FarmLink

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2017
Research Report

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A word from our Chair

Welcome to the 2017 FarmLink Annual Research Report – it is with pleasure that we present a summary of the RD&E activities of FarmLink over the last 12 months.

We would like to thank our major funding and project partners – GRDC, Riverina LLS, CSIRO, NSWDPI, CSU, Functional Grains Centre, MLA, Graham Centre, Bayer Crop Sciences, Cropfacts, ACIAR, Clearview Consulting, Dow Agroscience, AGT, Best Environmental Technologies, Southern Farming Systems and Landmark. We rely on the vision that these organisations have for southern NSW farming to secure investment in the innovation that makes our farming future possible. We also acknowledge our other Partner Organisations Commonwealth Bank, GrainGrowers, Intersales, Temora Truck & Tractor Service, Hutcheon and Pearce and ADM whose involvement with FarmLink adds value and benefit for our members. We encourage our members to support the businesses that support agricultural RD&E and are investing in the future of the region.

We would like to thank our volunteer board members who continue to give freely of their time and experience to ensure the success of FarmLink. In 2018 we are seeing a changing of the guard with Robert Patterson leaving the board after 4 years. Robert joined the board at a time when significant effort was required to bring the finances and governance of the organisation into order. Robert's business and director experience along with his eagle-eyed attention to detail have been instrumental in the subsequent stabilisation of the business. On behalf of the Board, the staff and the members of FarmLink – a sincere thanks. Joining the Board in 2018 are Jenny Thompson (Illabo) and John Stevenson (Lockhart) both of whom have expertise that will greatly assist the Board, especially as they take up roles on the Audit and Risk and RD&E Committees, respectively.

This year's research report includes the last year of results from our GRDC funded Stubble Initiative project which is concluding in June 2018. We also have reports from projects focussed on weed management (competition, harvest control, summer control) and soil health (acidity, carbon, amelioration) plus mixed farming and livestock. We thank all of our authors and contributors and hope that you find the reports interesting and informative.

Finally, on a personal note, this is my last research report as Chair of FarmLink. At the AGM in March Lisa Anderson (Coolamon) will be taking over as Chair, and I will be leaving the Board. I have had the pleasure of sitting on the Board over the last 4.5 years as we have worked to restructure and reposition FarmLink. I am proud of what has been achieved over that time. We are very lucky to have such a committed Board and staff at FarmLink who have really worked to secure the organisation for the future. Thank you.

I first joined FarmLink as a member because of my interest in the research and my belief that local research is necessary to address local issues and improve our profitability. On the Board I got an insight into the effort required to make local RD&E happen and the huge impact that can be achieved when it does. I remain certain of the important role of farmer led research and look forward to the next phase of FarmLink with Lisa at the helm.

Darryl Harper

Chair of the FarmLink Board of Directors

Cindy Cassidy, FarmLink Chief Executive Officer and Darryl Harper, Chair of the FarmLink Board of Directors.

Our FarmLink Story

Productivity, profitability and sustainability - securing the future of farming

FarmLink is about the future of farming – productive, profitable and sustainable farms and farmers. We are committed to delivery of innovation for farmers in southern NSW and supporting them in the implementation of change on their farms and in their farm businesses. We believe that strong farm businesses create vibrant local communities.

Our governance

FarmLink is a not for profit company limited by guarantee established in 2004. The constitutional objectives of the company are focussed on Research Development and Extension (RD and E) activities designed to achieve profitable and sustainable farming businesses in southern NSW. We have approximately 800+ individual members involved in agriculture in SNSW representing 300+ farming, advisory, research and other agribusinesses

Our Reach

The FarmLink region covers 1.2mil ha of arable land across SNSW. The region encompasses high, medium and low rainfall production zones and a range of farming enterprises from continuous cropping, livestock and mixed farming enterprises. Acidic red duplex soils are dominant in the cereal and canola production zones across the region.

FarmLink reaches over 3000 people annually through our media and social media presence, events, activities and communications. FarmLink's activities and region involves 13 different local government areas. These include Temora Shire Council, Junee Shire Council, Coolamon Shire Council, Hilltops Shire Council, Wagga Wagga City Council, Cowra Shire Council, Cootamundra-Gundagai Shire Council, Greater Hume Shire Council, Lockhart Shire Council, Narrandera Shire Council, Bland Shire Council and Weddin Shire Council.

Our Business

FarmLink currently partners with GRDC, CSIRO, NSWDPI, LLS, Bayer, DAFF, Dow AgroSciences, AGT, Best Environmental Technologies, Hutcheon & Pearce, Landmark, MLA, CSU, Environmental Trust, Temora Shire Council and the Graham Centre to conduct RD and E activities at nine demonstration and/or field trial sites across our region including the TAIC. We have projects focussed on weed and herbicide tolerance management, soil micronutrient deficiency, carbon sequestration, stubble management, sheep genetics and mixed farming integration.

FarmLink has 17 corporate partners across the agribusiness sector. Our partnership packages have been designed to appeal to businesses and organisations with values and aspirations aligned with FarmLink's. We see our partnerships as opportunities to introduce our members to the valuable skills and expertise of businesses operating in agriculture across our region and for our partners to meet and better understand our farms and farmers. A FarmLink Partnership allows our farmers and regional businesses to grow long term, beneficial relationships.

Recently FarmLink has established a Farming Systems Partnership with Charles Sturt University and other farming systems groups to create a supply chain for agricultural training, research, development and extension in SNSW. Through this partnership, FarmLink contributes to RD&E priority setting, provides access to farmers, field trial capacity and industry work experience opportunities, and receives academic and scientific oversight of projects.

01

FarmLink Research Report 2017

A flexible approach to managing stubble profitably in the Riverina and Southwest Slopes of NSW

Trial Site Location

5 km SSE of Temora

Report Authors

Tony Swan, John Kirkegaard and Brad Rheinheimer (CSIRO Agriculture),Kellie Jones and Colin Fritsch (FarmLink), and James Hunt (La Trobe University (current address)).

Introduction

Previous studies have highlighted potential negative yield impacts of retained stubble in SNSW (Kirkegaard 1995; Scott *et al.* 2013), but strict no-till advocates recommend retaining all of the stubble to enhance water capture and storage, 'soil health' and crop yields. Over past decades, farmers and scientists have continued to examine a range of methods to flexibly manage stubble to improve profitability. These have included the adoption of minimum till (tine) or zero till (disc) seeding equipment, diversifying management strategies such as changing crop sequences/ nitrogen applications/ herbicide options, adopting various new harvesting options for weed seed control such as the Harrington weed seed destructor/chaff chutes or windrow burning, and using techniques such as stubble incorporation, grazing or baling stubble to reduce the stubble load. A late strategic burn can also be incorporated into the mix.

Take home messages

- Don't let stubble compromise the big things (weeds, disease, timeliness)
- Be flexible in your approach to managing stubble
- Pro-actively manage stubble for your seeding system and deep band N at sowing
- Diversify your crop sequence: add legumes to rotation with double break to reduce N input, reduce ARG weed seedbank and be more profitable
- Options to reduce stubble load include mulching, incorporation + nutrients, baling and grazing.
- If stubbles are too thick to sow through, consider strategic late burn, especially before 2nd wheat crop or if sowing canola into large stubbles. Increase of > 0.5t/ha wheat grain yield in 2nd wheat crop following burning.

Project Partners

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CSIRO

Funding Partners

GRDC Grains Research & Development Corporation

GRDC project code - CSP00174

REPORT ONE

Background

A canola (Brassica napus) crop followed by two wheat (Triticum aestivum) crops (C-W-W) has been a very common crop sequence during the last decade in the no-till farming systems that predominate in southern NSW. As the area comprises 50% of farms with mixed crop livestock enterprises (Kirkegaard *et al* 2011), post-harvest residue management by grazing or late burning has been part of the flexible approach to managing stubble. Increasing concern has been raised about the damage of these practices to soil health which prompted an experiment to be designed to investigate impacts of stubble burning and grazing on soil conditions and crop growth.

The addition of a break crop such as canola or a pulse legume into the sequence have been shown to be profitable in it's own right and an effective management tool for controlling weeds and diseases in stubble retained systems (Swan *et al.* 2015, Peoples *et al.* 2016). However, while farmers have found that there are many benefits for retaining stubble, increases in stubble loads in wetter seasons combined with a greater adoption of zero till seeding equipment, can negatively impact on herbicide flexibility, weed control and crop yield.

In this paper, we initially examine what questions farmers and advisors need to ask when managing stubble using a flexible approach and answer some of them by reporting results from the recent stubble management project (GRDC CSP00174). We examine the cost and effectiveness of various harvesting options that have been tested using farm equipment in the Southwest Slopes and Riverina. We report some of the main findings from two field experiments established in the Temora region over the past 4 to 8 years comparing different farming systems. The first experiment compared three management strategies (aggressive, sustainable and conservative) in a full factorial 4 year experiment located at the Temora Agriculture Innovation Centre (TAIC) using a single disc and a tine seeder on yield, gross margin and weed control. The second experiment, a long-term (8 year) field trial examining a canola–wheat-wheat (C-W-W) sequence determined the impact of post-harvest stubble management (heavy grazing, burning, or retaining stubble) on soil mineral N and wheat yield under no-till, controlled traffic cropping with strict summer fallow weed control.

Questions to ask when managing stubble using a flexible approach

It has been well documented that to successfully establish a crop into a full stubble retained system requires an integrated management approach incorporating three main stages of stubble management - pre-harvest, post-harvest/pre-sowing, and finally at sowing (Ref 1,2,3,4,5). During these periods, a series of questions (some outlined below) need to be addressed by farmers to successfully establish a crop.

- What is my preference for tillage system?
- What is my seeding system?
- What is my row spacing and accuracy of sowing?
- What crop will be planted into the paddock next year?
- What is the type of crop residue?
- What is the potential grain yield and estimated amount of crop residue?
- Is the crop lodged or standing at harvest?
- What is the desired harvest speed and harvest height?
- How uniform is the spread of straw from my harvester?
- Should I spread residue or place in a narrow windrow?
- Do I have a weed problem which requires intensive HWSC, chaff carts or chutes?
- Will the stubble be grazed by livestock?
- Am I prepared to process stubble further post-harvest: mulch, incorporate, bale?
- If incorporating stubble, should I add nutrients to speed up the decomposition process?
- What is the risk of stubble-borne disease in next years crop?
- Am I likely to encounter a pest problem next year: mice, slugs, earwigs, weevils, snails?
- What is the erosion risk based upon soil type and topography?
- Do I need to burn or what else can I do?

Prior to harvest, all crops should be assessed to estimate grain yield, potential stubble load and weed issues. As a rule of thumb, the stubble load following harvest will be approximately 1.5 to 2 times the grain yield for wheat and between 2 to 3 times the grain yield for canola (ref 4, 5). There is no perfect stubble management strategy for every year. Crop rotations, weeds, disease, pests, stubble loads, sowing machinery and potential sowing problems will largely dictate how stubble should be managed.

Table 1: The crop rotation for each sequence in the three management strategies in a fully phased experiment at TAIC between 2014 and 2017.

Management Strategy	Sequence	Crop 2014	Crop 2015	Crop 2016	Crop 2017
Aggressive	4	Wheat 1 (H)	Wheat 2 (H)	Canola RR	Wheat 1 (H)
Aggressive	6	Wheat 2 (H)	Canola RR	Wheat 1 (H)	Wheat 2 (H)
Aggressive	10	Canola RR	Wheat 1 (H)	Wheat 2 (H)	Canola RR
Sustainable	1	Barley	Legume Hay	Canola TT	Wheat (L)
Sustainable	3	Wheat (L)	Barley	Legume Hay	Canola TT
Sustainable	7	Legume Hay	Canola TT	Wheat (L)	Barley
Sustainable	9	Canola TT	Wheat (L)	Barley	Legume Hay
Conservative	2	Wheat 1 (L)	Wheat 2 (L)	Canola TT	Wheat 1 (L)
Conservative	5	Wheat 2 (L)	Canola TT	Wheat 1 (L)	Wheat 2 (L)
Conservative	8	Canola TT	Wheat 1 (L)	Wheat 2 (L)	Canola TT

Methods and Materials

Part 1: Harvest stubble management – Harvest height

Eight commercial harvesters were tested between 2014 and 2016 on farm scale strips across the South West Slopes and Riverina to examine the effect of cutting height (15 to 60cm) on harvest efficiency and grain yield. The harvesters included a Case 7240, Case 8240, John Deere 5680, Case IH1920, John Deere 9770, Case 8230 and New Holland 8090. A prototype Integrated Harrington Seed Destructor (iHSD) was also tested in Temora, NSW in December 2015, Inverleigh in December 2015 and Furner, SA in January 2016.

Part 2: Strategy Management Experiment – Impact on weeds, yield & profitability

The experiment was located on a red chromosol soil with surface pHCaCl_2 of 5.0 (0-10 cm) and 4.6 (10-20 cm) and little slope at the Temora Agricultural Innovation Centre (TAIC) 4 km N of the township of Temora in SE NSW (S 34.49°, E 147.51°, 299 m ASL). A fully phased systems experiment was established in 2014 at a site with high levels of Group B resistant annual ryegrass ARG (average seedbank of 1864 plants/m^2) to compare the yield, profitability and sustainability of three management strategies in a stubble retained no-till (Flexi-Coil tine seeder with Stiletto deep banding & splitting boots) and zero-till (Excel single-disc seeder with Arricks' wheel) farming system (Table 1). Nitrogen was applied at sowing by deep banding below the seed (tines) or surface applied pre-sowing (disc) at either 20 or 40 kgN/ha (Table 2).

Table 2: The planned crop density and seed bed nitrogen quantity/application method at sowing for each crop in the three management strategies for both opener types.

Management Strategy	Crop	Plant Density (plants/m2)	Seed bed Nitrogen Quantity (kgN/ha)		N type and application
			Tine^	Disc#	
Aggressive	Wheat 1 (H)	150	40	40	Urea IBS
Aggressive	Wheat 2 (H)	150	40	40	Urea IBS
Aggressive	Canola RR	40	20	20	SOA IBS
Sustainable	Barley	120	20	20	Urea IBS
Sustainable	Wheat (L)	80	20	20	Urea IBS
Sustainable	Legume Hay	40	Nil	Nil	Nil
Sustainable	Canola TT	40	20	20	SOA IBS
Conservative	Wheat 1 (L)	80	20	20	Urea IBS
Conservative	Wheat 2 (L)	80	20	20	Urea IBS
Conservative	Canola TT	40	20	20	SOA IBS

 # Nitrogen spread on soil surface prior to sowing (Disc)
^ Nitrogen deep banded below the seed using stiletto boots (Tine)

Pre-emergent and post emergent grass herbicides were applied to the three management strategies as outlined in Table 3. One of the main difference between the herbicides applied in the disc and tine systems related to trifluralin being used in the tine systems, but not in the disc systems, due to crop safety restrictions. Insecticides and fungicides were applied to treatments at sowing and during the crop development to minimise the effects of disease or insect damage.

The annual ryegrass ARG (Lolium rigidum Gaudin) seedbank was initially measured in March 2014 prior to sowing by taking 40 soil cores, each 58 mm in diameter x 50 mm deep. All plots were then measured in February or March of 2015, 2016 and 2017 by taking 8 cores in each plot to determine the change in ARG seedbank relating to management strategies. The soil was cooled at 4°C for 7 days, then emptied into seedling trays in a glasshouse that were kept wet for the following 3 months. All ARG seedlings emerging were counted fortnightly and removed from each tray before being re-wetted.

Three soil cores (42 mm diameter) were taken in April of each year in each plot to a depth of 1.6m and segmented for analysis (0.1 segments to 0.2m depth and 0.2m segments to 1.6m depth) with an additional 4 foot cores taken at 0-0.1m and 0.1-0.2m depths, with cores bulked according to depths. Soil from each depth increment was analysed for mineral N (NH_4 and NO_3). Nitrogen was applied to all crops except the legume hay crop at GS31 (cereals) or stem elongation (canola) at different amounts determined by the starting soil mineral nitrogen concentration to attain a predicted yield of 70% of maximum potential as determined by Yield Profit ® for each year. Grain yields were measured by plot header harvesting only the middle 4 rows and by hand harvesting large areas (> 1.0m^2) of crop and threshing to measure the total dry matter production, harvest index and to estimate the amount of crop residue returned to the plot.

ARG, soil mineral N and grain yield were analysed by ANOVA with "Treatment" as (Management/ Sequence) x Opener, and "Block" as Block/Plot pair/Plot using GenStat 18 software package (VSN International Ltd.). The ARG data often required transformations using either loge or square root to normalise the residuals. Results in the tables are reported following back transformation and significant difference indicated by letters. Significance is assumed at the 95% confidence level and tests of mean separation were made using Fisher's least significant difference for the 95% confidence level.

Table 3: The herbicides applied at sowing and in-crop to control herbicide resistant annual grasses at TAIC for each management strategy x opener type.

Management Strategy	Crop	IBS Herbicides x Opener		In-Crop Grass Herbicides
		Tine	Disc	Tine and Disc
Aggressive	Wheat 1 (H)	Sakura ® @ 118g/ha + Avadex Xtra® @ 2L/ha	Sakura ® @ 118g/ha + Avadex Xtra® @ 2L/ha	Atlantis® @ 0.33L/ha
Aggressive	Wheat 2 (H)	Boxer Gold ® @ 2.5L/ha	Boxer Gold ® @ 2.5L/ha	Atlantis® @ 0.33L/ha
Aggressive	Canola RR	Rustler® @ 1L/ha + TriflurX® @ 2L/ha	Rustler® @ 1L/ha	Roundup Ready® @ 0.9kg/ha (2 & 6 leaf)
Sustainable	Barley	Boxer Gold ® @ 2.5L/ha	Boxer Gold ® @ 2.5L/ha	Nil
Sustainable	Wheat (L)	Sakura ® @ 118g/ha + Avadex Xtra® @ 2L/ha	Sakura ® @ 118g/ha + Avadex Xtra® @ 2L/ha	Atlantis®@ 0.33L/ha
Sustainable	Legume Hay	Nil	Nil	
Sustainable	Canola TT	Rustler® @ 1L/ha + Gesaprim® @ 1.1kg/ha + TriflurX® @ 2L/ha	Rustler® @ 1L/ha + Gesaprim® @ 1.1kg/ha	Status® @ 0.5L/ha + Gesaprim® @ 1.1kg/ha
Conservative	Wheat 1 (L)	Diuron @ 1L/ha + TriflurX® @ 2L/ha	Diuron (500g/L) @ 1L/ ha	Atlantis® @ 0.33L/ha
Conservative	Wheat 2 (L)	Diuron (500g/L) @ 1L/ha + TriflurX® @ 2L/ha	Diuron (500g/L) @ 1L/ ha	Atlantis® @ 0.33L/ha
Conservative	Canola TT	Gesaprim® @ 1.1kg/ha + TriflurX® @ 2L/ha	Gesaprim® @ 1.1kg/ha	Status® @ 0.5L/ha + Gesaprim® @ 1.1kg/ha

Part 3: Grazing x Stubble Management Experiment – Impact of grazing, burning or retaining stubble on soil nitrogen, crop yield and profitability

The experiment was located on a red chromosol soil with surface pHCaCl$_2$ of 5.0 (0-10 cm) and 4.85 (10-20 cm) and little slope 5 km SSE of the township of Temora in SE NSW (S 34.49°, E 147.51°, 299 m ASL). Treatments were applied in two different phases in adjoining areas of a paddock which had been in lucerne pasture (Medicago sativa) since 2005. In Phase 1, lucerne was terminated with herbicide in late spring 2008; in Phase 2 it was terminated in late winter 2009. Following lucerne removal, large plots (7.25 x 16 m) were established which allowed all operations to be conducted using controlled traffic. All plots were fenced so they could be individually grazed by sheep. Lime was evenly applied at a rate of 2.5 t/ha across all plots in April 2009.

In both phases, the two grazing treatments (nil graze – NG, stubble graze – SG) were applied in a factorial randomised complete block design with two stubble management treatments (stubble burn – SB, stubble retain – SR) and four replicates. Following harvest in each year (late November-early December), weaner ewes grazed stubbles in the SG treatment (average 2263 sheep.days/ha). The stubble burn treatments were applied in mid to late March of each year.

Crops were sown in mid-late April in all years of the experiment, and both crop phases were kept in a rotation of canola-wheat-wheat (Table 4). All crops in both phases between 2009 and 2016 were inter-row sown using a plot seeder equipped with contemporary no-till seeding equipment consisting of six Flexi-Coil 250 kg break out tines set on 305 mm row spacing and fitted with Agmaster® boots, 12 mm knife points and press wheels. Summer weeds that emerged at the site were controlled with herbicide within 5-10 days of emergence, and all in-crop weeds, disease and pests were controlled with registered pesticides such that they did not affect yield. The same rate of synthetic fertilisers were applied to all treatments determined annually following soil analysis to ensure the treatment with the lowest mineral nitrogen concentration was able to yield to 70% of maximum potential as determined by Yield Profit® for that year.

Table 4: Crop sequence of Canola (C)–Wheat (W)–Wheat (W) in Phase 1 and Phase 2 of the trial following lucerne pasture (P) since 2005. 2nd wheat crop in bold.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Phase 1	P	W	C	W	**W**	C	W	**W**	C
Phase 2	P	P	W	C	W	**W**	C	W	**W**

Prior to seeding each year two soil cores (42 mm diameter) were taken per plot to a depth of 1.6 m and segmented for analysis (0.1 segments to 0.2 m depth and 0.2 m segments to 1.6 m depth). Six additional cores were taken for 0-0.1 m and 0.1-0.2 m depths, and cores were bulked according to depths. Soil from each depth increment was analysed for mineral N (NH_4 and NO_3). Grain yield was measured using a plot header harvesting only the middle four rows of each seeding run to remove edge effects from rows adjacent to tram tracks. Grain yields were also measured by hand harvesting large areas (> 1.0 m^2) of crop and threshing to measure the total dry matter production, harvest index and to estimate the amount of crop residue returned to the plot.

Soil mineral N and grain yield were analysed using mixed linear models with grazing, stubble, rotational position (1st or 2nd wheat crop after canola) and year as fixed effects, and block and phase as random effects in the GenStat 18 software package (VSN International Ltd.). Significance is assumed at the 95% confidence level and tests of mean separation were made using Fisher's least significant difference for the 95% confidence level, estimated by doubling the average standard error of means.

Monthly, annual and growing season rainfall (April-Oct) at Temora is outlined in Table 5. In 2010, 2011 and 2016, harvest for the canola was delayed until late November early December and wheat until early December, so the November rainfall could be added to GSR in those years

Table 5: Monthly and annual rainfall data (mm) from Temora airport 2008-2017

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual (mm)	GSR
2008	43	69	41	26	7	17	48	22	27	24	39	59	423	171
2009	22	14	16	53	7	58	32	8	24	23	24	44	327	205
2010	6	109	79	39	41	22	59	63	63	87	105	76	749	374
2011	62	196	72	17	17	18	25	46	30	48	108	64	702	201
2012	62	59	24	5	16	18	44	38	15	17	35	30	363	153
2013	10	40	20	2	52	87	18	25	29	15	47	9	354	228
2014	21	25	56	70	31	74	5	24	29	17	18	66	436	250
2015	61	21	3	49	20	51	79	54	10	13	90	29	481	276
2016	57	9	8	9	90	113	61	71	205	42	5	34	704	591

Results

Part 1: Harvest stubble management – Harvest height

Using a stripper front or harvesting high is the quickest and most efficient method to produce the least amount of residue that needs to be threshed, chopped and spread by the combine. Harvesting high (40-60 cm) compared to 15 cm increased grain yield and combine efficiency by reducing bulk material going through the header and reduced harvests costs by 37 to 40% (Table 6). As a general rule, there is a 10% reduction in harvest speed for each 10 cm reduction in harvest height (Table 6). Slower harvest speed across a farm also exposes more unharvested crop to the risk of weather losses (sprouting, head/pod loss, lodging) during the harvest period, and the cost of this is not accounted for in Table 6.

Table 6: Harvesting wheat low or high using a JD9770 combine in 2014 (Ref 7). Ground speed was altered to achieve similar level of rotor losses at both harvest heights. Values are means of three replicates STS yield monitor and all differences are significant (P<0.05). Operating costs determined at $600/hr.

Harvest height	Efficiency (ha/h)	Speed (km/hr)	Fuel (l/ha)	Yield (t/ha)	Cost $/ha	Cost $/ton
60cm	9.5	10.6	5.4	2.19	$63.2	$28.7
15cm	5.7	6.2	9.6	2.05	$105.3	$50.1
% Change to 15cm	**-41%**	**-42%**	**+78%**	**-6%**	**+40%**	**+57%**

There is substantial evidence indicating wide spread resistance or partial resistance of ARG to a wide range of herbicide groups across south eastern Australia (Broster *et al*. 2011). Harvest weed seed control (HWSC) which includes narrow windrow burning, chaff carts, chaff lining, direct baling, and mechanical weed seed destruction is an essential component of integrated management to keep weed populations at low levels and thus slow the evolution and spread of herbicide resistance ARG. HWSC requires crops to be harvested low in order for weed seeds to be captured in the chaff fraction from the combine, and if practiced provides an additional reason to harvest low. The prototype Integrated Harrington Seed Destructor (iHSD) was tested in Temora, NSW in December 2015, Inverleigh in December 2015 and Furner, SA in January 2016 at a constant speed of 4 km/hr to compare the efficiency and cost with non-weed seed destruction methods (Table 7). We found no significant difference in grain yield when harvesting at 15 cm cf 30 cm at 4 km/hr, but there a 9% increase in engine load and 11% reduction in fuel efficiency (Table 7). However, when the weed seed destructor was activated, there was a 33% increase in engine load which resulted in a 40% reduction in the fuel efficiency of the header (Table 7).

Table 7: A Case 9120 harvesting wheat conventionally at 30 cm, harvesting at 15 cm for baling or narrow windrow burning and harvesting at 15 cm with a prototype iHSD at Furner, SA in 2016. (Data supplied by GRDC project SFS00032)

	Harvest height	Grain Yield (t/ha)	Speed (km/hr)	Engine Load (%)	Fuel (l/ha)	Fuel Efficiency (l/hr)
Conventional Harvest - Burn	**30cm**	4.7	3.8	59.8	14.3	52.7
Windrow Bale/burn	**15cm**	4.6	4.0	65.5	16.4	59.5
iHSD	**15cm**	4.6	4.0	88.7	22.7	87.8
lsd @ P<0.05)		**ns**	**ns**	**2.26**	**1.36**	**2.18**
% Change to 15 cm				**+9%**	**+11%**	**+11%**
% change to iHSD				**+33%**	**+37%**	**+40%**

Part 2: Results from the Strategy Management Experiment 2014-2017

Stubble load: The cereal stubble load following harvest in 2014 and 2015 ranged between 6.3 and 7.7 t/ha. By April 2016, the cereal stubble / ryegrass DM load that crops were sown into ranged between 7-10 t/ha (Table 8). Following the 2016 decile 9 season with high grain yields, the cereal stubble / ryegrass DM quantity increased in many treatments with a further 8-10 t/ha added to the previous 3 years undecomposed stubble. To ensure all treatments could be established in April 2017, the cereal stubble load was reduced in all treatments to between 4-6 t/ha (total amount of straw at sowing) by baling excess stubble.

Table 8: Stubble type and quantity (t/ha) in April 2016 that crops were sown into at Temora.

Management Strategy	Stubble type & year	Crop 2016	Disc (t/ha)	Tine (t/ha)
Aggressive	Wheat 1 (H)	Wheat 2 (H)	7	8
Aggressive	Wheat 2 (H)	RR Canola	9	8
Conservative	Wheat 1 (L)	Wheat 1 (L)	7	7
Conservative	Wheat 2 (L)	TT Canola	8	9
Sustainable	Barley	Vetch	10	9

The most profitable crop across all management strategies between 2014 and 2016 were canola with an average nett margin of between $694 and $769/ha/year and a profit/cost ratio of between $1.40 (aggressive strategy) to $1.80 (sustainable strategy) for every $1 spent (Table 9a). The highest grain yield was produced by the hybrid RR canola in 2014 and 2015 (2.2 t/ha and 3.1 t/ha, respectively), however, this required an increase of 20% in average total costs (Table 9a). The decile 9 season of 2016 (Table 5) resulted in all canola yielding between 2.8 and 3.0 t/ha (Table 11). The introduction of diversity with the sustainable strategy resulted in an average net margin over the three years of $512/ha/year which is higher than in the aggressive strategy ($498/ha/year) and 25% higher than the conservative strategy, with 10% lower cost than the aggressive ($465 cf $517/ha/year) and thus higher profit:cost ratio ($1.12 cf $0.96) (Table 9b). A major difference in the average total costs between the sustainable and either the aggressive or the conservative strategies was the 30-35% saving in nitrogen costs (Table 9b). The vetch hay treatment were profitable in it's own right with an average net margin over the three years of $416/ha/yr and a profit:cost ratio of $0.90:$1.00. It also reduced the fertiliser N input for the following and subsequent crops by up to $39/ha/year.

Table 9a: Average net margins (EBIT) and profit:cost ratio averaged across openers at Temora, 2014-2016

Cropping Strategy	Crop Type	Average Total Cost 2014-16 ($/ha/yr)	Average Net Margin 2014-16 ($/ha/yr)	Average 3yr Profit:Cost ratio
Aggressive	Canola RR	$524	$722	1.4
Aggressive	Wheat (yr 1)	$525	$378	0.7
Aggressive	Wheat (yr 2)	$504	$394	0.8
Conservative	Canola TT	$452	$694	1.5
Conservative	Wheat (yr 1)	$415	$289	0.7
Conservative	Wheat (yr 2)	$419	$261	0.6
Sustainable	Vetch (Hay)	$463	$416	0.9
Sustainable	Canola TT	$426	$769	1.8
Sustainable	Wheat	$492	$422	0.9
Sustainable	Barley	$478	$441	1.0

Table 9b: Average nitrogen & total costs, net margins and profit:cost ratio for each management strategy combined for opener type

	Average N costs ($/ha/yr)	Average Total Cost 2014-16 ($/ha/yr)	Average Net Margin 2014-16 ($/ha/yr)	Average 3yr Profit: Cost ratio
Aggressive	$109	$517	$498	$0.96
Conservative	$103	$429	$415	$0.95
Sustainable	$70	$465	$512	$1.12

The barley phase in the sustainable strategy produced the highest yielding cereal crop in all years and were 12% more profitable than the second wheat crop in either the aggressive or conservative strategies (Table 9a), despite record low barley prices in the 2016/17 season. The second wheat grain yield in both the aggressive and conservative strategies were lower (reduction of between 0.3 and 0.7 t/ha) than wheat grain yield following canola (Table 11). Similar results were found in grazing x stubble management experiment (Table 17). There were no significant differences in the net margin of strategies when sown with either the disc or tine openers, except in the conservative strategy when sown with a disc opener. The profit:cost ratio was reduced from $1.14 for every $1 spent to $0.75 (Table 10).

Table 10: Average net margins across all crop types for each crop system by opener type between 2014 and 2016 at Temora, NSW.

Management Strategy	Net Margins 2014 ($/ha)		Net Margins 2015 ($/ha)		Net Margins 2016 ($/ha)		Average Net Margins 2014-16 ($/ha/yr)		Profit:Cost ratio 2014-2016	
	Tine	Disc	Tine	Disc	Tine	Disc	Tine	Disc	Tine	Disc
Aggressive	$424	$422	$569	$591	$533	$449	$508	$487	$0.98	$0.94
Conservative	$441	$171	$540	$463	$537	$336	$506	$323	$1.14	$0.75
Sustainable	$488	$493	$520	$525	$552	$495	$520	$504	$1.14	$1.10

Table 11: Effect of management strategy on crop grain yields sown with disc and tine openers at Temora, NSW, 2014-2016

Management Strategy	Seq	Crop 2014	Crop 2015	Crop 2016	Grain/DM Yield 2014 (t/ha)		Grain/DM Yield 2015 (t/ha)		Grain/DM Yield 2016 (t/ha)	
					Disc	Tine	Disc	Tine	Disc	Tine
Aggressive	4	Wh 1 (H)	Wh 2 (H)	Can RR	3.1	3.0	3.9	3.5	2.9	3.0
Aggressive	6	Wh 2 (H)	Can RR	Wh 1 (H)	3.2	2.9	3.1	3.1	5.5	6.0
Aggressive	10	Can RR	Wh 1 (H)	Wh 2 (H)	2.2	2.2	3.5	3.4	4.9	5.3
Sustainable	1	Barley	Leg Hay	Can TT	4.2	4.5	2.9	3.4	2.9	3.0
Sustainable	3	Wh (L)	Barley	Leg Hay	3.3	3.1	5.0	5.0	3.9	4.0
Sustainable	7	Leg Hay	Can TT	Wh (L)	4.2	4.2	2.6	2.4	5.2	5.8
Sustainable	9	Can TT	Wh (L)	Barley	1.8	1.7	3.5	3.3	6.0	6.1
Conservative	2	Wh 1 (L)	Wh 2 (L)	Can TT	1.9	2.5	2.8	3.0	2.8	3.0
Conservative	5	Wh 2 (L)	Can TT	Wh 1 (L)	1.5	2.9	2.1	2.4	2.4	4.7
Conservative	8	Can TT	Wh 1 (L)	Wh 2 (L)	1.6	2.1	3.6	3.5	3.3	4.4

Effect of management strategy on weeds

The average annual ryegrass seedbank across the trial area in February 2014 were 1864 plants/m^2. Both the aggressive and sustainable management strategies significantly reduced the ARG seedbank to 351 plants/m^2 by February 2016, significantly lower than in the conservative strategy (Table 12).

However, following the wet 2016 season with a soft late finish, the sustainable strategy had reduced the ARG seed bank measured in February 2017 by 70% compared to the aggressive strategy, with the conservative strategy increasing ARG seedbank by 600% to above 4000 seeds/m^2 (Table 12). There were significant main effects of opener type (disc vs tine) on ARG seedbank populations in 2016 and 2017 with lower ARG seedbank populations in 2016 (650 seeds/m^2 in tine cf 1080 seeds/m^2 in disc) and 2017 (384 seeds/m^2 in tine cf 944 seeds/m^2 in disc) (data not shown). When comparing strategy by opener types, there were no significant difference between the aggressive and sustainable strategy x opener type in 2016 but by February 2017, the sustainable strategy sown with a tine seeder had reduced the average ARG seedbank population by 95% to 82 seeds/m^2. The aggressive strategy (disc and tine) and sustainable (disc) reduced the ARG seedbank by 75% to an average of 472 seeds/m^2 (Table 13). The average ARG seedbank in the conservative strategy increased to 2322 and 7631 seeds/m^2 when sown with a tine and disc opener, respectively (Table 13). There was a general increase in ARG seedbank in all wheat crops sown in 2016 in the conservative strategy by a factor of 2 to 10 with a 230% increase in sequence 5 sown with a disc opener compared to a tine opener (17671 *cf* 5261 seeds/m^2, Table 14).

By February 2017, the competitive 2016 barley crop reduced the ARG to 43 seeds/m^2 (Table 15) or to 28 and 64 seeds/m^2, respectively sown with a tine or disc opener (Table 14). The double break of the legume hay 2015/canola TT 2016 in the sustainable strategy sown with a tine opener was also very effective at reducing ARG seedbank (Table 14). The canola single break tended to be more effective at reducing ARG seedbank populations when sown with a tine seeder however, the double break in the sustainable strategy was more effective.

Table 12: Main effect of management strategy on ARG seedbank averaged across disc and tine openers at Temora, NSW, 2014-2017.

	Seedbank Feb 2015	Seedbank Feb 2016	Seedbank Feb 2017
Management Strategy	seeds m/^{2}	seeds m/^{2}	seeds m/^{2}
Sustainable	865b	449b	145c
Aggressive	556b	253b	573b
Conservative	2276a	2830a	4188a
P value	0.003	<0.001	<0.001
Transformation required	#	*	#

* No lsd - data analysed by square root and back transformed. Letters indicate significant difference.

No lsd - data analysed by log e and back transformed. Letters indicate significant difference.

Table 13: Main effect of management strategy x opener type (disc & tine) on ARG seedbank at Temora, NSW, 2014-2017.

Management Strategy		Seedbank Feb 2015	Seedbank Feb 2016	Seedbank Feb 2017
	Opener	seeds/m^2	seeds/m^2	seeds/m^2
Sustainable	Tine	734cd	346c	82
Aggressive	Tine	866c	300c	498
Conservative	Tine	1291b	1840b	2322
Sustainable	Disc	1020c	562c	260
Aggressive	Disc	356d	207c	659
Conservative	Disc	4008a	4045a	7631
P value		<0.001	0.023	0.345
Transfor-mation		#	*	#

The expensive herbicides such as Sakura®, Boxer Gold® and Rustler® provided good early weed control in both the aggressive and conservative strategies as indicated by the low ARG plant numbers in June of each year whereas, there were significantly higher early ARG plant numbers in the conservative strategy (Table 15). There were significant effects of strategy x sequence x opener type with higher ARG plant numbers in the conservative strategy sown with a disc opener compared to a tine opener (Canola TT: 2014 = 99 vs 16, 2015 = 117 vs 10 and 2016 = 452 vs 140 in disc vs tine; data not shown). There were similarly higher plant numbers in the wheat sown with a disc than with a tine seeder. The higher early ARG populations resulted in a greater increase in ARG panicles, especially in the 2nd wheat crop in 2016 (466 panicles/m^2 in tine vs 1066 panicles/m^2 in disc – data not shown). In contrast, in the sustainable strategy, all sequences by November 2016 had low numbers of ARG panicles and although not significantly lower than the aggressive strategy, had significantly less ARG seedlings in the seedbank in 2017 (Table 15).

Tables 14: The effect of Management strategy x sequence on ARG seed bank of each year between 2015-17 for disc and tine openers at Temora, NSW, 2014-2017.

Seq no.	Mgmt strategy	Strategy sown with a tine seeder				Seedbank Feb 2015 seeds m/²	Seedbank Feb 2016 seeds m/²	Seedbank Feb 2017 seeds m/²
		Crop 2014	Crop 2015	Crop 2016	Crop 2017			
9	Sustainable	Canola TT	Wheat (L)	Barley	Legume Hay	551	190ef	28
7	Sustainable	Legume Hay	Canola TT	Wheat (L)	Barley	368	146ef	198
3	Sustainable	Wheat (L)	Barley	Legume Hay	Canola TT	757	502def	125
1	Sustainable	Barley	Legume Hay	Canola TT	Wheat (L)	1887	676def	65
10	Aggressive	Canola RR	Wheat 1 (H)	Wheat 2 (H)	Canola RR	734	114f	590
6	Aggressive	Wheat 2 (H)	Canola RR	Wheat 1 (H)	Wheat 2 (H)	1026	250ef	441
4	Aggressive	Wheat 1 (H)	Wheat 2 (H)	Canola RR	Wheat 1 (H)	864	645def	478
8	Conservative	Canola TT	Wheat 1 (L)	Wheat 2 (L)	Canola TT	410	269ef	2122
5	Conservative	Wheat 2 (L)	Canola TT	Wheat 1 (L)	Wheat 2 (L)	2071	1096cde	5271
2	Conservative	Wheat 1 (L)	Wheat 2 (L)	Canola TT	Wheat 1 (L)	2533	6288a	1108
				Strategy sown with a disc seeder				
9	Sustainable	Canola TT	Wheat (L)	Barley	Legume Hay	800	164ef	64
7	Sustainable	Legume Hay	Canola TT	Wheat (L)	Barley	368	692def	119
3	Sustainable	Wheat (L)	Barley	Legume Hay	Canola TT	552	156ef	488
1	Sustainable	Barley	Legume Hay	Canola TT	Wheat (L)	6694	1892bcd	1212
10	Aggressive	Canola RR	Wheat 1 (H)	Wheat 2 (H)	Canola RR	248	108f	742
6	Aggressive	Wheat 2 (H)	Canola RR	Wheat 1 (H)	Wheat 2 (H)	329	77f	513
4	Aggressive	Wheat 1 (H)	Wheat 2 (H)	Canola RR	Wheat 1 (H)	553	571def	750
8	Conservative	Canola TT	Wheat 1 (L)	Wheat 2 (L)	Canola TT	2453	2746bc	8022
5	Conservative	Wheat 2 (L)	Canola TT	Wheat 1 (L)	Wheat 2 (L)	6905	5868a	17677
2	Conservative	Wheat 1 (L)	Wheat 2 (L)	Canola TT	Wheat 1 (L)	3801	3807ab	3103
P value						0.375	0.007	0.35
Transformation required to normalise residuals						#	#	#

Table 15: Effect of management strategy x sequence on ARG plant numbers in June, ARG panicle numbers in November and ARG seedbank between 2014-17 averaged across disc and tine openers at Temora.

						ARG (plants m/²)			ARG (panicles m/²)			ARG Seedbank (seeds m/²)		
Seq no.	Mgmt strategy	Crop 2014	Crop 2015	Crop 2016	Crop 2017	2014	2015	2016	2014	2015	2016	2015	2016	2017
9	Sustainable	Canola TT	Wheat (L)	Barley	Leg. Hay	30cd	1d	5de	5bcd	14cdef	7c	663c	176d	43f
7	Sustainable	Legume Hay	Canola TT	Wheat (L)	Barley	148a	3cd	2e	13b	9f	8c	368c	151d	153e
3	Sustainable	Wheat (L)	Barley	Leg. Hay	Canola TT	4d	6bc	115ab	3cd	31cde	7c	647c	595cd	247de
1	Sustainable	Barley	Leg. Hay	Canola TT	Wheat (L)	51bc	20ab	24c	156a	0f	7c	3555ab	1204bc	279de
10	Aggressive	Canola RR	Wheat 1 (H)	Wheat 2 (H)	Canola RR	27cd	2cd	4e	2d	11ef	26bc	427c	112d	665cd
6	Aggressive	Wheat 2 (H)	Canola RR	Wheat 1 (H)	Wheat 2 (H)	8d	4c	2e	13bc	2f	23bc	692c	151d	473d
4	Aggressive	Wheat 1 (H)	Wheat 2 (H)	Canola RR	Wheat 1 (H)	6d	3cd	11cd	6bcd	50bcd	20bc	581c	610cd	602cd
8	Conservative	Canola TT	Wheat 1 (L)	Wheat 2 (L)	Canola TT	49bc	6bc	60b	12bc	90b	376a	1003abc	1183bc	41051b
5	Conservative	Wheat 2 (L)	Canola TT	Wheat 1 (L)	Wheat 2 (L)	92b	35a	207a	224a	84bc	705a	3782a	3014b	9604a
2	Conservative	Wheat 1 (L)	Wheat 2 (L)	Canola TT	Wheat 1 (L)	51bc	37a	202a	151a	376a	49b	3103ab	4970a	1863bc
P value						<0.001	0.004	<0.001	<0.001	<0.001	0.028	0.035	0.002	0.018
Transformation required to normalise residuals						*	#	#	#	*	#	#	*	#

** No lsd - data analysed by square root and back transformed. Letters indicate significant difference.*
 # No lsd - data analysed by log e and back transformed. Letters indicate significant difference.

