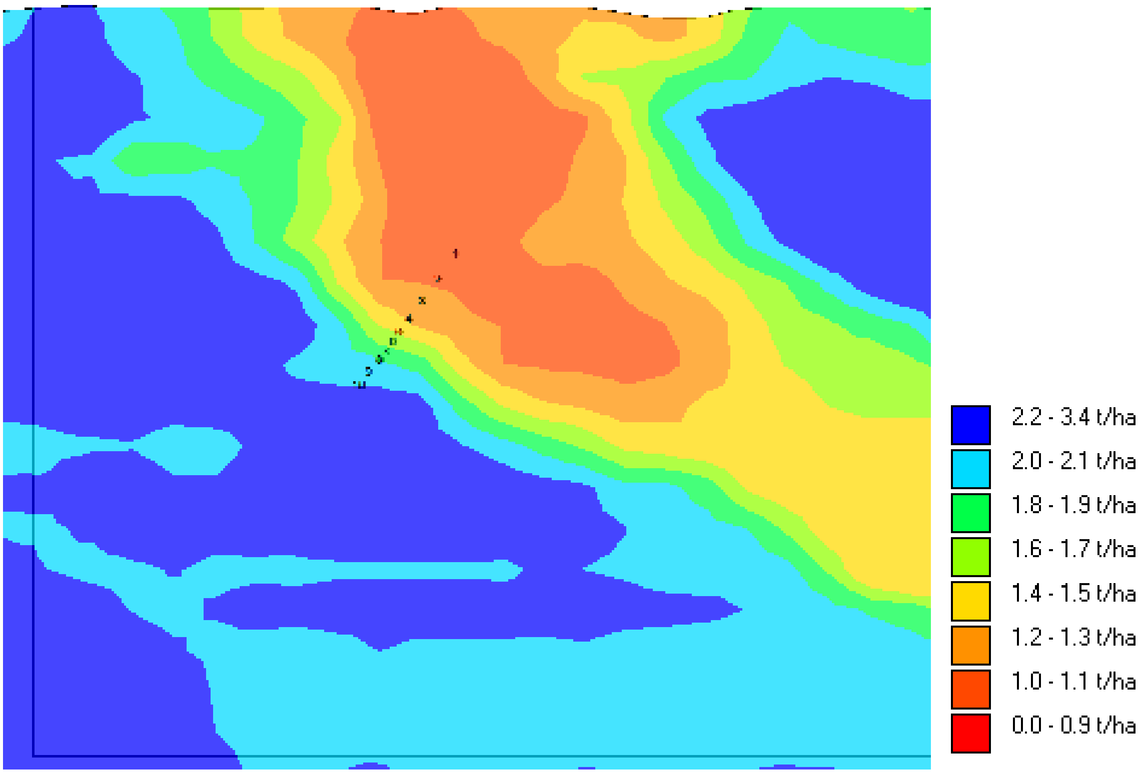

Figure 4: Lentil grain yield (2014) for Fogdens Dam paddock at transect area and location of transect points.