Part 3: RESULTS from Grazing x Stubble Management Experiment 2009-2016

Grazing is an effective, inexpensive method of reducing stubble while burning removes stubble, assists in reducing disease carryover, reduces certain seedling pests and weed populations. Over the eight years of the experiments, neither burning nor grazing affected yield in the 1st wheat crop after canola (Table 16). However, both heavy grazing and burning increased yield in the second wheat crop after canola and the effects were partly additive (Table 16). Across all years, grazing and burning alone increased yield of the 2nd wheat crop on average by 0.7 t/ha and 0.8 t/ha respectively, but when applied together increased yield by 1.0 t/ha. In three of the four phase years in which the 2nd wheat crop was grown, burning increased yield by between 0.5 and 0.6 t/ha, but in one year (2013) by 1.4 t/ha.

Grazing stubble increased soil mineral N by 13 kg/ha in the first wheat crop (Table 17) and by 33 kg/ha in the 2nd wheat crop, and there was no interaction between grazing and stubble treatments. Burning stubble had no significant effect on soil mineral N in the 1st wheat crop, but increased soil mineral N by an average of 13 kg/ha in the 2nd wheat crop (Table 17).

Averaged across both phases for the seven years of this experiment, grazing and then retaining the stubble generated the highest gross income (Table 18). If the grazing was valued assuming one dry sheep equivalent (DSE) consumed 7.6 MJ of energy per day at an agistment rate of $0.4/DSE/week, the grazing value of the stubble was $117/ha/year with an additional increase of $55/ha/year due to higher yields and higher N availability (Total increase = $172/ha yr).

Table 16: Mean grain yield (t/ha) for either 1st or 2nd wheat crop following canola under different grazing and stubble treatments between 2009 and 2016. P-value and LSD are from the three-way interaction between grazing treatment, stubble treatment and rotational position and means followed by the same letters are not significantly different from each other.

		Rotational position	
Graze treatment	Stubble treatment	1st wheat	2nd wheat
Nil Graze	Retain	4.58b	3.93c
Stubble graze	Retain	4.63b	4.58b
Nil Graze	Burn	4.63b	4.68b
Stubble graze	Burn	4.73ab	4.89a
	P-value	0.007	
	LSD (P=0.05)	0.18	

Table 17: Mean soil mineral N (kg/ha N) to 1.6 m depth prior to sowing following either 1st or 2nd wheat crops following canola for different grazing and stubble treatments between 2009-2016. P-values and LSDs are for two way interactions between either grazing treatment of stubble treatment and rotational position.

	Grazing treatment		Stubble treatment	
Rotational position	Nil graze	Stubble graze	Burn	Retain
1st wheat	107	120	110	117
2nd wheat	92	125	115	102
P-value	0.031		0.035	
LSD (P=0.05)	13		13	

Table 18: Gross income per year averaged across both phases for all years (2010-2016) of the experiment at Temora.

Graze treatment	Stubble treatment	Assuming grazed stubble has no value	Assuming grazed stubble has a value
Nil graze	Retain	$1,231	$1231
	Burn	$1,269	$1269
Stubble graze	Retain	$1,286	$1403
	Burn	$1,277	$1397

Discussion

There is no perfect stubble management strategy for every year with crop rotations, weeds, disease, pests, stubble loads, grazing and machinery largely dictating how to manage the stubble successfully. How a farmer answers the questions outlined on page 2 for each paddock and each farm and is able to adapt his/her farming system will influence their ability to handle stubble profitability.

A flexible approach to managing stubble means crops can be harvested high or low depending on the season and situation, stubbles can then be grazed with considerable economic advantage, straw baled and sold, mulched, incorporated or burnt. The flexible strategy provides a range of options for all farming systems and seeder types to improve profitability while trying to maximize the stubble retained.

We found that using a stripper front or harvesting high is the quickest and most efficient method to harvest grain that produces the least amount of residue at the lowest costs. However, if farmers plan to harvest high but intend to sow with a tine seeder, they may need to determine how they can reduce their stubble load to ensure there are no major problems with the timeliness of sowing the following crop. Large stubble loads potentially create issues for all sowing systems with regards to the type and effectiveness of herbicides that can be applied, the ability of the pesticides to reach the soil surface/ weed or insect, and the effect that the thick stubble load could have on the emerging seedling. Narrow windrow burning has proved very effective in reducing ARG seedlings, but in cereal paddocks with high stubble loads, it may be necessary to incorporate mechanical methods of control such as harvesting low with a HWSD to assist in reducing herbicide resistant ARG seed set, although this will be more expensive and be slower.

One of the negatives we found when sowing wheat into tall wheat stubble (45 cm cf 15 cm) was that seedlings received less radiation and were exposed to cooler temperatures, which often resulted in a reduced early growth and a reduction in tiller number. In our experiments, this didn't persist to a reduction in grain yield, however, the Riverine Plains group found a significant reduction in 2014 in grain yield (4.98 t/ha cf 5.66 t/ha with lsd @ $P<0.05$ = 0.45 t/ha) in tall compared to short stubble.

In the strategy management experiment, we compared two canola-wheat-wheat sequences against a diversified sequence (canola-wheat-barley-vetch for hay). One was aggressively managed for weed control and to maximize yield which included more crop competition, more expensive herbicides, the inclusion of a hybrid RR canola and higher rates of N at sowing (deep banded in tine opener only) against a conservatively managed sequence with cheaper herbicides, lower crop densities, lower rates of N at sowing and cheaper crop types. The third comparison, a diverse or sustainable cropping strategy allowed each crop to be sown into a less antagonistic stubble i.e. wheat into canola, barley into wheat, vetch into barley and cut for hay followed by, canola sown into low stubble load.

The income from the vetch hay combined with highly effective weed control and the additional N plus water conservation, especially preceding the higher value and risky crops such as canola, were able to make the sustainable strategy a reliable profitable management option for farmers wanting to retain stubble. The double break from the legume hay/canola treatment combined with the crop competition from the barley crop was extremely effective at reducing ARG seedbank to below that of the aggressive canola-wheat-wheat sequence under extremely wet and dry seasonal conditions when sown with a disc or tine opener. The benefit of the double break was most noticeable following the wet season of 2016. With no knockdown applied before the early sowing in 2016, the expensive pre-emergent herbicides sprayed in the aggressive and sustainable strategies such as Sakura®, Boxer Gold® and Rustler® proved extremely effective at controlling the early ARG populations even with high stubble loads (Table 15). However, all pre-emergent herbicides had become ineffective by August 2016 as late ARG plants emerged in the first 3 weeks of August. As crop topping was not possible in this experiment, late control of ARG was left to increased crop competition from barley and/or in combination with the benefits of the legume hay or canola crop in the sustainable tine strategy that resulted in significantly lower ($P=0.082$) ARG panicles compared to the 1st or 2nd wheat crop in the aggressive strategy (data not shown). In comparison, the conservative management strategy although reasonably profitable especially when sown with a tine opener, was largely ineffective at reducing the ARG seedbank, which significantly increased following the wet 2016 season. The ability to apply trifluralin as a pre-emergent herbicide with a tine opener reduced the ARG seedbank compared to the conservative strategy sown with a disc opener, however, the conservative strategy would not be recommended with either opener type where there is any ARG weed problem.

Deep banding of N was incorporated into the management strategy (tine only) of this experiment. The amount of applied N at sowing captured by wheat crops has been found to increase when deep banded below the seed in the presence or absence of stubble (Kirkegaard et al. 2017). Although the rates of N deep banded were 122 kgN/ha, similar results from 2017 have been observed with rates at 100 kgN/ha. Similar benefits are expected to have occurred in the cereal and canola crops sown with the tine opener in the management experiment as N was deep banded at sowing. The application of early N applied to the soil surface pre sowing with a disc opener may have resulted in slower early growth. There is the potential for mid-row banding technology to be used with disc openers to apply N deep below the seed at sowing.

With careful planning and diverse management, burning can be kept for those occasions where the system needs to be reset which can result in farmers retaining stubble for another series of years. A late burn, conducted wisely just prior to sowing to minimise the time the soil is exposed is one option farmers may need to consider when dealing with large stubble loads. Grazing and burning canola stubbles had no effect on the yield of the 1st wheat crop following canola, but grazing or burning the stubble of the first wheat crop increased yield substantially in the 2nd wheat crop. Whilst this difference could logically be attributed to various biotic mechanisms such as disease, no treatment differences were recorded within the very low level of stubble-borne diseases (yellow leaf spot, crown rot, Zymoseptoria tritici) that were present at the site in some years. It thus appears more likely that N dynamics are principally responsible for the observed differences in yield.

Grazing and burning stubbles increased soil mineral N accumulation during the summer fallow to a much greater extent in the 2nd wheat crop compared to the 1st wheat crop presumably due to both higher amounts and higher C:N ratio of wheat stubble compared to canola stubble which would lead to more N immobilisation (Hunt et al. 2016). The average increase in mineral N due to grazing in the 2nd wheat treatment was 33 kg/ha N. Hunt et al. (2016) suggested that grazing either removed C from the system or neutralised C with potential immobilising power of 52 kg/ha N. Under the no till surface-retained residue management practiced at this site, immobilisation would presumably occur over several years as residues slowly decompose. The greater effect of grazing stubble on mineral N compared to burning stubble in this experiment is likely due to differences in the timing of the two treatments with respect to soil measurement. The grazing treatment was applied immediately after harvest, giving 4 to 5 to months between removal of stubble by grazing and measurement of soil N. In contrast, the burn treatment was applied only ~1 month before measurement of soil mineral N, giving less time for differences in N immobilisation to act before the pre-sowing soil N tests. Both treatments influenced grain yield as they both would have presumably altered in-season net N mineralisation. The results suggest that where disease is absent or controlled and good crop establishment achieved, N immobilisation by wheat residue can significantly reduce crop yield in subsequent wheat crops.

Beyond the effects of N dynamics on grain yield, burning stubble also reduced frost-induced sterility of the 2nd wheat crop from 59 to 30% following severe frosts of -2.6°C, -1.8°C and -3.6°C (screen temperatures) that occurred on the 15, 16 and 18 October in 2013. In that year, grazing increased the yield of the 2nd wheat crop by 1.0 t/ha, burning by 1.4 t/ha and combined by 1.6 t/ha. However, no differences in frost-induced sterility were measured in any other year of the experiment.

It must be recognised that some of the negatives to burning include loss of nutrients (amount depends on temperature), increased regulation and potential losses of soil from erosion. Increasing restrictive regulations are being implemented that also make burning more difficult in the future. In some shires, a single burn requires 6 people, 2 fire control units (1 with 5000L and the other with 500L) and you are not able to leave the paddock until NO smoke is detected.

Conclusion

It is extremely important for farmers NOT to compromise managing weeds, disease or being able to sow their crop in a timely manner due to excessive stubble loads. Farmers need to be pro-active in managing their stubble which should have commenced before harvest and continued until sowing to ensure their stubble management will suit their seeding system. It has been shown that by diversifying a crop rotation (increasing the number of pulse crops and barley), deep banding nitrogen, managing pests and diseases, managing stubble by baling or grazing that it is easier to manage stubble without the need to burn. A diversified sustainable management strategy incorporating a double break crop offers a profitable farming system with reduced nitrogen costs that is effective at controlling weeds. Farmers can also retain their stubble in most years even when establishing crops with a tine opener. However, if the stubble load remains too large or the potential weed/disease/pest burden remains too high, then a one off strategic late burn can be used to "re-set" the system.

We recommend that growers wishing to retain all stubble should avoid growing wheat after wheat, that residue loads are reduced by grazing and/or burning where wheat is to be grown following wheat, or supplementary N is applied to offset that immobilised by the residue. Grazing wheat stubbles can increase the yield of subsequent wheat crops due to less immobilisation and greater availability of mineral N to subsequent wheat crops. Burning wheat stubble residues also increased yield of subsequent wheat crops, but did not increase pre-sowing soil mineral N to the same extent as grazing, possibly due to later timing. However, both treatments presumably influenced in-crop N availability and thereby crop yield. Burning wheat stubble can also reduce frost damage in subsequent wheat crops and increase yield accordingly in frosty seasons.

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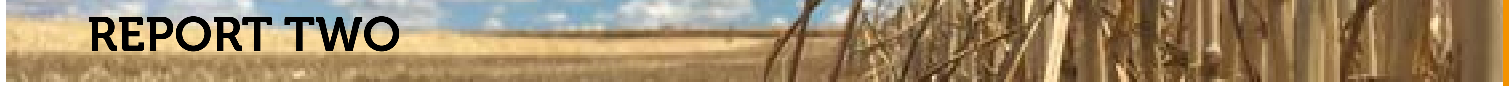

REPORT TWO

The effects of stubble on nitrogen tie-up and supply

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Project codes - GRDC CSP186, CSP174

Take home messages

Cereal stubble should be thought of as a source of C for microbes, not as a source of N for crops. In no-till systems, only ~6% of the N requirement of crops derived from the stubble.

N tie-up by cereal residue is not just a problem following incorporation – it occurs in surface-retained and standing-stubble systems and can reduce wheat yields by 0.3 to 0.4 t/ha.

Management is reasonably straightforward – supply more N (5 kg N for each t/ha of cereal residue) and supply it early to avoid impacts of N tie-up on crop yield and protein.

Deep-banding N can improve the N uptake, yield and protein of crops, especially those in stubble-retained systems.

Background

Most dryland farmers in Australia retain all, or most of their crop residues (wherever possible) to protect the soil, retain soil moisture and maintain soil fertility in the long term. However, a pro-active and flexible approach to stubble management that recognises and avoids situations in which stubble can reduce productivity or profitability makes sense, and has been promoted as part of the GRDC Stubble Initiative (Swan *et al.*, 2017a). One such situation is where large amounts of retained stubble, especially high C:N ratio cereal stubble, "ties-up" soil nitrogen leading to N deficiency in the growing crop that may reduce yield. The timing, extent and consequences of N tie-up are all driven by variable weather events (rainfall and temperature) as well as soil and stubble type, so quite different outcomes may occur from season to season and in different paddocks. In this paper we firstly review in simple terms the process of N tie-up or immobilisation as it is known, to understand the factors driving it. We then provide the results from a series of recent experiments in southern NSW (both long-term and short-term) that serve to illustrate the process, and the ways in which the negative consequences can be avoided while maintaining the benefits of stubble.

The process of "N-tie up" (immobilisation) – put simply

Farmers are always growing two crops – the above-ground crop (wheat, canola, lupins etc) is obvious, but the below-ground crop (the microbes) are always growing as well; and like the above-ground crop they need water, warm temperatures and nutrients to grow (there's as much total nutrient in the microbes/ha as in the mature crop, and 2/3 are in the top 10cm of soil!). There are two main differences between these two "crops" – firstly the microbes can't get energy (carbon) from the sun like the above-ground plants, so they rely on crop residues as the source of energy (carbon). Secondly they don't live as long as crops – they can grow, die and decompose again ("turnover") much more quickly than the plants – maybe 2-3 cycles in one growing season of the plant. The microbes are thus immobilising and then mineralising N as the energy sources available to them come and go. In a growing season it is typical for the live microbial biomass to double by consuming carbon in residues and root exudates – but they need mineral nutrients as well. Over the longer-term the dead microbe bodies (containing C, N, P, S) become the stable organic matter (humus) that slowly releases fertility to the soil. In the long-term, crop stubble provides a primary C-source to maintain that long-term fertility, but in the short-term the low N content in the cereal stubble means microbes initially need to use the existing soil mineral N (including fertiliser N) to grow, and compete with the plant for the soil N.

A worst-case scenario

That simplified background helps to understand the process of immobilisation, when and why it happens, and how it might be avoided or minimised. Imagine a paddock on 5th April with 8t/ha of undecomposed standing wheat stubble from the previous crop after a dry summer. A 30mm storm wets the surface soil providing a sowing opportunity. Fearing the seeding equipment cannot handle the residue, but not wanting to lose the nutrients in the stubble by burning, the residue is mulched and incorporated into the soil. A canola crop is sown in mid-April with a small amount of N (to avoid seed burn) and further N application is delayed until bud visible due to the dry subsoil.

So in this case, the cereal stubble (high carbon and low nitrogen – usually ~90:1) is well mixed through a warm, moist soil giving the microbes maximum access to a big load of carbon (energy)

– but not enough nitrogen (microbe bodies need a ratio of about 7:1). The microbes will need all of the available N in the stubble and the mineral N in the soil, and may even break-down some existing organic N (humus) to get more N if they need it (so carbon is lost from the soil!). The microbes will grow rapidly, so when the crop is sown there will be little available mineral N - it's all "tied-up" by the microbes as they grow their population on the new energy supply. Some of the microbes are always dying as well but for a time more are growing than dying, so there is "net immobilisation". As the soil cools down after sowing, the "turnover" slows, and so is the time taken for more nitrogen to be released (mineralised) than consumed (immobilised) and net-mineralisation is delayed. Meanwhile - the relatively N-hungry canola crop is likely to become deficient in N as the rate of mineralisation in the winter is low. This temporary N-deficiency if not corrected or avoided, may or may not impact on yield depending on subsequent conditions.

Based on the simple principles above, it's relatively easy to think of ways to reduce the impact of immobilisation in this scenario:

1. The stubble load could be reduced by baling, grazing or burning (less C to tie up the N)
2. If the stubble was from a legume or canola rather than cereal (crop sequence planning) it would have lower C:N ratio and tie up less N.
3. The stubble could be incorporated earlier (more time to move from immobilisation to mineralisation before the crop is sown)
4. N could be added during incorporation (to satisfy the microbes and speed up the "turnover")
5. More N could be added with the canola crop at sowing (to provide a new source of N to the crop and microbes), and this could be deep-banded (to keep the N away from the higher microbe population in the surface soil to give the crop an advantage)
6. A different seeder could be used that can handle the higher residue without incorporation (less N-poor residue in the soil)
7. A legume could be sown rather than canola (the legume can supply its own N, can emerge through retained residue and often thrives in cereal residue).

In modern farming systems, where stubble is retained on the surface and often standing in no-till, control-traffic systems, less is known about the potential for immobilisation. In GRDC-funded experiments as part of the Stubble Initiative (CSP187, CSP00174), we have been investigating the dynamics of N in stubble-retained systems. Here we provide examples from recent GRDC-funded experiments in southern NSW, and discuss the evidence for the impact of immobilisation and provide some practical tips to avoid the risks of N tie-up.

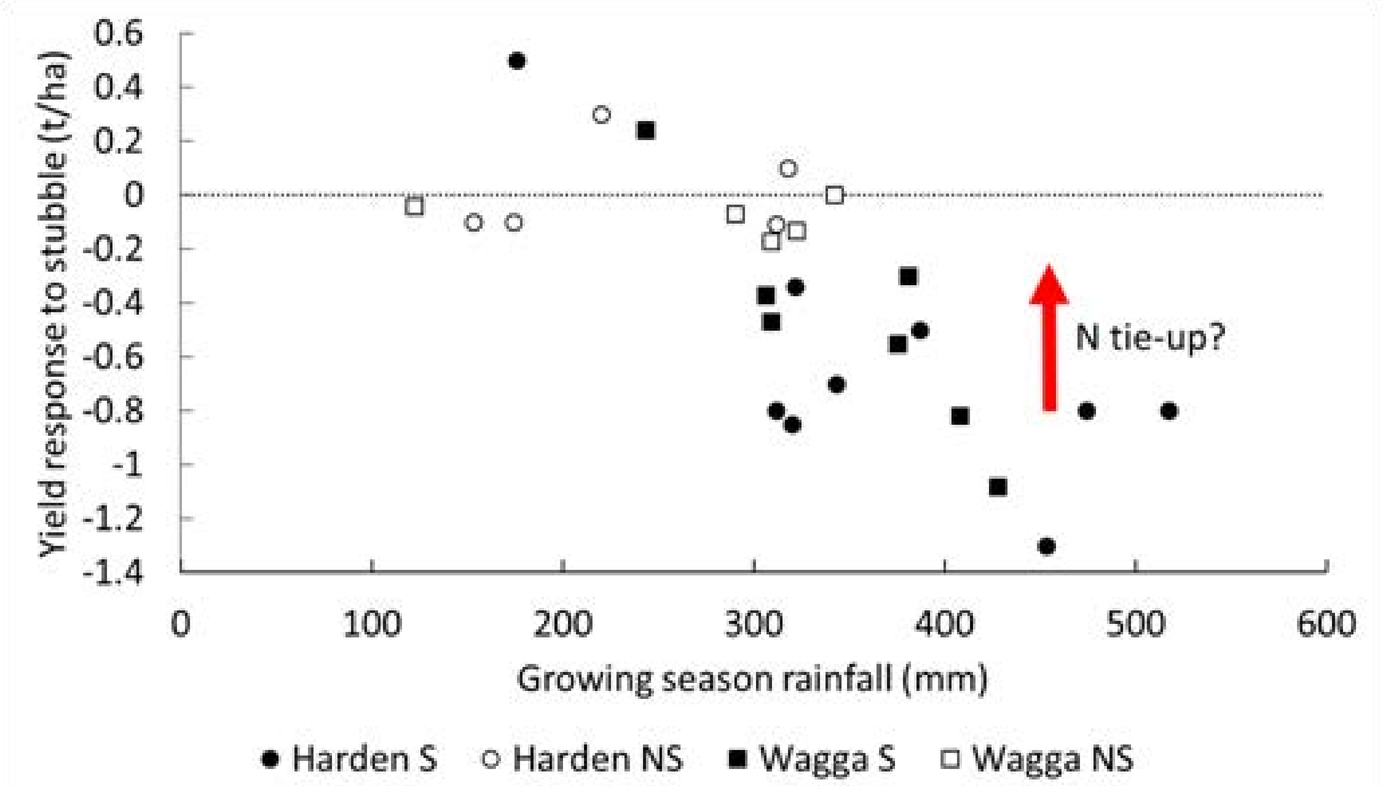

Figure 1: Effect of retained stubble on wheat yield is worse in wetter seasons at the Harden (circles) and Wagga (squares) long-term tillage sites. Open symbols where difference between retain and burnt were not significant (NS), solid where significant (S).

Can stubble really reduce yield significantly in no-till systems – and is N-tie up a factor?

Harden long-term site

In a long-term study at Harden (28 years) the average wheat yield has been reduced by 0.3 t/ha in stubble retained vs stubble burnt treatments, but the negative impacts of stubble were greater in wetter seasons (Figure 1). Nitrogen tie-up may be implicated in wetter years, due to higher crop demand for N and increased losses due to leaching or denitrification. But we rarely found significant differences in the starting soil mineral N pre-sowing. For many years, we were not convinced N tie-up was an issue (though we had insufficient measurements to confirm it).

In 2017, we implemented two different experiments in sub-plots at Harden to investigate the potential role of nitrogen tie-up in the growth and yield penalties associated with stubble. A crop of wheat (cv. Scepter) was sown on 5 May following a sequence of lupin-canola-wheat in the previous years. In both the stubble-retained and stubble-burnt treatments we compared 50 or 100 kg N/ha broadcast as urea at sowing in one experiment, and compared the 100 kg N/ha surface applied with 100 kg/N deep-banded below the seed. The pre-sowing N to 1.6 m was 166 kg N/ha in retained and 191 kg N/ha in burnt, but was not significantly different. Plant population, growth and N content at GS 30 did not differ between treatments (data not shown) but by anthesis, the biomass and tiller density were significantly increased by the additional 50 kg/ha of surface-applied N in the stubble-retained treatment, while there was no response in the stubble burnt treatment. At harvest, both stubble retention and increased N improved grain yield, but the increase due to N was higher under stubble retention (0.6 t/ha) than stubble burnt presumably due to improved water availability. The increase in yield with higher N, and the low protein overall (and with low N) suggests N may have been limiting at the site, but the water-saving benefits of the stubble may have outweighed the earlier effects of immobilisation.

Deep-banding the N fertiliser had no impact on crop biomass or N% at GS 30, but increased both the biomass and N content of the tissue at anthesis more in the retained-stubble than in burnt stubble (Table 2). Retaining stubble decreased biomass overall but not tissue N. N uptake (kg/ha) at anthesis was significantly increased by deep-banding in both stubble treatments, however the increase was substantially higher in the stubble-retain treatment than in the burn treatment (38 kg N/

Table 1: Effect of additional surface applied and deep-placed N on wheat response in stubble burnt and retained treatments at Harden in 2017.

Treatment		Anthesis		Harvest (@12.5%)	
Stubble	N	Biomass (t/ha)	Tillers (/m^2)	Yield (t/ha)	Protein (%)
Retain	50	7.1	324	4.3	8.8
	100	8.4	401	4.9	9.6
Burn	50	8.8	352	4.2	9.3
	100	8.7	372	4.5	10.5
LSD (P<0.05)	Stubble	0.9	ns	0.2	ns
	N	0.5	33	0.1	0.2
	Stubble x N	0.8	38	0.2	ns

Table 2: Effect of surface-applied and deep-banded N on wheat response in stubble-burnt and stubble-retained treatments at Harden in 2017.

Treatment		Anthesis			Harvest (@12.5%)	
Stubble	100 N	Biomass (t/ha)	Tissue N (%)	N Uptake (kg N/ha)	Yield (t/ha)	Protein (%)
Retain	Surface	8.1	1.1	91	4.5	9.3
	Deep	9.1	1.4	129	5.1	10.2
Burn	Surface	8.9	1.2	104	4.5	10.3
	Deep	9.5	1.3	119	5.0	10.8
LSD (P<0.05)	*Stubble*	0.6	ns	ns	ns	0.8
	N	0.2	0.1	8	0.2	0.4
	Stubble x N	0.6	0.2	12	ns	ns

*Table 3: Effect of stubble burning on grain yields at Temora in Phase 1 and 2. Crops in italics are canola, and bold are the 2nd wheat crops. * shows where significantly different (P<0.05)*

Phase	Treatment	2009	2010	2011	2012	2013	2014	2015	2016	2017
Phase 1	Retain	1.7	*4.2*	4.6	4.4	*0.7*	3.8	4.1	*3.2*	3.7
	Burn	1.7	*4.0*	4.6	5.0*	*1.0*	3.8	4.6*	*3.2*	3.2
Phase 2	Retain	-	6.3	*3.4*	4.5	2.0	*2.0*	5.5	5.2	*2.1*
	Burn	-	6.2	*3.5*	4.8	3.4*	*2.0*	5.3	5.7*	*2.4*

ha *cf* 15 kg N/ha). The overall impact of deep-banding on yield persisted at harvest, but there was no effect, nor interaction with stubble retention, presumably due to other interactions with water availability. However the fact that deep-banding N has had a bigger impact in the stubble retained treatment provides evidence of an N-related growth limitation related to retained stubble. It's appearance at anthesis, and not earlier, presumably reflects the high starting soil N levels which were adequate to support early growth but the cold dry winter generated N deficiencies as the crop entered the rapid stem elongation phase. The increased protein content related to both burning and deep-banding and its independence from yield, suggest on-going N deficiencies generated by those treatments.

Temora site

At Temora, a 9-year experiment managed using no-till, controlled traffic, inter-row sowing (spear-point/press-wheels on 305mm spacing) in a canola-wheat-wheat system investigated the effects of stubble burning and stubble grazing on soil water, nitrogen and crop growth. In the stubble retain treatment, stubble was left standing through summer, and fallow weeds were strictly controlled. In the stubble grazed treatment weaner ewes were allowed to crash graze the stubble immediately after harvest for a period of 7-10 days and weeds were controlled thereafter. Stubble was burnt in mid-late March and the crop sown each year in mid-late April. Nitrogen was managed using annual pre-sowing soil tests whereby 5 kg/ha N was applied at sowing and N was top-dressed at Z30 to attain 70% of maximum yield potential according to Yield Prophet® (see Swan *et al.*, 2017 for full details).

Burning

In un-grazed treatments, retaining stubble, rather than burning had no impact on the yield of canola or the first wheat crop over the 9 years, but consistently reduced the yield of the second wheat crop by an average on 0.5 t/ha (Table 3). This yield penalty was associated with an overall significant reduction in pre-sowing soil mineral-N of 13 kg/ha, while there was no significant difference in pre-sowing N for the first wheat crop (Table 4).

Table 4: Mean effect of stubble burning or grazing across years and phases on soil mineral N (kg N/ha) to 1.6m depth prior to sowing either 1st or 2nd wheat crops at Temora. LSD for interaction of treatment and rotational position where P<0.05.

Rotation position	**Stubble treatment**		**Grazing treatment**	
	Retain	**Burn**	**No graze**	**Graze**
1st wheat	117	110	107	120
2nd wheat	102	115	92	125
LSD (P<0.05)	13		13	

Grazing

Grazing stubbles never reduced the yield of any crop at the site, but increased the yield of the second wheat crop by 1.2 t/ha in 2013 (Phase 1) and by 1.0 t/ha in 2015 (Phase 2) Table 5. This was unrelated to pre-sowing soil N in 2013 (both had ~85 kg N/ha at sowing) where we suspect increased frost effects in the ungrazed stubble – while in 2015, the yield benefit was related to pre-sowing N with an extra 61 kg/ha N at sowing in the grazed plots. Overall, grazing increased the pre-sowing N by 13 kg/ha in the first wheat crop and by 33 kg/ha in the second wheat crop (Table 4).

*Table 5: Effect of grazing stubble on grain yields at Temora in Phase 1 and 2. Crops in italics are canola, and bold are the 2nd wheat crops. * shows where significantly different (P<0.05)*

Phase	**Treatment**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Phase 1	**No graze**	1.7	*4.2*	4.6	**4.4**	*0.7*	3.8	**4.1**	*3.2*	3.7
	Graze	1.7	*4.3*	4.5	**4.8**	*0.9*	3.7	**5.3***	*3.3*	3.3
Phase 2	**No graze**	-	6.3	*3.4*	4.5	**2.0**	*2.0*	5.5	**5.2**	*2.2*
	Graze	-	6.2	*3.3*	4.8	**3.0***	*2.2*	5.6	**5.6***	*2.3*

Deep N placement

In an adjacent experiment at Temora in the wet year of 2016, deep N placement improved the growth, N uptake and yield of an N-deficient wheat crop but this occurred in both the stubble retained and the stubble removed treatments and there was no interaction suggesting N availability was not reduced under stubble retention (Table 6). However we believe the level of N loss due to waterlogging in the wet winter and the significant overall N deficiency may have masked these effects which were more obvious at Harden in 2017.

*Table 6. Effect of deep banding vs surface applied N (122 kg N/ha as urea) at seeding, at Temora NSW in 2016 (starting soil N, 58 kg/ha). The crop captured more N early in the season which increased biomass and yield in a very wet season. (Data mean of 3 stubble treatments). *indicates significant differences (P<0.01). (Data source: Kirkegaard et. al., CSIRO Stubble Initiative 2016 CSP00186)*

Treatments	**Z30**			**Anthesis**			**Grain Yield (t/ha)**
	Biomass (t/ha)	**N%**	**N-uptake (kg/ha)**	**Biomass (t/ha)**	**N%**	**N-uptake (kg/ha)**	
Surface	1.4	3.8	51	7.8	1.3	103	4.0
Deep	1.4	4.4*	60	9.2*	1.5*	136*	5.2*

Post-sowing N tie-up by retained stubble

The evidence emerging from these studies suggests that even where cereal crop residues are retained on the soil surface (either standing or partially standing) and not incorporated, significant N immobilisation can be detected pre-sowing in some seasons. The extent to which differences emerge are related to seasonal conditions (wet, warm conditions) and to the time period between stubble treatment (burning or grazing) and soil sampling to allow differences to develop. However, even where soil N levels at sowing are similar between retained and burnt treatments (which may result from the fact that burning is done quite late) ongoing N immobilisation POST-SOWING by the microbes growing in-crop is likely to reduce the N available to crops in retained stubble as compared to those in burnt stubble. This was demonstrated in 2017 at Harden where the additional 50 kg N/ha applied at sowing completely removed the early growth reduction observed in the stubble-retained treatment, although due to the overall water limitation at the site, this did not translate into yield.

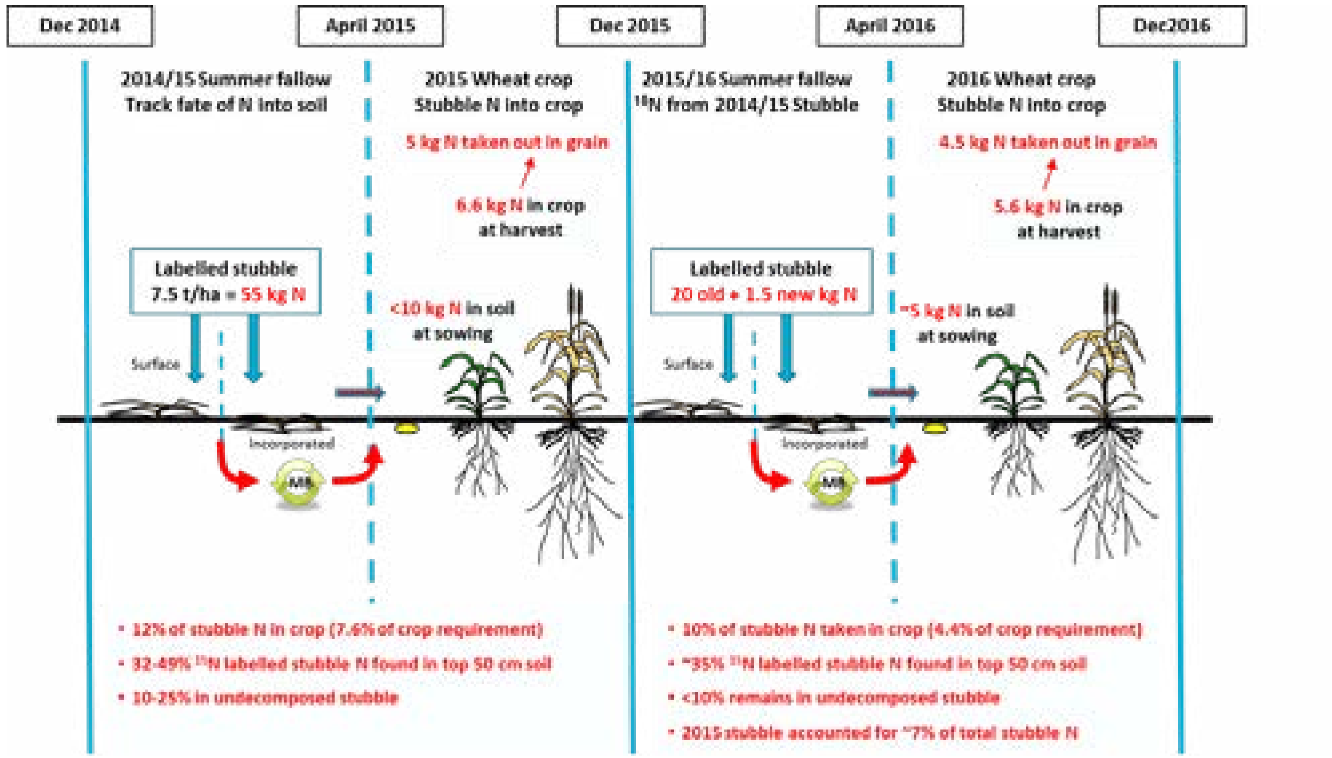

Figure 2. The fate of the N contained in retained wheat stubble over two years in successive wheat crops following the addition of 7.5 t/has of wheat stubble containing 55 kg/ha N. The successive crops took up 12% (6.6 kg N/ha) and 10% (5.6 kg N/ha) of the N derived from the original stubble representing only 7.6% and 4.4% of the crops requirements. Most of the stubble N remained in the soil (35%) or was lost (33%).

Cereal stubble isn't a good source of N for crops

Studies at 3 sites in southern Australia (Temora, Horsham and Karoonda) have tracked the fate of the N in stubble to determine how valuable it is for succeeding wheat crops under Australian systems. Stubble labelled with ^{15}N (a stable isotope that can be tracked in the soil) was used to track where the stubble N went. At Temora (Figure 2), of the 55 kg/ha of N contained in 7.5 t/ha of retained wheat residue retained in 2014, only 6.6 kg/ha N (12 %) was taken up by the first crop (representing 12 % of crop requirement); and 5.6 kg/ha N (10%) was taken up by the second wheat crop (4.4% of crop requirement). The majority of the N after two years remained in the soil organic matter pool (19.1 kg N/ha or 35%) and some remained as undecomposed stubble (10% or 5.5 kg N/ha). Thus we can account for around 67% of the original stubble N in crop (22%), soil (35%) and stubble (10%) with 33% unaccounted (lost below 50 cm, denitrified). In similar work carried out in the UK which persisted for 4 years, crop uptake was 6.6%, 3.5%, 2.2% and 2.2% over the 4 years (total of 14.5%), 55% remained in the soil to 70 cm, and 29% was lost from the system (Hart *et al.*, 1993). The main point is that the N in cereal stubble represented only 6% of crop requirements over two years (7.6% Year 1; 4.4% Year 2) and takes some time to be released through the organic pool into available forms during which losses can occur.

Conclusion

Our studies have confirmed a risk of N-tie up by surface-retained and standing cereal residues which may occur in-season, rather than during the summer fallow, and so may not be picked up in pre-sowing soil mineral N measurements. Yield penalties for retained residues were significant, but confined to successive cereal crops, and could be reduced by reducing the stubble load or by applying more N (~5kg N per t/ha of cereal residue) and applying it earlier to the following crop. Deep placement of the N improved N capture by crops irrespective of stubble management, but was especially effective in stubble-retained situations. In summary, N tie-up is an easily managed issue for growers with suitable attention to the management of stubble and N fertiliser.

Useful resources

http://www.farmlink.com.au/project/maintaining-profitable-farming-systems-with-retained-stubble

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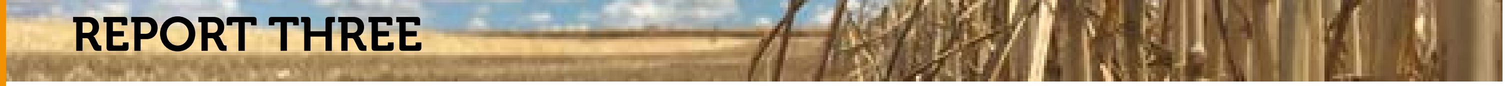

The effect of grazing and burning stubbles on grain yield and quality and gross margins in no-till and zero-till controlled traffic farming systems in SNSW (2017 update)

Tony Swan (CSIRO Agriculture), Kellie Jones (FarmLink Research), Brad Rheinheimer (CSIRO Agriculture), Colin Fritsch (FarmLink Research), James Hunt (CSIRO Agriculture, La Trobe University (current address)), John Kirkegaard (CSIRO Agriculture).

Project code - GRDC CSP00174

Take home messages

- In 2017, the average canola grain yield was 2.3t/ha with an oil content of 45.5% and a gross income of $1239, with the highest grain yields and gross incomes attained when sown with a disc opener or spear point opener when retaining stubble.
- The wheat grain yield and gross income were significantly higher when the stubble was retained and not burnt ($3.5t/ha cf 3.2t/ha and $928/ha/yr cf $838/ha/yr), with higher plant dry matter (DM) at anthesis when sown with either a disc or spear point opener compared to the deep knife point. There was no significant main effect of opener type on wheat grain yield or gross income.
- In both phases, the stubble graze (SG) treatments had higher starting soil mineral nitrogen. Grazing stubbles with sheep speeds up N cycling and reduces N tie-up by the stubble. When yield is N limited, this can increase grain yield and quality.
- Over the nine-year experiment, grazing and then retaining stubble has been the most profitable treatment.
- Over the nine years, there was on average a 500kg/ha reduction in wheat grain yield in the 2nd wheat crop where stubble was retained and not burnt.
- Following four years of comparing grazing (Nil Graze, Stubble Graze, Winter & Stubble Graze) by stubble (Burn or Retain) by opener type (Disc, Spear point, Deep knife point), the surface soil strength and soil bulk density were increased when using a disc opener, but there was no significant difference in water infiltration between the disc and tine openers. Similarly, grazing reduced water infiltration under both disc and tine openers, with less water infiltrating following the WGSG or SG treatments compared to the NG treatment.
- The bulk soil pH measurement (0-10cm) does not always provide a good guide for soil pH!
- The subsurface soil (7.5-20cm) acidified between March 2009 and March 2017. The addition of 2.5t/ha of lime in April 2009 and incorporated with deep knife points inter-row sown annually was not sufficient to move the lime down to the subsurface layer.

Background

A livestock enterprise, particularly sheep, in conjunction with a wheat-based cropping enterprise has long formed the basis of mixed farming systems throughout south eastern Australia. This enterprise mix is symbiotic, with sheep able to consume and give value to otherwise wasted by-products from cropping (crop residues, weather damaged and spilt grain, early vegetative crop growth) whilst the legume-based pastures used for sheep production allow paddocks to be spelled from crop production, increase soil nitrogen and reduce crop weeds and diseases. The presence of both livestock and crops also diversifies the farm business, offsetting production and price risk and increasing resilience. In recent times much attention has been given to the potential for conservation farming practices such as no-till seeding with complete stubble retention and controlled traffic to increase crop yields and water-use efficiency. Advocates argue that the full potential of no-till and controlled traffic may not be realised if sheep are grazed on cropped country, as they remove residue cover and trample soils, but there is little contemporary research evidence to support this view. We report results from a long-term experiment designed to test whether sheep grazing in no-till and zero-till farming systems damage soil and reduce crop yields. Results from the first four years of this experiment (2009-2012) are available online (www.farmtrials.com.au/trial_details.php?trial_project_id=16648). Results from 2013-2016 were presented in the FarmLink 2016 and 2017 annual reports. This paper presents results from the final year of the experiment in 2017 and includes a summary of grain yield and gross income from continuously cropped treatments between 2010 and 2017.

Methodology

The experiment was were located on a red chromosol soil 5 km SSE of the township of Temora in SE NSW (519 mm average annual rainfall, 313 mm average Apr-Oct rainfall, 206 mm Nov-Mar rainfall) and consists of three stubble grazing treatments;

1. Nil graze (NG)
2. Stubble graze (SG)
3. Winter graze and stubble graze (WGSG)

These were applied in a factorial design with two stubble retention treatments;

i. Stubble retention (SR)

ii. Stubble burn (SB)

Between 2013 and 2017 these treatments were split for three different seeding furrow opener types;

A. Deep knife-point (AgMaster 12 mm - disturbs soil below seed)

B. Spear-point (Keech - does not disturb soil below seed)

C. Single disc (Excel with Arricks Wheel residue managers)

These experimental treatments were applied in two different phases in adjoining areas of a farmer's paddock which had been in lucerne pasture since 2005. In phase 1, lucerne was sprayed out in late spring 2008, in phase 2 it was sprayed out in late winter 2009. Following lucerne removal, large plots (7 x 16 m – incorporating three individual plot-seeder runs of 1.83 m width and 1.5 m of permanent tram tracks) were established which allowed all operations to be conducted using controlled traffic. Lime was spread at 2.5t/ha in April 2009 across both phases prior to sowing in 2009. All plots were fenced so they could be individually grazed by sheep. Between 2009 and 2012, all plots were sown with deep knife points attached to FlexiCoil 250 kg break-out tines on a linkage mounted plot-seeder on 305 mm row spacing. From 2013, both spear Keech points and deep knife points were attached to the FlexiCoil, and the discs were mounted on a trailing bar with air-seeder also on 305 mm row spacing. Crops were sown from mid-April to early May in all years of the experiment and followed a canola-wheat-wheat rotation.

Table 1: Crop sequence of Canola (C) – Wheat (W) – Wheat (W) in Phase 1 and Phase 2 of the experiment following lucerne pasture (P) since 2005. Second wheat crop is shown in bold.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Phase 1	P	W	C	W	**W**	C	W	**W**	C	W
Phase 2	P	P	W	C	W	**W**	C	W	**W**	C

In 2017, phase 1 was sown to Lancer wheat at 77kg/ha with MAP & Impact Endure (200ml/ha) @ 40kg/ha, following pre-emergent applications of Sakura® @ 118g/ha, Avadex Xtra® @ 2L/ha, Lorsban® @ 900ml/ha and Fast-tac Duo® @ 100ml/ha. Mesurol® (20g/kg Methiocarb) @ 5.5 kg/ha was spread across trial post sowing to control slatters, millepedes, slugs and false wireworm. Phase 2 was sown to SF TurbineTT canola on the 2nd May at 2.9kg/ha with MAP & Impact Endure (200ml/ha) @ 40kg/ha, following pre-emergent application of propyzamide @ 1L/ha, Atrazine® 900WG @ 1.1kg/ha, Lorsban® @ 900ml/ha and Fast-tac Duo® @ 100ml/ha. Mesurol® (20g/kg Methiocarb) @ 5.5 kg/ha was spread across trial post sowing to control slatters, millepedes, slugs and false wireworm, with a follow-up application two weeks later.

No winter grazing of either the wheat or canola occurred in 2017 so that we could examine the long term effects (2009-2016) of the treatments on the 2017 grain yield.

Nitrogen was top-dressed on both phase 1 and 2 as urea at 130kg/ha on the 1st August. In phase 1, broadleaf weeds were sprayed with a mix of Paridigm® @ 25ml/ha and Agritone®LVE (570g/L) @ 600ml/ha. In phase 2, in-crop herbicides included Atrazine® 900WG @ 1.1kg/ha and Clethodim @ 500ml/ha. The wheat in phase 1 was sprayed with Prosaro® @ 300ml/ha and Transform® @ 100ml/ha on the 9th September and the canola in phase 2 at 20-30% flowering with Prosaro® @ 450ml/ha and Transform® @ 100ml/ha.

Grain yields were measured using a plot header harvesting the bordered inside 4 rows only of each seeder run to remove the edge effects from rows adjacent to tram tracks. Grain yields were also measured by hand harvesting large areas (>1.0 m^2) of crop and threshing, which also allowed total dry matter production, harvest index and amount of the residue returned to plots to be calculated. Grain protein, moisture and test-weight were estimated from NIR, and screenings as per receival protocols. Binned grades were determined from quality parameters, and prices determined using 2017 grain prices for the day of harvest. Inputs and non-tonnage dependent operations in all treatments were identical, therefore only gross income is calculated in the economic analysis.

Following harvest in each year (late November-early January), large weaner ewes grazed the stubble residues in both treatments 2 and 3 over a 1 week period (SG and WGSG treatments) at an intensity of 2263 DSE/ha/days. In January 2017, four medium sized weaners (55kg) grazed the canola stubble and five weaners grazed the wheat stubble for 4.7days (2000-2500 DSE/ha/days). The amount of stubble present in plots was measured before and after grazing to calculate how much sheep had consumed. Stubble was analysed for feed quality (metabolisable energy), and the number of grazing days was calculated based on one dry sheep equivalent (DSE) consuming 7.6 MJ of energy per day. Grazing value was priced assuming an agistment rate of $0.4/DSE/week. Sheep were not removed from the plots if it rained during grazing.

The stubble was burnt (SB treatment) in mid- to late-March of each year. Summer weeds that emerged at the site were promptly controlled with herbicide.

Infiltration Measurement

At the end of the summer fallow period in March 2017, all crop residues were removed from a 1 m^2 area in three treatments (NGSR, SGSR and WGSR) where crops between 2013 and 2016 were sown with disc and deep knife point openers. The water infiltration rates were measured using a drip infiltrometer (McCallum et al., 2004), the surface soil strength (0-5mm) measured using a hand-held penetrometer (Geotester) and soil bulk density (0-5cm) measured using soil coring rings.

Soil pH measurement

In phase 1 in the NGSR treatment only, surface soil pH (0-20cm) was measured in March 2017 where both the disc and spear point opener had been used between 2013 -2016 for seed establishment. Soil samples were removed in 2.5cm increments to 10cm and 5cm increments between 10cm and 20cm. Soil pH ($CaCl^2$) was measured in 0.05M Calcium Chloride, and compared to initial soil pH ($CaCl^2$) results from 2009.

Monthly, annual and growing season rainfall (April-October inclusive) at Temora is outlined in Table 2.

Table 2: Monthly and annual rainfall data (mm) from Temora airport 2009-2017

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual (mm)	GSR (mm)
2009	22	14	16	53	7	58	32	8	24	23	24	44	327	205
2010	6	109	79	39	41	22	59	63	63	87	105	76	749	374
2011	62	196	72	17	17	18	25	46	30	48	108	64	702	201
2012	62	59	24	5	16	18	44	38	15	17	35	30	363	153
2013	10	40	20	2	52	87	18	25	29	15	47	9	354	228
2014	21	25	56	70	31	74	5	24	29	17	18	66	436	250
2015	61	21	3	49	20	51	79	54	10	13	90	29	481	276
2016	57	9	8	9	90	113	61	71	205	42	5	34	704	591
2017	22	8	44	16	29	0.2	18	49	0.6	63	48	101	399	175

Results 2017

In 2017 there was 108mm of summer rainfall (Dec 2016-March 2017), 175mm growing season rainfall (April-Oct inclusive) and a total annual rainfall of 399mm. Only 16mm of rain fell in April (8mm between the 25-27th April), so surface soil (0-5cm) was wetter in the SR treatments than in the SB treatments pre-sowing in phase 1 (Table 3) and phase 2 (Table 5). The soil moisture content was also 1 to 2% higher in the 5-15cm layer pre-sowing where stubble was retained. There was no significant rainfall until the 14th May (20mm), so the seedlings had to germinate and emerge on the stored surface soil moisture.

By the end of May 2017, there were no significant differences in wheat emergence between grazing and stubble treatments with the average population of 120 plants/m^2 (Table 4). However, significantly more plants emerged when sown with the disc opener compared to either the spear or deep knife points, irrespective of grazing treatment (Table 4).

Table 4: Wheat plant establishment populations (m^2) in Phase 1 in May 2017.

	Wheat emergence	NG	Wheat emergence SG	WGSG
Opener	(plants/m^2)	(plants /m^2)	(plants/m^2)	(plants /m^2)
Disc	130	125	130	134
Spear	120	120	133	106
Deep Knife	110	107	111	112
lsd (p=0.05)	4.9			

Table 3: Gravimetric soil moisture (0-5cm) and Soil mineral nitrogen (0-1.75m) in April 2017 across all opener types in Phase 1.

	Soil Mineral Nitrogen (0-1.75m)	Gravimetric soil moisture (0-5cm) Burn	Retain
Graze	(kgN/ha)	(%)	(%)
NG	83	4.4%	7.1%
SG	107	4.6%	5.9%
WGSG	106	3.8%	5.4%
lsd (p=0.05)	20	0.7%	

The increased emergence in the disc and spear NG or SG treatments was probably the result of improved seed placement and reduced soil moisture loss between sowing and the follow-up rain two weeks later. The reduced emergence in the WGSG treatment was due to the drier and harder soil surface. However, all treatments had sufficient plant populations to achieve yield potential in 2017.

By the end of May 2017, the average canola plant population was 46 plants/m^2 across all treatments. There were significantly fewer plants established in the NGSR compared to the NGSB (Table 5), but all treatments had > 34 canola plants/m^2. The reduction in canola emergence in the NGSR treatments was probably related to the heavy wheat stubble load (7t/ha in the NGSR vs 4-5t/ha in the WGSGSR and SGSR treatments) and was most affected when sown with deep knife points (Deep = 34 plants/m^2). However, all treatments had sufficient plant numbers to achieve potential yield. The NGSR and SGSR had higher soil moisture in the 0-5cm layer and at least 1% higher moisture in the 5-15cm layer, which assisted the plants in early growth.

Table 5: Gravimetric soil moisture (0-5cm) and Soil mineral nitrogen (0-1.75m) in April 2017, and canola plant populations (plants/m^2) across all opener types in Phase 2 in May 2017.

		Gravimetric soil moisture (0-5cm)	Mineral Nitrogen (0-1.75m)	Canola emergence
Graze	**Stubble**	(%)	(kgN/ha)	(plants/m^2)
NG	**Burn**	5.2%	91	53
SG	**Burn**	5.8%	95	47
WGSG	**Burn**	5.7%	93	43
NG	**Retain**	8.0%	103	38
SG	**Retain**	6.3%	141	46
WGSG	**Retain**	5.3%	95	52
lsd (p=0.05)		0.88%	23.7	5.7

In Phase 1 following the 2016 canola crop, there was significantly more soil mineral nitrogen (23 to 24 kgN/ha) remaining in the SG and WGSG treatments compared to the NG treatments in April 2017 (Table 3), with 65-75% of the mineral nitrogen in the surface 35cm (data not shown). Similarly, in phase 2, following the 2016 wheat crop, there was significantly more soil mineral nitrogen (38 to 50 kgN/ha) in the SGSR compared to all other treatments (Table 5), with 61-75% of the mineral nitrogen in the surface 35cm (data not shown).

Anthesis: The average wheat DM yield at anthesis in phase 1 was 7t/ha. There was significantly less wheat DM when sown with the deep knife points and a significant interaction between openers and grazing (Table 6). In phase 2, there was significantly less canola DM when sown with the deep knife point compared to both the spear and disc openers, and significantly more canola DM in the SG treatments compared to either the NG or WGSG treatments (Table 7).

Table 6: Phase 1 - Wheat dry matter (t/ha) at anthesis (18th October) for the three opener types, and the interaction between opener type and graze treatment.

	Wheat DM	Wheat DM NG	(Graze x SG	Opener) WGSG
Opener	(t/ha)	(t/ha)	(t/ha)	(t/ha)
Disc	7.2	6.5	7.3	7.8
Spear	7.4	7.1	7.7	7.5
Deep Knife	6.5	6.2	7.4	6.0
lsd (p=0.05)	0.34	0.97		

Table 7: Phase 2 – Canola dry matter (t/ha) at anthesis (29th September) for the three opener types, and for the three graze treatments.

	Canola DM		Canola DM
Opener	(t/ha)	**Grazing**	(t/ha)
Disc	6.0	**NG**	5.5
Spear	6.1	**SG**	6.3
Deep Knife	5.4	**WGSG**	5.6
lsd (p=0.05)	0.51		0.61

Crop Maturity

In Phase 1 at crop maturity, there was an average wheat DM yield of 7.2t/ha, wheat grain yield of 3.3t/ha with a protein concentration 12.2%. There were no grazing effects, but there was a significant main stubble effect with a 0.8t/ha increase in DM and 0.3t/ha in grain yield where stubble was retained (Table 8). There was also a significant main effect of opener type on wheat DM with a reduction of 0.4t/ha and an increase in protein concentration of 0.4% when the crop was established with a deep knife point (Table 8).

Table 8: Phase 1 – Main effects from the stubble treatment and opener type on wheat DM, grain yield and protein % in December 2017.

Stubble treatment	Plant DM (t/ha)	Grain yield (t/ha)	Protein (%)	Gross Income 2017 ($/ha)	Opener	Plant DM (t/ha)	Grain yield (t/ha)	Protein (%)
Burn	6.8	3.16	12.2	$838	**Disc**	7.34	3.4	11.8
Retain	7.6	3.48	12.1	$928	**Spear**	7.38	3.4	12.1
					Deep Knife	6.88	3.2	12.5
lsd (p=0.05)	0.41	0.20	ns	$50.3		0.41	ns	0.29

The average wheat gross income for 2017 was $882/ha. However, there was a significant increase in gross income of $90/ha where stubble was retained (Table 8). There was also an interaction between opener type, grazing and stubble treatment for total maturity DM, grain yield and gross income (Table 9).

Table 9: Phase 1 - Interaction between grazing treatments, stubble treatments and opener type on wheat DM at anthesis and crop maturity, grain yield, protein % and gross income in 2017.

Opener	Graze	Stubble	Anthesis DM (t/ha)	Wheat DM at maturity (t/ha)	Grain Yield (t/ha)	Protein (%)	Gross Income 2017 ($/ha)
Disc	WGSG	Retain	8.4	8.1	3.7	11.8	$995
Spear	WGSG	Retain	7.5	7.7	3.7	12.1	$979
Spear	NG	Retain	7.2	7.8	3.7	12.0	$978
Disc	SG	Retain	7.5	8.4	3.6	11.8	$950
Knife	NG	Retain	6.4	7.3	3.5	12.7	$936
Knife	SG	Retain	7.9	7.9	3.5	12.1	$936
Spear	SG	Burn	7.8	7.7	3.4	12.0	$899
Spear	SG	Retain	7.5	7.5	3.3	12.4	$891
Knife	WGSG	Burn	6.0	6.7	3.3	12.9	$883
Disc	NG	Retain	6.6	7.1	3.3	11.5	$856
Spear	WGSG	Burn	7.6	6.7	3.1	12.6	$848
Disc	SG	Burn	7.2	7.2	3.2	11.9	$836
Spear	NG	Burn	6.9	6.9	3.2	11.8	$831
Knife	WGSG	Retain	6.0	6.4	3.0	12.8	$830
Disc	WGSG	Burn	7.1	6.4	3.2	12.0	$829
Knife	NG	Burn	5.9	6.5	3.1	12.1	$829
Disc	NG	Burn	6.3	6.9	3.2	11.7	$808
Knife	SG	Burn	7.0	6.6	2.9	12.6	$780
lsd (p=0.05)			ns	1.04	0.53	ns	$132
lsd (p=0.05) same level Graze x stubble							$128
lsd (p=0.05) same level Stubble							$74

In phase 2 at crop maturity, there was an average canola DM yield of 7.3t/ha, grain yield of 2.3t/ha, oil content of 45.5% and average gross income of $1239/ha. There was significantly more canola dry matter when established with both spear and disc opener (Table 10), and there was a higher gross income when the canola was established with a disc opener compared to a deep knife point (disc @ $1308/ha cf knife @ $1173/ha).There were significant interactions between opener type and stubble treatment in grain yield, oil content and gross income with lower grain yield, reduced oil content and less gross income where the SR treatment were sown with a knife point or where the SB treatments were sown with a spear point (Table 10).

Table 10: Canola DM, grain yield and oil % and gross income from phase 2 in 2017.

Opener	Stubble treatment	Canola DM (t/ha)	Grain yield (t/ha)	Oil (%)	Gross Income 2017 ($/ha)
Disc	**Retain**	7.7	2.35	45.9	$1288
	Burn		2.37	45.6	$1328
Knife point	**Retain**	6.8	2.08	45.2	$1130
	Burn		2.23	45.7	$1216
Spear point	**Retain**	7.2	2.47	45.5	$1343
	Burn		2.09	45.2	$1131
lsd (p=0.05)		0.45	0.30	0.39	$158.5
lsd (p=0.05) same level stubble			0.26	0.23	$138.5

Results for 2010-2017

Across the eight years of the experiment in both phases (2010-2017), there has been a significant decrease in wheat grain yield in the NGSR treatment compared to the NGSB treatment (Tables 11 and 12). In 2012, 2015 and 2016, this resulted in a 0.5t/ha reduction in grain yield due to lower soil nitrogen concentrations and increased nitrogen tie up by retaining the stubble (Table 11). The soil mineral nitrogen concentration was always 15 to 20kgN/ha lower in March of each year in the NGSR compared to the NGSB treatment (data not shown). The combined effect of lower soil mineral nitrogen concentrations and lower air temperatures (Frost) in 2013 resulted in a 1.6t/ha decrease in wheat grain yield in phase 2 between the NGSR and NGSB treatments (Table 12). Similarly, the 0.6t/ha decrease in grain yield in the SGSR compared to the SGSB treatment was due to frost (Table 12). Interestingly, in 2017 in the 1st wheat crop, there was a significant increase in grain yield where stubble was retained compared to stubble burnt (Tables 8 and 11).

Table 11: Grain yield between 2010 and 2017 in Phase 1 sown with deep knife points.

Graze treatment	Stubble treatment	Canola 2010	Wheat 2011	Wheat 2012	Canola 2013	Wheat 2014	Wheat 2015	Canola 2016	Wheat 2017
NG	**Retain**	4.2	4.6	4.4	0.7	3.8	4.1	3.2	3.5
	Burn	4.0	4.6	5.0	1.0	3.8	4.6	3.2	3.1
SG	**Retain**	4.3	4.5	4.8	0.9	3.7	5.3	3.3	3.5t
	Burn	4.2	4.6	4.7	1.1	3.8	5.2	3.3	2.9
WGSG	**Retain**	3.9	5.2	4.5	0.7	3.4	3.6	3.1	3.0
	Burn	4.1	5.3	4.9	0.7	3.2	3.9	3.2	3.3
								ns	0.49

Table 12: Grain yield between 2010 and 2017 in Phase 2 sown with a knife point.

Graze treatment	Stubble treatment	Wheat 2010	Canola 2011	Wheat 2012	Wheat 2013	Canola 2014	Wheat 2015	Wheat 2016	Canola 2017
NG	**Retain**	6.3	3.4	4.5	2.0	2.0	5.5	5.2	2.2
	Burn	6.2	3.5	4.8	3.4	2.0	5.3	5.7	2.1
SG	**Retain**	6.2	3.3	4.8	3.0	2.2	5.6	5.3	2.2
	Burn	6.4	3.3	4.9	3.6	2.0	5.7	6.1	2.3
WGSG	**Retain**	6.5	3.1	4.7	2.4	1.5	3.9	5.1	1.8
	Burn	6.5	3.1	4.7	2.7	1.7	3.8	5.0	2.3
								0.35	ns

In several years (2012, 2013, 2015), the wheat grain yield in the 2nd wheat crop in the SGSR treatment was significantly higher than in the NGSR treatment. Grazing stubble increased the soil mineral N available prior to sowing and in 2015, it almost doubled the amount in phase 1. This result was verified by surface N measurements taken immediately before and immediately after stubble grazing, which showed that mineral N in the SGSR treatment was twice that in the NGSR treatment.

Gross Incomes

Averaged across both phases for the eight experimental crops, grazing and then retaining the stubble has the highest gross income (Table 13). Even if no value is placed on grazing the stubble, the SGSR treatment grossed $72/ha per year more than the NGSR treatment over the eight years. However, the difference between the NGSR and the SGSR would be greater if a value was placed on grazing the stubble. Similarly, there has been no value associated with grazing the cereal or canola in winter (WGSG treatment). Over the past eight seasons, between 300 and 800kg/ha of crop DM was removed annually by grazing in winter. The additional value of this needs to be added to the long term gross income.

Table 13: Gross income per year averaged across both phases for all years (2010-2017) of the experiment when sown with tine openers (deep knife and spear points).

Graze treatment	Stubble treatment	2010-2017 Assuming grazed stubble has no value ($/ha/yr)
NG	Retain	$1201
	Burn	$1232
SG	Retain	$1273
	Burn	$1241
WGSG	Retain	$1151
	Burn	$1170
P value		0.033
lsd (p=0.05)		$34.30

Infiltration Measurements

Grazing reduced water infiltration rates measured in March 2017 in the SG and WGSG treatments compared to the NG (Table 14). Four years of establishing crops with either a disc or a tined opener, generated no effect on water infiltration rates (average 23mm/hr) across all graze treatments (NG,SG, WGSG) where the stubble was retained (Table 14). There was also no effect of stubble on water infiltration rate with an average infiltration rate of 24.7mm/hr (Table 15). However, the infiltration rate was only reduced in the WGSG compared to the SG or NG treatments when crops were sown with a tined seeder (Table 16). However, infiltration rates in all treatments were often higher than the usual rainfall intensity in the region (Meteorology, 2016).

Table 14: The main effect of the grazing treatments where stubble was retained on the steady state infiltration rate averaged across disc and tine openers, and the main effect of opener between 2010-2017.

Graze treatment	Opener	Steady State Infiltration rate (mm/hr)	Opener	Steady State Infiltration rate (mm/hr)
NG	Disc & Tine	28.1	Disc	21.8
SG	Disc & Tine	22.6	Tine	24.1
WGSG	Disc & Tine	18.0		
lsd (P+0.05)		5.86		ns

Generally, sowing with a disc seeder increased the surface soil bulk density and soil strength compared to sowing with a tined opener, with the winter grazing treatment only increasing in soil strength and bulk density when sown with a tine opener (Table 16). However, the soil strength were not to levels detrimental to plant growth (>2000 KPa).

Table 15: The main effect of the grazing treatments on the steady state infiltration rate averaged across stubble treatment (burn and retain) between 2010-2017, and the main effect of the stubble treatment where crops were sown with a tined opener.

Graze treatment	Stubble Treatment	Steady State Infiltration rate (mm/hr)	Stubble Treatment	Steady State Infiltration rate (mm/hr)
NG	Burn & Retain	28.9	Burn	25.3
SG	Burn & Retain	24.0	Retain	24.1
WGSG	Burn & Retain	17.0		
lsd (P+0.05)		5.57		ns

Table 16: Soil bulk density and surface soil strength between the graze treatments for disc and tine openers where the wheat stubble was retained between 2010-2017.

Graze treatment	Disc (g/m²)	Tine (g/m²)	Soil strength (kPa)	Opener	Bulk Density (0-5cm)	Soil strength (kPa)
NGSR	1.34	1.24	442	Disc	1.35	699
SGSR	1.36	1.23	503	Tine	1.27	441
WGSGSR	1.35	1.33	765			
lsd (P=0.05)	0.09		162		0.03	58.5

Soil pH measurements

The bulk soil pH measurement (0-10cm) does not always provide a good guide for the soil pH!

The soil pH ($CaCl_2$) in the surface 0-10cm has increased between March 2009 and March 2017 following the application and initial incorporation of 2.5t/ha of lime in April 2009 by deep knife points, and inter-row sowing annually until 2012, and then by either a spear/deep knife or disc opener between 2013 and 2017. However, over the same period, the subsurface layer (10-20cm) acidified (reduced from 4.85 to 4.47). There was no significant difference in soil pH ($CaCl_2$) between opener types (disc or spear point), presumably due to the initial four years of incorporation with a deep knife point. Not only had the average soil pH in the 10-20cm layer acidified, but the depth from 7.5cm to 10cm had reduced to < pH 4.5, with the 10-15cm layer acidifying to a pH of 4.36 (Table 17).

Table 17: The changes in soil pH ($CaCl_2$) between 2009 and 2017 in Phase 1 in the NGSR treatments for disc and tine openers and soil pH in 2.5cm increments.

Depth	March 2009 Soil pH ($CaCl_2$)	March 2017 Soil pH ($CaCl_2$)		Depth	Average Soil pH ($CaCl_2$)
		Disc	Tine		
0-10cm	4.75	5.04	5.04	0-2.5cm 2.5-5cm	5.74 5.22
10-20cm	4.85	4.44	4.49	5-7.5cm	4.73
				7.5-10cm 10-15cm 15-20cm	4.48 4.36 4.57
lsd (P=0.05)	0.09	ns			0.11

This indicates that the practice of relying on direct drilling techniques to incorporate lime to negate the acidification of the subsoil, does not work. It is therefore recommended that enough lime be applied to increase the soil pH to 5.5 ($CaCl_2$) and the lime incorporated using offset disc plough or other mixing implement to a depth of the acidification layer. The acidification of the subsurface layer has been found at numerous locations across the Riverina and South West Slopes where crops have been sown over the past 10-15 years using no till techniques on all row spacings and even where the seed was sown at 90 degrees to the previous year's crop. One method of incorporation that reduces the possibility of erosion would be to spread the lime post-harvest onto a large cereal stubble and incorporate as soon as possible post-harvest to give sufficient time for the cereal to break down.

Acknowledgments

The research undertaken as part of this project and the earlier WUE project over the past nine years has only been made possible by the significant contribution from growers and consultants through trial co-operation and the support of the GRDC, and for their continued support. The authors would like to especially thank the Coleman family for the long-term use of their land, the access to livestock and their facilities. We would like to thank the many local growers who have also provided livestock, machinery and trucking capabilities when required to keep the trial managed efficiently. We would also like to acknowledge the guidance from the regions knowledgeable consultants who have given their time freely over the past nine years. This has been greatly appreciated. Lastly, we also acknowledge the expert technical assistance provided by both CSIRO staff (Mel Bullock, Byron Corcoran, Matt Lynch, Tom McLucas) and FarmLink Research (Paul Breust, Tony Pratt and Kylie Dunstan) over the years. Funding was provided by GRDC Projects FLR00005; CSP00174; CSP00186.

02

FarmLink Research Report 2017

Optimising summer weed control – preserve soil moisture and reduce impact of variability in growing season rainfall

Trial Site Location Temora Agricultural Innovation Centre, Temora NSW

Report Authors

Kellie Jones, FarmLink

Introduction

Research focusing on crop water use efficiency (WUE) has demonstrated the importance of summer weed control in conserving soil moisture for subsequent crops. The value of conserving soil moisture over summer in achieving improved crop establishment and final yield under dry growing conditions has been demonstrated over the last decade as farmers have experience drought along with more variable rainfall patterns and an apparent 'shortening' of spring.

Growers are keen to maximize the yield potential of crops in an increasingly variable environment and have embraced the philosophy of summer weed control. This farm practice brings with it questions related to the cost/benefit associated with the timing and frequency of summer spraying along with the trade-off between weed control for moisture & nitrogen conservation, reduction in weed burdens and summer feed for livestock on mixed farms. Optimising the summer weed control practice will help farmers to better respond to climate variability.

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Project Code - RV01210

Funding Partners

NSW GOVERNMENT
Local Land Services Riverina

Aim

This project is focused on one area that may assist farmers to mitigate or adapt to the impacts of climate variability. Specifically, the project aims to investigate the costs and benefits of four different, commonly used summer weed control strategies – single spray, regular & frequent spraying over summer, grazing and a no management strategy as a control. Benefit will be described in terms of the differences in moisture retention over summer and final soil nitrogen. While cost will be described in terms of the differential in input and management costs of each strategy.

Method

- The field trial located at the Temora Innovation Centre, was replicated 3 times and commenced following harvest 2016. The trial was established in a Spitfire wheat stubble and was sown to Suntop wheat in 2017.
- The four treatments are listed in Table 1:

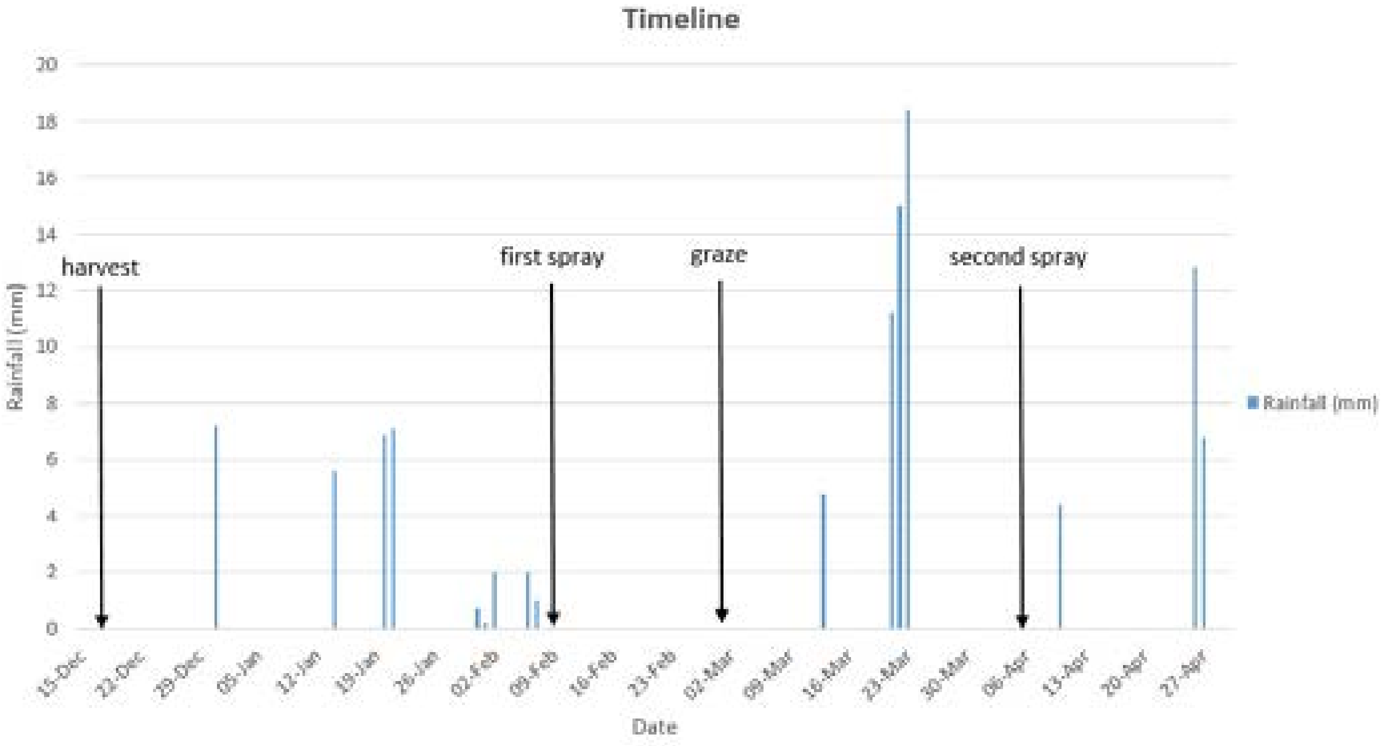
Table 1. list and description of the four treatments applied in this trial.

No.	Treatment	Description
1	Single spray	one spray application of herbicide 10-12 days after first major rain event (>15mm)
2	Multiple spray	Spray application 10-12 days after each major rain event (<15mm)
3	Graze	Graze by sheep 10-12 days after first major rain event (<15mm). Six sheep per plot for 5 days (600 DSE grazing days)
4	Control	No weed control

- Soil samples were collected at the commencement and completion of the trial and analyzed for soil moisture and nitrogen comparison.
- Photos and weed counts were undertaken on all the plots 10-12 days after the first major rain event of the summer and again at the end of the trial.
- The gravimetric moisture content was measured using a dry-weight basis equation:

$$\text{Gravimetric moisture content} = \frac{\text{(grams of wet soil} - \text{dry soil)}}{\text{grams of dry soil}}$$

- then calculated into millimetres using the standard bulk density of 1.3 for 0-10cm and 1.5 for 10-20cm. Kilograms of nitrogen per hectare were also calculated using the above bulk density figures.



Graph 1. Timeline of treatment application, sampling and rainfall events during 2016.

Results

Table 2. Final average weed plants per square metre. Including and not including volunteer wheat in the count.

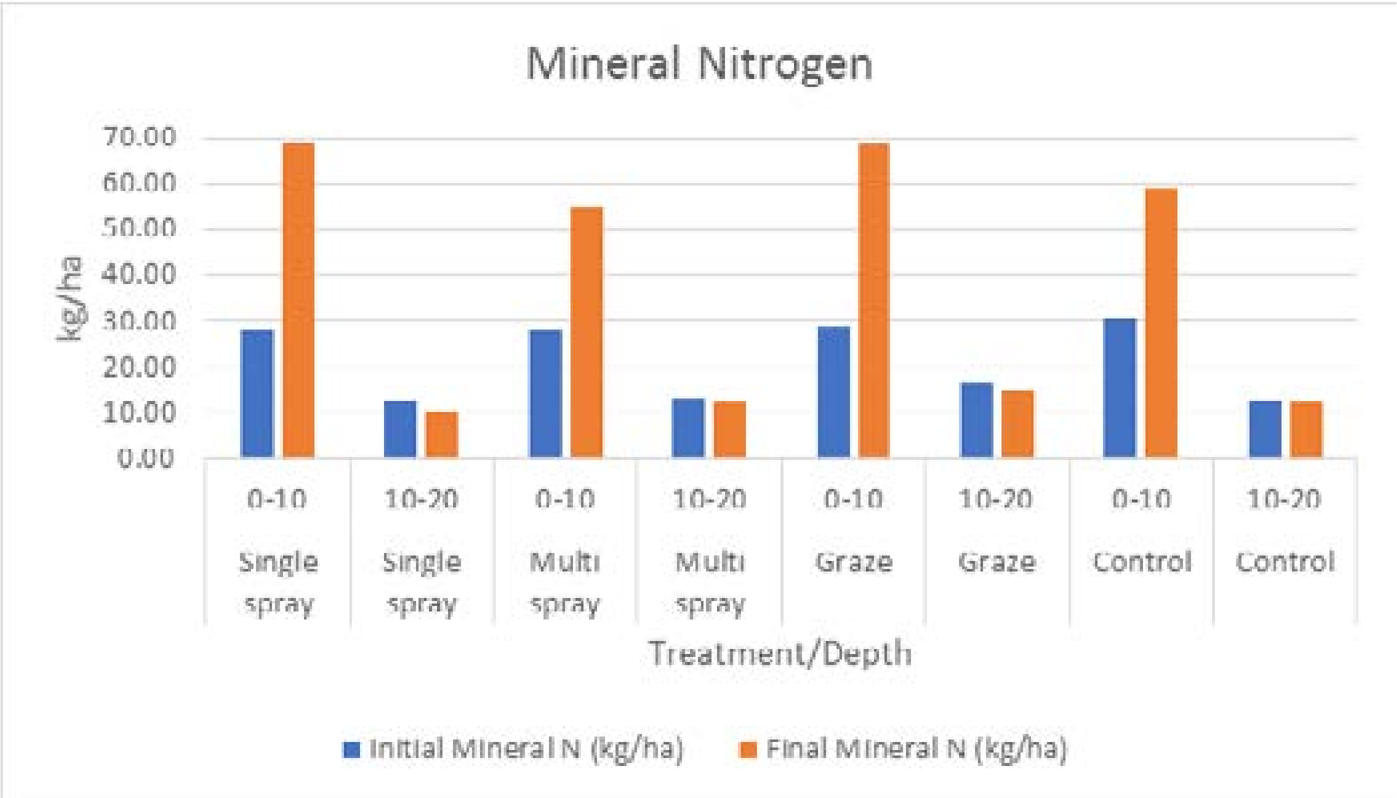
	*including volunteer wheat	*not including volunteer wheat
Treatment	**Final Avg plant/m²**	**Final Avg plant/m²**
Single Spray	79b	18a
Multi Spray	4c	2b
Graze	159a	31a
Control	122ab	22a
LSD (P = 0.05)	44.3	14.6

Table 2 shows there was significantly less weed plant numbers in the multiple spray treatment when comparing to the other three treatments, when volunteer wheat is and isn't included in the data. There was no treatment effect in terms of weed plant numbers on the single spray, graze and control treatment when volunteer wheat was not included. However, when volunteer wheat was included in the collection of data, there was a larger spread in results. The multi-spray treatment was most effective, followed by the single spray treatment, the control had was not significantly better than the graze treatment, or worse that the single spray treatment.

Table 3. Initial and final volumetric moisture content average at a depth of 0-10cm and 10-20cm.

Treatment	Initial Moisture 0-10cm (mm)	Initial Moisture 10-20cm (mm)	Final Moisture 0-10cm (mm)	Final Moisture 10-20cm (mm)
Single spray	4.1	7.4	19	14.3
Multi spray	4.0	7.7	19.5	16.9
Graze	3.7	7.8	18.5	13.6
Control	4.5t	9.5	19.1	13.8
LSD (P = 0.05)	No significant difference	No significant difference	No significant difference	No significant difference

Table 3 shows that the trial began with uniform moisture over all the plots down to 20 centimetres, except for the control treatment which had a higher level of 9.5mm of moisture stored at 10 – 20 centimetres. However, this high figure did not carry through to the end of summer. The final moisture analysis shows there was no effect on moisture retention between treatments at the depth 0 – 10 and 10-20 centimetres. The multiple spray treatment proved to be superior at moisture conservation over the other treatments, but it was of no significant difference.



Graph 2. Initial and final mineral nitrogen (ammonium + nitrate) at a depth of 0-10cm and 10-20cm.

The statistics in graph 2 show that there was no difference between treatments when comparing Initial and final mineral nitrogen. The mineral nitrogen increased over the summer period at the depth of 0-10cm, while at 10-20cm levels remained constant.

Table 4. Cost analysis per treatment, displayed as dollars per hectare.

Treatment	Chemical ($/ha)	Contractor/agistment rate ($8/ha)	Total ($/ha)
Single Spray	$15.70	$8.00	$23.70
Multi Spray	$31.40	$16.00	$47.40
Graze	-	30 cents/DSE/week	-$25.71
Control	-	-	$0.00

The cost analysis (table 4) shows the multiple spray treatment is double the cost of the single spray treatment, while the grazing treatment gained $25.71 per hectare when an agistment rate of 30 cents per DSE (dry sheep equivalent) per week was used. The control treatment strategy was no weed control, therefore the cost was $0.00/ha.

Discussion

The multiple spray treatment had an average of only four weed plants per square metre including volunteer cereal and only 2 plants per square metre not including self-sown cereal. This is by far the best treatment when aiming to reduce weed plant numbers. The graze treatment had significantly more weeds than the single and multiple herbicide treatments, but had no effect when compared to the control treatment when controlling both weeds and volunteer wheat (image 1).

Image 1. Each treatment post final weed counts at the end of the trial. Photo taken April 24th, 2017.

There are many advantages for controlling weed numbers, by reducing the number of weeds, the seed set is reduced too. Weed seedbank numbers can increase significantly and very quickly if no management in undertaken, this can contribute to future weed burdens. Ultimately, the aim would be to run down the weed seed bank numbers by using effective management strategies until a second herbicide spray is not required. Other problems that arise from large weed populations are certain weeds can cause trouble when sowing, such as wire weeds tough long stems getting caught around tines of a seeder and cause blockages.

Grazing did not occur 10-12 days after the first rain event as stated in the original plan due to insufficient biomass, grazing occurred once there was sufficient biomass for the sheep to consume. However, it is important that the weeds were not left long enough to set seed, otherwise this would defeat the purpose of controlling weeds for the benefit of reducing weed seed bank numbers. Grazing should be monitored as some weeds such as loose strife and caltrop can be toxic to sheep in large quantities. It is likely that more weeds germinated following the second rainfall event that occurred post grazing, a second graze would have been beneficial.

Image 1. Each treatment post final weed counts at the end of the trial. Photo taken April 24th, 2017.