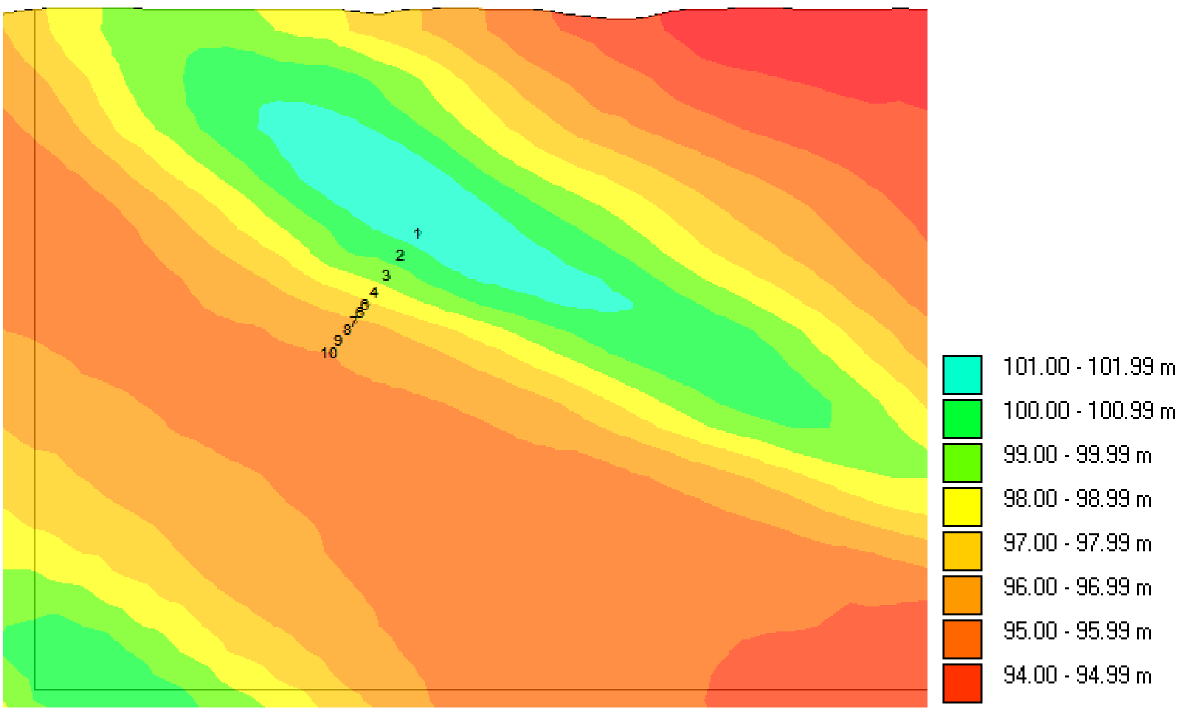

Figure 5: RTK elevation (2014) for Fogdens Dam paddock at transect area and location of transect points.

Table 30: Historical yield and NDVI data for the 10 point transect in paddock Fogdens Dam near Bute.

Point number	Distance from point 1 m	Elevation m	2011 Lupin NDVI 13th Aug	2011 Lupin yield t/ha	2012 Wheat NDVI 9th Oct	2012 Wheat yield t/ha	2014 Lentil NDVI 21st Sep	2014 Lentil yield t/ha
1	0	101.8	0.78	2.88	0.48	3.51	0.56	0.87
2	12	100.8	0.78	2.65	0.49	3.51	0.62	0.90
3	22	99.5	0.78	2.54	0.50	3.52	0.67	1.42
4	30	98.4	0.78	2.45	0.51	3.47	0.73	1.39
5	36	97.7	0.78	2.49	0.51	3.38	0.77	1.40
6	40	97.2	0.78	2.56	0.52	3.34	0.79	1.66
7	44	96.7	0.78	2.62	0.51	3.33	0.81	1.96
8	48	96.4	0.78	2.65	0.53	3.35	0.83	2.19
9	52	96.2	0.78	2.64	0.53	3.44	0.84	2.35
10	58	96	0.79	2.62	0.53	3.49	0.84	2.53

Table 31: results from Pearson's correlation matrix analysis showing the best average relationships with grain yield and NDVI for Lupin in 2011, Wheat in 2012 and Lentil in 2014, and the relationship with the lentil grain yield.

Depth	Measurement	Unit	Correlation Lupin, Wheat, Lentil yield and NDVI	Lentil yield
0 - 10cm	Phosphorus Colwell	mg/Kg	0.35	0.87
0 - 10cm	Potassium Colwell	mg/Kg	0.45	0.90
0 - 10cm	Organic Carbon	%	0.32	0.80
0 - 10cm	pH Level (CaCl2)	pH	-0.34	-0.81
0 - 10cm	DTPA Copper	mg/Kg	0.48	0.93
0 - 10cm	DTPA Manganese	mg/Kg	0.49	0.86
0 - 10cm	Exc. Calcium	meq/100g	0.42	0.82
0 - 10cm	Exc. Magnesium	meq/100g	0.48	0.86
0 - 10cm	Exc. Potassium	meq/100g	0.42	0.88
0 - 10cm	Exc. Sodium	meq/100g	0.50	0.90
0 - 10cm	Boron Hot CaCl2	mg/Kg	0.43	0.95
0 - 10cm	PBI		0.46	0.95
0 - 10cm	Conductivity	dS/m	0.37	0.60
10 - 30cm	pH Level (CaCl2)	pH	0.36	0.59
0 - 90cm	Available soil S	kg/ha	0.50	0.78
0 - 10cm	MIR Clay	%	0.51	0.91
0 - 10cm	MIR Silt	%	0.52	0.86
10 - 30cm	MIR Clay	%	0.37	0.81
10 - 30cm	MIR Silt	%	0.46	0.79

Table 32: 0 – 10cm soil test data for transect points 1 – 10 Fogdens Dam paddock near Bute.