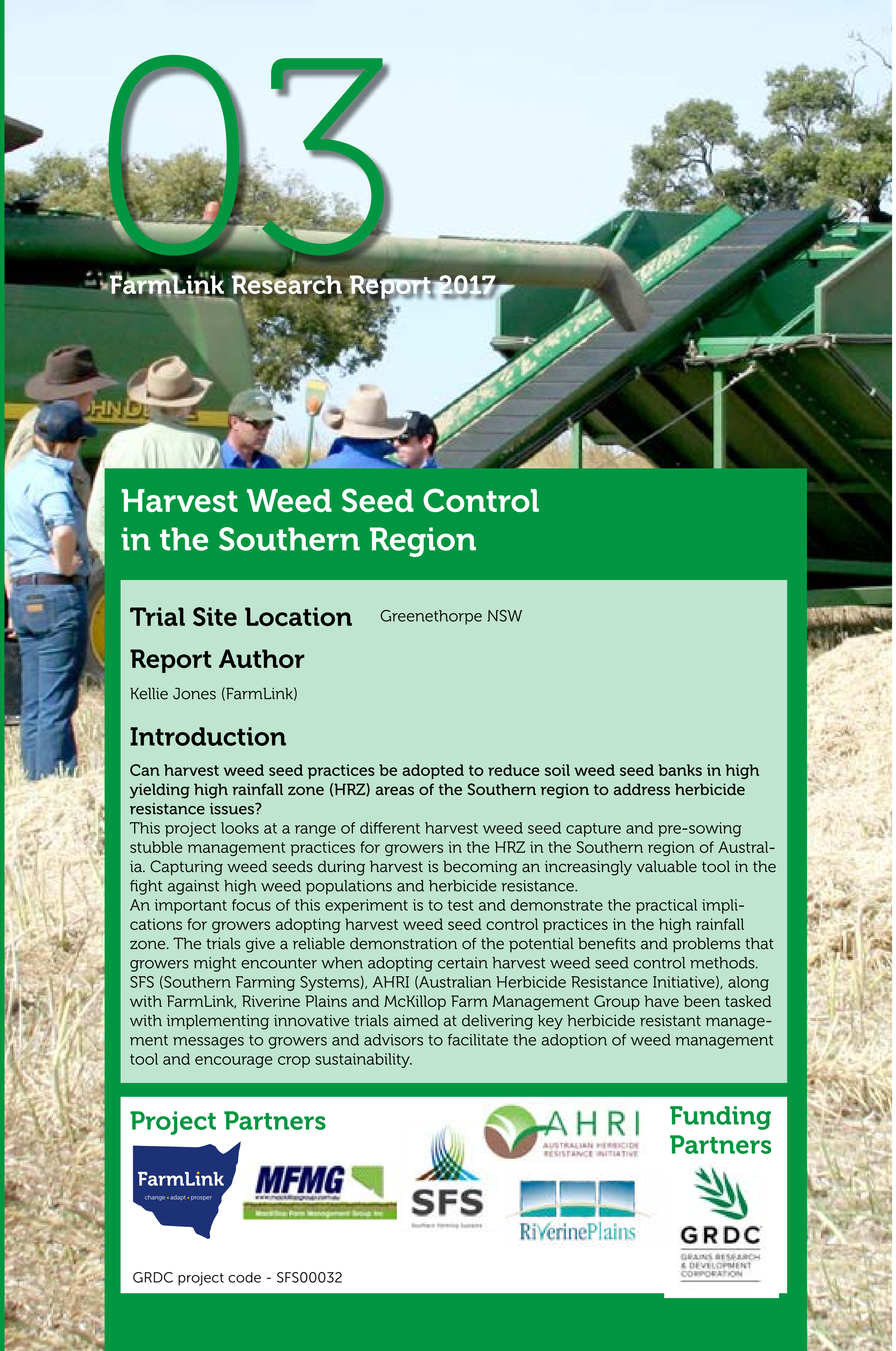
Moisture is removed from the soil profile over summer through transpiration and evaporation, evaporation can have an effect down to 20cm. At the conclusion of the trial, there was very little difference in moisture content between treatments at 0-10cm in the soil profile. While there was a small difference noticeable at 10-20 centimetre's, it was of no significant difference. The lack of difference in the 0-10cm layer is most likely due the rainfall received prior to the soil samples being taken. The 10-20cm layer would have also been somewhat affected by the rainfall event. The multiple spray treatment conserved the most moisture at 10-20cm, followed by the single spray treatment. There was no difference in moisture conservation in the graze and control treatment. It is noted that the total volume and frequency of rain that fell over this summer period was low compared to the long-term averages, and this will have had the effect of reducing the biomass of weeds produced and reducing the difference in impact between treatments.

Effective management of weeds over a summer fallow can conserve moisture for the crop in the following year. This can be very advantageous if there is a dry start to the season, emerging crops may gain a head start. Extra moisture isn't the only advantage for emerging crops, some weeds may affect subsequent emerging crops due to their allelopathic abilities. Some common summer weeds found in our area with this ability is crumb weed and caltrop.

There was no treatment effect on the final mineral nitrogen levels across all the treatments. The slight increase of nitrogen in the 0-10cm segment over summer was due to mineralization of organic matter.

The multiple spray treatment is by far the most expensive summer weed control strategy, but it is also the most effective. Although the grazing treatment made an income of $25.71 per hectare, it had no control of weed numbers and no impact on nitrogen or moisture retention. The cost of these strategies need to be weighed up against the advantages, both short and long term. Situations may vary from farm to farm, some control strategies may suit better than others. Some of these variables include; weed numbers and type, whether livestock are available or if they must be brought in, if spray equipment is available or a contractor is to be used, the list goes on. The climate over summer can have a massive impact on selecting a control strategy too.

It's important to keep in mind that this was a short-term project, results drawn from this trial only reflect the 2016/17 summer season. Accumulating this data over 3 or more summer seasons would produce more accurate results by considering seasonal variability.



03

FarmLink Research Report 2017

Harvest Weed Seed Control in the Southern Region

Trial Site Location

Greenethorpe NSW

Report Author

Kellie Jones (FarmLink)

Introduction

Can harvest weed seed practices be adopted to reduce soil weed seed banks in high yielding high rainfall zone (HRZ) areas of the Southern region to address herbicide resistance issues?

This project looks at a range of different harvest weed seed capture and pre-sowing stubble management practices for growers in the HRZ in the Southern region of Australia. Capturing weed seeds during harvest is becoming an increasingly valuable tool in the fight against high weed populations and herbicide resistance.

An important focus of this experiment is to test and demonstrate the practical implications for growers adopting harvest weed seed control practices in the high rainfall zone. The trials give a reliable demonstration of the potential benefits and problems that growers might encounter when adopting certain harvest weed seed control methods. SFS (Southern Farming Systems), AHRI (Australian Herbicide Resistance Initiative), along with FarmLink, Riverine Plains and McKillop Farm Management Group have been tasked with implementing innovative trials aimed at delivering key herbicide resistant management messages to growers and advisors to facilitate the adoption of weed management tool and encourage crop sustainability.

Project Partners

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MFMG

SFS

AHRI AUSTRALIAN HERBICIDE RESISTANCE INITIATIVE

RiverinePlains

Funding Partners

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

GRDC project code - SFS00032

Objectives

To analyse and investigate various innovative harvest weed seed control methods suitable for the FarmLink HRZ and demonstrate the potential benefits or problems growers might face when adopting these methods.

Method

2015 – Replicated Experiment Treatments

In November 2015, a farm scale experiment was established in Greenethorpe, NSW, to compare various methods of dealing weed seed during harvest. The experiment layout consisted of three treatments, replicated four times, which gave a total of twelve strips 200 metres long by 12 metres wide.

Table 1. 2015 harvest weed seed replicated trial treatments

Treatment	Code	Description
1	CH	Conventional Harvest – harvested with the spreaders on at 30cm, stubble was meant to be burnt as a blanket burn prior to sowing. However, the location of the trial is a mixed farming enterprise, the paddock was grazed and there was not enough stubble to get a good burn.
2	WSM	Weed Seed Mill – harvested at 15cm using a prototype integrated harvest weed seed mill (PIM).
3	WB	Windrow Burn – harvested at 15cm, windrow strip to be burnt prior to sowing.

2016 – Un-replicated Demonstration Treatments

In 2016 an un-replicated demonstration was established over the 2015 site, the three treatments from 2015 were kept in the same location, while two new treatments were added alongside. The five un-replicated strips were 12 metres wide by 200 metres long, giving a total of five strips.

Table 2. 2016 harvest weeds seed demonstration treatments

Treatment	Code	Description
1	CH	Conventional Harvest – harvested with the spreaders on at 25-30cm, stubble to be burnt as a blanket burn prior to sowing.
2	WSM	The weed seed mill was unavailable for this year, the strip was harvested at 10-15cm and placed in a windrow, to be burnt prior to sowing in 2017
3	WB	Windrow Burn – harvested at 10cm, windrow strip to be burnt prior to sowing.
4	CC	Chaff Cart – cut at 10-15cm, chaff dumped at the end of the strip. To be burnt prior to sowing in 2017
5	HH	High Harvest – Harvested at 35-40cm, windrow strip to be burnt prior to sowing.

Assessments

Soil cores (10cm) were taken pre-harvest in the first year (2015 and 2016) of the trial and pre-sowing each year to determine the weed seed bank numbers, this was completed using a foot corer. The soil samples were grown out in trays and each germinated seed counted. Weed plant and inflorescence counts were taken pre and post-harvest to assess the amount of ryegrass inflorescence cut and sent through the header and how much remained intact in the paddock.

Its important to remember that the inflorescence that were cut by the header were not removed from the paddock, but taken in through the front of the header and sent out the back as chaff. An inflorescence is the flowering stem of a rye-grass plant (image 1). Spikelets on 10 inflorescence collected at random were counted for each strip to get an average of spikelets per square metre. Each spikelet has between three to nine seeds (GRDC 2014).

Data including yield, speed, fuel usage, engine capacity and engine speed was recorded during harvest using a commercial harvester. This was to highlight the practical implications of adopting harvest weed seed control methods. The trial was set up to give a reliable demonstration of the potential benefits or problems growers may encounter using these approaches.

Results

Inflorescence counts were taken pre and post-harvest in 2015 (Table 4), the conventional harvest treatment had the lowest amount of inflorescence cut at harvest, with a sum of 59.5%. While the weed seed mill and windrow burn treatments had a higher inflorescence cutting percentage of 65.4% and 64.1%.

The 2016 pre-harvest inflorescence counts (Table 5) were performed for all five of the treatments. Comparisons were made for the first three treatments using data from the previous year. There are no comparisons for the chaff cart and the high harvest treatments, as they were only introduced to the trial at the end of 2016. Counts will be taken again at rye grass flowering in 2017 for the comparison of all treatments. According to inflorescence counts (Table 5), the conventional harvest treatment had the greatest reduction in inflorescence numbers during 2015 and 2016, with a reduction of 31.3%. The weed seed mill treatment had a reduction of 8% and the windrow burn treatment had a 4.3% increase of inflorescence numbers.

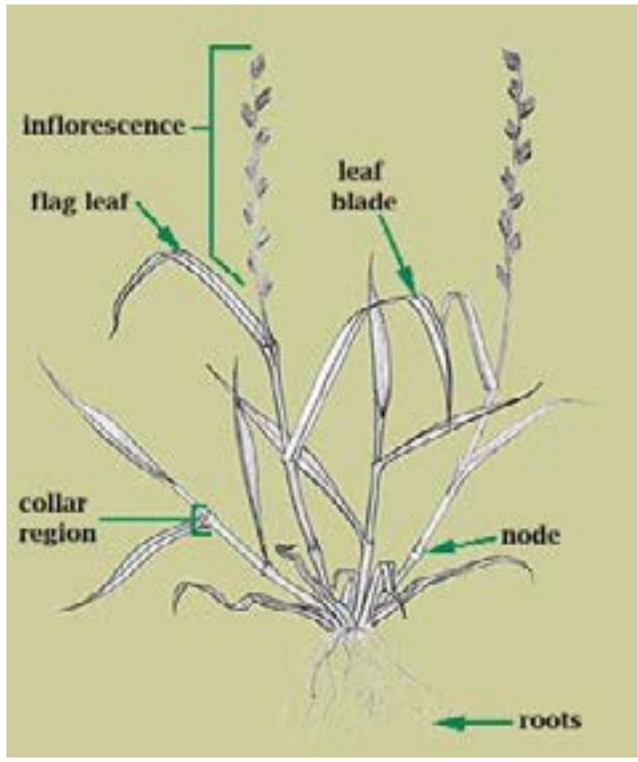

Image 1. Anatomy of annual ryegrass (Hannaway 2017)

Table 3. Treatment average weed seedbank results from the 2015 replicated trial.

Treatment	Pre-Harvest Weed Seed Bank (2015) (seeds/m^2)
Conventional Harvest	1989
Weed Seed Mill	1910
Windrow Burn	2706

Table 4. Annual rye grass inflorescence counts pre and post-harvest 2015.

Treatment	Pre-harvest Inflorescence Count (2015) (inflorescence/m^2)	Post-harvest Inflorescence Count (2015) (inflorescence/m^2)	Inflorescences cut at harvest
Conventional Harvest	178.1	72.2	59.5%
Weed Seed Mill	143.0	49.5	65.4%
Windrow Burn	181.7	65.2	64.1%

*Table 5. Pre-harvest inflorescence counts, 2015 vs 2016, taken at annual rye grass flowering. * No 2015 Pre-harvest inflorescence counts for these treatments because they were not introduced until 2016.*

Treatment	Pre-harvest Inflorescence Count (2015) (inflorescence/m^2)	Pre-harvest Inflorescence Counts (2016) (inflorescence/m^2)	Inflorescence Change (%)
Conventional Harvest	178.1	122.4	-31.3%
Weed Seed Mill	143.0	131.5	-8.0%
Windrow Burn	181.7	189.6	4.3%
Chaff Cart	NA*	176.2	NA*
Harvest High	NA*	87.0	NA*

Spikelet numbers per square metre dropped between 2015 and 2016 (table 6). Information such as yield, speed, fuel usage, engine capacity and engine speed was recorded during harvest for both 2015 and 2016 for each treatment. That data is currently being analysed and will be available once completed.
*not implemented in 2015

Table 6. Pre-harvest seed counts, 2015 vs 2016, taken at annual rye grass flowering.

Treatment	Spikelet Counts (2015) (spikelet/m^2)	Spikelet Counts (2016) (spikelet/m^2)	Spikelet Change (%)
Conventional Harvest	3597.6	1814.0	-49.6%
Weed Seed Mill	3024.5	1934.4	-36.0%
Windrow Burn	3924.7	3183.4	-18.9%
Chaff Cart	NA*	2796.3	NA*
Harvest High	NA*	1263.0	NA*

Discussion

The conventional harvest treatment had 59.5% of inflorescence cut during harvest (Table 4), while the other two treatments, weed seed mill and windrow burn, had 65.4% and 64.1% cut. The difference in the treatments can be explained by the cutting height of the harvester. The conventional harvest treatment was cut at 30cm off the ground, the other two treatments were harvested at 15cm. Adjusting the height of the cutter bar of the header from 30cm to 15cm, only improved the collection of ryegrass by 5% and there were still many inflorescences lying flat below 15cm. No harvester is 100% efficient at picking up all weed seeds, and no matter which harvest weed seed method is used, none are 100% efficient at destroying them. The goal is to manage and bring down weed seed numbers over time using the most efficient method for your farming system.

The difference in pre-harvest inflorescence counts from 2015 and 2016 (Table 5) produced an unexpected result. The conventional harvest treatment had the greatest decline when compared to the other treatments. This was unexpected for a few reasons. Firstly, this treatment was cut at 30cm, our results show that harvesting at 30cm instead of 15cm leaves approximately 5% more inflorescences intact (Table 4). Secondly, the conventional harvest treatment was harvested with the spreaders on and was grazed rather than blanket burned. This treatment should have had the least difference in inflorescence counts from one season to the next. Another unexpected outcome was that the windrow burn treatment increased inflorescence numbers by 4.3%. It is likely that sampling variation is the cause of this unusual result. Lateral spatial variability across the paddock plays a big role in some of the inconsistent data. Further years of this trial are needed to get a clearer view of the impact of treatments.

We observed spikelets/m^2 reduce between 2015 and 2016 for all three treatments (Table 6). The 2016 crop was canola, canola is more competitive and has better herbicide options for grass weeds than wheat, which was the crop in 2015. The paddock received a spray of Roundup on July 31. These two strategies combined have the potential to limit weed vigour, resulting in less spikelets per inflorescence. Even though there was an increase in inflorescence numbers between 2015 and 2016 for the windrow burn treatment, the reduction in spikelets number per inflorescence in 2016 meant there was still an overall reduction of 18.0% in spikelets/m^2.

Other aspects growers could consider when deciding which weed seed management strategy to employ on their farm is how readily these practices can be adopted while using existing machinery, fuel usage, terrain and wear and tear on harvesters when harvesting low. ■

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04

FarmLink Research Report 2017

Crop Competition for Weed Control in SNSW

Trial Site Location Temora Agricultural Innovation Centre

Report Authors

Kellie Jones, Andrew Lockley

Introduction

Weeds cost grain producers $146/ha or $2,305 million pa in Southern New South Wales (Llewellyn *et al*, 2016). GRDC notes increasing herbicide resistance of grass and broadleaf weeds (https://grdc.com.au/Resources/IWMhub/ Section-1-Herbicide- resistance, sourced 2017). Integrated and non-herbicide weed management strategies are required to avoid widespread resistance of crop weeds. Crop management to increase competitiveness against weeds is one of these tools available. Higher seeding rates and more competitive cultivars are promoted as effective tools for decreasing reliance on herbicides (Condon *et al*. 2017). Despite these findings, crop management for improved weed competition has not been widely adopted by growers in SNSW.

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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

GRDC project code – FLR00008

Objectives

To increase adoption of crop/weed competition strategies through local validation of increased seeding rates & broadcast seeding as management practices to reduce weed effects in canola, wheat & barley.

Method

Eight different combinations of seeding rate and herbicide were applied as treatments for wheat, barley and canola in 3 randomised blocks (see table 1)

- 3 Blocks
  - Block 1 – Dyna Gro 560TT Canola
  - Block 2 – Planet Barley
  - Block 3 – Beckom Wheat
- There 8 were treatments replicated 4 times per block – see Appendix 1 for block and replication design
- To ensure even distribution of weeds in the plots, attain annual rye (ARG) grass spread prior to sowing and incorporate using harrows.
- Data was collected as follows –
  - crop emergence counts, one month after sowing
  - ARG emergence counts, one month after sowing
  - ARG panicle counts, at flowering
  - Crop yield

Results

Emergence

The high sowing rate minus herbicide treatment had a significantly higher wheat emergence count when compared to all the treatments (Figure 1). The second highest wheat emergence rate was the high sowing rate plus herbicide. The seed

Table 1. Treatment description and sowing rate for each crop block.

Treat-ment No.	Treatment	Rate (kg/ha)
1	- Grower standard practice seeding rate - Pre-emergent herbicide - Knife point press wheels	Canola: 3kg Barley: 50kg Wheat: 60kg
2	- Low seeding rate - Pre-emergent herbicide - Knife point press wheels	Canola:1.5kg Barley: 20kg Wheat: 40kg
3	- High seeding rate - Pre-emergent herbicide - Knife point press wheels	Canola: 5kg Barley: 80kg Wheat: 100kg
4	- Grower standard practice seeding rate - Pre-emergent herbicide - Seed broadcast across surface, lightly harrowed	Canola: 3kg Barley: 50kg Wheat: 60kg
5	- Grower standard practice seeding rate - No pre-emergent herbicide - Knife point press wheels	Canola: 3kg Barley: 50kg Wheat: 60kg
6	- Low seeding rate - No pre-emergent herbicide - Knife point press wheels	Canola:1.5kg Barley: 20kg Wheat: 40kg
7	- High seeding rate - No pre-emergent herbicide - Knife point press wheels	Canola: 5kg Barley: 80kg Wheat:100kg
8	- Grower standard practice seeding rate - No pre-emergent herbicide - Seed broadcast across surface, lightly harrowed	Canola: 3kg Barley: 50kg Wheat: 60kg

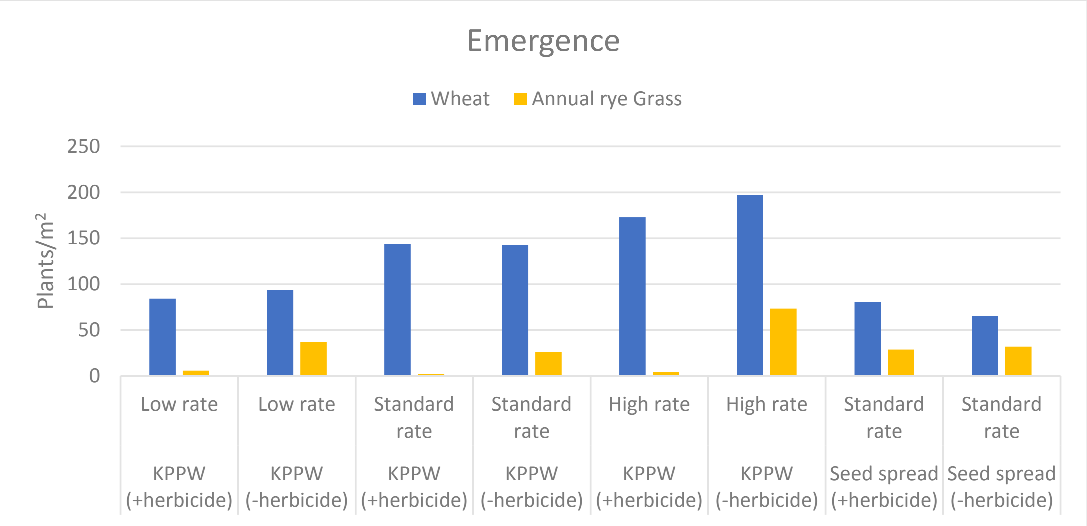

Figure 1. average emergence counts of wheat and annual rye grass in a one square metre area, taken one month after sowing. KPPW = knife point press wheel.

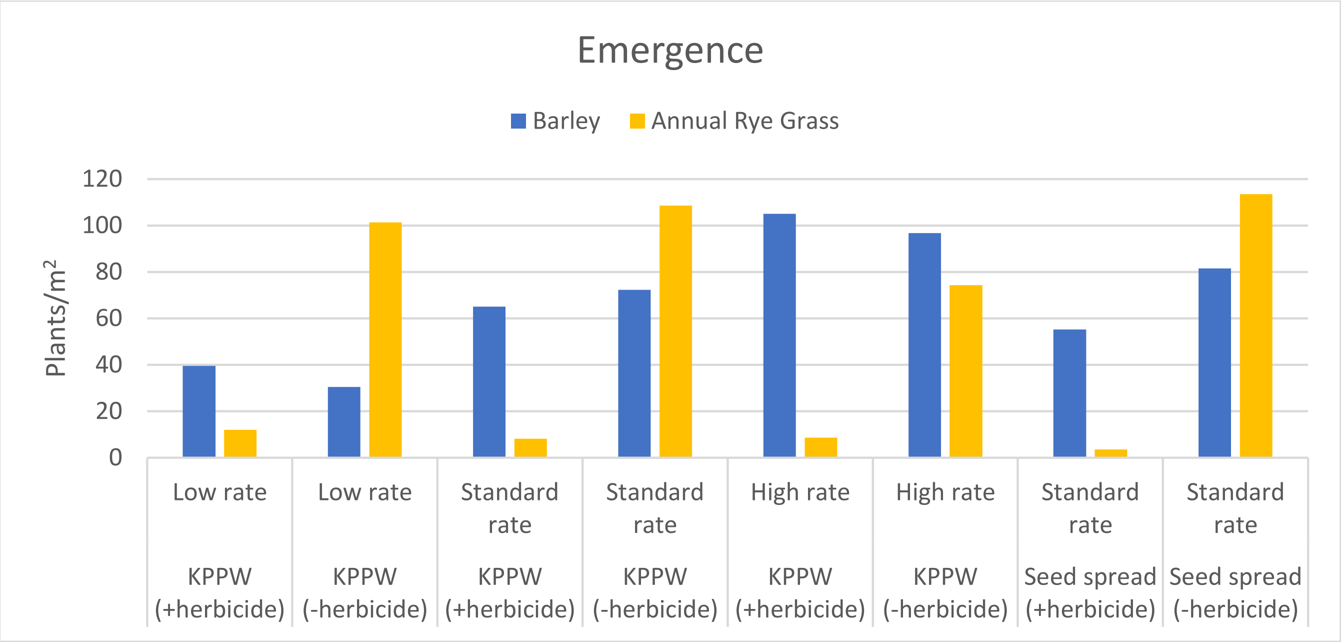

Figure 2. average emergence counts of barley and annual rye grass in a one square metre area, taken one month after sowing. KPPW = knife point press wheel.

spread at the standard rate of 60kg/ha without herbicide had the lowest emergence counts numerically, but statistically it was equivalent to the seed spread with herbicide or a low sowing rate including herbicide.

All the wheat treatments with no pre-emergent herbicide spray applied had an equivalent emergence of ARG. The treatments that had pre-emergent herbicide applied also had equivalent ARG emergence.

Numerically the two low barley sowing lower rate treatments had the lowest barley emergence (Figure 2), but statistically there was no obvious trend. The four barley treatments that had herbicide applied had significantly less ARG emerge than the treatments without herbicide applied. There were no significant differences between the sowing rates within each herbicide treatment (+/-).

Numerically the two canola low sowing rate treatments had the lowest canola emergence (Figure 3), statistically there was no obvious trend between treatments. The four canola treatments with herbicide applied had significantly less ARG emerge than the treatments with no herbicide. In the treatments that had herbicide applied, sowing rate had no impact on emergence counts. In respect to the treatments that had no herbicide application, the ARG emergence was significantly lower in the low sowing rate treatment than the standard sowing rate and seed spread treatment, but equivalent to the high sowing rate.

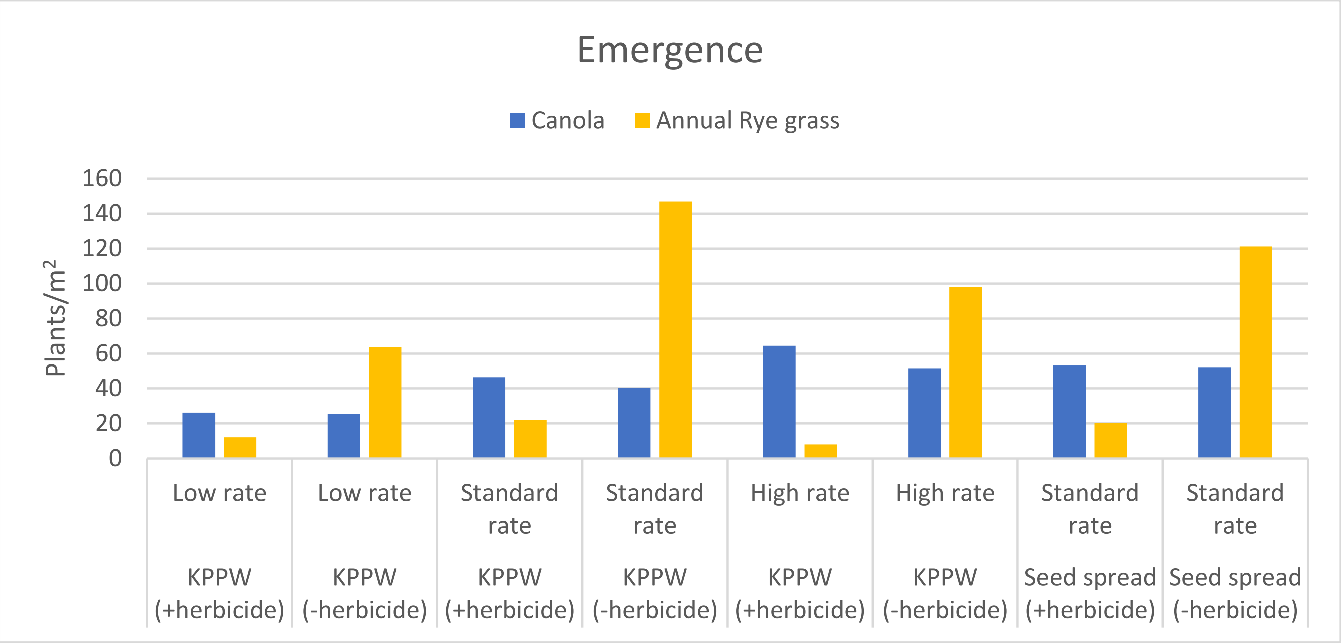

Figure 3. average emergence counts of canola and annual rye grass in a one square metre area, taken one month after sowing. KPPW = knife point press wheel

Panicle counts

When crop types are compared, numerically ARG panicle populations are lowest in the wheat plots, except for the high sowing rate minus herbicide treatment (Table 2). Regardless whether herbicide was applied, the low sowing rate of wheat treatments had significantly less ARG panicles than the high sowing rate and seed spread treatments. The low ARG panicle numbers of the standard sowing rate treatments were statistically equivalent to the low sowing rate treatments.

The low and standard barley sowing rate, both herbicide included and excluded, had the lowest panicle count and were statistically equivalent. The seed spread, plus and minus herbicide, and the high sowing rate minus herbicide had the highest panicle count. Every treatment had statistically equivalent number of ARG panicles present when compared to its corresponding sowing rate partner, except for the high rate treatments where the plus herbicide treatment proved to be better at supressing ARG panicle numbers.

The ARG panicle counts in the high canola sowing rate and seed spread treatments, both including and excluding herbicide had significantly higher numbers than the other treatments. The two low sowing rate treatments and the standard sowing rate minus herbicide had statistically the lowest panicle counts, all three were statistically equivalent.

Table 2. average annual rye grass panicle counts in a one metre square area, for each crop type and treatment. KPPW = knife point press wheel. t=Mean descriptions are reported in transformed data units, and are not de-transformed.

Treatment	**Sowing Rate**	**Wheat (panicles/m^2)**	**Barley (panicles/m^2)**	**Canola (panicles/m^2)**
KPPW (+herbicide)	Low	1.4d	40.8d	59.2c
KPPW (-herbicide)	Low	3.3d	50.0d	49.2c
KPPW (+herbicide)	Standard	12.6bcd	39.2d	140.0b
KPPW (-herbicide)	Standard	10.5cd	71.7cd	63.5c
KPPW (+herbicide)	High	86.3ab	104.2bc	260.8a
KPPW (-herbicide)	High	130.7a	154.2a	231.7a
Seed spread (+herbicide)	Standard	139.5a	137.5ab	229.2a
Seed spread (-herbicide)	Standard	71.5abc	152.5a	215.9a
LSD (P=.05)		0.81t	47.0	58.5
Standard Deviation		0.55t	32.0	39.7
CV		39.01	34.08	25.4

Yield

There was very little variation in yield between treatments sown to wheat. The maximum across all wheat treatments was 700kg/ha. Every treatment yielded equal to its equivalent sowing rate partner, including and excluding herbicide. Both of the high sowing rate treatments were statistically higher yielding than both of the seed spread treatments and the low sowing rate minus herbicide treatments, every other treatment was statistically equivalent.

There was large variation in yield results between the treatments sown to barley. There was a difference of 1.9t/ha between the lowest and highest yielding plots. The low and high rate treatments were significantly different to their equivalent sowing rate partner, both the treatments that had herbicide applied proved to be greater yielding than the treatments with no herbicide. The two standard sowing rate treatments were equivalent to the high sowing rate that had no herbicide applied.

Canola yields were minimised by a frost, so were well under 200kgs, much less than the targeted yield of near 2 tonne. This would have impacted yield outcome.

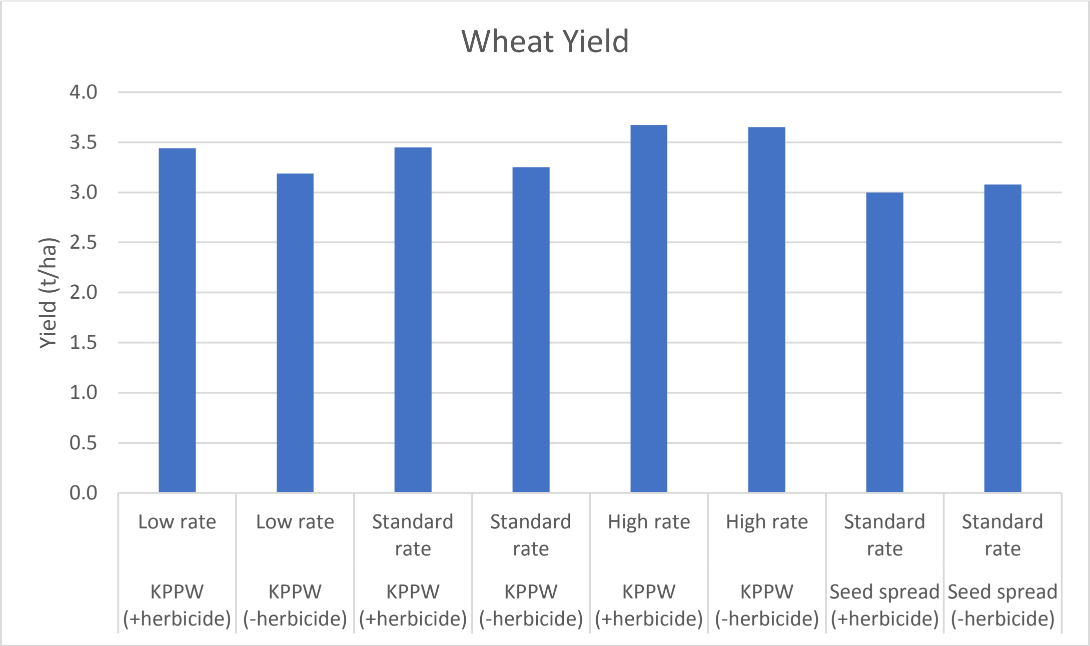

Figure 4. average yield (t/ha) for each wheat treatment. KPPW = knife point press wheel.

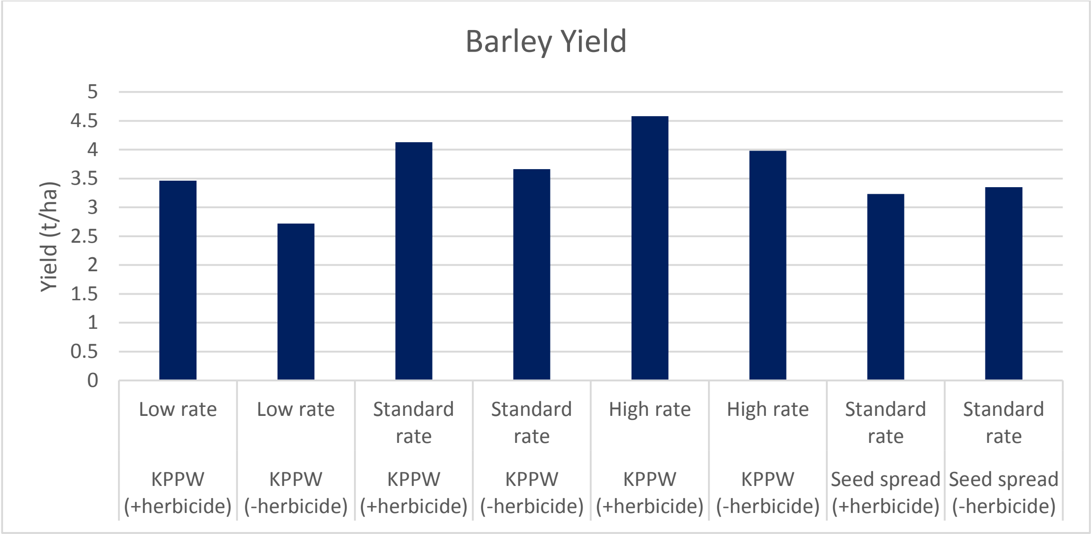

Figure 5. average yield (t/ha) for each barley treatment. KPPW = knife point press wheel.

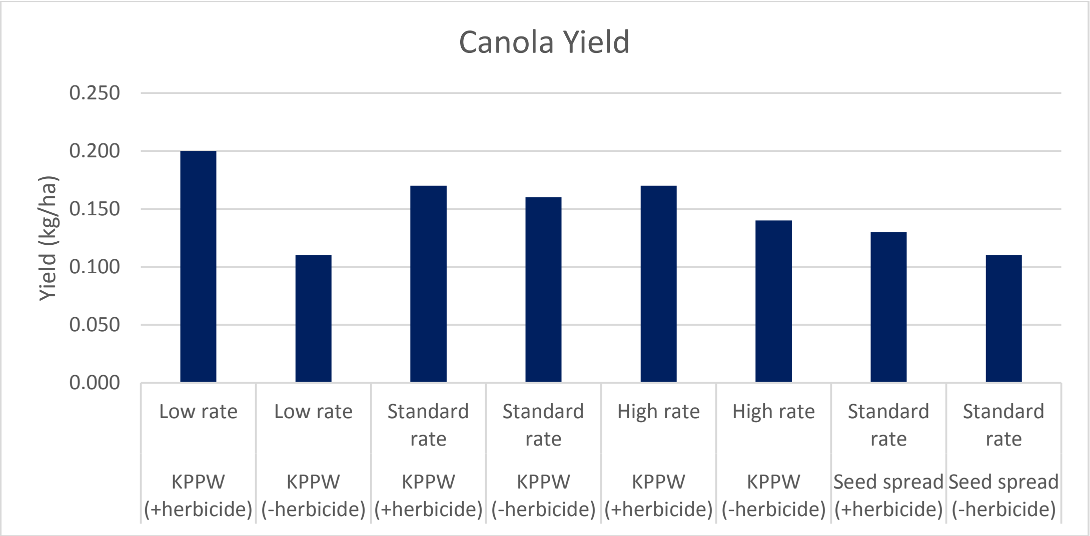

Figure 6. average yield (t/ha) for each canola treatment. KPPW = knife point press wheel.

Discussion

Season Effect

All three crop blocks were sown on May 4, with marginal moisture in the top 10cm of the soil profile.

The year 2017 was the driest year since 2006 for New South Wales (Australian Government BOM 2017a). Rainfall was 18% below average. December was the only month with above average rainfall. Growing season rainfall for the Temora demonstration site was 243mm and 491mm for the whole year. The clear nights meant cooler than average minimum temperatures during winter. The mean minimum temperature for winter for NSW was the lowest since 1997 (Australian Government BOM 2017a). Temora had 65 nights of 0°C or below temperatures, and 4 nights of below -5°C during the growing season (Australian Government BOM 2017b). The climate throughout 2017 undoubtedly had the greatest impact on yields, grain quality and changes in soil characteristics than any other variable.

Emergence

Wheat:

As expected the high sowing rate treatments had the highest emergence, and the seed spread and low rate treatments had lower, similar wheat emergence.

It was unexpected that the high sowing rate plus herbicide had lower emergence than its equal rate treatment minus herbicide.

Numerically every treatment that received herbicide had a significantly lower ARG emergence count than the treatments that didn't receive herbicide. Statistically, only the high sowing rate treatments had a significant difference in ARG emergence.

High sowing rate minus herbicide had the highest wheat and ARG emergence. Wheat is not competitive at this growth stage, and wheat emergence numbers had no impact on ARG emergence.

Barley:
There was no obvious trend in barley emergence when comparing sowing rates or herbicide treatments. Sowing rate had no effect on ARG emergence at all at this early growth stage, however herbicide application had a major effect on supressing ARG plants.

Canola:
Numerically the high sowing rate and seed spread treatments had the highest canola emergence. Statistically there was no trend in emergence as most treatments were statistically equivalent.

Sowing rate had no effect on ARG emergence in the treatments that had herbicide applied. However, there were statistical differences in ARG emergence in treatments that did not receive herbicide, but this was most likely due to spatial variation. Its is unlikely that canola populations could effect ARG emergence numbers at such an early stage.

Panicle count

Wheat:
Low sowing rate treatments had the lowest ARG panicle counts, significantly lower than the high and seed spread treatments, but equivalent to the standard sowing rate treatments.

There was no statistical difference between equivalent sowing rates where herbicide was or wasn't applied. Herbicide had no effect on ARG panicle numbers.

High early ARG emergence numbers correspond with high panicle numbers in the high sowing rate minus herbicide treatment. This treatment still yielded the same as its sowing rate equal that had herbicide applied, which had much lower ARG emergence and panicle populations.

Barley:
Much like the wheat, the low and standard sowing rate treatments, plus and minus herbicide, had the lowest panicle counts and were all statistically equivalent.

The only time herbicide effected the treatments was in the high sowing rate treatment where the application of herbicide proved to reduce ARG panicle numbers.

Canola:
The canola follows the same trend as the wheat and barley blocks, the low and standard sowing rates have significantly lower ARG panicle counts than the high and seed spread treatments. Evident in all three crops was the fact that crops sown at a high rate run out of room and moisture before they can develop lots of tillers, reducing competition for sunlight against ARG.
Wheat was the best competitor with ARG panicles generally lower in wheat crop compared to barley and canola.

Yields

Wheat:
Very little variation was observed in wheat yields, regardless of sowing rate or herbicide application. Every treatment yielded equal to its equivalent sowing rate partner

Both of the high sowing rate treatments were statistically higher than both of the seed spread treatments and the low sowing rate minus herbicide treatments. Every other treatment was statistically equivalent.

Barley:
Herbicide application had a greater effect on barley yields.
The low and high rate treatments were significantly different to its equivalent sowing rate partner, both of the treatments that had herbicide applied proved to be greater yielding than the treatments with no herbicide.

Canola:
Was really knocked around by the season, a combination of frost and moisture stress impacted yield significantly. The best performing treatment only yielded 200kg/ha.

The low rate herbicide treatment was the only treatment to have a yield statistically higher than its low sowing rate partner that excluded herbicide. All other treatments produced equivalent yields when compared to the sowing partner.

Appendix 1

Figure A1. Trial layout of crop type blocks. B = buffer.

B	8	1	7	2	4	3	6	5	B
B	4	5	8	6	2	7	3	1	B
B	6	3	5	7	1	4	8	2	B
B	1	2	3	4	5	6	7	8	B

Figure A2. Treatment map for each crop type block. Four reps by eight treatments. B = buffer.

References

Llewellyn R, Ronning D, Clarke M, Mayfield A, Walker S, Ouzman J (2016) Impact of Weeds on Australian Grain Production, The cost of weeds to Australian grain growers and the adoption of weed management and tillage practices, report for GRDC. CSIRO, Australia.

05

FarmLink Research Report 2017

Can soil organic matter be increased in a continuous cropping system in the low to medium rainfall zone?

Report Authors

Harm van Rees and Anne Jackman (Cropfacts P/L), Kellie Jones (FarmLink), Jeff Baldock (CSIRO)

Introduction

- Eight trial sites were established across SE Australia to investigate whether soil carbon levels can be increased in No-Till farming, inclusive of adding nutrients to aid the biological breakdown of stubble into soil organic matter. After three and five years of treatments no increase in soil carbon could be demonstrated
- We demonstrated that soil carbon is very unlikely to increase with current farming practices. But we do know that No-Till and stubble retention protects the soil from wind and water erosion and over a longer time-frame the soil carbon levels may increase. However, based on these results it is likely that any potential increases in soil carbon will be small.

Project Partners

FarmLink change • adapt • prosper
CSIRO
Crop Facts Pty Ltd

GRDC project code - CRF00002

Funding Partners

GRDC Grains Research & Development Corporation
Australian Government Department of Agriculture
clean energy future

Why do the trial?

Soil Organic Matter has physical, chemical and biological functions in soil. Increasing soil organic matter levels may improve the capacity of these functions in the soil, thereby improving the soils' resilience to degradation and possibly improving the soils productivity. Increasing soil organic matter also sequesters atmospheric CO_2 which acts as a sink for Green House Gas emissions.

Increasing soil organic matter on broad-acre farms in the Australian wheat-sheep zone has been very difficult to achieve with long term trials showing little or no increase in soil carbon regardless of management practices imposed. Recent research undertaken by CSIRO at a medium to high rainfall site in NSW, has demonstrated that increasing soil carbon was possible if residues are pulverised and incorporated with a rotary cultivator together with an application of sufficient fertiliser nutrients (N, P and S) to enhance soil biological activity to break down the crop residues into soil organic matter (Kirkby et al. 2016). This innovation was adapted to broadacre farming methods and tested over a three and five-year cropping rotation with Farm Groups at eight sites across the southern grain belt. The sites were located at Minnipa - EPARF, Hart, Birchip - BCG and Temora - FarmLink for five years, and SFS -Winchelsea, SFS – Cressy Tasmania, CWFS - Condobolin and MSF - Ouyen.

Soil Organic Matter consists of three fractions – Particulate (POC), Humus (HOC) and Resistant (ROC). The three fractions have different physical, chemical and biological functions in soils: The proportions of the three fractions as components of the soil organic matter were measured and are reported in these results.

POC:
- Reducing soil crusting and improving infiltration,
- Improving soil friability,
- Lowering the soil bulk density,
- Increasing Plant Available Water (note – POC has a small effect on the Drained Upper Limit of the soil but because clay loam soils in relatively dry environments such as in the Temora region are rarely at Drained Upper Limit, this benefit is only minor,
- Storage and cycling of nutrients,
- Food source for soil micro-organisms.

HOC:
- Improving soil friability
- Storage and cycling of nutrients,
- Soil pH buffer (reducing acidification)
- Improving the Cation Exchange Capacity (CEC)
- Food source for soil micro-organisms
- Mineralisation of ammonium and nitrate (plant available N).

ROC:
- Binding detrimental ions (such as aluminium)
- Some effect on the Cation Exchange Capacity (CEC).

It is clear that if soil carbon levels can be increased, the benefits for improving the soil physical, chemical and biological condition would be significant.

How was it done?

Eight sites were established in SE Australia to test whether soil carbon levels can be increased by retaining stubble and applying additional nutrients to enhance soil biological activity to breakdown the stubble into soil organic matter. Four of these sites were maintained for three years, the other four sites for five years. The site with FarmLink in Temora was maintained for five years.

The trial compared stubble retention versus stubble removal, with the application of additional fertiliser nutrients to aid the breakdown of stubbles into soil organic matter over a cropping rotation. Each season the stubble load of the previous crop was determined, and additional nutrients were applied as a treatment to enhance the breakdown of stubble into soil organic matter.

Soil microbes use stubble as a food source and convert stubble into humus. Stubble is carbon rich relative to the other essential nutrients required by microbes and additional nutrients are required by the soil microbes to convert stubble into humus. The amount of NPS required by the microbial population to break down stubble into humus is worked out from:

- 1 tonne of carbon as humus contains 80kg N, 20kg P and 14kg S
- 1 tonne of wheat stubble contains 450kg carbon, of which 70% is lost to the atmosphere (hence 135kg carbon is retained for every tonne of stubble)
- For the soil microbes to convert this amount of stubble carbon into humus requires 10.8kg N, 2.7kg P and 1.9kg S
- 1 tonne of wheat stubble already contains 5kg N, 0.5kg P and 1kg S
- Hence for every tonne of wheat stubble an additional 5.8kg N, 2.2kg P and 0.9kg S is required to enable the soil microbes to break down stubble into humus.

The trial was established at the FarmLink experimental site at Temora in 2012. Treatments were replicated 4 times and consisted of:

- Stubble: (i) retained and left standing; (ii) cultivated and incorporated prior to sowing; (iii) removed prior to sowing.
- Nutrients: (i) normal application of NPS to optimise production; (ii) additional nutrients applied at sowing to enhance microbial activity to breakdown stubble into soil organic matter. (Note – the Yield Prophet model was used to optimise N requirements in-crop)

The trial ran for five cropping seasons (2012 to 2016). At the end of the trial, in March 2017, all treatment plots were soil sampled to 30cm depth with three replicate cores taken in each plot. Each core was divided into 0-10 and 10-30cm sections. Each sample was air dried and analysed for Bulk Density, Total soil carbon (Leco) and the fractions of soil organic matter – Particulate (POC), Humus (HOC) and Resistant (ROC) using MIR.

Treatment crop yields were recorded.

What happened?

i. Trial rotation and crop yield.

Over the five-year trial there were no differences in yield between treatments (Table 1). Which implies that the additional nutrients applied as a treatment were not used by the crop for yield but were available to the soil microbes for potential stubble breakdown into humus.

Table 1. Crop rotation and yield over five years of treatments (2012 to 2016) at Minnipa.

Stubble treatment	**Nutrition treatment**	**Yield (t/ha)**	**Yield (t/ha)**	**Yield (t/ha)**	**Yield (t/ha)**	**Yield (t/ha)**
		2012	**2013**	**2014**	**2015**	**2016**
GSR (April to October rainfall mm)		179	260	315	309	685*
Crop type / variety		Wheat Spitfire	Wheat Dart	Canola TT	Wheat Suntop	Barley LaTrobe
Stubble removed	Normal practice	6.3	3.1	2.3	2.7	3.4
Stubble removed	" plus NPS	6.8	3.1	2.5	3.4	4.3
Stubble standing	Normal practice	6.3	3.1	2.4	2.6	2.8
Stubble standing	" plus NPS	6.6	3.1	2.6	3.2	4.0
Stubble incorporated	Normal practice	6.9	3.1	2.5	2.8	4.0
Stubble incorporated	" plus NPS	6.4	3.2	2.4	2.8	3.3
	LSD (0.05)	**0.6**	**NS**	**NS**	**NS**	**NS**

* *severe waterlogging from 262mm of rain in September resulted in flooding and waterlogging (trial was difficult and uneven to harvest)*

At the other three sites with a five year rotation (Minnipa, Hart and Birchip) there were no differences in crop yield between treatments.

ii. Change in soil carbon after five years of treatments

The average soil carbon content of the topsoil (0-10cm) at Temora was 1.6% and 0.7% in the subsoil (10-30cm). After five years of trial work there was no difference in total soil carbon (t/ha, 0-30cm) at Temora (Table 2) nor at the other three trial sites. (Note: in this study soil carbon was measured with the Leco technique, these values are generally 20% higher than the more traditionally used analysis for soil carbon with the Walkley Black technique).

Table 2. Soil carbon (t/ha, 0-30cm) after five years of treatments (2012 to 2016) at four trial sites

Stubble treatment	Nutrition treatment	Soil C (Leco) 0-30cm (t/ha)			
		EPARF	Hart	BCG	FarmLink
Stubble removed	Normal practice	38.1	50.5	31.8	42.9
Stubble removed	" plus NPS	38.3	53.0	29.8	44.0
Stubble standing	Normal practice	37.0	49.7	32.0	42.5
Stubble standing	" plus NPS	35.7	49.7	31.9	44.5
Stubble incorporated	Normal practice	37.9	51.9	30.9	39.8
Stubble incorporated	" plus NPS	39.0	53.0	31.4	41.5
Double stubble	Plus NPS		52.6*		
	LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**

* *Annual application of double the stubble load plus additional NPS at Hart only*

At the Hart site an extra treatment was included – each year the stubble load was doubled and the required additional nutrients were applied. This treatment did not result in higher soil carbon levels (Table 2) after five years of experimentation.

iii. Soil carbon fractions

At FarmLink and the other three trial sites the treatments did not result in changes in the soil organic matter fractions. After five years of treatment applications the soil carbon fraction proportions were: 10% POC, 68% HOC and 22% ROC.

What does this mean?

In the SE Australian low to medium rainfall zone it is difficult to increase soil carbon levels using current farming techniques, even if additional nutrients are applied to enhance soil microbial activity for the breakdown of stubble into soil organic matter. The previous research undertaken in southern NSW where significant increases in soil carbon were measured (Kirkby et al. 2016), included pulverising the residues with a flail mulcher followed by incorporation with a rotary cultivator – this treatment was not applied in our trials because we regarded it unlikely that farmers could be persuaded to pulverise stubbles and cultivate the soil to see a potential increase in soil carbon.

Eight sites in SE Australia undertook the trial work outlined in this paper, four of the sites were maintained for three years, and four sites – including at Temora – for five years. At all sites the result was the same – an increase in soil carbon could not be demonstrated with the treatments outlined in this paper.

The take home message in relation to soil carbon is that it is unlikely to increase with current farming practices. But we do know that No-Till and stubble retention protects the soil from wind and water erosion and over a longer time-frame soil carbon levels may increase. However, based on these results it is likely that any potential increases in soil carbon will be small.

References

Kirkby CA, Richardson AE, Wade LJ, Conyers M, Kirkegaard JA (2016).
Inorganic nutrients increase humification efficiency and C-sequestration in an annually cropped soil. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0153698

Acknowledgements

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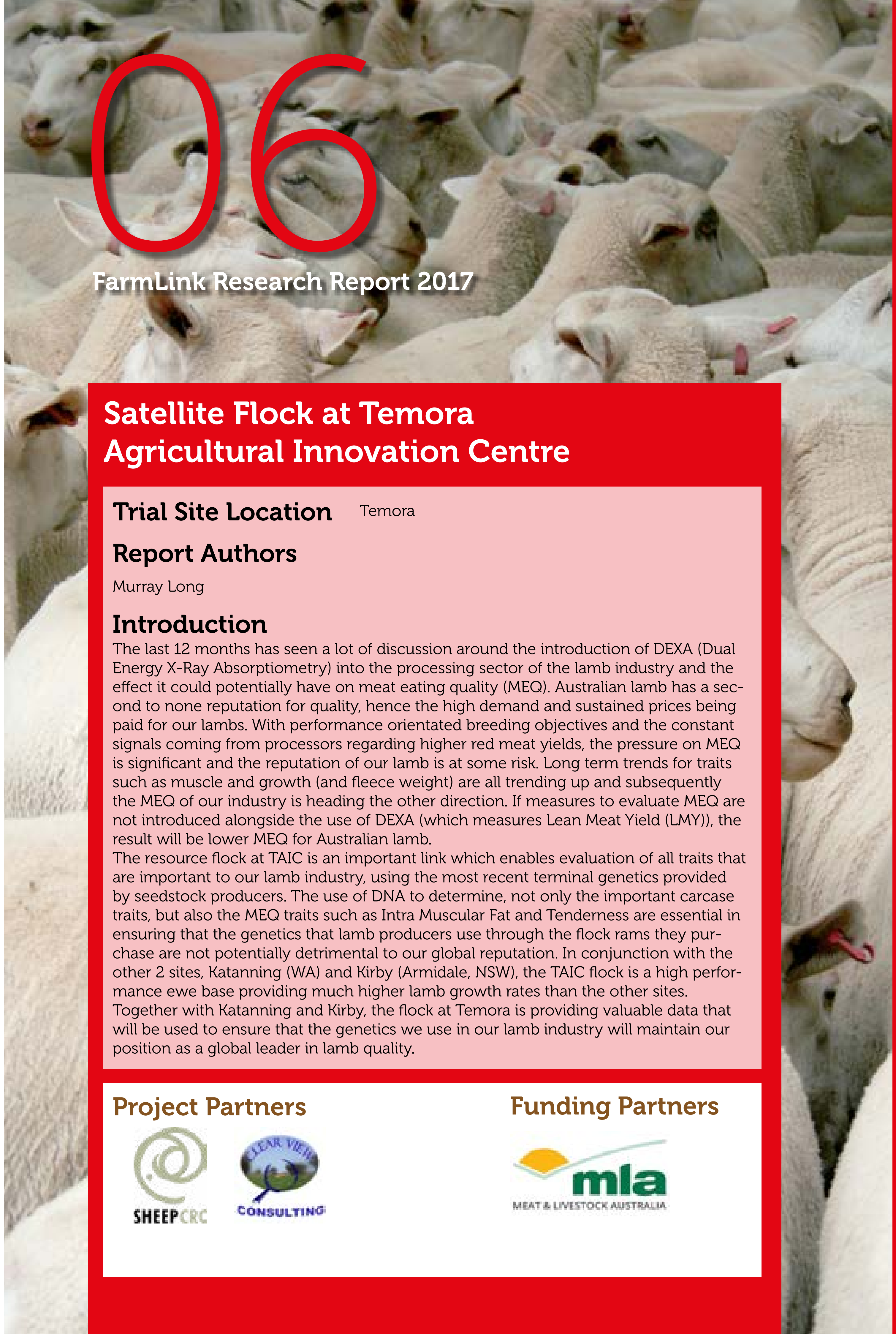


06

FarmLink Research Report 2017

Satellite Flock at Temora Agricultural Innovation Centre

Trial Site Location

Temora

Report Authors

Murray Long

Introduction

The last 12 months has seen a lot of discussion around the introduction of DEXA (Dual Energy X-Ray Absorptiometry) into the processing sector of the lamb industry and the effect it could potentially have on meat eating quality (MEQ). Australian lamb has a second to none reputation for quality, hence the high demand and sustained prices being paid for our lambs. With performance orientated breeding objectives and the constant signals coming from processors regarding higher red meat yields, the pressure on MEQ is significant and the reputation of our lamb is at some risk. Long term trends for traits such as muscle and growth (and fleece weight) are all trending up and subsequently the MEQ of our industry is heading the other direction. If measures to evaluate MEQ are not introduced alongside the use of DEXA (which measures Lean Meat Yield (LMY)), the result will be lower MEQ for Australian lamb.

The resource flock at TAIC is an important link which enables evaluation of all traits that are important to our lamb industry, using the most recent terminal genetics provided by seedstock producers. The use of DNA to determine, not only the important carcase traits, but also the MEQ traits such as Intra Muscular Fat and Tenderness are essential in ensuring that the genetics that lamb producers use through the flock rams they purchase are not potentially detrimental to our global reputation. In conjunction with the other 2 sites, Katanning (WA) and Kirby (Armidale, NSW), the TAIC flock is a high performance ewe base providing much higher lamb growth rates than the other sites. Together with Katanning and Kirby, the flock at Temora is providing valuable data that will be used to ensure that the genetics we use in our lamb industry will maintain our position as a global leader in lamb quality.

Project Partners

SHEEP CRC

CLEAR VIEW CONSULTING

Funding Partners

mla MEAT & LIVESTOCK AUSTRALIA

Background

The contract was awarded to operate a resource flock at Temora in 2015, and last year an artificial insemination program involving 200 ewes joined to 61 sires comprising of predominately Poll Dorset and White Suffolk genetics with a few Southdown and Suffolk sires was conducted. The resulting lambs were processed at JBS Bordertown in December (5 months of age) and averaged close to 30Kg dressed weight with a dressing % of over 47%. These lambs consistently achieved growth rates of 400-450 gms/day over the 5 months and provided a scenario for evaluation not previously experienced from the other 2 resource flock sites.

DNA was taken from not only the lambs in this trial but also the ewes used and coupled with the pedigree information of the ewes, provides a complete genetic picture of the traits and their correlations. The process of linking DNA to both phenotypic and hard to measure traits is achieved through the analysis of a SNP (pronounced "snip") chip which contains 50,000 pieces of DNA or SNP's. In simple terms the presence or absence of these SNP's determines the effect those SNP's have on the expression of that trait. DNA is collected on a blood card and sent for processing. The information comes back to Sheep Genetics Australia and is presented to breeders or industry as a breeding value in the same way that ASBV's (Australian Sheep Breeding Values) are expressed. The process of evaluating MEQ traits is expensive and time consuming and the results from the previous years lambs have just been finalised and are currently being evaluated.

The number of ewes from the 2017 joining was increased to 300 and involved the use of 70 terminal sires from across a wide cross section of seedstock producers. It is important to note that for the first time this year, seedstock producers donated the semen for this project whereas in previous years they had been compensated for the cost of collection. The mix of sires also included genetics from the Dorper and white Dorper breeds as well as the Poll Dorset, White Suffolk, Suffolk and Southdown breeds.

The intention is to maintain the number of joined ewes at 300+ for 2018 with a similar mix of young sires. By continually updating the DNA data base and the correlations between observed and genomic predictions, the increased use of DNA as a performance evaluation will continue to ensure that we select the best genetics for use within our commercial flocks.

Results

Scanning of the ewes in April showed a conception rate of around 51.5% for the AI program which was below expectations and certainly below what would normally be expected from a typical AI program using White Suffolk ewes. This was probably due to several factors, firstly the ewes were consistently in a higher than average condition score due to the amount of feed on offer leading up to the AI program which doesn't always go well for high conception rates and secondly, the day(s) of the AI coincided with 40°C+ temperatures, again not ideal in reducing stress on the ewe.

The ewes lambed early in July under a totally different scenario to the previous year when we experienced cold wet miserable conditions. 245 lambs were born giving 156% lambing rate with only 6% of lambs either dead at birth or not surviving the first 48 hrs, a good result and due to the favourable lambing conditions. Of the ewes scanned in lamb, only 3.5% of scanned foetuses (9) were lost between scanning and lambing, a much better result than the previous year (18%). There were a few lamb losses between lambing and weaning due to mismothering and unexplained circumstances resulting in 215 lambs to weaning of which 211 were sent to JBS for processing

The lambs were grown in Lucerne pasture at TAIC and achieved average growth rates of 466 gms/day from birth to 3 months of age, falling away a fraction when the drier conditions began to take effect just prior to sale time.

At 4 months of age, these lambs were scanned for muscle and fat then slaughtered in 2 groups at JBS, Bordertown to allow for the expansive measurements that were conducted on each carcase. The lambs this year were a more even group of lambs and for the first 3 months achieved growth rates slightly higher than the lambs from the previous year. The dressing percentage of these lambs was 50%, a figure reinforced by the scan data that showed the muscling on these lambs to be exceptional. Average weight at scanning was 53.9 Kg with a fat depth of 4.6 mm and muscle depth of 31.2 mm.

	14th October	**6th November**
Average Weight (Kg)	49.4	53.9
Growth Rate (Gms/day)	466	418

At slaughter, the following results were achieved;

Weight Class Summary	**LMB**		
Range	Bodies	%	Total Weight
16-17.99kg	2.0	0.9	35.6
18-19.99kg	6.0	2.8	114.1
20-21.99kg	19.0	9.0	401.7
22-23.99kg	21.0	10.0	481.2
24-25.99kg	37.0	17.5	925.3
26-29.99kg	75.0	35.5	1501.0
30-31.99kg	27.0	12.8	837.8
32kg&Over	24.0	11.5	805.9
Total	211.0	100.0	5682.6
Average Carcase weight			26.93

Fat Class Summary	**LMB**	
Range	Bodies	%
Fat Class 1	1.0	0.5
Fat Class 2	47.0	22.4
Fat Class 3	71.0	33.5
Fat Class 4	52.0	24.6
Fat Class 5	40.0	19.0
Total	211.0	100.0

Discussion

The importance of this information is not limited to the stud producers who can access the individual breeding values for a wide range of traits.

There is no doubt that as we increase the scope and accuracy information available to industry, lamb processors will use this information to select the right lambs to ensure maximum return for their business and also to ensure that the lambs they are processing fit consumer demands. There are already grids that are priced based such as the one below that penalise on weight and fat score and reward for lambs that fall within the grid where they can maximise returns. If predictions of Lean Meat Yield, that is the percentage of saleable red meat on each carcase, are achievable through the use of DEXA, such a grid could possibly exist based on LMY with price signals for lambs that fall below a specific level. As LMY is negatively correlated to MEQ, these would send a dangerous message to lamb producers. When MEQ becomes possible to measure "in chain" another grid could potentially exist incorporating all these traits. Sounds like a nightmare? Well not if the lamb producer is able to access the level of technology that can ensure the lambs they are breeding and the rams they are sourcing are meeting the criteria that processors demand.

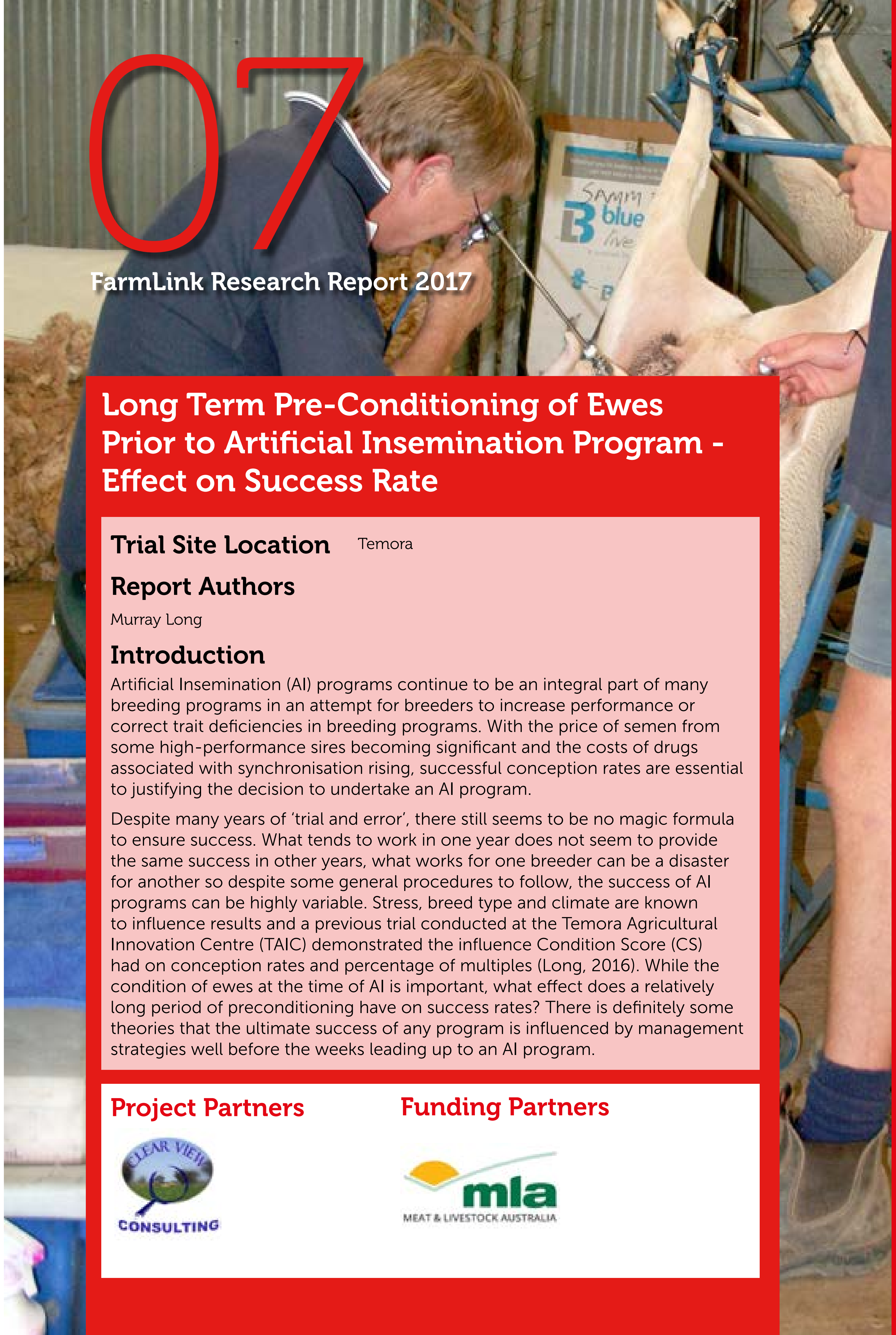
Grade	Fat Scr	Teeth	Price										
New Season Lambs			**8.0-**	**8.0+**	**12.0+**	**16.0+**	**18.0+**	**20.0+**	**22.0+**	**24.0+**	**26.0+**	**30.0+**	**32.0+**
N1	1	Milk	0.40	1.60	2.00	5.30	6.10	6.10	6.10	6.10	6.10	6.10	5.80
N2	2	Milk	0.40	1.90	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	6.10
N3/N4	3-4	Milk	0.40	1.90	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	6.10
N5	5	Milk	0.40	1.90	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	6.10
Second Cross Lambs			**8.0-**	**8.0+**	**12.0+**	**16.0+**	**18.0+**	**20.0+**	**22.0+**	**24.0+**	**26.0+**	**30.0+**	**32.0+**
S1	1	Milk	0.20	1.20	2.00	5.30	6.10	6.10	6.10	6.10	6.10	6.10	5.60
S2	2	Milk	0.20	1.50	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	5.90
S3/S4	3-4	Milk	0.20	1.50	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	5.90
S5	5	Milk	0.20	1.50	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	5.90
First Cross Lambs			**8.0-**	**8.0+**	**12.0+**	**16.0+**	**18.0+**	**20.0+**	**22.0+**	**24.0+**	**26.0+**	**30.0+**	**32.0+**
F1	1	Milk	0.20	1.20	2.00	5.30	6.10	6.10	6.10	6.10	6.10	6.10	5.60
F2	2	Milk	0.20	1.50	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	5.90
F3/F4	3-4	Milk	0.20	1.50	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	5.90
F5	5	Milk	0.20	1.50	2.30	5.60	6.40	6.40	6.40	6.40	6.40	6.40	5.90

The use of genomics at the lamb producer level is now a reality with whole flock genomic profiling available to Merino producers who can determine the average level of performance in their ewe flock for a range of traits. This enables better selection of flock rams to correct any deficiencies within their flock.

The use of genomics for terminal and maternal seedstock producers has been significant and the genomic predictions now form part of the ASBV that you can use to select flock rams. The information gained from the resource flocks at Temora, Katanning and Kirby ensure that the genomic prediction from DNA are constantly updated to ensure the values are accurate as new sires enter the industry.

The lamb industry will change as more information becomes available to not only lamb producers, but processors and consumers.

The MLA resource flocks are funded through until 2020 and flocks such as the one located at TAIC must be maintained if the information we have already gathered is to retain its significance and accuracy.



07

FarmLink Research Report 2017

Long Term Pre-Conditioning of Ewes Prior to Artificial Insemination Program - Effect on Success Rate

Trial Site Location

Temora

Report Authors

Murray Long

Introduction

Artificial Insemination (AI) programs continue to be an integral part of many breeding programs in an attempt for breeders to increase performance or correct trait deficiencies in breeding programs. With the price of semen from some high-performance sires becoming significant and the costs of drugs associated with synchronisation rising, successful conception rates are essential to justifying the decision to undertake an AI program.

Despite many years of 'trial and error', there still seems to be no magic formula to ensure success. What tends to work in one year does not seem to provide the same success in other years, what works for one breeder can be a disaster for another so despite some general procedures to follow, the success of AI programs can be highly variable. Stress, breed type and climate are known to influence results and a previous trial conducted at the Temora Agricultural Innovation Centre (TAIC) demonstrated the influence Condition Score (CS) had on conception rates and percentage of multiples (Long, 2016). While the condition of ewes at the time of AI is important, what effect does a relatively long period of preconditioning have on success rates? There is definitely some theories that the ultimate success of any program is influenced by management strategies well before the weeks leading up to an AI program.

Project Partners

Clear View Consulting

Funding Partners

mla
MEAT & LIVESTOCK AUSTRALIA

Background

As part of the Meat and Livestock Australia (MLA) resource flock located at the Temora Agricultural Innovation Centre (TAIC), 300 mixed aged White Suffolk ewes were joined using laparoscopic AI on the 31stJanuary/1st February 2017. These ewes were programmed using CIDR's and given 2ml PMSG (Serum Gonadotrophin) after CIDR removal which was staggered to eliminate any timing effects.

The ewes had had vastly different histories for the 12 months prior to commencement of AI programming with one group flushed on Lucerne before CIDR insertion.

Top mob - The ewes from the previous years AI program at TAIC which had been grazed on Lucerne all through lambing to weaning when they were shifted onto cereal stubbles through to AI

General mob – These ewes lambed down and reared lambs on natural pasture the previous year at TAIC and were moved to Lucerne after their lambs were weaned. They were blended with the other mobs AI at CIDR insertion.

Home mob – A group of ewes that were introduced to TAIC from a dryland block where they had lambed and weaned lambs on natural pasture. Upon being shifted to TAIC, were given first preference on cereal stubbles through to CIDR insertion when combined with the other mobs.

The ewes were assessed for condition score at weaning the previous year, condition scored and weighed prior to being programmed, at scanning, conditioned scored at lambing and weights and condition scores taken at weaning. The objective was to, despite the different histories, achieve similar condition scores and weights on all ewes at AI (see Table 1)

Table 1. Average Condition score and weights at stages during trial.

	WEAN 2016	JOINING 2017		SCANNING 2017		PRE LAMBING	WEANING 2017	
	CS	CS	WT	CS	WT	CS	CS	WT
TOP	3.7	4.1	85.2	4	88.5	4	4	92.3
GENERAL	2.6	4.2	86.9	3.9	86	3.7	4.1	98
HOME	2.8	3.5	75	3.6	82.4	3.7	4	95.6
AVERAGE		**4.0**	**83.2**	**3.9**	**86.6**	**3.9**	**4**	**97.1**

All mobs were combined at CIDR insertion and run together to AI from which the AI sires were randomly allocated. The program was conducted over 2 days which also provided vastly different climatic scenario as seen in Table 2. The effect of the different temperatures on conception was also assessed.

Table 2. Climate data from TAIC for the days of the AI program

TEMORA	MIN Temp. (°C)	MAX Temp. (°C)	Rainfall (mm)	Comment
31st January 2017	21.0	37.1	0	Followed 43 °C day
1st February 2017	19.4	22.9	2.4	*Lowest Max in Feb*

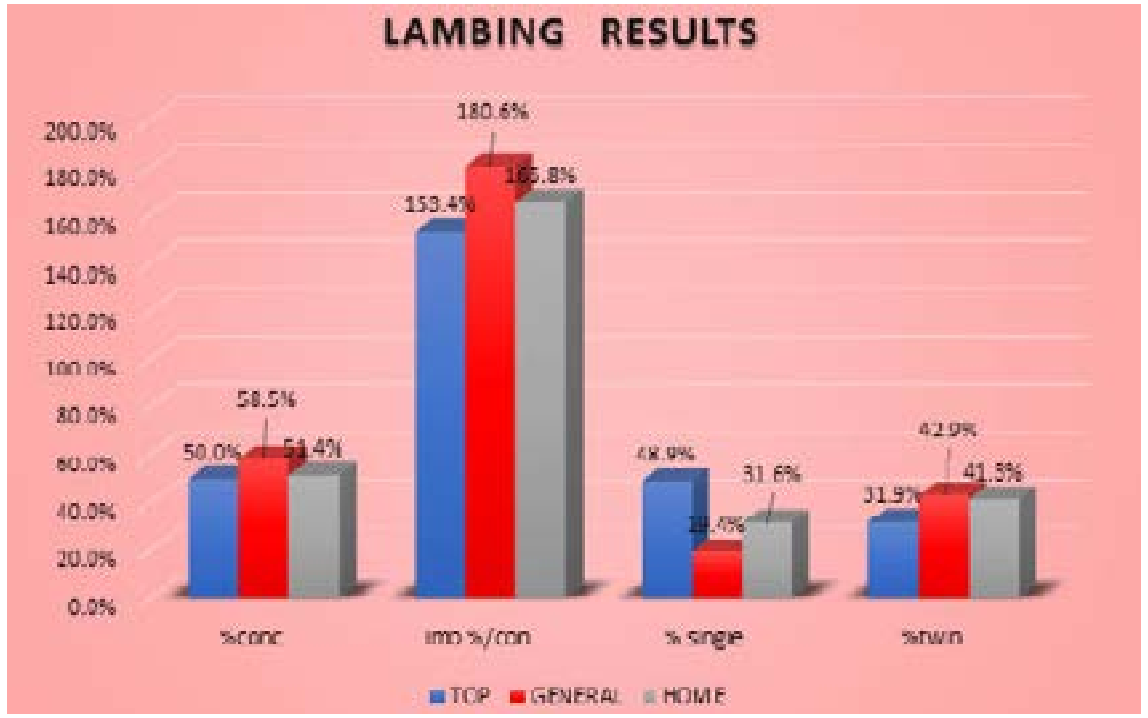
Following AI, the combined mobs were managed together on cereal stubble until lambing when they were placed on Lucerne through lambing to weaning. Backup rams were introduced at day 12 post AI and scanning conducted at 66 days post AI. At pregnancy scanning, the ewes were assessed as either in lamb to the AI program (singles and multiples), in lamb to the backup ram (backup) or dry at that time. The rams were still with the ewes at scanning raising the possibility that some of the dry ewes may have had undetectable foetuses. All but two (2) ewes from the combined mobs eventually lambed however the early scanning did perhaps indicate the readiness of the ewes to conceive quickly to the backup ram once AI had failed.

Results

The AI program delivered an overall conception rate across the two days of 52%, just below the average figure for you would expect for terminal ewes (industry average 60-65%). However, there was a range in conception rates across the treatments with the GENERAL mob having the best success rate (59%) and the TOP and HOME mob averaging 50% and 51% respectively.

When the lambing percentage was calculated for each treatment, the difference between the treatments was even more evident. The GENERAL mob had a lambing percentage of 181% whereas the TOP mob was 153% and the HOME mob slightly better at 166%. This was as a result of the number of multiples conceived compared to singes as seen in Figure 1. with almost half the conceptions in the TOP mob being singles compared to only 19% in the GENERAL mob. With only 3 sets of triplets scanned across the treatments, these were not included in the results.

Figure 1. Comparison of lambing percentages across treatments



When the results of the scanning in relation to the conceptions from the backup ram were analysed, it was the TOP mob that had the highest percentage of ewes immediately conceiving (85%) and consequently the lowest percentage of dry ewes detected at the early scanning. The GENERAL mob was the next best at conception to the backup ram (73%) with the HOME mob not as quick to conceive to the backup (69%) and consequently the highest percentage of dry ewes. It must be remembered that all but 2 of these ewes across all treatments lambed so this comparison is only looking at the ability of the ewes to get in lamb immediately after the AI failed which may provide some indication of the difference between conception using AI compared to natural joining.

The effect of temperature on success rate was not as you might expect with the ewes inseminated on 31st January (hotter day) achieving a conception rate of 57.2% while those inseminated on the cooler day (1st February) has a conception rate of 48.5%. The breakup of these results is seen in Table 3.

Table 3. Effect of temperature conditions on conception rates

	DAY 1 (31st January)	DAY 2 (1st February)
CONCEPTION %	57.2%	48.5%
SINGLES	21.4%	20.1%
TWINS/TRIPLETS	35.9%	28.6%
DRY	11.3%	8.0%
BACKUP	31.4%	43.3%

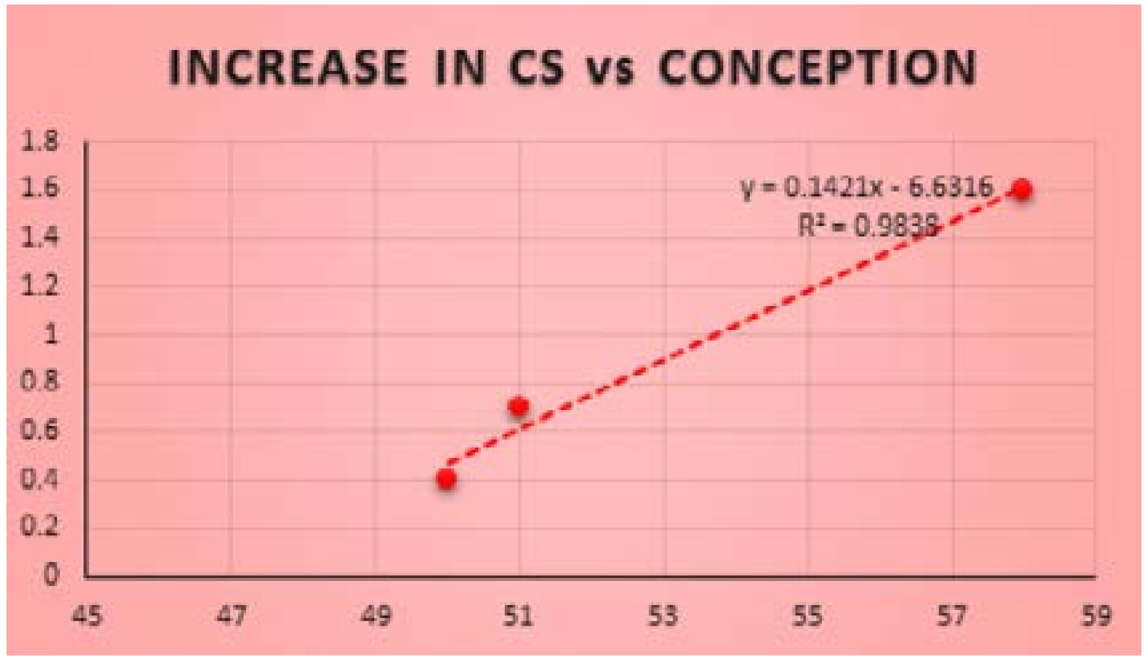


Figure 2. Increase in condition score effect on AI Conception.

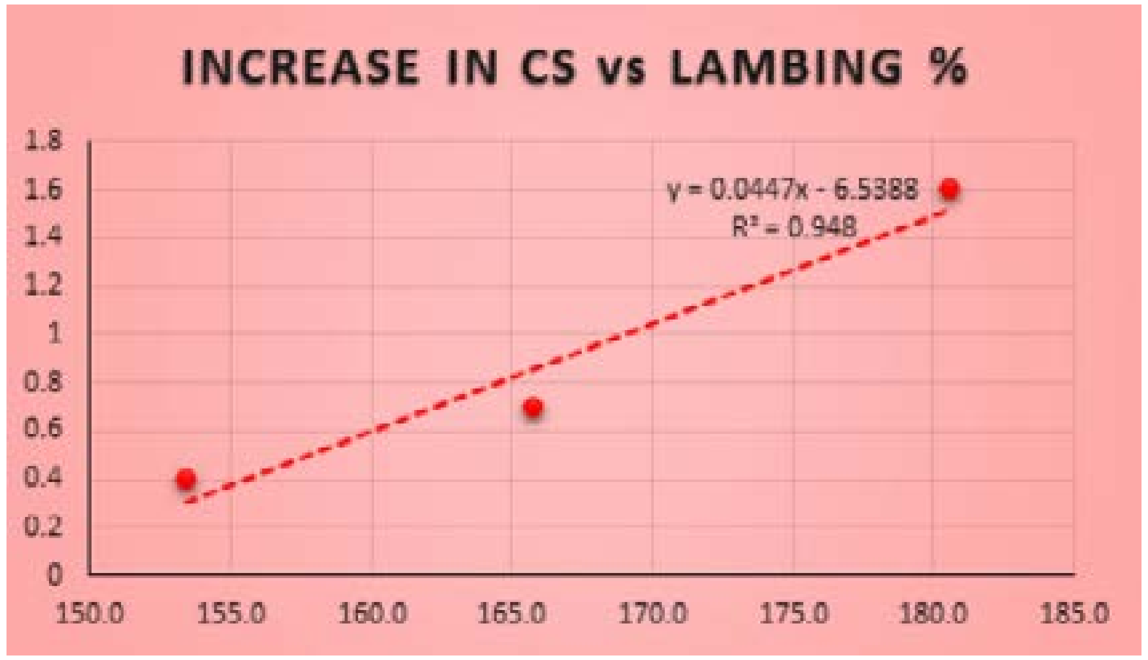


Figure 3. Increase in Condition Score and effect on lambing percentage

Discussion

Initial comparison of the results would seem to indicate that maintaining ewes at a high condition score and body weight through lambing to the following joining seems to hinder good conception in an AI program. This not only affected conception but also the lambing percentage with a much higher proportion of singles to multiples. The best results were achieved by using ewes that had reared lambs and lost condition score which was subsequently increased leading up to AI by grazing on Lucerne. The ewes that were grazed on good cereal stubbles to increase body CS and weight (HOME) did not achieve the same gain in conception and lambing percentage as the GENERAL mob but still much better than the TOP mob. Was this a Lucerne effect or was there something else driving the gain in conception? It has long been considered that Lucerne associated with AI programs is not conducive to successful conception rates which tends to conflict with the flushing effect of Lucerne in natural joining programs (MLA news, 2016). The other finding from this study that seems to confirm that AI programs are inherently different to the processes of natural joining is the ease at which a majority of the TOP mob fell immediately in lamb to the backup ram but failed to achieve good conception rates to AI.