Point	P Colwell	K Colwell	OC	EC	pH (CaCl2)	pH (H2O)	DTPA Cu	DTPA Fe	DTPA Mn	DTPA Zn	CEC	Exc. Al	Exc. Ca	Exc. Mg	Exc. K	Exc. Na	Boron CaCl2	PBI
	mg/Kg	mg/Kg	%	dS/m	pH	pH	mg/Kg	mg/Kg	mg/Kg	mg/Kg		%	%	%	%	%	mg/Kg	
1	34	148	0.56	0.025	4.9	5.8	0.31	35.77	6.66	1.65	2.65	4.15	68.68	16.60	9.43	1.13	0.21	18
2	39	171	0.84	0.03	5.0	5.9	0.38	35.82	7.28	2.14	3.18	2.68	69.29	16.38	10.08	1.57	0.27	18
3	38	153	0.79	0.029	4.9	5.9	0.41	38.92	7.95	2.64	3.51	2.45	71.31	17.68	7.13	1.43	0.33	20
4	38	170	0.82	0.019	5.0	5.9	0.43	48.05	9.53	2.92	3.67	2.94	70.07	16.36	9.27	1.36	0.35	21
5	49	199	0.98	0.031	4.7	5.8	0.49	55.96	9.98	2.76	4.24	3.56	70.27	15.80	8.96	1.41	0.43	28
6	51	185	1.12	0.049	4.6	5.9	0.49	62.65	11.82	2.61	4.10	4.83	68.08	16.35	9.03	1.71	0.42	25
7	56	241	1.08	0.046	4.6	5.6	0.69	69.30	11.59	1.99	4.39	4.72	66.10	15.27	12.08	1.82	0.45	31
8	57	228	0.94	0.04	4.5	5.5	0.61	71.39	11.44	1.99	4.11	7.23	62.58	17.04	10.96	2.19	0.47	34
9	62	210	0.99	0.057	4.4	5.4	0.71	82.52	14.75	3.03	4.06	8.28	61.64	17.26	9.86	2.96	0.52	33
10	55	276	1.22	0.037	4.6	5.7	0.94	67.21	22.12	2.18	6.35	3.82	66.11	17.94	9.29	2.83	0.60	39

Table 33: 10 – 30cm soil test data for transect points 1 – 10 Fogdens Dam paddock near Bute.

Point	Phosphorus Colwell	Potassium Colwell	Conductivity	pH Level (CaCl2)	pH Level (H2O)
	mg/Kg	mg/Kg	dS/m	pH	pH
1	32	180	0.027	5.4	6.3
2	37	164	0.023	5.1	6.2
3	44	205	0.017	4.9	6.1
4	44	174	0.019	4.7	6.0
5	51	193	0.024	4.8	5.9
6	29	169	0.086	7.5	8.4
7	33	177	0.027	5.1	6.2
8	37	114	0.035	6.3	7.1
9	31	180	0.097	7.2	8.3
10	20	199	0.093	7.2	8.2

Table 34: 0 – 90 cm available soil nitrogen and sulphur (kg/ha) soil test results for transect points 1-10 for Fogdens Dam near Bute.

Point	Available soil N kg/ha	Available soil S kg/ha
1	33.02	18.59
2	31.72	14.04
3	42.64	13.78
4	36.14	12.87
5	33.54	16.9
6	50.96	41.08
7	39	53.56
8	46.8	51.48
9	31.2	99.19
10	27.82	212.94

Table 35: MIR soil texture analysis for transect points 1 – 10 (excluding 9) for three horizons with approximate depths, A; 0 – 10cm, B; 10 – 30cm and C; 30 – 80cm