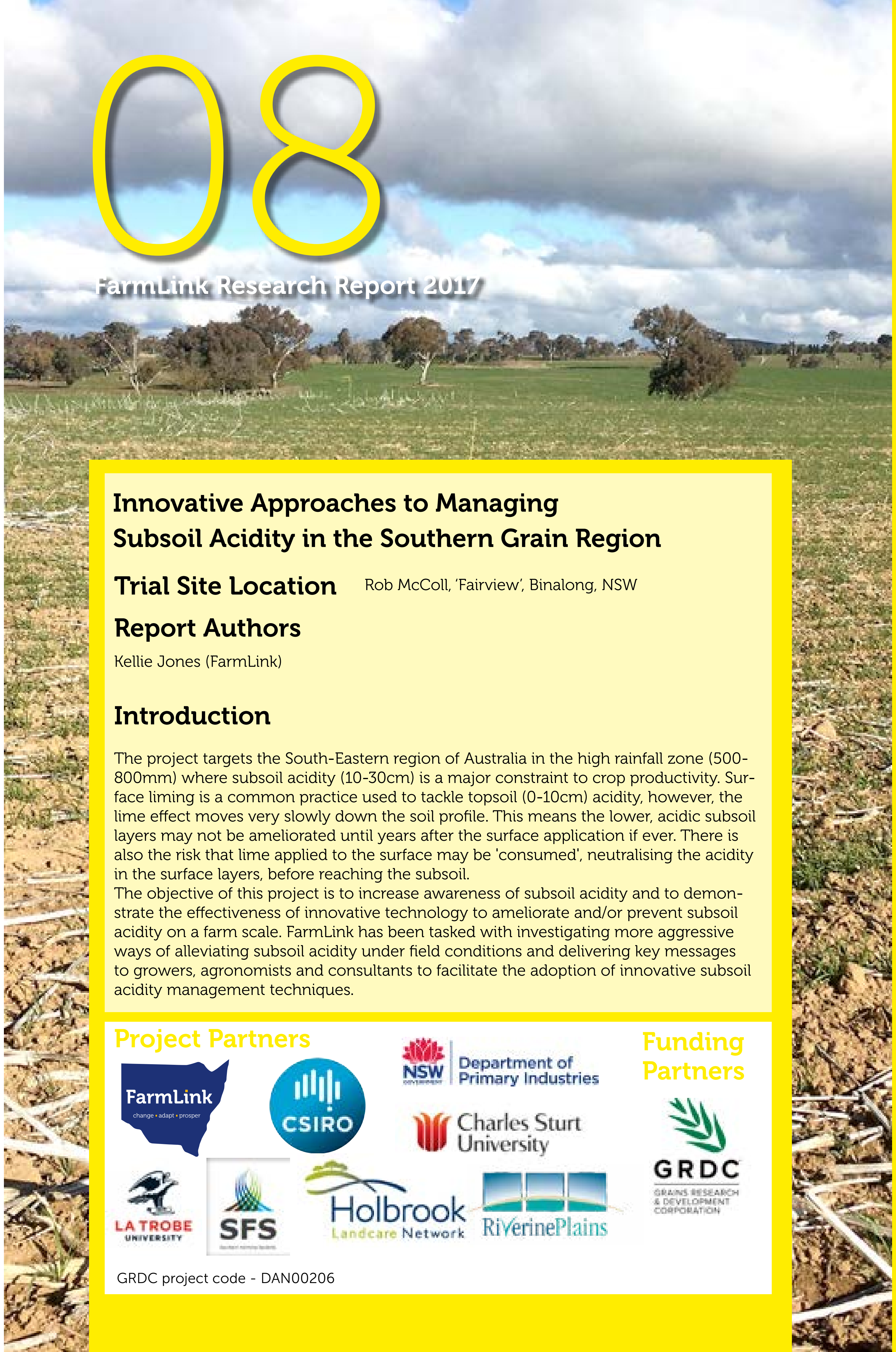
So, what could be the reason for the differences in conception and lambing percentages in this study? There has long been the belief that it is not what happens on the day or the days leading up to an AI program that determines the success of the program but it all happens well before AI date. If we isolate the condition scores of the 3 treatments and look at the increase in CS between weaning in 2016 and joining in 2017 ((4 months), there is a good relationship between the magnitude of increase in CS and the success of the program as seen in Figure 2 and 3.

Although the number of data points is limited to the average of the 3 treatments, there is a general trend indicating the bigger the differential (increase) in CS between weaning and joining with AI, the better the success rate of the AI program. The effect using Lucerne had on this result cannot be determined but if there was any negative effect using Lucerne, it has been well and truly compensated for by the greater increase in condition score. This result of dropping CS and then "rebuilding" condition has been espoused by many good sheep breeders as essential to gaining the best results from a breeding program. The general rule of thumb for an AI program is to have them on a rising plane of nutrition leading up to and continuing through the AI program. This was the case in this program as the ewes continued to gain weight and CS post AI, but it may also be the degree of the increase in CS that has an effect.

The effect of temperature on the day of the AI program is perhaps further evidence that it is not so much the influence of a single occurrence but a combination of events that ultimately determines the success or otherwise of an AI program. The process itself assumes that given, the ewes are cycling on the day of insemination, all ewes will be potentially in lamb when they are returned to the paddock. It is the combination of events that happen around that day that ultimately determines whether the embryo 'sticks' or not. The fact that the cooler day produced a lower conception rate does not correspond with the theory that heat stress is detrimental to good AI success but there are potentially other factors that could have affected the result? The procedures followed were the same for both days; just another anomaly of AI and why results are sometimes highly unpredictable.

Acknowledgements

The satellite flock is funded by MLA as part of the maintenance of the national resource flock to continue the findings from the Sheep CRC regarding genomic analysis.



08

FarmLink Research Report 2017

Innovative Approaches to Managing Subsoil Acidity in the Southern Grain Region

Trial Site Location Rob McColl, 'Fairview', Binalong, NSW

Report Authors

Kellie Jones (FarmLink)

Introduction

The project targets the South-Eastern region of Australia in the high rainfall zone (500-800mm) where subsoil acidity (10-30cm) is a major constraint to crop productivity. Surface liming is a common practice used to tackle topsoil (0-10cm) acidity, however, the lime effect moves very slowly down the soil profile. This means the lower, acidic subsoil layers may not be ameliorated until years after the surface application if ever. There is also the risk that lime applied to the surface may be 'consumed', neutralising the acidity in the surface layers, before reaching the subsoil.

The objective of this project is to increase awareness of subsoil acidity and to demonstrate the effectiveness of innovative technology to ameliorate and/or prevent subsoil acidity on a farm scale. FarmLink has been tasked with investigating more aggressive ways of alleviating subsoil acidity under field conditions and delivering key messages to growers, agronomists and consultants to facilitate the adoption of innovative subsoil acidity management techniques.

Project Partners

FarmLink
CSIRO
NSW Department of Primary Industries
Charles Sturt University
La Trobe University
SFS
Holbrook Landcare Network
RiverinePlains

Funding Partners

GRDC Grains Research & Development Corporation

GRDC project code - DAN00206

REPORT ONE

Objectives

FarmLink's role is to establish two paddock scale replicated experiments to –

- Increase awareness of subsoil acidity
- Demonstrate effectiveness of innovative technology to ameliorate and/or prevent subsoil acidity on a farm scale

Method

Site 1 – Binalong, established 2016

One of the two of our large-scale on-farm experiment sites was established in the east of the FarmLink region in Binalong, NSW, in late February 2016. The site is located in the high rainfall zone (HRZ), with an average annual rainfall of 647mm. Sites were selected with the following target soil characteristics -

- Target sub-surface soil acidity
  - 0-10cm: pH ($CaCl_2$) 4.0-4.5. If limed, preferring <5.0%
  - 10-20cm: pH ($CaCl_2$) < 4.3, exchangeable Al% >20%
  - 20-30cm: pH ($CaCl_2$) < 4.6, exchangeable Al% >10%
- Location
  - High annual rainfall >500mm
  - Flat, uniform
  - Cropped for three consecutive years

The paddock is severely acidic and a high exchangeable aluminium level, fitting the trial site selection criteria perfectly.

The experiment included four treatments replicated three times (see *Appendix* for trial layout). The four treatments include surface liming, deep ripping, deep ripping with lime and deep ripping with an organic amendment, lucerne pellets were selected as the organic amendment. See *Table 1* for a more detailed description of the treatments. The treatments were implemented in the first year of the trial, with the site to be monitored for three years (2016-2018). The second year of monitoring was completed in 2017.

Table 1. treatments and descriptions for Binalong site implemented in 2016

	Treatments	Description
1	Surface liming	No lime was added due to the site receiving 3.5t/ha of surface lime in 2015. As we can see in Table 2, the pH in 0-10cm is 5.75 which is close to the target pH of 5.5.
2	Deep ripping only	Ripping occurred at a depth of 30cm and at width 50 cm between rippers. The surface was not limed due to liming in 2015.
3	Deep ripping + lime	2.6 t/ha of lime was placed at 10-30cm to target subsoil acidity.
4	Deep ripping + organic amendment	As above with organic amendment, i.e lucerne pellets at 10t/ha.

The treatments were implemented using a dual depth delivery (3-D) ripping machine designed and fabricated by NSW Department of Primary Industries. The 3-D ripping machine allows lime and other organic amendments to be accurately placed at two depths from 10–30cm. After the treatments were applied in 2016, the grower then sowed 970CL grazing canola at 3kg/ha on 300mm spacings at a 45°C angle to the deep rip lines. This was to ensure the seeder did not sow directly over the rip lines and it eliminated the need for the commercial size seeder having to be on 250mm row spacings. The same principle was used in 2017, when Spitfire wheat was sown at a rate of 70kg/ha.

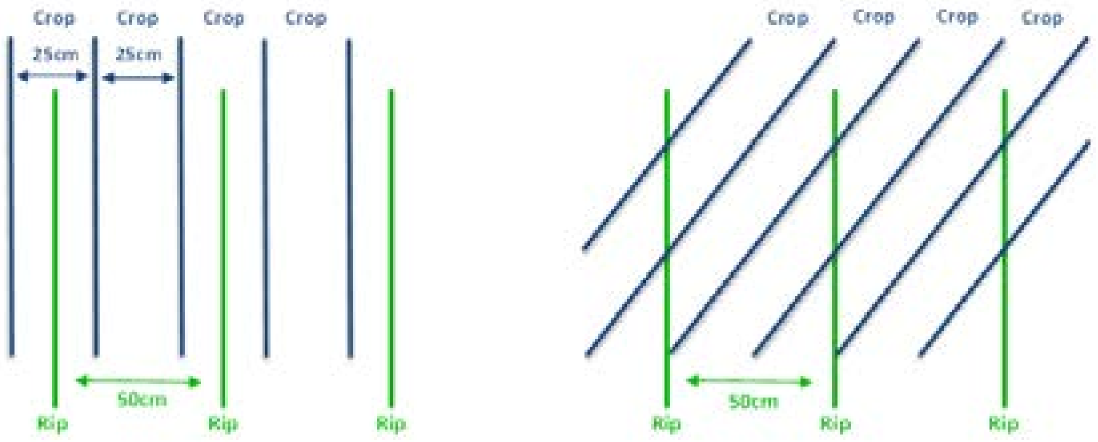


Figure 1. Initial crop sowing plan (left) vs current plan (right)

Another farm scale site will be set up at the beginning of 2019. The site will have the same selection criteria, treatments and assessments. Several assessments will be undertaken over three cropping seasons, using both statistical and observational methods. These assessments include; emergence counts, anthesis and harvest dry matter cuts, header yield data, grain quality testing and initial and final soil sampling.

Binalong Results

Below in *Figure 2*, the pH ($CaCl_2$) of the 0-10cm surface layer was 5.8, then dropped to 4.2 at a depth of 10-30cm. Similar to the exchangeable aluminium pattern, the pH began to increase below the 30cm mark. The exchangeable aluminium percent spiked dramatically to almost 19%, in the 10-20cm, then reduced to approximately 13% in the 20-30cm profile. Below 30cm, the exchangeable aluminium was below 1%.

In 2016, the surface liming treatment had the highest canola emergence count of 32.6 plants/m^2, while in 2017 the deep ripping treatment had the highest wheat emergence count of 111.3 plants/m^2 (Figure 3). The deep organic amendment treatment had the lowest canola emergence count of 18.5 plants/m^2 in 2016. In 2017, the deep liming treatment had the lowest wheat emergence counts of 99.3 plants/m^2.

Figure 4 shows surface liming had the lowest yield in 2016, yet it the highest yield in 2017. Deep liming had one of the highest yields in 2016 but had the lowest yield in 2017. The deep ripping, deep liming and organic amendment had similar yields, while surface liming had a yield of 4.5 t/ha, 3.9-4.0t/ha, in 2017.

Table 2 shows there is a substantial difference in canola oil and protein (2016) between the organic amendment treatment and the other three treatments. There was very little difference in wheat protein (2017) between all the treatments.

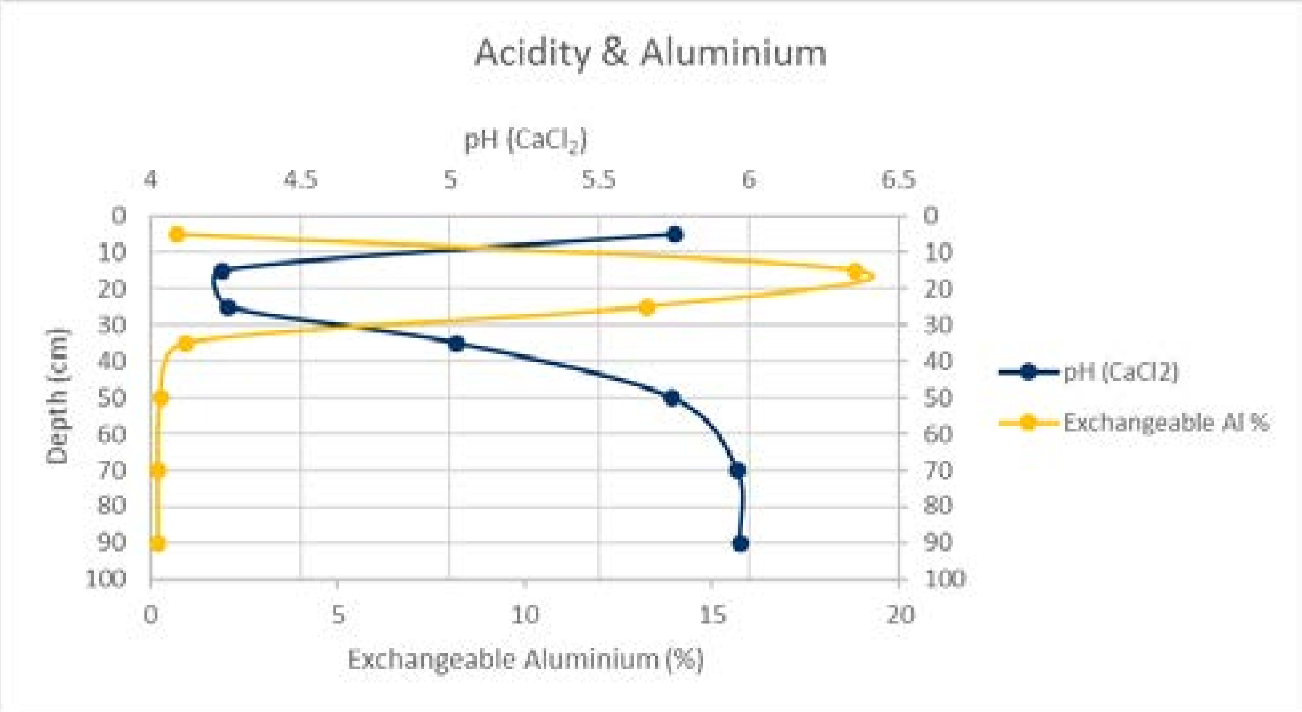


Figure 2. pH ($CaCl_2$) and exchangeable aluminium percentage from the initial soil samples averaged across the Binalong experimental site in 2016.

Discussion

Soil acidification is a natural process that is accelerated by agricultural activity, such as high yielding crops, product removal and fertilizer (Small, 2016). Soil becomes more acidic when plant material is removed from a paddock, because most of these products are alkaline and removal leaves the soil more acidic (Hollier & Reed, 2005). Acidification can decrease the availability of essential nutrients, while increasing the impact of toxic elements (Hollier & Reed, 2005). This subsequently reduces plant production. There are also other disadvantages such as decline in soil structure and effect on essential soil biological functions (Hollier & Reed, 2005). The task of alleviating sub soil acidity cannot be solved with the standard practice of surface liming because lime moves slowly through the soil profile, the alkalinity will most likely be

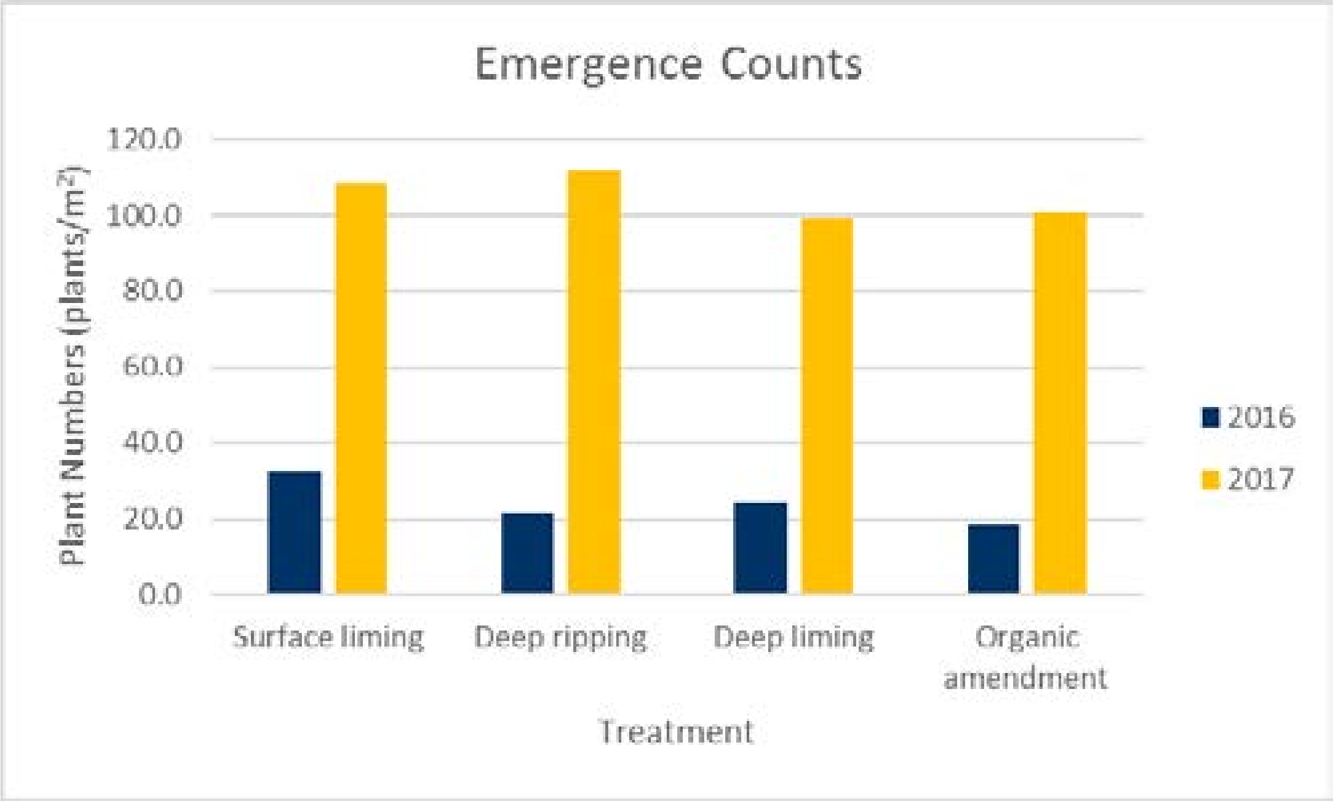


Figure 3. Emergence counts taken in 2016 (canola) and 2017 (wheat)

used up prior to reaching the acidic sub soil layers.

Baseline soil samples were taken at the beginning of the trial (*Figure 2*), prior to treatments being implemented. Samples were collected in 10 centimetre increments to a depth of 40 centimetres, and from there increased to 20 centimetre increments to a depth of 1 metre. The samples were analysed for exchangeable aluminium percentage and pH (calcium chloride method). The pH began at 5.8 in the top 10cm of top soil, but it quickly dropped to 4.2 and 4.3 at 10-20cm and 20-30cm. Then as expected, the pH increased below the 30cm depth. Producers should aim for a top soil (0-10cm) pH ($CaCl_2$) of 5 or above and a subsoil (10-30cm) pH ($CaCl_2$) of 4.8 or higher (Small 2016). Therefore, it's important to test and monitor soil down to at least 30cm, rather than the standard practice of 0-10cm. Field test kits are an easy and inexpensive option to get a rough indication if there is a change in pH down the soil profile. The exchangeable aluminium was very low in the 0-10cm soil layer, then increased drastically to approximately 19% at the depth of 10-20cm. The aluminium level began to decrease to 13% at 20-30cm, then dropped back down to less than 1% as the pH increased to above 5. An exchangeable aluminium percentage above 5% will begin to effect root growth of acid sensitive species. A small decline in pH in soils where aluminium is present can result in a large increase in exchangeable aluminium (Upjohn et al 2005). Crops sensitive to aluminium will have poor root development, resulting in restricted water and nutrient access from deeper in the soil profile.

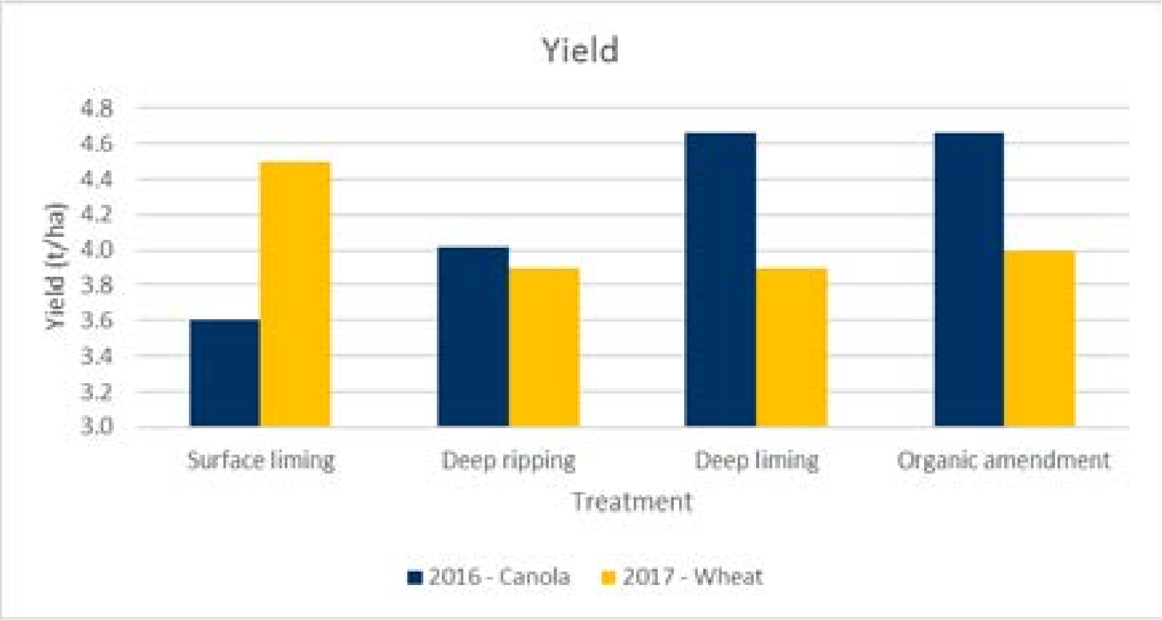


Figure 4. 2016 (canola) and 2017 (wheat) treatment yields.

Table 2. 2016 & 2017 grain quality, canola oil content (%) & grain protein (%) and wheat protein (%).

	Canola - 2016	Canola – 2016	Wheat - 2017
Treatment	Average Oil (%)	Average Protein (%)	Average Protein (%)
Surface liming	46.4	18.87	14.4
Deep ripping	46.5	19.07	14.8
Deep liming	46.1	19.43	14.2
Organic amendment	42.8	22.77	14.5

No emergence trend formed over 2016 and 2017 when comparing treatments for either canola or wheat *(Table 2)*. In 2016, the organic amendment treatment had the lowest plant emergence, it had 43% less plants than the surfacing liming treatment which had the highest emergence. There was only 11% difference between deep ripping, the top performing treatment in 2017, and deep liming, the poorest performing treatment in terms of plant emergence.

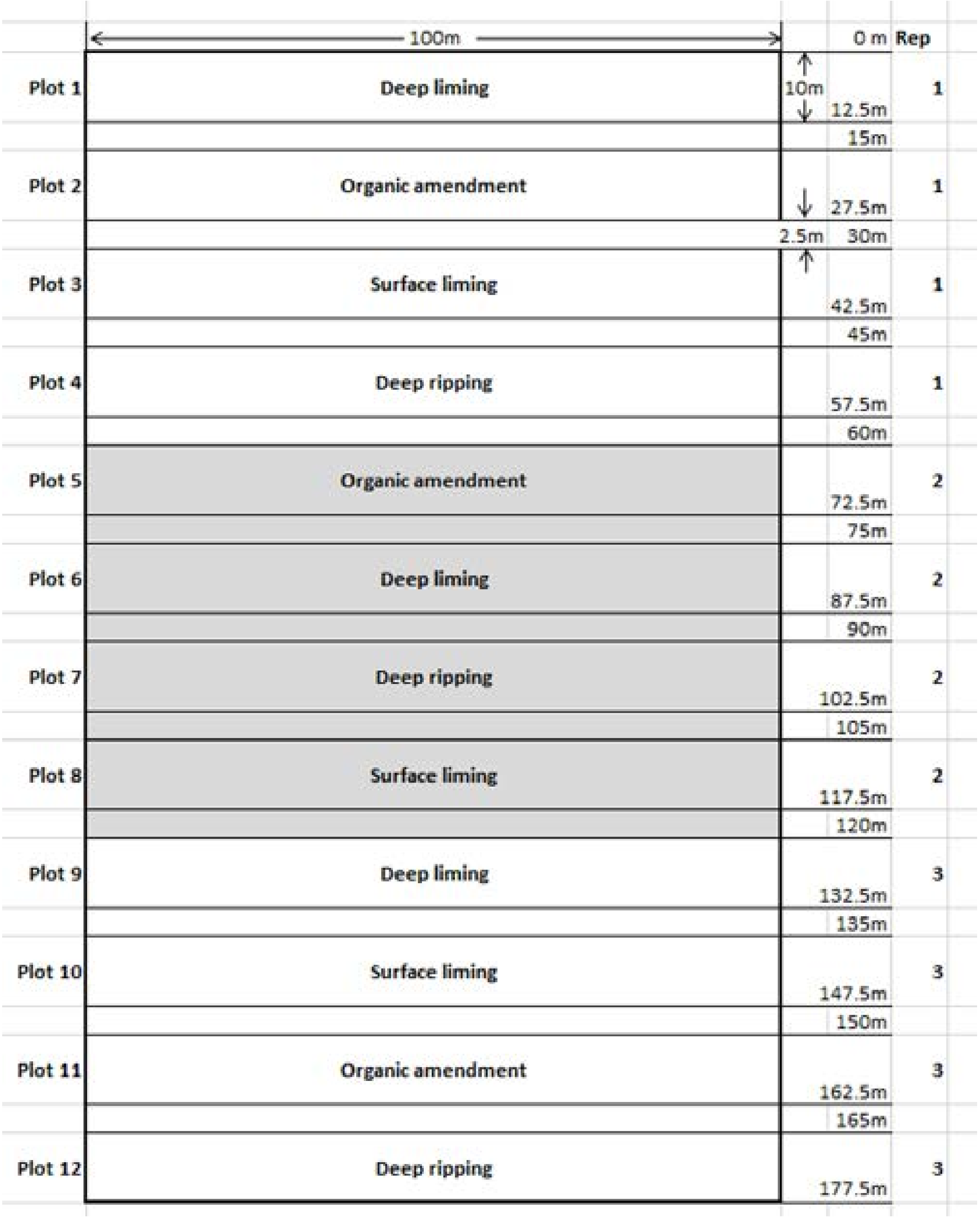
Figure 4 shows an inverse relationship between the canola yield in 2016 and the wheat yield from 2017. The surface liming treatment had the lowest yield in 2016 and the highest yield in 2017. The surface liming treatment was the only treatment that had a positive influence yield in 2017, the deep lime, deep rip and organic amendment all yielded approximately 4t/ha.

In 2016 there was a clear treatment effect in canola oil content. All treatments had an average canola oil content of 46% or higher, except for the organic amendment treatment which had an average oil content of 42.8%. Protein levels generally work in an inverse relationship to oil content (GRDC 2009). There was very little difference in average protein levels across all the treatments in 2017. There was only 0.6 difference between the highest and lowest average protein in 2017.

Final soil samples will be taken at the conclusion of the experiment in 2018, after harvest. The protocol for the final samples will be the same as the protocol for the initial samples. Except, cores will be taken on rip line and in-between the rip lines in the strips that were ripped. The initial soil sample results will be separated into treatments for the comparison in the final report.

There are many variables that can influence the results, such as crop type, seasonal climate, various environmental pressures and how long the treatments continue to effect results after the first and only application. A further year of research and analysis from this site and other sites will give strength to these findings.

Appendix



	100m	0 m	Rep
Plot 1	Deep liming	12.5m	1
		15m	
Plot 2	Organic amendment	27.5m	1
		30m	
Plot 3	Surface liming	42.5m	1
		45m	
Plot 4	Deep ripping	57.5m	1
		60m	
Plot 5	Organic amendment	72.5m	2
		75m	
Plot 6	Deep liming	87.5m	2
		90m	
Plot 7	Deep ripping	102.5m	2
		105m	
Plot 8	Surface liming	117.5m	2
		120m	
Plot 9	Deep liming	132.5m	3
		135m	
Plot 10	Surface liming	147.5m	3
		150m	
Plot 11	Organic amendment	162.5m	3
		165m	
Plot 12	Deep ripping	177.5m	3

Figure A1. Large scale site layout.

Figure A2. Aerial view of the Binalong site, taken 2016.

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REPORT TWO

Prepared by Dr G. Li and H. Burns (guangdi.li@dpi.nsw.gov.au)
http://www.dpi.nsw.gov.au/agriculture/soils/acidity

This article provides an overview of this major GRDC funded project that commenced in 2015. This issue also highlights the framework and key features of the experimental design for the long-term field experiment near Cootamundra in southern NSW.

Project Background

Subsoil acidity is a major constraint to crop productivity in the high rainfall zone (500–800 mm) of south-eastern Australia. The surface application of lime is commonly used to combat topsoil acidity. However, lime moves very slowly down the soil profile so subsoil acidity will only be ameliorated after years of surface application. In addition, at the current commercial rates of about 2.5 t/ha, most of the added alkalinity is consumed in the topsoil and has limited effect on neutralizing subsoil acidity or counteracting subsoil acidification.

Experimentation

A long-term field experiment was established in 2016 at Dirnaseer, west of Cootamundra, NSW, to monitor long-term soil chemical, physical and biological processes. A range of laboratory soil incubation studies and glasshouse experiments will be conducted under controlled environments to compare effects of various combinations of soil amendments on soil amelioration processes. These inform the most efficient soil amendments, optimum rates and best placements in the soil profile for current and future field experiments.

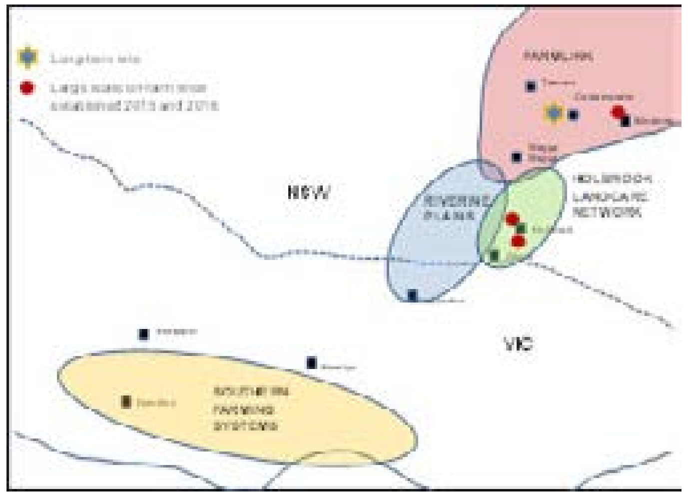
A series of large scale field experiments will also be conducted on farmers' paddocks to demonstrate the benefits of the most effective soil amendments and innovative technologies across different soil and climate conditions in NSW and Victoria.

Aim

This project will investigate innovative technology to deliver novel soil amendments, such as calcium nitrate and magnesium silicate, lucerne pellets as well as lime, directly into the subsoil (10-30 cm) to ameliorate acidity.

Target region

The project covers major high rainfall cropping areas from southern NSW to south-west Victoria.



Framework of long-term field experiment

'Ferndale', Dirnaseer, west of Cootamundra, NSW

Objectives

- To manage subsoil acidity through innovative amelioration methods that will increase productivity, profitability and sustainability.
- To study soil processes and measure the long-term changes in soil chemical, physical and biological properties.

Treatments and design

- Four crops in sequence
- Six soil amendments
    - Control, no amendment
    - Surface liming, target pH 5.5 at 0-10 cm
    - Deep ripping only (30 cm depth)
    - Deep ripping + lime, target pH 5.0 at 0-30cm
    - Deep ripping + lucerne pellets (15 t/ha)
    - Deep ripping + lime + lucerne pellets
- Three replicates in a split-plot design

Key features

- Phased design. There are 4 crops in the rotation, arranged in a fully phased design. Each crop will appear once in any given year a) to assess responses of different crops to different soil amendments; b) to compare treatment effect, taking account of seasonal variation.
- Crop rotation cycle. One crop rotation cycle will take four years to complete with the crop sequence as wheat-canola-barley-grain legume.

Table 1. Crop rotation cycle and phases

		Phase 1	Phase 2	Phase 3	Phase 4
Year 1	2016	**W1**	C2	B3	F4
Year 2	2017	C2	B3	F4	**W1**
Year 3	2018	B3	F4	**W1**	C2
Year 4	2019	F4	**W1**	C2	B3
Year 5	2020	**W1**	C2	B3	F4
Year 6	2021	C2	B3	F4	**W1**
Year 7	2022	B3	F4	**W1**	C2
Year 8	2023	F4	**W1**	C2	B3
Year 9	2024	**W1**	C2	B3	F4
Year 10	2025	C2	B3	F4	**W1**
Year 11	2026	B3	F4	**W1**	C2
Year 12	2027	F4	**W1**	C2	B3
Year 13	2028	**W1**	C2	B3	F4
Year 14	2029	C2	B3	F4	**W1**
Year 15	2030	B3	F4	**W1**	C2
Year 16	2031	F4	**W1**	C2	B3

Crop code:

W1, crop at phase 1 as wheat; C2, crop at phase 2 as canola; B3, crop at phase 3 as barley; F4, crop at phase 4 as faba bean for early sowing, or field pea for late sowing.

- Soil amendment cycle. Soil amendments will be applied every 8 years in years 1 and 9, pending availability of funding.
- Soil samples. All soil samples will be archived for long-term storage.
- Data management. All data will be uploaded into the Katmandoo database.

Measurements

- Soil chemical properties
    - Deep soil coring at 10 cm intervals to 40 cm and 20 cm intervals from 40 to 100 cm
    - Shallow soil coring at 10 cm intervals to 40 cm
    - pH in $CaCl_2$; exchangeable Al, Ca, Mg, Mn, K and Na
    - Soil total C and N, organic C (Heanes)
    - Colwell P
- Soil physical properties
    - Particle size distribution
    - Soil aggregation stability
    - Penetrometer measurement
- Soil biological properties
    - Soil microbial diversity
    - Earthworm population and biomass
- Soil moisture and root depths
    - Neutron moisture meter measurements
    - Rooting depth and root density
- Agronomy measurements
    - Establishment count
    - Tiller count
    - Anthesis DM
    - Harvest DM
    - Grain yield and quality ■

REPORT THREE

Prepared by Dr G. Li and H. Burns (guangdi.li@dpi.nsw.gov.au)
http://www.dpi.nsw.gov.au/agriculture/soils/acidity

3-D Ripping Machine

A dual depth delivery (3-D) ripping machine has been built to provide accurate placement of soil amendments at two depths from 10 to 30 cm. This issue highlights some early observations from the long-term field site near Cootamundra in southern NSW, established in 2016.

Figure 1. The 3-D Ripping Machine. The coulters in front of each ripping tyne and the back roller produce a flat seedbed. Photo by Guangdi Li

Key features

- Dual amendment boxes: two boxes to hold lime (up to 150 kg) and organic amendment (up to 1 tonne) separately
- Dual feeding systems: two feeding augers to deliver lime (up to 4 t/ha) and organic amendment (up to 20 t/ha) simultaneously
- Dual delivery depths: two exit points and plates on each tyne to allow lime and/or organic amendment to be placed evenly from 10-30cm
- Dual metering systems: two separate fluted-roller metering systems with variable gear boxes to ensure accurate application rates as required
- Base unit: Grizzly Ripper
- Ripping tyne: 5 tynes with 50 cm spacing

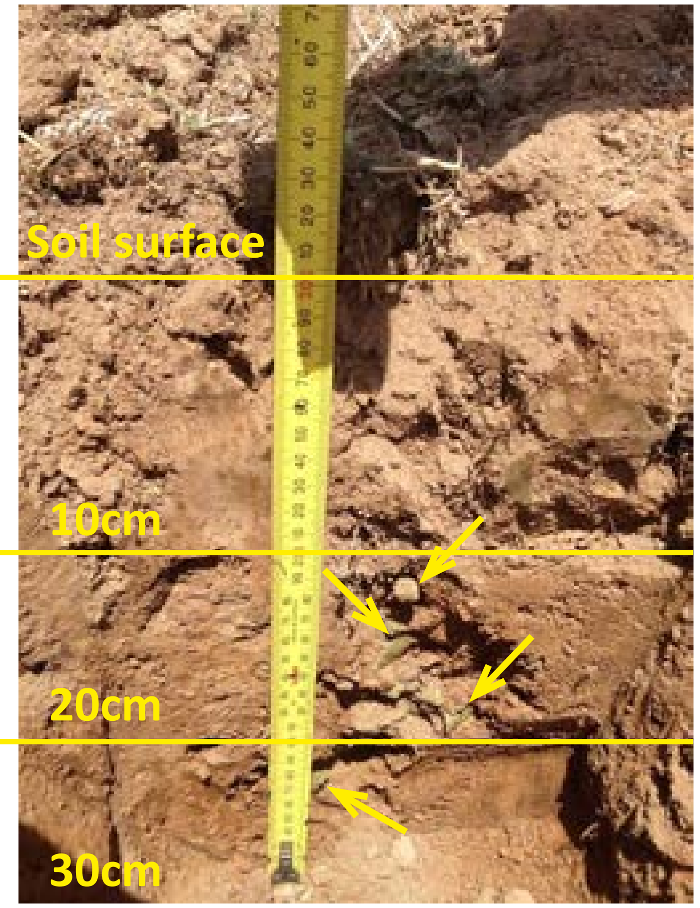


Figure 2. Dual delivery systems place lime and/or organic amendment at depths from 10 to 30 cm. Yellow arrows are pointing to lucerne pellets. Photo by Guangdi Li

- Ripping depth: down to 50cm with 200 HP tractor.
- Front coulter: to break topsoil and prevent surface layer being lifted
- Back roller: to compress soil behind the ripper and leave a flat surface ready for sowing.

Soil strength under amendments

'Ferndale', Dirnaseer, west of Cootamundra, NSW

Penetrometer readings

A penetrometer was used to test the soil strength 5 months after treatments were imposed. The contour map was produced from penetrometer readings at 50 mm intervals across a section of plot down to a depth of 485 mm (Figure 4).

- For the unripped treatment, there was an obvious compaction layer at 8-20 cm. The cultivation and sowing operation was at 0-8cm.
- For the ripped treatment, there was distinct ripping effect, showing rip lines at 50 cm intervals.
- For the ripped with lucerne pellets treatment, it seems the ripping effect was beyond the ripping depth (30 cm).
- The long-term ripping effect will be monitored over time.

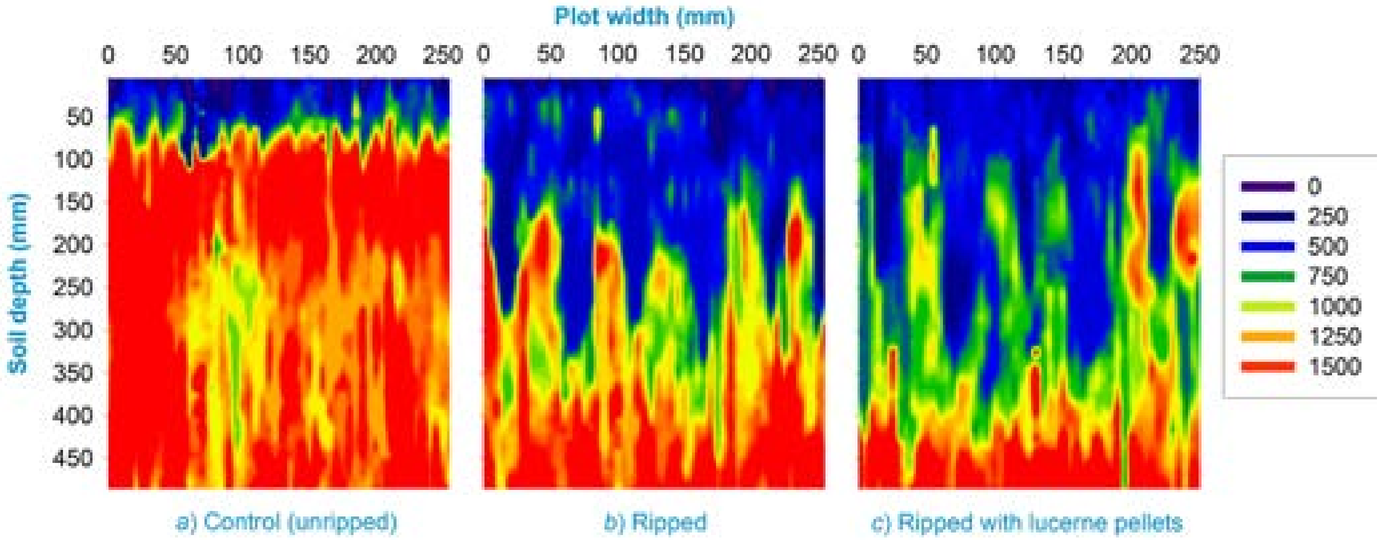


Figure 2. Penetrometer readings (kPa) on plots under a) Control; b) Ripped and c) Ripped with lucerne pellets treatments (5 months after treatments were imposed)

Deep liming *Deep liming + lucerne pellets*

Figure 3. Gregory wheat plots on 29 August 2016. Crop was sown on 21 May 2016. Photo by Guangdi Li.

Initial crop responses

There were visible crop responses to soil amendments for wheat, barley and canola crops at the seedling stage in year 1. Deep ripping with lucerne pellets produced more seedling dry matter compared with the control treatment. The ripping only treatment also improved crop growth.

REPORT FOUR

Prepared by Dr P. Ryan (peter.ryan@csiro.au)
http://www.dpi.nsw.gov.au/agriculture/soils/acidity

Genetic potential for yield improvements on acid soils in Australia's major grain crops

A scoping study provides an overview of current knowledge of acid soil tolerance in the major winter crops species (wheat, barley, canola and pulses).The review listed known mechanisms and genes controlling Al and Mn tolerance and proposed strategies for improving tolerance in certain species.

Project background

Crop yields begin to be limited when soil pH falls below 5.0 in $CaCl_2$. Australia's major grain crops (wheat, barley, canola and pulses) continue to be affected by acid soils (Figure 1) and total losses to agriculture are estimated to be $900 to $1,585 million per annum (Hajkowicz 2005).

Acid soils present many stresses to plants but chief among them is aluminium (Al^{3+}) toxicity which inhibits root growth (Figure 2). Although acid soils can develop naturally, certain agricultural practices increase the rate of acidification. If left unmanaged acidification will degrade agricultural land and cause larger yield losses in the future.

The most effective management practice for slowing and even reversing acidification is the application of lime (calcium carbonate) but it can take years for the lime to correct pH in the subsoil below 10 cm. This is particularly true in minimum tillage production systems. Crops and cultivars with a greater tolerance to acid soils are important resources for farmers because they maintain production and income while amelioration efforts continue.

It is unlikely that the genetic yield potential of Australia's major crops on acid soils has been fully realised. Further increases in production could be achieved through standard breeding strategies, from wider crosses to related species and from genetic engineering (Ryan *et al*. 2011).

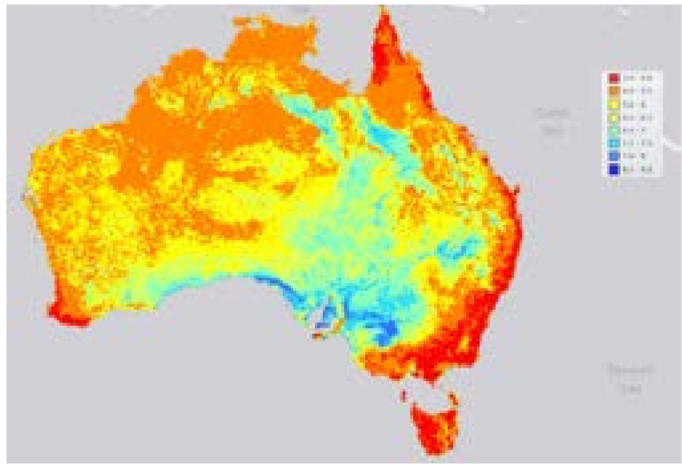


Figure 1. Distribution of acid soil in Australia. Data show the estimated value for soil pH at 5-15 cm depth. Source is the Soil and Landscape Grid of Australia (http://www.asris.csiro.au/viewer/TERN/)

Potential for improvement

- Bread wheat is Australia's largest crop so even small yield increases on acid soils can significantly impact production. Most cultivars are already reasonably tolerant to low pH because they possess the major gene for tolerance that controls the Al^{3+}-activated malate release from root tips. Further improvements might be possible by pyramiding other known QTL and by introducing genes from highly-tolerant cereals such as rye or triticale.
- Barley, Australia's second largest grain crop, is more sensitive to acid soils than wheat. Nevertheless there is some genotypic variation and breeders have exploited this variation to develop a commercial cultivar "Litmus". Litmus yielded significantly better than other elite barley cultivars on acid soils in Western Australia. More advanced material is currently being generated and this could expand the total area of barley cultivation.
- Durum wheat is among the most sensitive cereal species to acid soils. It shows very little genotypic variation in tolerance so cultivation is restricted to non-acid regions of South Australia, Victoria and northern NSW. Although production is small compared to bread wheat durum it is a lucrative crop with strong market potential. Recent programs at CSIRO have successfully increased the acid tolerance of durum by introducing genes from hexaploid wheat (Han et al. 2016). These lines could raise production significantly by increasing yields and expanding the area under cultivation.
- Canola is Australia's third major grain crop and also more sensitive to acid soils than bread wheat. Genotypic variation for acid soil tolerance appears to be small and so breeding strategies to improve adaptation to acid soils may have limited success. However since canola is one of two genetically-modified crops currently grown in Australia biotechnology could be used to increase production on acid soils.
- Pulses have become popular choices for crop rotations. Substantial benefits would result from improving the acid soil-tolerance of pulses because, apart from the lupin species, most are sensitive or very sensitive to acid soils. Any improvement in the tolerance of chickpea, lentils, faba bean or field pea would be welcomed by farmers across Australia. Significant genotypic variation for acid soil-tolerance has been reported in most of these pulse species. Whether the cultivars grown in Australia have reached their genetic yield potential on acid soils is unknown and should be a priority for breeders.

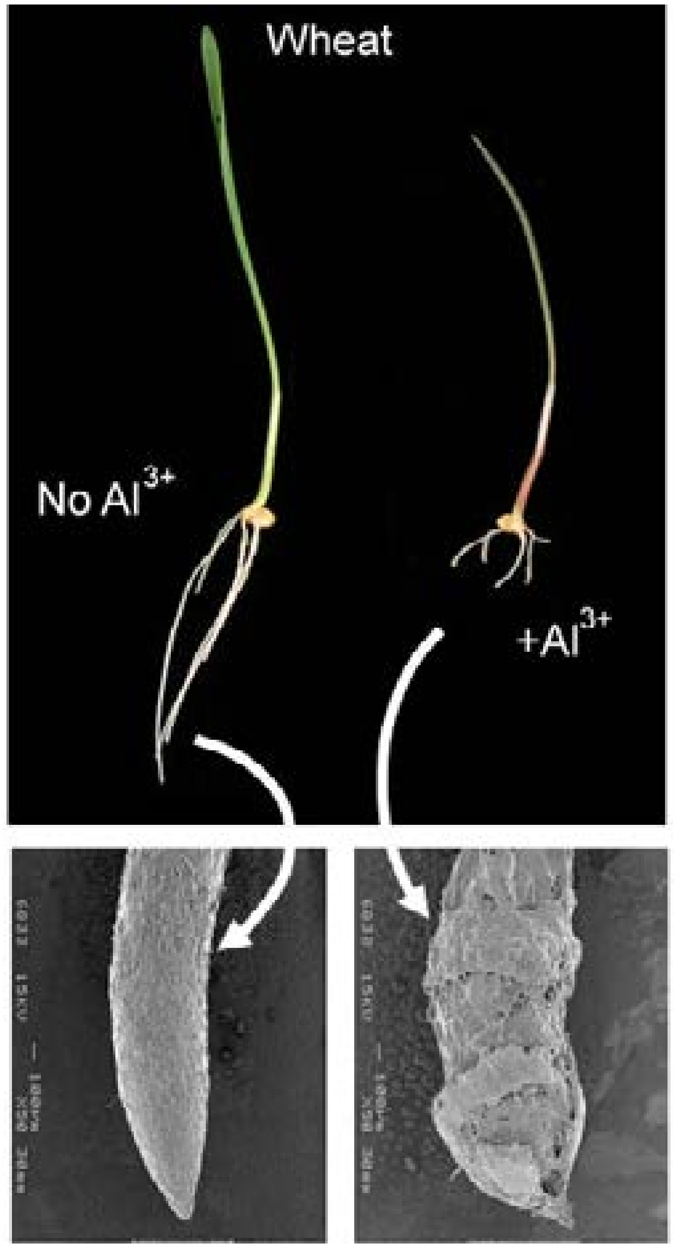


Figure 2. The Al^{3+} ions prevalent in acid soils inhibit root growth by damaging the root tips where cell division and elongation occurs (Micrographs by E. Delhaize)

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Ryan PR, Tyerman SD, Sasaki T, Furuichi T, Yamamoto Y, Zhang WH, Delhaize E. 2011. The identification of aluminium-resistance genes provides opportunities for enhancing crop production on acid soils. Journal of Experimental Botany 62, 9-20.

REPORT FIVE

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http://www.dpi.nsw.gov.au/agriculture/soils/acidity

La Trobe University Component

La Trobe University is one of the key research partners in this major GRDC funded project which started in 2015. In this issue, we provide an overview of the laboratory and glasshouse experiments that the La Trobe University team will conduct over four years.

Project background

Subsoil acidity is a major limitation to crop productivity, primarily due to high concentrations of aluminium (Al) which limit root development and function. Innovative solutions to ameliorate subsoil acidity are needed since traditional application of lime on the soil surface is not effective at depth. Placement of ameliorants, including lime and/or organic materials, placed directly into acidic soil layers via deep ripping, is thought to be a promising approach.

The La Trobe team, led by Professor Caixian Tang, will conduct experiments to compare the effects of various organic and inorganic amendments, their rates and depth of placement on ameliorating soil acidity. The promising products, based on research results, will be recommended to field research team to implement in the field when available and if appropriate.

Figure 1. Glasshouse facility at La Trobe University. Photo by Clayton Butterly.

Photo by Clayton Butterly.

Experimental plan

Over the next 4 years, the La Trobe team will conduct a series glasshouse/laboratory experiments in the following areas:

- Evaluate the effectiveness of a range of inorganic (lime, gypsum and nutrients) and organic amendments (composts, animal wastes and crop residues) and their combinations to ameliorate subsoil acidity;
- Quantify the effectiveness of the amendments placed at various depths at different application rates with the best amendment treatments identified from previous screening experiments;
- Examine the effects of surface-applied lime alone or mixed with compost or gypsum on alkalinity movement in soil profiles and use a range of crop residues differing in ash alkalinity to examine their effects on the movement of surface applied lime to deep soil layers; and
- Assess the effectiveness of calcium nitrate alone and in combination with P and other nutrients in ameliorating subsoil acidity and to study the N use efficiency by crops with fertilizers placed at various depths.

Soils

In addition to soils with specific characteristics from both Victoria and New South Wales, the experiments conducted by the La Trobe team will utilize soils from the various field sites of the larger project, including the long-term field site at Dirnaseer, West of Cootamundra, NSW.

Experimental techniques

The La Trobe team will utilize their state-of-the art laboratory facilities at the Centre for AgriBioscience at the La Trobe University, Melbourne Campus. In particular they will;

- Conduct experiments in controlled environment rooms and automated glasshouses.
- Use Al sensitive (ES8) and tolerant (ET8) wheat cultivars to quantify crop responses to various soil amendments.

Figure 2. Laboratory facilities at La Trobe University. Photos by Clayton Butterly.

Figure 3. Typical acidic soil profile in Victoria. Photo by Clayton Butterly.

- Quantify changes in soil pH using 0.01 M CaCl2 extracts (1:5 soil:extract).
- Examine changes in dissolved organic carbon in soil extracts or leachates using an automated organic carbon analyser.
- Determine Al concentrations in soil extracts (0.01 M CaCl2) using inductively coupled plasma-optical emission spectroscopy (ICP-OES) and colourimetrically with pyrocatechol violet and the contribution of Al to the cation exchange capacity in amended soils.
- Assess changes in soil microbial biomass carbon using chloroform fumigation-extraction combined with organic carbon analysis.
- Estimate amendment decomposition rates by measuring temporal patterns of CO_2 release using an infra-red gas analyser.
- Measure crop biomass and root morphology (root length, diameter and volume) using a WinRHIZO Pro scanning system.
- Characterise the nutrient and Al content of root and shoot biomass using ICP-OES following digestion of plant material with nitric-perchloric acids.

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Charles Sturt University Component

Charles Sturt University (CSU) is one of the research partners in this major GRDC funded project, led by NSW Department of Primary Industries. This is an overview of the CSU component.

Subsoil acidity issues

Crop production in southern NSW is strongly constrained by subsurface and subsoil acidity, which in many cases are a direct result of soil acidification brought about by agriculture.

Although Al and Mn toxicity are the major constraints in acid soils and can severely restrict plant growth, they are not the only ones (Table 1).

Acid soil sensitive plants, such as canola and barley, grown in soils where the subsurface and or the subsoil is acidic, develop small and shallow root systems (Figure 1). Such poorly developed root systems restrict access to moisture and nutrients, particularly nitrate, from the subsurface soil thereby severely reducing the yield potential of the plant.

Liming can easily ameliorate soil acidity by increasing soil pH, eliminating Al toxicity and possibly reducing Mn toxicity. However, the current practice of only liming the soil surface layer does not result in amelioration of subsurface acidity.

Lime will only ameliorate the pH in the soil layer in which it has been incorporated and therefore can eliminate acid soil related stresses in that layer only. Liming of the lower acidic layers is a slow process, requiring the repeated application of lime to the surface layer for the alkalinity to move down the soil profile and ameliorate the subsurface acid layer. Thus, the combined use of liming with acid soils tolerant cultivars would provide, in the interim, maximised crop growth.

Therefore, there is a need to find alternative agronomic approaches and amendments to ameliorate soil acidity that develops at depth.

Figure 1. Differential response of Al tolerant (Dayton) and Al sensitive (Kearney) grown in limed (L, pHCaCl2 5.7) and unlimed (U, pHCaCl2 4.2) acid soil. Photo by Sergio Moroni.

Table 1. Major constrains to plant growth under acid soils conditions

Decrease in		
metal cation concentration	→	Mg, Ca and K deficiency
P and Mo solubility		P and Mo deficiency
Inhibition of		
metal cation uptake	→	Mg, Ca and K deficiency
root growth		Reduced nutrient and water uptake
Increase in		
leaching		Nutrient deficiency
H^+ concentration	→	H^+ toxicity
Al3+ concentration		Al^{3+} toxicity
Mn^{2+} concentration		Mn^{2+} toxicity

Key research objectives

Over the duration of the project the CSU team will conduct a major field experiment and a series of laboratory and controlled environment experiments to determine the following:

- What is the mechanism by which selected organic and/or inorganic amendments ameliorate an acid soil?
- What is the level of tolerance to soil acidity among cereals, canola and pulses varieties currently available in the market?
- What is the interaction between crop × acid soil × soil amendments?

Lab/glasshouse experiments

- Quantifying responses of crop varieties in acid soils
- Quantifying the effectiveness of amendments in PVC columns with stratified acid soils layers
- Quantifying the crops × soil amendment interactions in acid soils

Field experiment

A sub-soil acidic site at Rutherglen will be used to quantify the ameliorative effect of lime, lucerne pellets, rock phosphate and magnesium silicate in the subsoil on crop performance and soil improvement.

Table 2. Soil treatments at the Rutherglen field site.

ID	Treatment	Description
1	Nil amendment	Control, no amendment
2	Rip only	Ripping to 30cm
3	Surface liming	Surface liming to pH5.5
4	Surface liming	Surface liming to pH5.0
5	Deep liming	Deep liming to pH5.0 to 30cm
6	Deep dolomite	Deep dolomite to pH5.0 to 30cm
7	Deep MgSi (High)	Deep MgSi at 8 t/ha
8	Deep MgSi (low)	Deep MgSi at 4 t/ha
9	Deep RPR (High)	Deep phosphate rock at 8 t/ha
10	Deep RPR (low)	Deep phosphate rock at 4 t/ha
11	Deep phosphorus	Deep P at 15 kg/ha
12	Deep lime+P	Deep liming + P at 15 kg/ha
13	Deep lucerne pellet1	Deep lucerne pellet at 15 t/ha
14	Deep lucerne pellet2	Deep lucerne pellet at 7.5 t/ha

Figure 2. Pot experiment at the glasshouse facilities at Charles Sturt University. Photo by Sergio Moroni.

Figure 3. Canola crop at the Rutherglen field site. Photo by Sergio Moroni.

REPORT SEVEN

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http://www.dpi.nsw.gov.au/agriculture/soils/acidity

Comparison of a range of amendments on alleviating aluminium and manganese toxicity in wheat

This issue covers an experiment that the La Trobe University team conducted to assess different soil amendments for their potential in ameliorating soil acidity.

Introduction

Soil acidity (pH<5.5 in calcium chloride) with aluminium (Al^{3+}) and manganese (Mn^{2+}) toxicities is a major constraint to global food production. In acid soils Al-toxicity inhibits root growth and function by interrupting root elongation and Mn toxicity limits shoot growth by interfering with a variety of biochemical pathways, including photosynthesis. Phosphorous (P) is often the most limiting macro nutrient in acidic soils. While lime application to increase pH is an effective practice, it is limited in treating soil acidity at depth, especially when applied at the surface.

In this study seventeen organic and inorganic amendments were evaluated in two contrasting soils to ameliorate soil acidity either due to their ability to directly bind exchangeable Al^{3+} and Mn^{2+}, increase pH directly, or via decarboxylation, supply plant nutrients and have organic compounds that could potentially move deep into soil profiles.

Experimental design

Two soils were collected from 10-20 cm soil layers: a Dermosol from Kinglake West, Victoria and a Sodosol from Holbrook, New South Wales. The Dermosol had pH of 4.1, pH buffer capacity (pHBC) of 86 $mmol_c$/kg/pH and extractable Al^{3+} of 12 µg/g. The Sodosol had pH of 3.9, pHBC of 23 $mmol_c$/kg/pH, extractable Al^{3+} of 1 µg/g and extractable Mn^{2+} of 70 µg/g.

Amendments used were: lime, dolomite, gypsum, KH2PO4, cow manure, sheep manure, poultry litter, dairy compost, immature hot mix compost, biosolids, brown coal, southern blue gum biochar, wheat straw biochar, poultry manure biochar, wheat straw, lucerne hay and kelp powder. All organic amendments were mixed with the soils at a rate of 1% soil weight. Lime and dolomite were applied to achieve a pH of 6, gypsum was applied equivalent to calcium added from lime and KH_2PO_4 was added at 338 mg/kg soil (3 times basal P).

Al-sensitive wheat, ES8, was grown for 7 weeks in a glasshouse experiment. ET8 (Al-tolerant wheat) was grown as a control to verify biological Al^{3+} toxicity as it is a isogenic pair of ES8 except for an Al^{3+}-activated malate transporter.

Figure 1. Wheat (Al-sensitive ES8) plants at harvest in a Sodosol and a Dermosol (49 days after sowing). Photo by Dominic Lauricella.

Results

- Poultry litter, poultry manure biochar (PM Biochar), dairy compost, biosolids and sheep manure consistently performed better across both soils.
- The different response between the soils is due to the Sodosol having a much lower pHBC and less Al^{3+} compared to the Dermosol (Sodosol had less ability to resist soil chemical changes).
- A variety of soil chemical changes were observed with most treatments decreasing $CaCl_2$-extractable Al and Mn.
- While pH change is generally a critical factor, soil pH was not significantly increased under most of treatments.
- The best organic amendments contained the highest concentrations of P and Olsen-P had a stronger relationship with shoot biomass responses than any other measured soil property.
- This slow release of P from amendments as they breakdown enables plants to take up more P by reducing the amount of P that is fixed by the acid soils.
- Poultry litter and poultry manure biochar showed very similar effects in ameliorating soil acidity, it is possible that the effects poultry manure biochar would persist much longer due to its greater ability to resist breakdown than an easily decomposable poultry litter.

Key messages

- On-farm plant-based amendments such as lucerne hay proved successful in significantly increasing plant biomass in the less hostile Sodosol.
- In the more hostile Dermosol, only high quality organic amendments such as manures with high concentrations of P increased crop biomass.
- Future research should identify organic amendments that not only have the ability to influence pH, Al3+ and Mn2+ toxicity, but also supply key plant nutrients to overcome the strong P-fixing capacity of acid soils.

Project partners and contacts

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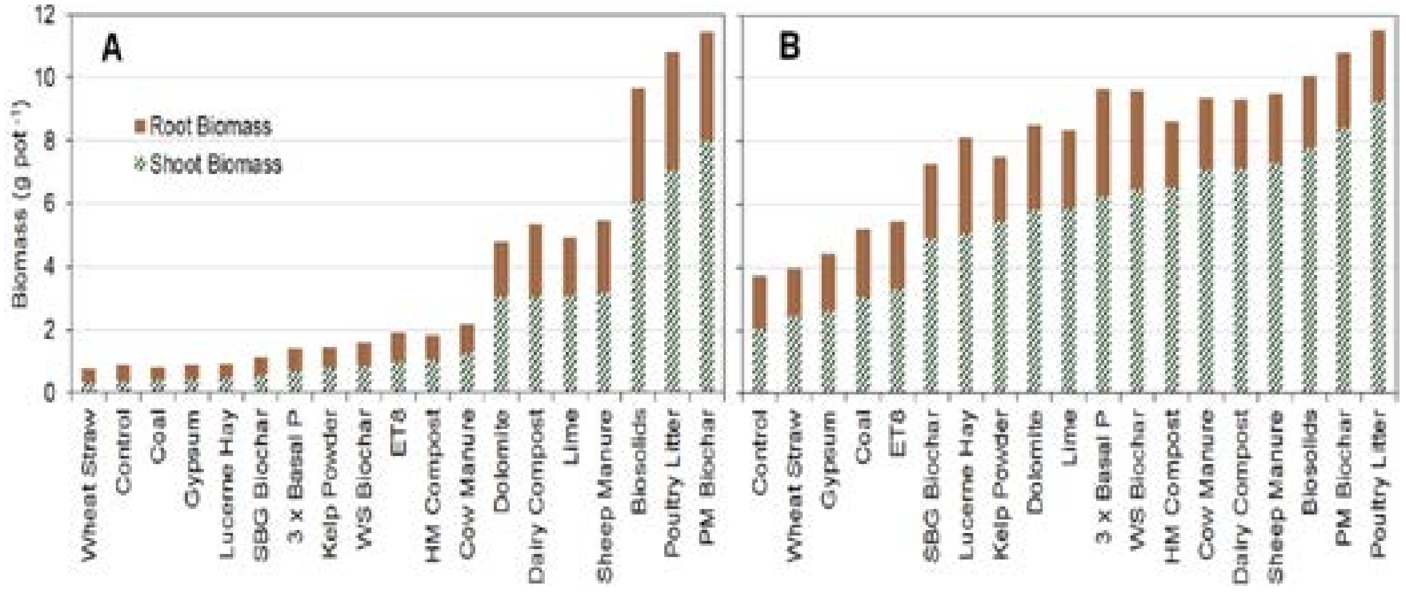
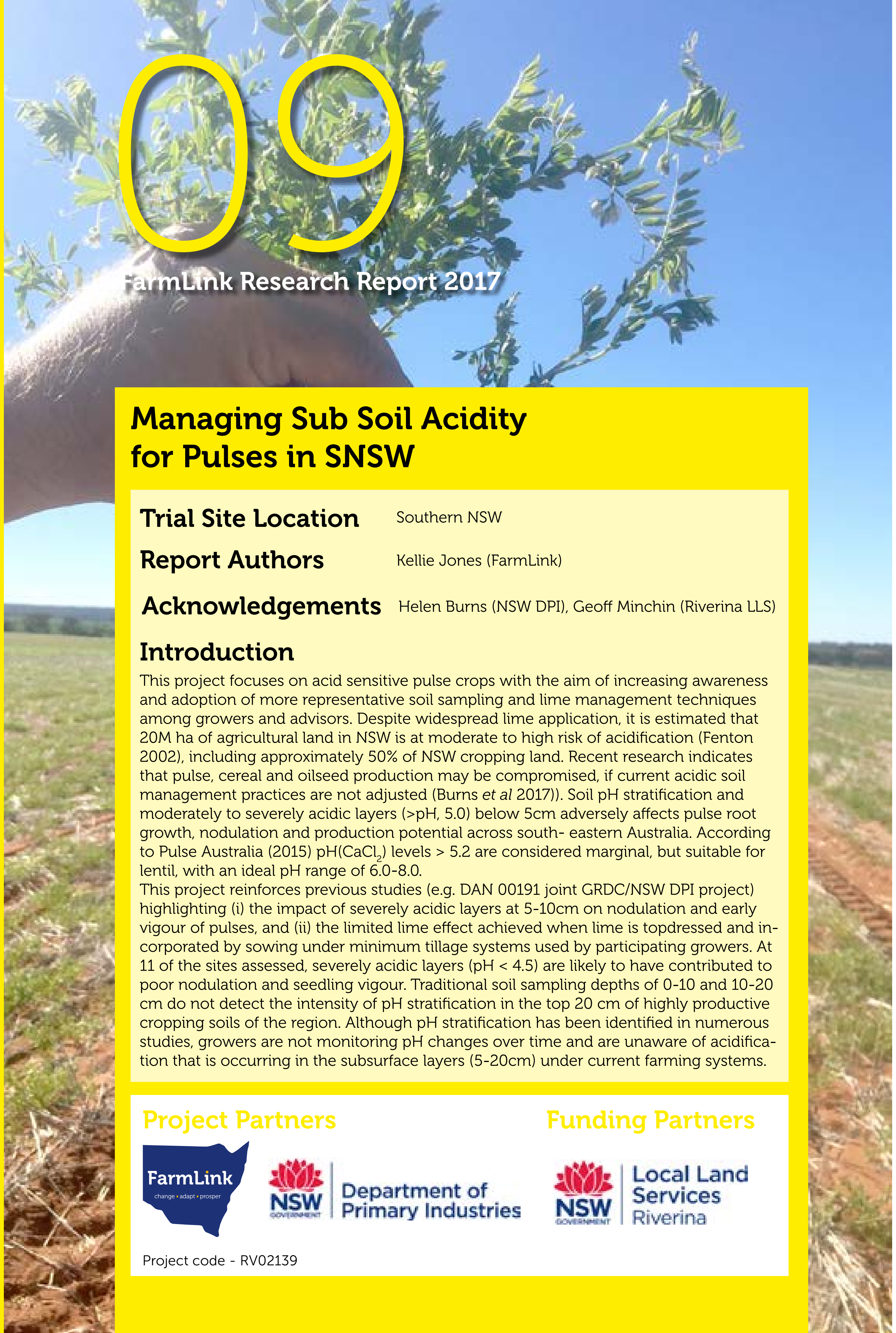


Figure 2. Effect of treatments on shoot and root biomass (g/pot) of Al-sensitive wheat ES8 grown in a Dermosol (A) and Sodosol (B) at 49 days after sowing. ET8 = Al-tolerant wheat, SBG = Southern blue gum, WS = Wheat straw, PM = Poultry manure, Basal P = 112.5 mg/kg KH2PO4, HM = Immature hot mix (n = 4).



09

FarmLink Research Report 2017

Managing Sub Soil Acidity for Pulses in SNSW

Trial Site Location	Southern NSW
Report Authors	Kellie Jones (FarmLink)
Acknowledgements	Helen Burns (NSW DPI), Geoff Minchin (Riverina LLS)

Introduction

This project focuses on acid sensitive pulse crops with the aim of increasing awareness and adoption of more representative soil sampling and lime management techniques among growers and advisors. Despite widespread lime application, it is estimated that 20M ha of agricultural land in NSW is at moderate to high risk of acidification (Fenton 2002), including approximately 50% of NSW cropping land. Recent research indicates that pulse, cereal and oilseed production may be compromised, if current acidic soil management practices are not adjusted (Burns *et al* 2017)). Soil pH stratification and moderately to severely acidic layers (>pH, 5.0) below 5cm adversely affects pulse root growth, nodulation and production potential across south- eastern Australia. According to Pulse Australia (2015) pH(CaCl$_2$) levels > 5.2 are considered marginal, but suitable for lentil, with an ideal pH range of 6.0-8.0.

This project reinforces previous studies (e.g. DAN 00191 joint GRDC/NSW DPI project) highlighting (i) the impact of severely acidic layers at 5-10cm on nodulation and early vigour of pulses, and (ii) the limited lime effect achieved when lime is topdressed and in-corporated by sowing under minimum tillage systems used by participating growers. At 11 of the sites assessed, severely acidic layers (pH < 4.5) are likely to have contributed to poor nodulation and seedling vigour. Traditional soil sampling depths of 0-10 and 10-20 cm do not detect the intensity of pH stratification in the top 20 cm of highly productive cropping soils of the region. Although pH stratification has been identified in numerous studies, growers are not monitoring pH changes over time and are unaware of acidification that is occurring in the subsurface layers (5-20cm) under current farming systems.

Project Partners

FarmLink change • adapt • prosper

NSW Government Department of Primary Industries

Funding Partners

NSW Government Local Land Services Riverina

Project code - RV02139

Objectives

- To validate findings from 'Nitrogen Fixing Break Crops and Pastures for HRZ Acid Soils' Burns et al (DAN00191) for pulse crops (specifically lentils) in the low to medium rainfall zone.
- To facilitate expansion of this high value pulse by developing skills of growers and advisors to identify soil types and paddocks suitable for lentil production and to promote effective management of acidic soils.

Method

In 2017, 10 commercial lentil crops were identified in the eastern medium and western low rainfall zones, At Merriwagga, Monia Gap, Yenda, Binya, Barellan, Methul, Temora, North and South Marrar and Lockhart. At each location, 'Good' and 'Bad' sites were visually selected to represent areas of vigorous and poor crop growth. GPS coordinates of these sites were recorded. Both the Good and Bad sites at each location were situated in the same paddock* and had the same paddock histories. Crop and soil samples were collected from each site for testing and assessment approximately three to four months after sowing, with further samples taken in October at mid-pod fill growth stage of the crop (Table 1).

* an additional Good site was selected at Marrar North in an adjacent hillside paddock

An initial assessment of pH at each site at different depths was conducted using a 'dig stick' and off the shelf pH indicator test kits (see Image 1).

This project was designed to test whether differences in crop growth (i.e. at the 'Good" and 'Bad' site at each location) could be explained by low soil pH and effectiveness of nodulation'. Comparing sites within a single paddock avoided variation due to differing paddock histories, management practices and climate variables.

Twenty plants, with intact roots systems were collected randomly at each site. Roots were washed and scored for effective nodulation using assessment codes from the British Columbia Ministry of Forestry (Anon 1991) (Appendix 2), with 25 the maximum possible score. Due to the exceptional dry conditions during the crop growing season, it was decided that biomass dry matter weights at mid-pod fill, rather than grain yield, would be most beneficial in a year such as 2017, as there was a risk that the crops would run out of moisture and not produce harvestable grain.

Image 1: Soil sampling and pH testing using a 'Dig stick' and off the shelf pH test kit.

Assessments:

Table 1. Assessments carried out throughout 2017 in each of the 10 commercial lentil crops.

Assessment	Description
Soil Sampling	- 20 cores per site - Segmented at 5cm intervals down to 20cm, with increments from each core combined (i.e. 4 samples per site) - Analysed for pH (CaCl$_2$)
Nodulation Score (Anon 1991) (Appendix 2)	- 20 plants were randomly selected and assessed from each site - Plant vigour, nodule number, colour, appearance and position on the roots were assessed, giving an average nodulation score for each site out of a maximum score of 25
*Mid-pod Fill Biomass	- 10 x 0.25m^2 quads taken per site, averaged. Samples were oven-dried, and results expressed as tonnes of dry matter per hectare (t DM/ha)

**Mid-pod fill biomass cuts were taken instead of harvest biomass cuts due to the dry season. It was unknown if all the locations would make it through to harvest.*

Results

Sowing depth for lentil crops assessed for this project ranged from 5 to 10cm. All crops were treated with a rhizobia inoculant strain specific to lentil (Group E). Crops at Lockhart, Marrar South, Marrar North, Temora and Methul (5 of the 10 locations) had received a lime application (topdressed and not incorporated) within the last 3 years, at rates ranging from 1 to 2 t/ha. Crops at Merriwagga, Monia Gap, Binya, Yenda and Barellan had no history of lime use. The soil pH profiles for 20 sites assessed are shown in Figure 1. Based on the Pulse Australia guidelines that recommend pH>5.2 for growth of lentil plants and effective rhizobia function and nodule formation the sites were separated into 'Low pH' or 'High pH' groups depending on pH readings in the 5-15cm layers.

The benefit of finer sampling can be seen for the Low pH sites. A sample depth for 0-10cm would return a pH reading of 4.8 and fail to detect the elevated pH at 0-5cm (5.2) and the 0.8 unit drop in pH at 5-10cm.

Note that at most sites nodules were unusually small and lacked pink coloration (leghaemoglobin pigmentation) at many of the sites assessed for nodulation in August, indicating low nodule activity. Unseasonably dry and cold conditions from June to the end of August impacted on crop growth and nodule development and activity. A number of sites were revisited in September, when it was noted that nodule size and colour had improved with warmer spring temperatures.

The nodulation scores at the Low pH sites ranged from 2.3 to 12.8 out of a maximum 25. Taking into account the exceptional conditions in 2017, for this project any score above 10 was considered reasonable, although the nodulation assessment protocol used for this project (Appendix 2) indicate a score > 14 is reasonable. The nodulation scores at the High pH sites ranged from 11.8 to 19.9, with only the 3 'Good' sites in the 'Low pH group at Barellan, Marrar South and Marrar North (Good 2) scoring above 15.

Figure 2 Nodulation scores and biomass dry matter weights for each of the sites (10 locations), for the three lentil varieties monitored.

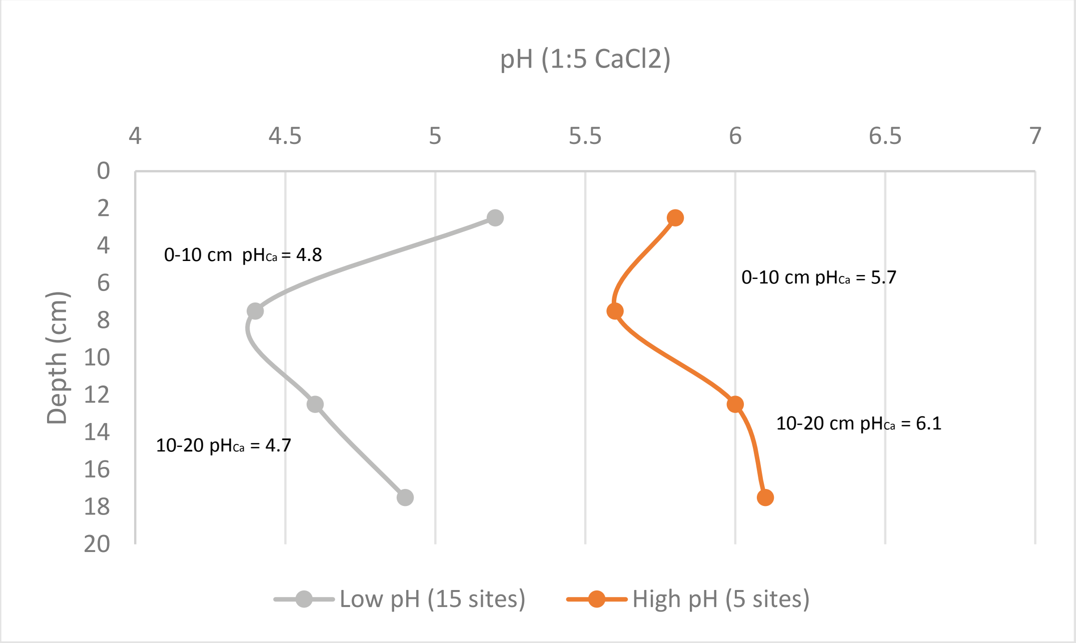


Figure 1. Averages of the pH readings for the 5cm increment across all sample site show stratification of soil pH in the profile. The 'Low pH' group include 2 sites at Merriwagga, Binya, Yenda, Temora, Methul, Marrar North and 1 site at Marrar South. The 'High pH' group include 2 sites at Monia Gap and 1 site each at Barellan, Marrar South and Marrar North.

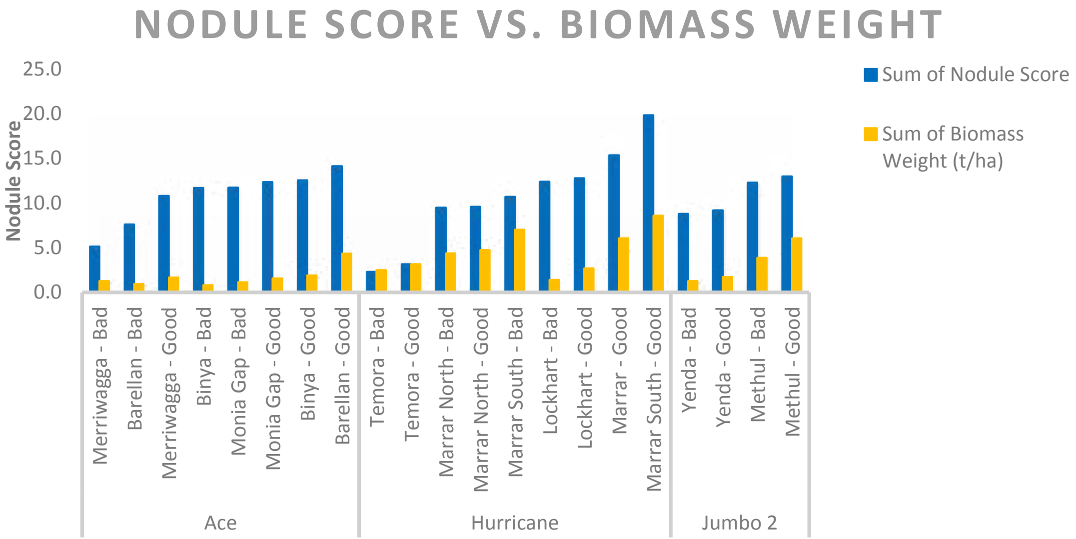


Figure 2. Nodulation score and biomass weight (t DM/ha) from Good and Bad sites at 10 locations, grouped by lentil variety - Ace, Hurricane and Jumbo 2.

Eastern Medium Rainfall Zone

Lockhart

The Good (Image 2) and Bad sites at Lockhart have very similar soil pH values at depths from 5-15cm (Figure 3). At the depth of 0-5cm, the pH of the Good site was 5.0, 0.4 of a pH unit higher than at the Bad site. The values for both sites were the same at the 5-10cm and 10-15cm segments. Roots from the Bad site were poorly developed (Image 3) and appeared to be stunted compared with roots from the Good site. Roots from both sites were concentrated in the surface 6cm of soil, possibly in response to the severely acidic layer (pH 4.2) below 5cm.

Image 2: Lockhart 'Good' site 18/8/17

Image 3: Shallow root growth on lentils at Lockhart 'Bad' site 18/8/17

The subsurface layers below 5cm for both sites are below the pH considered suitable for lentil crops. At sowing, the lentil seed and rhizobia would have been placed into the severely acidic layer (pH of 4.2) at 5-10cm. Therefore, it is not surprising that as shown in Table 2 the nodulation scores for both sites (12.8 and 12.4) were similar. Roots from both sites were concentrated in the surface 6cm of soil, possibly in response to the severely acidic layer (pH 4.2) below 5cm.
There is a large difference of 1.3t/ha of biomass for such a small difference in nodulation score.

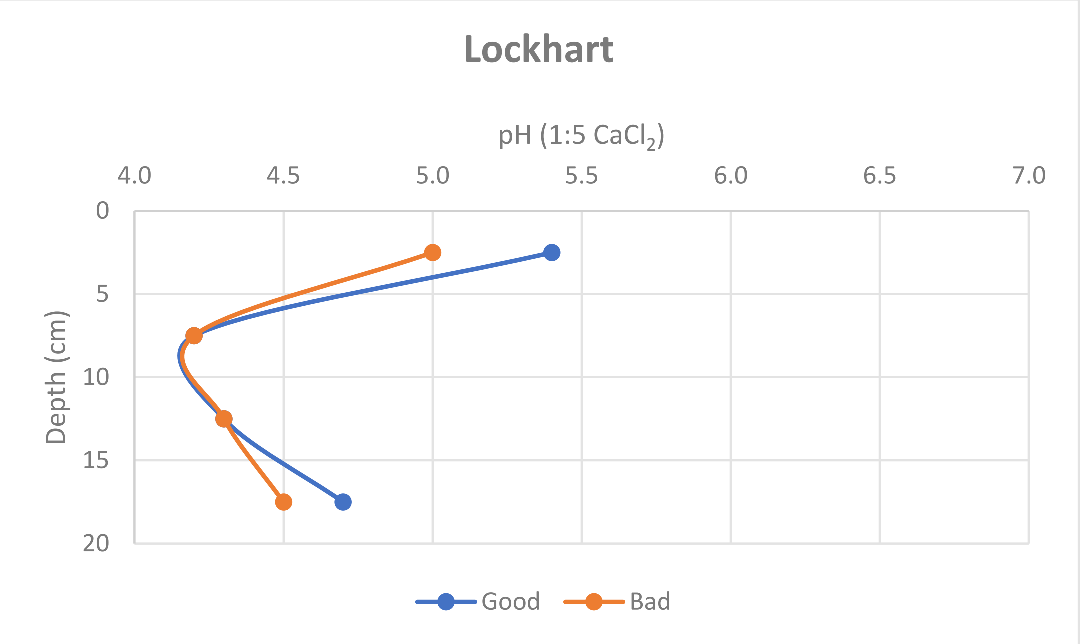


Figure 3. Lockhart high ('Good') and low ('Bad') pH site pH (CaCl2) readings.

Table 2. Lockhart high ('Good') and low ('Bad') pH site nodulation score and biomass cut (t DM/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Lockhart - Good	Hurricane	12.8	2.7
Lockhart - Bad	Hurricane	12.4	1.4

Marrar North

The pH readings at the three sites for the Marrar North (image 4 & 5) location follow a very similar pattern down the soil profile, the pH decreases after 0-5cm then begins to increase again after 10-15cm (Figure 4). The elevated pH in the 0-5cm surface layer at all sites is the result of a history of lime application; with 1.3 t/ha applied and incorporated in 2011 and 2t/ha in 2016, when the lime was top dressed. The lime effect does not appear to have had an impact below 5cm. As is the case with the Lockhart site, the sowing depth of the lentil seed at the Good and Bad sites coincided with a severely acidic layer (pH < 4.5), which is low enough to affect nodulation scores (9.6 and 9.5, respectively) shown in Table 3. The nodules were very small and pale colour indicated that they were inactive. However, a pH reading of 5.2 at 5-10cm at site Good 2 is in the acceptable range for nodulation. This site was an elevated area and would not have been subjected to the severe frosts and cold temperatures encountered at the low lying Good and Bad sites. Nodulation score of 15.4 for Good 2 site indicated effective nodulation – there were more nodules, they were larger and pink, so actively fixing nitrogen.