	A Horizon				B Horizon				C Horicon			
Point	MIR Sand %	MIR Clay %	MIR Silt %	MIR Texture	MIR Sand %	MIR Clay %	MIR Silt %	MIR Texture	MIR Sand %	MIR Clay %	MIR Silt %	MIR Texture
1	96	0	4	sand	86	6	7	loamy sand	49	32	18	sandy clay loam
2	96	0	4	sand	92	4	4	sand	93	4	3	sand
3	95	1	4	sand	92	4	4	sand	91	5	3	sand
4	93	2	5	sand	92	4	5	sand	93	4	3	sand
5	92	3	5	sand	90	6	4	sand	68	23	10	sandy clay loam
6	92	3	5	sand	90	6	5	sand	68	23	9	sandy clay loam
7	90	5	5	sand	66	23	10	sandy clay loam	40	39	22	clay loam
8	86	6	8	loamy sand	69	21	10	sandy clay loam	54	30	16	sandy clay loam
10	74	14	11	sandy loam	70	18	12	sandy loam	38	39	22	clay loam

2016 paddock surveys

Spatial analysis of 5 lentil paddocks 2016

Co-operators – Bill Trengove, Craig Ayles, Andrew Morony, Stewart Johns, Nathan Hewett

How was it done?

Five paddocks to be sown to lentils in 2016 were selected based on the variability in soil type and the availability of historical yield data. Historical satellite NDVI imagery was sourced and the paddocks were mapped with the Veris MSP3 for pH, EC, and OM. The data collected was combined and used to select eight points in each of the paddocks with contrasting yield, NDVI and soil characteristics. During the season measurements at the 40 points included soil tests, penetrometer resistance, leaf tissue nutrient analysis, root nodulation and biomass were used to identify restrictions to plant growth by calculating correlations with historical grain yield.

A sixth paddock was identified as a useful target for measurement that had a sand hill with only one season of recent cropping history. Prior to that it had been left as native pasture. Paired samples were taken in and out of the historically uncropped area.

Results

<u>Historical data</u>

From the historical data (Table 41) including lentil grain yield and NDVI the paddocks were easily divided into sand hill and swale production areas. Generally, the sands were lower yielding than the swale areas, however within the sand area, relatively lower and higher yielding areas were also identified.

There are positive relationships between historical lentil grain yield and 2016 lentil biomass, R^2 values for the five paddocks range from 0.27 – 0.54.

<u>Soil and plant nutrient data</u>

Across the five paddocks, there was no consistent characteristic from either soil or leaf tissue samples, that could explain the differences in lentil NDVI or yield across the entire cropping region. However, within a single paddock there were differences between some nutrients, including but not limited to, nitrogen, phosphorus, potassium, sulphur, manganese and copper.

<u>Nodulation</u>

Lentil root nodulation did not have a consistent response to lentil grain yield or biomass across the five paddocks (data not presented)

<u>Penetrometer resistance</u>

Soil compaction may be a limiting factor on these sands. Data collected in 2016 indicates that there are differences between the different sand types that were identified. The red sands, which were some of the lowest yielding, had the highest levels of penetrometer resistance at 300mm (Figure 8). All soil types had similar soil strength at 200mm depth.

On top of the 44 points that were intensively sampled, an additional five points were selected in the Trengove paddock where it was visually clear that wheel tracks from a previous harvest were related to reduced biomass and the lentils turning yellow. These points were tested for penetrometer resistance and on average there was higher soil strength on the yellow lentil areas compared to the adjacent healthy crop.

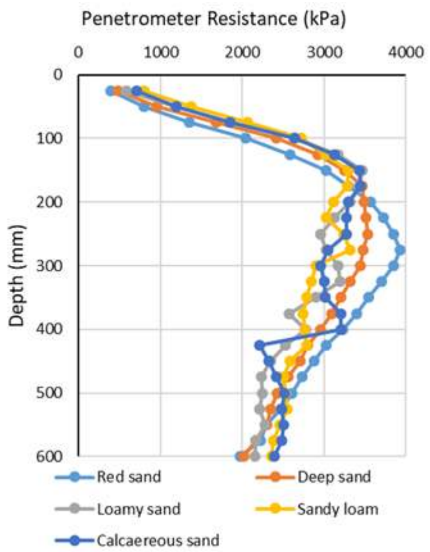

Figure 6. Penetrometer resistance measurements from the five original paddocks, September2016 grouped by soil type.

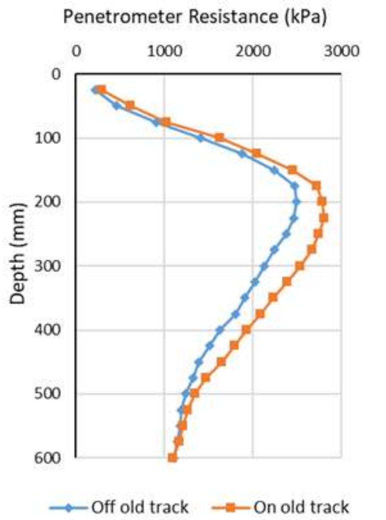

Figure 7 Penetrometer resistance from Trengove paddock on and off of historical harvester wheel tracks, September 2016

<u>The sixth paddock</u>

Although not in the original project proposal, the additional sandhill has provided some valuable insights into lentil performance on sands in this region. The area with limited cropping history produced 89% more dry matter than the adjacent continually cropped area. No yield data was collected due to the uneven topography over the top of the hill.

The most significant factors that may have affected the increase in biomass production are increased soil organic carbon from 0.8% to 1.2% and associated increases in nutrition. Available soil nitrogen averaged 36 kg/ha and 63 kg/ha for the long and short cropping histories, respectively. Available soil Sulphur averaged 8kg/ha and 16kg/ha for the long and short cropping histories, respectively. Soil potassium was 40% (0-10 cm) and 20% (10-30 cm) higher in the short cropping history. Manganese, magnesium and Exc. Calcium were also higher on the short cropping history. Higher levels of phosphorus and zinc in the long cropping history area would likely be a result of historical application during cropping and indicates that these nutrients are not limiting factors.

Soil penetrometer resistance to 400 mm was higher in the poor soil type, reaching 3000 kPa at 300 mm, this likely due to the increase machine traffic on the continuously cropped area. Below this depth resistance was higher in the good area although only reached a maximum of 2600 kPa. This may be associated with reduced soil moisture at depth due to the larger crop canopy.

Crop root growth begins to be restricted at 1500 kPa and can be severely restricted above 2500 kPa, (DAFWA, Identifying soil compaction, 2016)

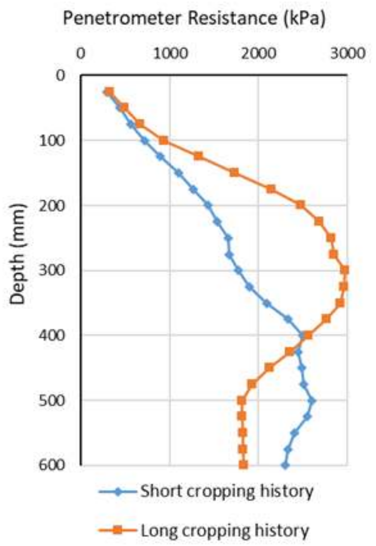

Figure 10 Penetrometer resistance from Fidges paddock for soils with short and long cropping history, September 2016

Table 36 A subset of the soil and lentil nutrient analysis and the relationships with historical lentil grain yield for the five original paddocks.

Grower	Point	Soil Description	Ave lentil yield (% of mean)	kg DM/ha	Lentil whole top tissue analysis				Lentil whole top tissue analysis							CSBP Soil test 0 - 10cm							CSBP Soil test 10 - 30cm					CSBP 0 - 90cm	
					K	S	Cu	Mn	N	K	Mg	S	B	Cu	Mn	Nitrate N 0-10	K Colwell 0-10	OC 0-10	DTPA Copper	DTPA Manganese	CEC	Boron Hot CaCl2	Ammonium N 10-30	Nitrate N 10-30	S 10-30	Conductivity 10-30	Nitrate N 30-60	Nitrogen 0-90	Sulphur 0-90
					%	%	mg/kg	mg/kg	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	mg/Kg	mg/Kg	%	mg/Kg	mg/Kg	CEC	mg/Kg	mg/Kg	mg/Kg	mg/Kg	dS/m	mg/Kg	kg/ha	kg/ha
Ayles	1	Deep sand	66	400	2.8	0.20	8.1	29.7	14.5	11.3	0.96	0.80	0.07	0.03	0.12	4	153.0	0.67	1.1	3.2	10.8	0.7	2	2.0	3.6	0.07	0.5	36	67
	2	Deep sand	91	387	2.2	0.23	6.6	33.5	14.6	8.7	0.89	0.89	0.07	0.03	0.13	4	153.0	0.70	1.1	2.9	10.2	0.6	1	1.0	2.2	0.06	0.5	31	40
	3	Calcareous sand	60	307	2.2	0.20	7.8	35.2	10.8	6.8	0.89	0.61	0.06	0.02	0.11	6	198.0	0.68	2.0	3.3	14.5	1.0	1	3.0	8.4	0.08	3.0	60	91
	4	Loamy sand	81	507	2.5	0.16	7.5	26.3	15.4	12.5	1.06	0.81	0.08	0.04	0.13	5	303.0	0.85	1.4	4.0	13.1	1.3	2	4.0	4.0	0.08	6.0	126	93
	5	Sandy loam	84	413	2.3	0.18	6.8	32.3	14.1	9.6	1.03	0.74	0.09	0.03	0.13	11	378.0	0.95	1.3	4.8	19.6	2.2	3	5.0	7.6	0.09	7.0	127	106
	6	Sandy loam	121	467	2.4	0.18	6.9	42.8	16.1	11.1	0.93	0.84	0.10	0.03	0.20	7	440.0	0.92	1.3	5.2	15.7	2.0	4	5.0	4.2	0.10	4.0	99	59
	7	Loamy sand	119	907	3.1	0.20	10.1	38.6	32.9	28.2	2.18	1.81	0.18	0.09	0.35	16	818.0	1.65	1.6	7.8	28.6	2.7	7	7.0	18.2	0.14	7.0	161	122
	8	Loamy sand	124	493	2.8	0.20	8.8	38.6	17.1	13.9	1.13	0.99	0.09	0.04	0.19	10	363.0	1.08	1.3	5.6	17.9	2.3	5	4.0	4.1	0.12	7.0	120	69
Relationship with historical lentil yield	Slope				0.006		0.016	0.153	0.160	0.015	0.008	0.009	0.001	0.001	0.002	0.097	5.860	0.009		0.049	0.131	0.024	0.068	0.043		0.001	0.057	1.079	
	R Squared value				0.19	0.00	0.12	0.53	0.36	0.33	0.23	0.36	0.45	0.30	0.55	0.35	0.47	0.48	0.00	0.60	0.31	0.56	0.63	0.33	0.00	0.60	0.26	0.33	0.00
Hewett	1	Deep sand	80	2061	2.3	0.14	6.5	34.1	47.8	46.4	4.33	2.88	0.43	0.13	0.70	4	249.0	0.76	0.7	6.1	13.3	0.8	1	2.0	4.7	0.08	6.0	103	73
	2	Red sand	42	1354	2.4	0.21	5.4	116.4	45.2	32.9	2.98	2.84	0.30	0.07	1.58	3	182.0	0.60	0.8	5.9	4.2	0.3	1	0.5	1.0	0.04	0.5	62	36
	3	Deep sand	34	1876	2.3	0.15	5.6	49.0	57.8	42.6	4.13	2.81	0.39	0.10	0.92	2	141.0	0.55	0.7	3.3	6.5	0.4	1	0.5	1.0	0.05	1.0	40	23
	4	Loamy sand	111	2168	2.4	0.17	6.4	53.9	65.3	51.2	5.64	3.69	0.45	0.14	1.17	5	214.0	0.94	0.7	4.6	10.0	0.6	3	1.0	2.6	0.07	5.0	94	76
	5	Red sand	51	1322	2.0	0.16	4.8	101.9	44.7	26.8	3.70	2.12	0.32	0.06	1.35	3	180.0	0.61	0.7	5.4	4.5	0.3	2	0.5	0.9	0.03	0.5	61	15
	6	Calcareous sand	123	1686	2.3	0.16	6.8	50.7	45.9	38.8	3.37	2.70	0.29	0.12	0.85	3	150.0	0.83	1.3	5.8	4.6	0.4	5	2.0	1.6	0.08	4.0	109	73
	7	Sandy loam	133	3315	3.2	0.28	10.3	66.1	93.8	106.4	9.61	9.28	1.03	0.34	2.19	8	313.0	1.23	1.2	12.5	13.6	1.3	9	2.0	8.9	0.10	10.0	181	476
	8	Sandy loam	116	2178	2.7	0.17	9.8	28.1	63.4	58.8	5.23	3.70	0.49	0.21	0.61	8	272.0	1.24	0.9	5.2	17.2	1.6	4	2.0	14.3	0.13	11.0	174	112
Relationship with historical lentil yield	Slope				0.006	0.000	0.040	-0.393	0.243	0.409	0.033	0.336	0.003	0.002	0.001	0.043	0.925	0.006	0.004	0.037	0.072	0.008	0.057	0.016	0.073	0.001	0.085	6.904	2.404
	R Squared value				0.38	0.14	0.62	0.25	0.33	0.43	0.39	0.34	0.30	0.52	0.01	0.55	0.36	0.77	0.47	0.29	0.33	0.39	0.67	0.68	0.36	0.62	0.67	0.74	0.40
Johns	1	Deep sand	49	918	2.8	0.13	5.7	25.7	30.8	25.5	1.93	1.19	0.17	0.05	0.24	3	192.0	0.64	0.6	2.9	12.0	0.8	2	0.5	1.5	0.06	0.5	40	24
	2	Deep sand	66	782	2.8	0.17	7.4	25.9	26.2	21.5	2.42	1.33	0.19	0.06	0.20	5	239.0	0.66	0.5	2.8	13.1	1.2	1	1.0	2.9	0.07	7.0	101	35
	3	Sandy loam	128	1192	2.9	0.16	6.6	47.7	41.2	35.0	3.22	1.91	0.24	0.08	0.57	6	196.0	0.92	0.7	3.3	9.9	0.8	5	2.0	2.1	0.07	3.0	75	29
	4	Sandy loam	112	1088	2.4	0.15	6.7	36.3	38.4	26.3	2.50	1.63	0.22	0.07	0.40	6	398.0	1.24	1.1	4.6	16.2	1.6	3	6.0	5.0	0.10	14.0	177	76
	5	Loamy sand	118	1458	2.9	0.18	9.5	29.2	46.8	42.3	3.79	2.63	0.31	0.14	0.43	5	249.0	1.28	0.8	5.7	14.5	1.3	3	3.0	2.5	0.07	8.0	129	45
	6	Red sand	46	1093	2.6	0.12	4.9	55.2	36.5	28.3	2.62	1.31	0.21	0.05	0.60	2	163.0	0.65	1.0	3.1	7.0	0.5	4	0.5	0.9	0.05	1.0	65	16
	7	Sandy loam	136	1129	3.5	0.21	10.1	36.7	41.3	39.5	3.27	2.37	0.30	0.11	0.41	5	447.0	1.40	1.0	5.0	18.3	2.0	5	6.0	4.5	0.10	14.0	179	85
	8	Sandy loam	128	1279	2.9	0.21	10.6	34.5	49.1	37.0	3.71	2.69	0.35	0.13	0.44	7	410.0	1.42	1.1	5.4	20.2	2.7	4	5.0	5.6	0.12	22.0	233	839
Relationship with historical lentil yield	Slope				0.004	0.001	0.043		0.155	0.150	0.014	0.014	0.001	0.001	0.001	0.036	2.056	0.008	0.003	0.024	0.076	0.126	0.023	0.050	0.031	0.000	0.135	1.267	2.827
	R Squared value				0.28	0.62	0.57	0.00	0.58	0.57	0.62	0.71	0.65	0.61	0.09	0.68	0.47	0.78	0.18	0.57	0.43	0.44	0.38	0.64	0.47	0.47	0.46	0.52	0.14
Morony	1	Deep sand	33	733	2.9	0.16	5.5	26.4	26.8	21.4	1.69	1.17	0.16	0.04	0.19	3	169.0	0.58	0.5	2.0	7.3	0.6	1	2.0	1.2	0.05	0.5	34	15
	2	Red sand	85	507	2.9	0.20	6.1	27.7	18.7	14.8	1.32	1.01	0.13	0.03	0.14	6	180.0	0.58	0.4	2.2	8.6	0.6	1	0.5	0.9	0.06	1.0	47	13
	3	Shallow rock	59	333	2.7	0.21	6.7	39.4	11.4	8.8	1.23	0.70	0.08	0.02	0.13	9	243.0	0.94	0.5	3.6	14.8	1.2	3	3.0	2.4	0.08	4.0	95	37
	4	Calcareous sand	76	413	2.6	0.21	6.7	37.7	15.0	10.7	1.24	0.87	0.10	0.03	0.16	5	283.0	0.86	0.5	3.8	14.8	1.1	1	2.0	3.2	0.08	6.0	95	58
	5	Calcareous sand	65	427	2.4	0.17	5.5	27.0	13.7	10.4	1.11	0.73	0.09	0.02	0.12	5	250.0	0.69	0.5	3.7	13.4	0.8	2	2.0	2.0	0.07	2.0	66	27
	6	Loamy sand	113	600	2.9	0.20	6.3	36.2	21.5	17.3	1.50	1.20	0.13	0.04	0.22	8	257.0	0.94	0.9	4.9	13.2	0.9	4	2.0	3.2	0.07	4.0	101	47
	7	Loamy sand	120	573	2.2	0.17	6.2	38.2	20.4	12.5	1.55	0.97	0.12	0.04	0.22	6	220.0	1.05	0.6	5.3	16.2	1.4	5	6.0	4.6	0.09	10.0	159	80
	8	Loamy sand	145	1013	2.6	0.19	7.0	29.5	37.8	26.0	3.14	1.93	0.25	0.07	0.30	7	264.0	1.01	0.7	3.2	12.5	1.1	3	2.0	3.0	0.09	5.0	104	40
Relationship with historical lentil yield	Slope				-0.003		0.009		0.121	0.062	0.011	0.007	0.001	0.000	0.001	0.024	0.459	0.004	0.002	0.002	0.034	0.004	0.026		0.021	0.000	0.050	0.722	0.325
	R Squared value				0.13	0.00	0.36	0.00	0.28	0.14	0.39	0.41	0.30	0.42	0.54	0.21	0.17	0.49	0.31	0.26	0.16	0.22	0.37	0.00	0.40	0.57	0.36	0.46	0.28
Trengove	1	Red sand	65	222	2.8	0.31	10.1	310.9	9.5	6.2	0.60	0.69	0.06	0.02	0.69	2	189.0	0.61	0.6	8.4	2.8	0.3	3	0.5	1.1	0.06	1.0	49	17
	2	Red sand	75	200	2.7	0.30	7.7	300.1	7.5	5.5	0.62	0.60	0.06	0.02	0.60	2	147.0	0.67	0.3	6.6	2.8	0.3	3	0.5	1.2	0.05	0.5	35	14
	3	Loamy sand	125	411	3.0	0.28	10.1	256.3	14.7	12.4	1.11	1.15	0.11	0.04	1.05	3	316.0	0.77	0.6	12.0	4.9	0.4	2	2.0	2.0	0.08	2.0	60	24
	4	Loamy sand	117	300	3.3	0.27	6.3	67.5	10.6	9.9	0.84	0.81	0.07	0.02	0.20	6	294.0	1.03	0.4	3.9	11.5	0.7	6	2.0	1.5	0.07	2.0	70	34
	5	Deep sand	90	356	3.1	0.26	10.2	291.1	13.1	11.0	0.89	0.92	0.09	0.04	1.03	3	245.0	0.69	0.7	6.6	4.1	0.4	3	1.0	1.3	0.05	2.0	98	23
	6	Loamy sand	127	344	2.5	0.24	9.8	187.5	13.2	8.4	0.90	0.83	0.09	0.03	0.65	3	208.0	1.11	0.9	10.2	5.9	0.5	4	2.0	1.4	0.06	4.0	129	35
	7	Sandy loam	117	500	3.0	0.23	7.1	131.5	19.2	14.9	1.40	1.15	0.11	0.04	0.66	7	298.0	0.79	0.5	6.8	6.9	0.4	3	3.0	1.4	0.07	2.0	83	34
	8	Sandy loam	116	400	3.14	0.24	9.06	85.6	15.64	12.56	0.92	0.96	0.08	0.04	0.34	7	282.00	0.79	0.69	8.39	11.22	0.48	2	2.0	1.7	0.08	5.0	118	50
Relationship with historical lentil yield	Slope					-0.009		-2.914	0.105	0.094	0.008	0.006	0.001	0.000	-0.002	0.052	1.874	0.006	0.003		0.092	0.004		0.032	0.009	0.000	0.041	0.828	0.356
	R Squared value				0.00	0.55	0.00	0.49	0.45	0.47	0.49	0.48	0.43	0.35	0.02	0.33	0.54	0.56	0.11	0.00	0.40	0.44	0.00	0.78	0.57	0.60	0.43	0.36	0.52
Average R squared value for the 5 paddocks					**0.19**	**0.26**	**0.33**	**0.25**	**0.40**	**0.39**	**0.42**	**0.46**	**0.43**	**0.44**	**0.24**	**0.42**	**0.40**	**0.62**	**0.21**	**0.35**	**0.33**	**0.41**	**0.41**	**0.49**	**0.36**	**0.57**	**0.44**	**0.48**	**0.27**

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List of Tables and Figures