Image 4: 'Bad' Marrar North site 18/8/17

Image 5: 'Good' Marrar North site 18/8/17

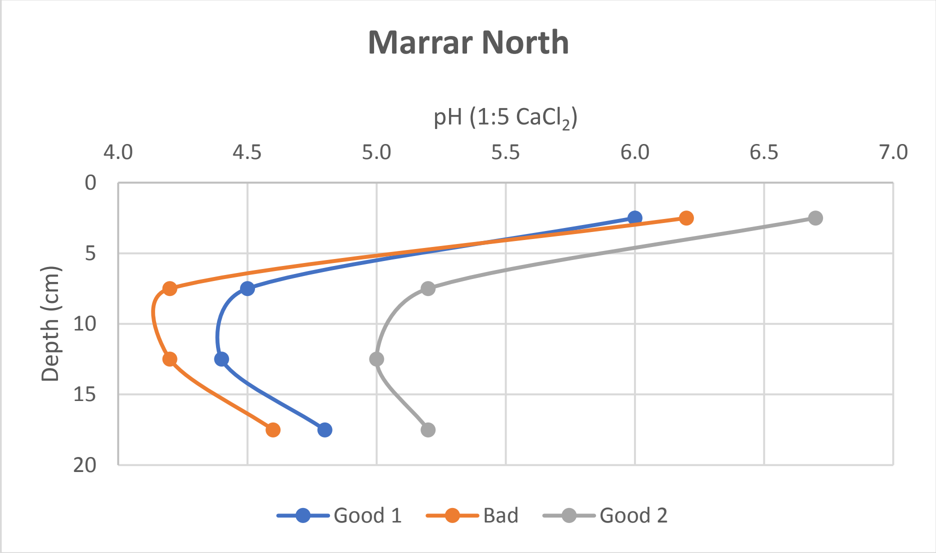


Figure 4. pH (CaCl$_2$) readings for Marrar North high ('Good'), low ('Bad') and very high ('Good 2') sites.*

There was very little difference in nodulation scores and biomass weights between the Good and Bad sites, and only 0.4t/ha difference in the biomass cut, which is not surprising given that there was very little difference in pH readings in the 5-15cm layers or nodulation scores. In contrast the nodulation score at the elevated Good 2 site (15.4) was the second highest across all 21 sites assessed and the crop had the second highest biomass weight (6.1 t DM/ha).

Table 3. Nodulation score and biomass cut (t DM/ha).Marrar North 'Good', Bad' and 'Good 2' pH sites

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Marrar North - Good	Hurricane	9.6	4.8
Marrar North - Bad	Hurricane	9.5	4.4
*Marrar North – Good 2	Hurricane	15.4	6.1

Marrar South

The pH profiles in Figure 5 show similar pH at 0-5cm at both the Marrar South Good and Bad sites (Images 6 & 7), with a difference of only 0.1 of a pH unit. Both sites' pH dropped at 5-10cm, the Good site dropped 0.6 of a unit to pH 5, while the Bad site dropped 1.1 units to 4.4.

Image 6: 'Bad' Marrar South site 18/8/17

Image 7: 'Good' Marrar South site 18/8/17

The higher pH readings for the Good site at all depths were reflected in the much higher nodulation score and biomass weight compared with the Bad site (Table 4). The nodulation scores were 19.85 and 10.7, respectively, while the biomass weights were 8.6 and 7.0 t DM/ha, respectively. The nodulation score and biomass weight for the Good site at Marrar South were the highest recorded across all sites. Appearance of nodules (colour and size) at the Good site was obviously better than for all other sites.

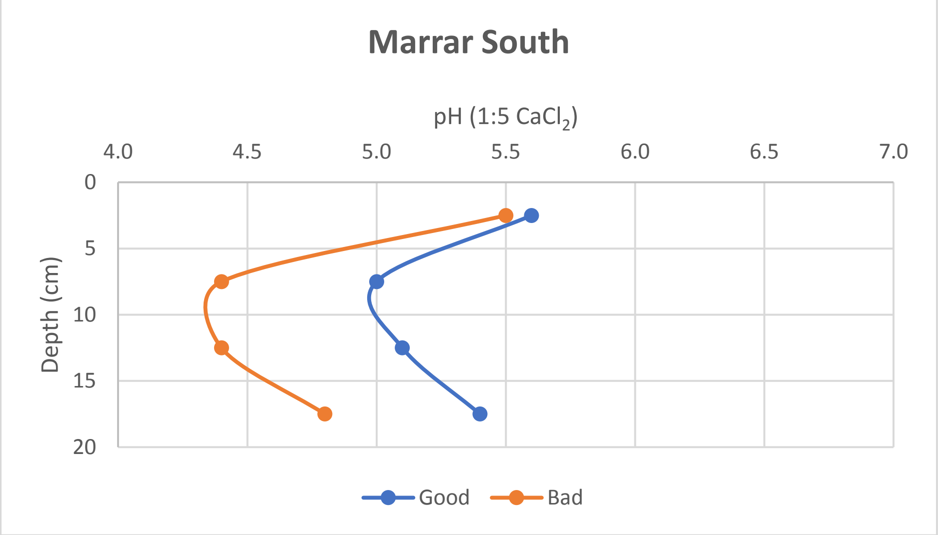


Figure 5. Marrar South high ('Good') and low ('Bad') pH site pH (CaCl$_2$) readings.

Table 4. Marrar South high ('Good') and low ('Bad') pH site nodulation score and biomass cut (t DM/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Marrar South - Good	Hurricane	19.9	8.6
Marrar South - Bad	Hurricane	10.7	7.0

Methul

The pH profile for the Good site at the Methul location (Figure 6 and Image 9) shows a similar pattern to other sites. The profile for the Bad site (Image 8) is unusual at the 10-15cm depth, which suggests sampling error. The Good site had a very high pH reading of 6.5 in the top 5cm of the soil profile, which then dropped back down to below 5 deeper in the profile. Although there are is no lime history available for this location. This sudden drop in pH is typical of paddocks with a recent history of lime, likely to be have been topdressed, but not incorporated. Topdressed, unincorporated lime results in an elevated pH in the surface 0-5cm and a marked drop in pH at 5-10cm.

Image 8: 'Bad' Methul site 25/8/17

Image 9: 'Good' Methul site 25/8/17

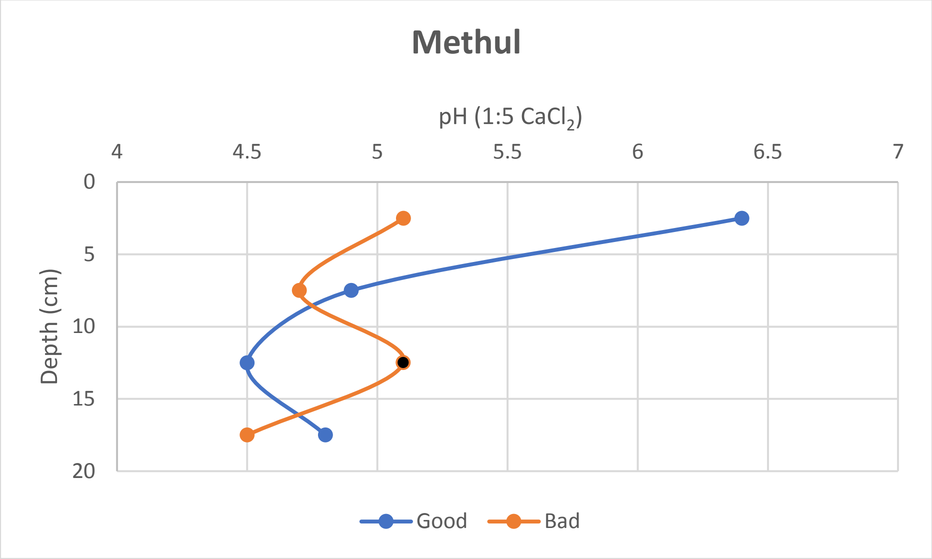


Figure 6. Methul high ('Good') and low ('Bad') pH site pH ($CaCl_2$) readings.

Table 5 shows a very small difference in nodulation scores when comparing the good and the bad sites, yet a huge difference of 2.2t/ha in biomass. This difference may be due to the more favourable pH in the 0-10cm layer and for root growth at the Good site. However, the difference is difficult to explain without accurate pH reading for the 10-15cm layer for the 'Bad' site.

Table 5. Methul high ('Good') and low ('Bad') pH site nodulation score and biomass cut (t DM/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Methul - Good	Jumbo 2	13	6.1
Methul - Bad	Jumbo 2	12.3	3.9

Temora

The pH profile at both the Good (Image 10) and Bad (Image 11) sites at Temora (Figure 7) indicate different soil types. Lime history for this location is not available, but the dramatic drop in pH from 5.5 in the surface layer to 4.2 in the 5-10cm layer indicates lime has been topdressed recently and not incorporated. The lower surface soil pH of 5.1 at the Bad site may be due to uneven lime application. At both sites the pH of the 5-10cm is moderately to severely acidic and unsuitable for root development and nodule formation and function.

Image 10: Temora 'Good' Site 15/9/17

Image 11: Temora 'Bad' site 15/9/17

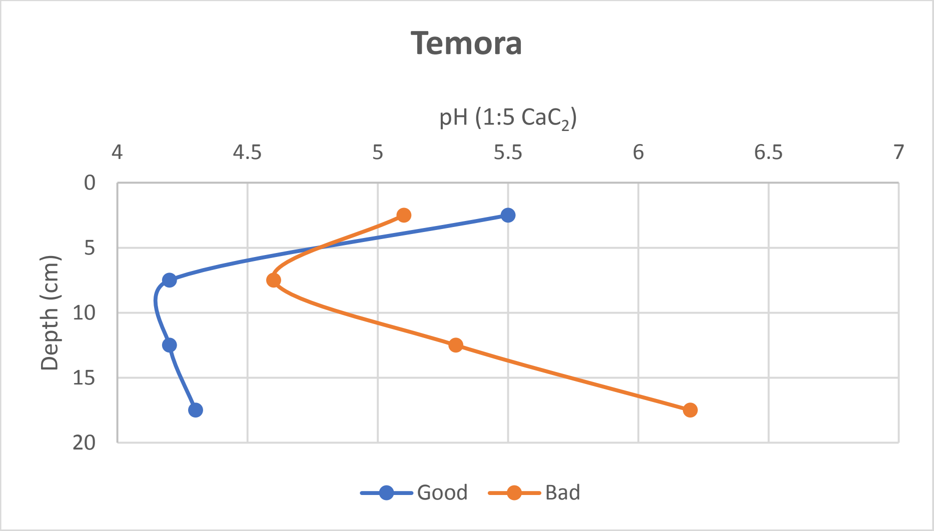


Figure 7. Temora high ('Good') and low ('Bad') pH site pH ($CaCl_2$) readings.

There were no nodules on plants collected from either site at Temora for nodulation scores of 3.2 and 2.3 for the Good and Bad sites, respectively (Table 6).

The biomass weights and nodule scores followed the same trend, low scores and weights and a small difference between sites.

The Temora location had by far the lowest nodulation scores and suggests failure of the inoculation process. This needs to be followed up as failed nodulation could not be attributed to pH alone.

Table 6. Temora high ('Good') and low ('Bad') pH site nodulation score and biomass cut (t DM/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Temora - Good	Hurricane	3.2	3.2
Temora - Bad	Hurricane	2.3	2.5

Western Low Rainfall Zone

Barellan

The Barellan paddock monitored for this project is a brown to grey medium clay, with no history of lime application. As shown in Figure 8, the pH profile at the Good site is relatively uniform compared with all other sites and pH readings are within the alkaline range considered optimal for lentil and Group E rhizobia. Despite being within the same paddock the soil at the Bad site (Image 12) is very different, with evidence of scalding and sodic soils in the bad area. Here the pH drops dramatically by 1.3 units from 6.5 at 0-5cm to 5.2 at 5-10cm (Image 14).

Although both the Good and Bad sites at Barellan are within the 'High pH group' shown in Figure 1, the hostile soil conditions in the 5-10cm layer at the Bad site appears to have affected both nodulation and biomass cuts. Nodulation score at the Good site (Image 13) was in the satisfactory range, at 14.2 compared with an unsatisfactory score of 7.6 at the Bad site. The better nodulation score at the Good site was reflected in a biomass weight, with 3.3t DM/ha greater than the Bad site Table 7.

Image 14: changes in pH at depth for the 'Bad' site at Barellan 24/8/17

Image 12: Barellan 'Bad' site 24/8/17

Image 13: Barellan 'Good' site 24/8/17

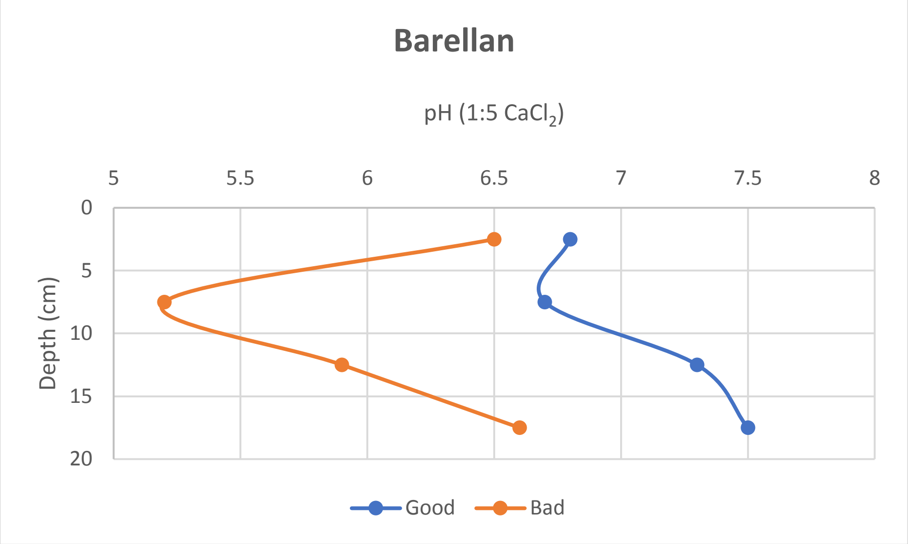


Figure 8. Barellan high ('Good') and low ('Bad') pH site pH ($CaCl_2$) readings.

Table 7. Barellan high ('Good') and low ('Bad') pH site nodule score and biomass cut (t DM/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Barellan - Good	Ace	14.2	4.3
Barellan - Bad	Ace	7.6	1.0

Binya

There is no history of lime application at the Binya location. The pH of the 0-5cm surface layer for both the Good (Image 16) and Bad (Image 15) sites, shown in Figure 9, are similar, but within the severely acidic range at 5-10cm. Despite this, the reasonable nodulation scores of 12.6 and 11.7, shown in Table 8, are surprising.

The pH at the Good site increases to > 5 at 10-20cm, while the pH at the Bad site is less than 5.0 at all depths. This higher pH at the Good site, which is in the satisfactory range for lentil, may explain the higher biomass weights for the Good site (1.9 t DM/ha) compared with only 0.8 t DM / ha at the Bad site.

Image 15: Binya 'Bad' site 24/8/17

Image 16: Binya 'Good' site 24/8/17

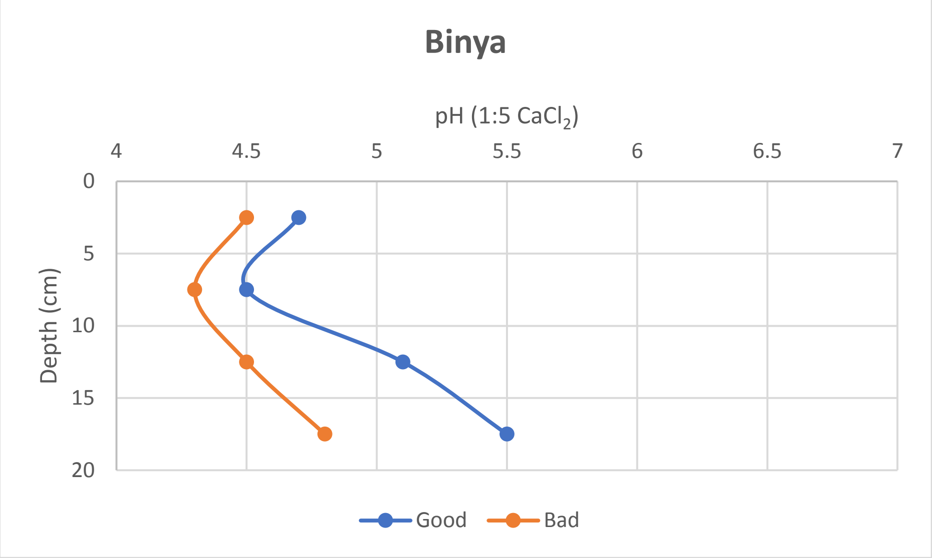


Figure 9. Binya high ('Good') and low ('Bad') pH site pH ($CaCl_2$) readings.

Table 8. Binya high ('Good') and low ('Bad') pH site nodule score and biomass cut (t DM/ha)

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Binya - Good	Ace	12.6	1.9
Binya - Bad	Ace	11.7	0.8

Merriwagga

There is no history of lime application at the Merriwagga location. The pH profiles at the Good (image 18) and Bad (Image 17) sites, shown in Figure 10, are similar to those for the Binya sites. The pH readings for the 0-5cm and 5-10cm layers for the Good site (4.9 and 4.9) are marginally higher than the Bad site (4.8 and 4.6). The nodulation score for the Good site (10.8) is only just 'reasonable', but is unsatisfactory for the Bad site (5.2).

Below 10cm, the pH of the Good site increases quickly to above 5.5, while the Bad site has a relatively uniform pH of 4.6 to 4.8 to depth. The higher pH in these subsurface layers at the Good site is within the range suitable for lentil. Overall the pH profile for the Good site is marginal for lentil crops, while the Bad site is moderately acidic at all depths. The biomass weights only differed by 0.4t/ha, the good site coming out on top.


Image 17: Merriwagga 'Bad' site 28/8/17


Image 18: Merriwagga 'Good' site 28/8/17

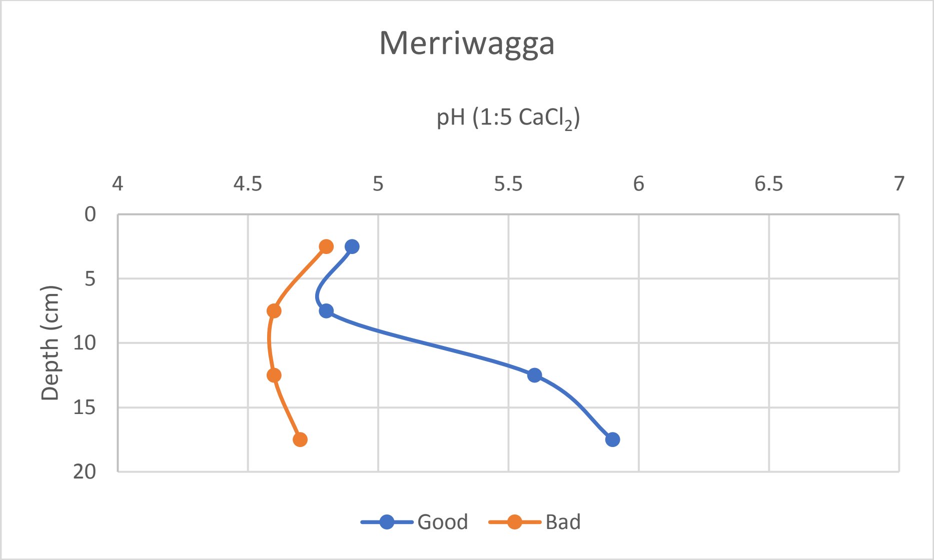


Figure 10. Merriwagga high ('Good') and low ('Bad') pH site pH ($CaCl_2$) readings.

Table 9. Merriwagga high ('Good') and low ('Bad') pH site nodule score and biomass cut (t DM/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Merriwagga - Good	Ace	10.8	1.7
Merriwagga - Bad	Ace	5.2	1.3

Monia Gap

The pH at both sites at Monia Gap was above 5 at all depths (Figure 11) and increased with depth. The Good site (Image 20) and the Bad site (Image 19) were not substantially different – although the Good site performed better on all counts.

The Monia Gap sites only differed by 0.6 points in the nodulation score and 0.4t/ha biomass weight. The Good site coming out on top for both assessments.


Image 19: Monia Gap 'Bad' site 28/8/17


Image 20: Monia Gap 'Good' site 28/8/17

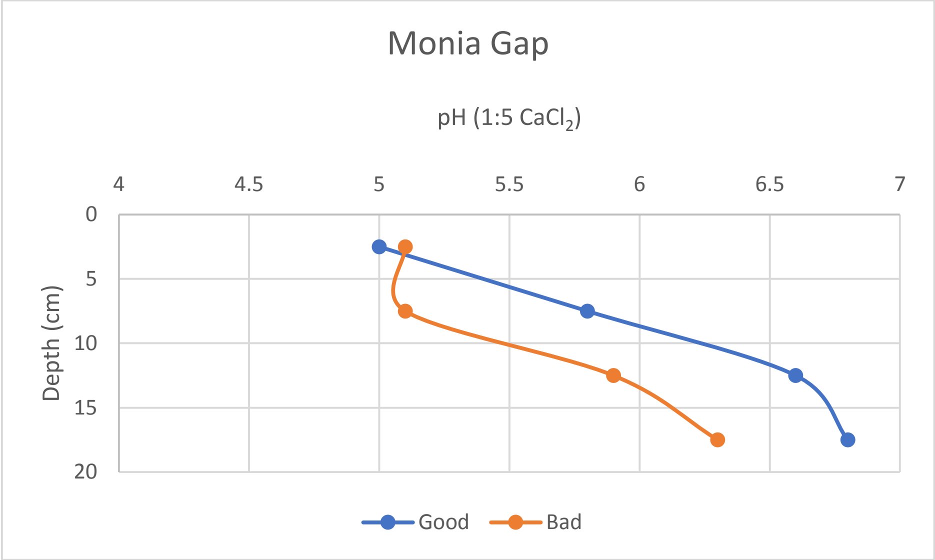


Figure 11. Monia Gap high ('Good') and low ('Bad') pH site pH ($CaCl_2$) readings.

Table 10. Monia Gap high ('Good') and low ('Bad') pH site nodule score and biomass cut (t DM/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Monia Gap - Good	Ace	12.4	1.6
Monia Gap - Bad	Ace	11.8	1.2

Yenda

The pH profiles for the Good (Image 22) and Bad (Image 21) sites at Yenda shown in Figure 11 are slightly unusual, the pH at the Good site at Yenda remains relatively constant down the profile, ranging from 4.5-4.3. The Bad site begins the same way, but lower, until the pH increases from 4.1 to 4.6 at 10-15cm (Image 23).

There was little difference in nodule score and biomass weights at the Good and Bad Yenda sites, as seen in Table 11. Between the two sites, there was a difference of 0.4 in nodule score and in biomass weight.

Image 23: Consistent pH profile of Yenda 'Bad' site 24/8/17

Image 21: Yenda 'Bad' site 24/8/17

Image 22: Yenda 'Bad' site 24/8/17

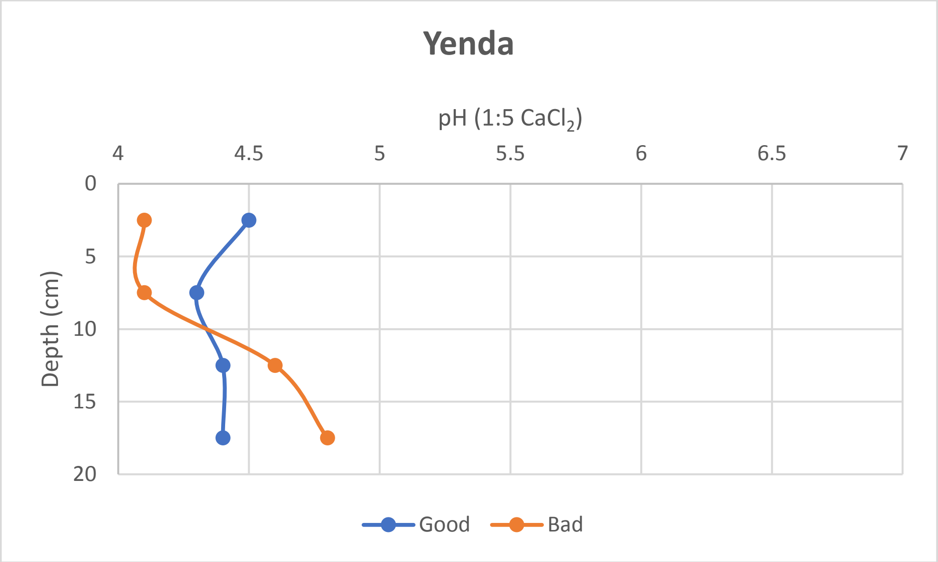


Figure 12. Yenda high ('Good') and low ('Bad') pH site pH (CaCl$_2$) readings.

Table 11. Yenda high ('Good') and low ('Bad') pH site nodulation score and biomass cut (t/ha).

Site	Variety	Nodulation Score	Biomass Weight (t DM/ha)
Yenda - Good	Jumbo 2	9.2	1.7
Yenda - Bad	Jumbo 2	8.8	1.3

Discussion

Despite being sensitive to acidic soils, the area of lentil and other acid sensitive pulse crops being grown across the southern NSW medium rainfall zone is expanding. One of the advantages of growing pulse crops is their ability to fix nitrogen. To be effective, the pulse must be well-nodulated, which is essential for early plant growth, vigour and production potential when sown into nitrogen depleted soils. However, being a relatively new crop to the area, there is little information available on the impact that acidic layers in the main root zone (0-20cm) can have on nodulation and production.

Because conditions across the region are extremely variable it is impossible to draw major conclusions from the results collected in a single growing season. In addition pH, was the only soil property measured, when in fact there are likely to be other constraints not detected.

None of the western locations (Merriwagga, Monia Gap, Binya, Yenda and Barellan) have any history of lime. The five eastern locations, Temora, Methul, Marrar North, Marrar South and Lockhart, have a relatively strong history of liming. The intense stratification and elevated pH in the surface 0-5cm is typical of the common practice of topdressing lime and incorporated by sowing under minimum disturbance systems.

The severely acidic layers detected at Merriwagga, Binya and Yenda and the correspondingly low nodulation scores recorded suggest that low pH may limit production potential of acid sensitive pulses such as lentil at these sites. According to Pulse Australia (2015) the ideal pH (CaCl$_2$) range for lentil is between 6 and 8, but yields have been satisfactory where pH is > 5.2. This guideline can be misleading as 5.2 is the critical lower limit for the main root zone (i.e. the top 20-25cm).

Eight out of the 10 Good sites had a higher pH result than the paired Bad sites at most depths. Only the Bad sites at the Yenda and Temora locations had a higher pH than the Good sites.

Low pH (pHCaCl$_2$ < 5.0) within the surface 0-10cm has been shown to reduce nodulation and restrict root growth (Burns et al). Acidic layers are not being detected when using the standard soil sampling method of 0-10cm and 10-20cm (Burns et al. 2017). Finer sampling intervals of 5cm were used in this project to detect pH stratification. It is particularly evident at the Low pH sites (Figure 1) where the pH is elevated within the surface 0-5cm layer, then drops dramatically at the 5-10cm depth. There is a trend toward higher pH in the 15-20cm layer at most sites, which is typical of the soils of southern NSW. The stratification detected by sampling 5cm intervals would not be detected sampling depths of 0-10cm and 10-20cm. Traditional sampling at 0-10cm (pHCa 4.8) is not detecting the acidic conditions that the emerging seedlings and rhizobia experience at 5-10cm (pHCa 4.4). Coarse sampling at 0-10cm creates the illusion that soil acidity is not a problem in the top 10 centimetres.

Carefully selecting a paddock is crucial for optimal growth in lentils. Paddock management also plays an important role, Burns et al (2017) states that under no-till systems, lime topdressing with no incorporation is ineffective in neutralising acidity below a depth of approximately 5cm. Lime remains concentrated in the surface layers with little movement, limiting lime effect and potential crop response. The most effective way to rapidly increase pH in the top 10cm is to effectively incorporate adequate rates of lime, at least 18 months before sowing sensitive species, to ensure lime has time to react.

Lentils and other acid-sensitive pulse crops are perceived as high production risk crops with inconsistent yields. Burns et al (2017) concluded that severely acidic layers were likely to be a major factor for inconsistent performance of acid sensitive pulses on slight and medium acidic soils in the medium and high rainfall zones. The risk of developing severely acidic layers can be reduced by implementing an effective liming program. A soil testing program that monitors changes in soil properties (e.g. pH) over time will provide growers and advisors with the information and confidence to adjust lime rates as required and identify the need for occasional strategic cultivation to incorporate lime. The GPS coordinates recorded for the sites included in this study, provide baseline data to commence a program of regular testing. Ideally this would occur at three to five year intervals, but will depend on funding availability.

References

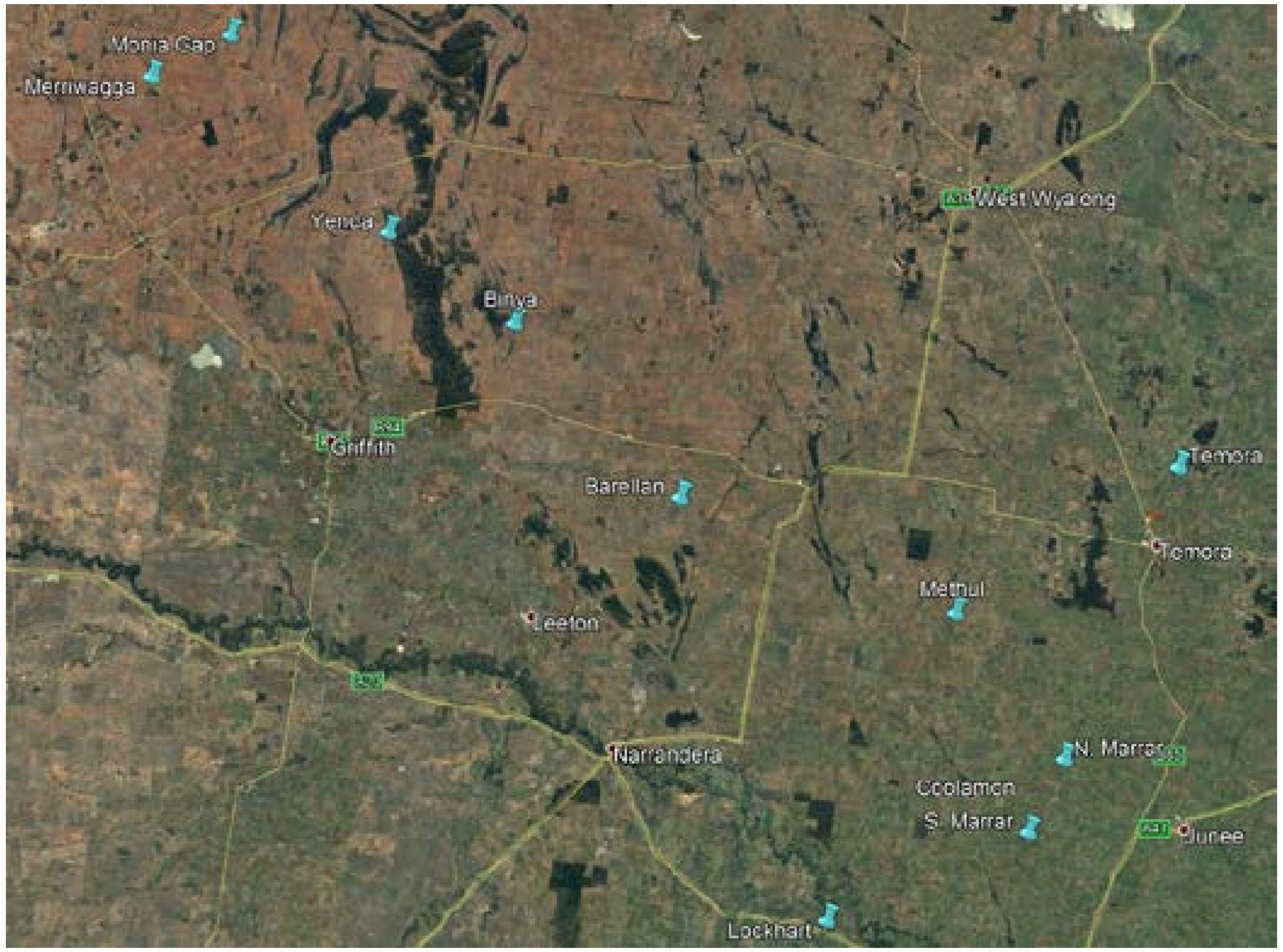
Anon (1991), Field Guide to Nodulation and Nitrogen fixation Assessment, British Columbia Ministry of Forestry.

Burns, H, Norton, M & Tyndall, P (NSW Department of Primary Industries, Wagga Wagga Agricultural Institute) 2017, 'Topsoil pH stratification impacts on pulse production in South East Australia', GRDC Update Papers, viewed 25 January, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/topsoil-ph-stratification-impacts-on-pulse-production-in-south-east-australia?

Pulse Australia 2015, Lentil Production: Southern region, Best Management Guide, viewed 24 January 2017, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

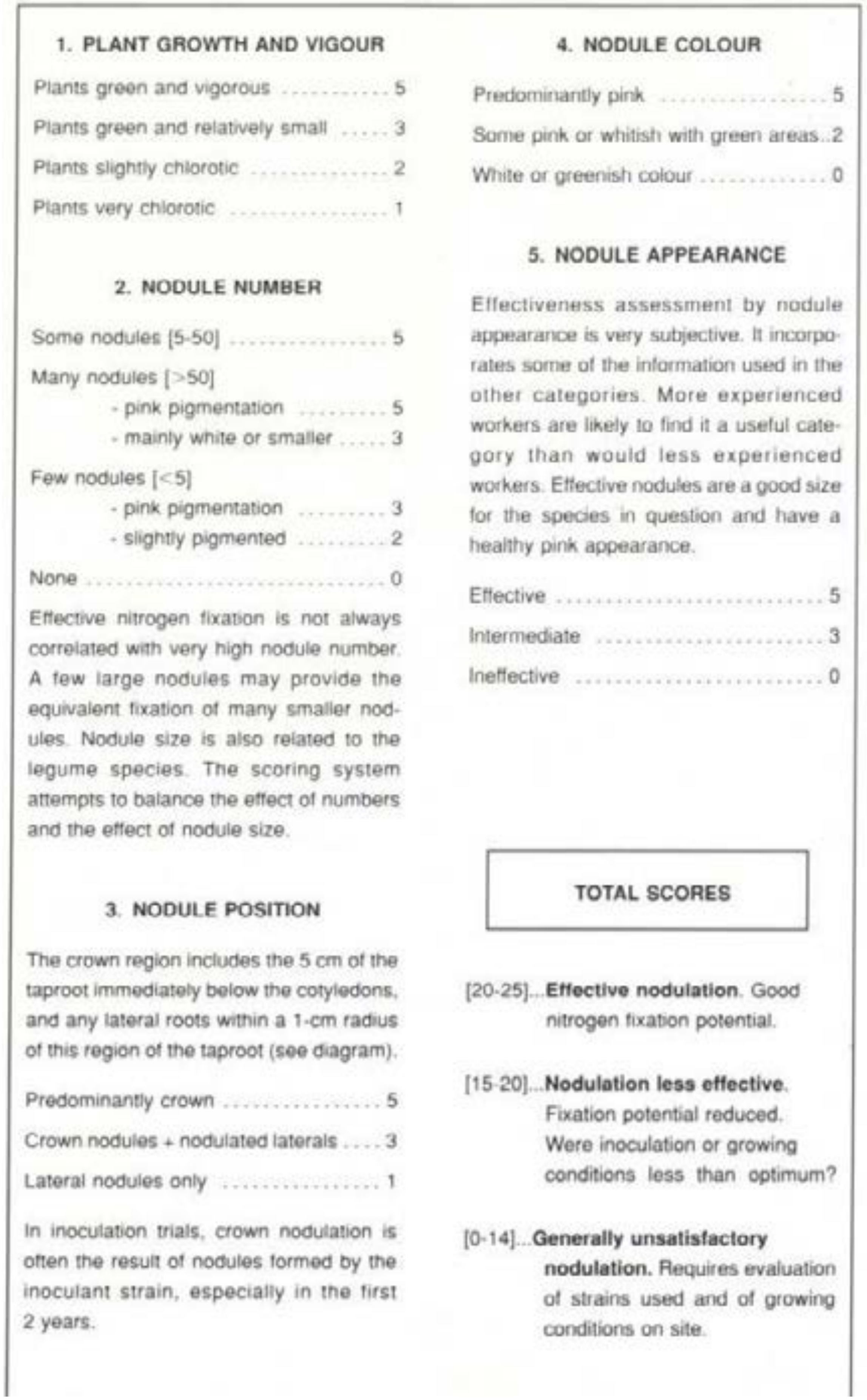
Appendix 1

Eastern medium rainfall zone and western low rainfall zone site locations.



Appendix 2

Nodulation assessment protocol (Anon 1991)



1. PLANT GROWTH AND VIGOUR

Plants green and vigorous	5
Plants green and relatively small	3
Plants slightly chlorotic	2
Plants very chlorotic	1

2. NODULE NUMBER

Some nodules [5-50]	5
Many nodules [>50]	
- pink pigmentation	5
- mainly white or smaller	3
Few nodules [<5]	
- pink pigmentation	3
- slightly pigmented	2
None	0

Effective nitrogen fixation is not always correlated with very high nodule number. A few large nodules may provide the equivalent fixation of many smaller nodules. Nodule size is also related to the legume species. The scoring system attempts to balance the effect of numbers and the effect of nodule size.

3. NODULE POSITION

The crown region includes the 5 cm of the taproot immediately below the cotyledons, and any lateral roots within a 1-cm radius of this region of the taproot (see diagram).

Predominantly crown	5
Crown nodules + nodulated laterals	3
Lateral nodules only	1

In inoculation trials, crown nodulation is often the result of nodules formed by the inoculant strain, especially in the first 2 years.

4. NODULE COLOUR

Predominantly pink	5
Some pink or whitish with green areas	2
White or greenish colour	0

5. NODULE APPEARANCE

Effectiveness assessment by nodule appearance is very subjective. It incorporates some of the information used in the other categories. More experienced workers are likely to find it a useful category than would less experienced workers. Effective nodules are a good size for the species in question and have a healthy pink appearance.

Effective	5
Intermediate	3
Ineffective	0

TOTAL SCORES

[20-25]...**Effective nodulation.** Good nitrogen fixation potential.

[15-20]...**Nodulation less effective.** Fixation potential reduced. Were inoculation or growing conditions less than optimum?

[0-14]...**Generally unsatisfactory nodulation.** Requires evaluation of strains used and of growing conditions on site.

Farmers Without Fences – Pakistan exchange program

Trial Site Location Pakistan and Southern NSW

Report Authors

Cindy Cassidy, FarmLink

Introduction

The Functional Grain Centre at CSU is undertaking a project with ACIAR to improve the productivity and profitability of pulse production in Pakistan. The project focuses on farmer driven improvements in agronomic practices and value adding opportunities. FarmLink is involved in the project to support development of farm led R&D activities in Pakistan and to facilitate that outcome, we are leading a sub project entitled "Farmers without fences". The sub project provides opportunity for farmers and researchers from Pakistan to visit Australia to interact with and learn from farmers and researchers here and vice versa. Pakistan will benefit from a better understanding of Australian farming practices and value chain management while Australian farmers and researchers will learn more about the international pulse market and develop closer interactions with pulse breeders and researchers.

The project commenced at the end of 2016. In 2017 project teams have been established around six sites in Pakistan. Baseline information has been collected at each site to identify the barriers to adoption of innovation in pulse production and the agronomic opportunities to increase production. Interesting regional and socioeconomic differences have been identified across the sites, which are spread over Pakistan.

An initial visit to Pakistan in 2016 revealed complexities and safety issues associated with travel to the country and within Pakistan. This, along with a slow start to on ground works in Pakistan, has meant that plans to take Australian farmers to Pakistan in 2017 were postponed until appropriate arrangements are put in place. The first exchange of Pakistani researchers to Australia occurred in February 2018.

Project Partners
FarmLink
FGC Functional Grains Centre
PULSE AUSTRALIA

Funding Partners
Australian Government
Australian Centre for International Agricultural Research

Project code - FWB16

Objectives

The broad objectives of the project are -

- To increase the productivity and profitability of pulses in cereal based cropping systems of Pakistan
- To facilitate pulse farmer and researcher exchange between Australia and Pakistan to support increased pulse production and value in both countries.

The objectives of the situational analysis conducted in 2017 in Pakistan were to collect baseline information to identify –

- The barriers to adoption of the proposed innovations for pulses
- The agronomic practices, technologies and available improved varieties that can increase the productivity and profitability of chickpea and lentils
- Opportunities to mitigate the effect of farm labour shortage on pulses production
- Value adding opportunities for lentil, chickpea and groundnut (peanut) crops at the village level
- Availability of quality seed supply for chickpea and lentil growers

The objective of the Pakistani project leader visit to Australia were to provide project participants with –

- An introduction to Charles Sturt University and the local project team
- Knowledge of pulse growing conditions and growers in southern NSW
- An overview of Australian grains industry and specifically the pulse industry
- Knowledge of the processing and value adding sector for Australian Pulses, and
- An introduction to Australian grains industry research community

Method

Situational Analysis 2017

In this project we are working with

- the three major pulse crops of Pakistan – Chickpea, Lentil & Groundnut or Peanut,
- fifteen farming families at each project site,
- six sites across the four provinces of Pakistan (Punjab, Khyber Pakhtunkhwa (PKR), Sindh and Baluchistan) selected based on their contribution to national pulse area and production (see figure 1).

A standard information sheet was prepared and used as the basis of facilitated workshops at each of the six sites. At each site the farm families were grouped into men, women and youth in order to account for gender and age-related differences in knowledge and experience and to overcome cultural issues associated with mixed gender gatherings.

Facilitated workshops were conducted in November 2017 and information about current farming practices and local pulse supply chain was collated.

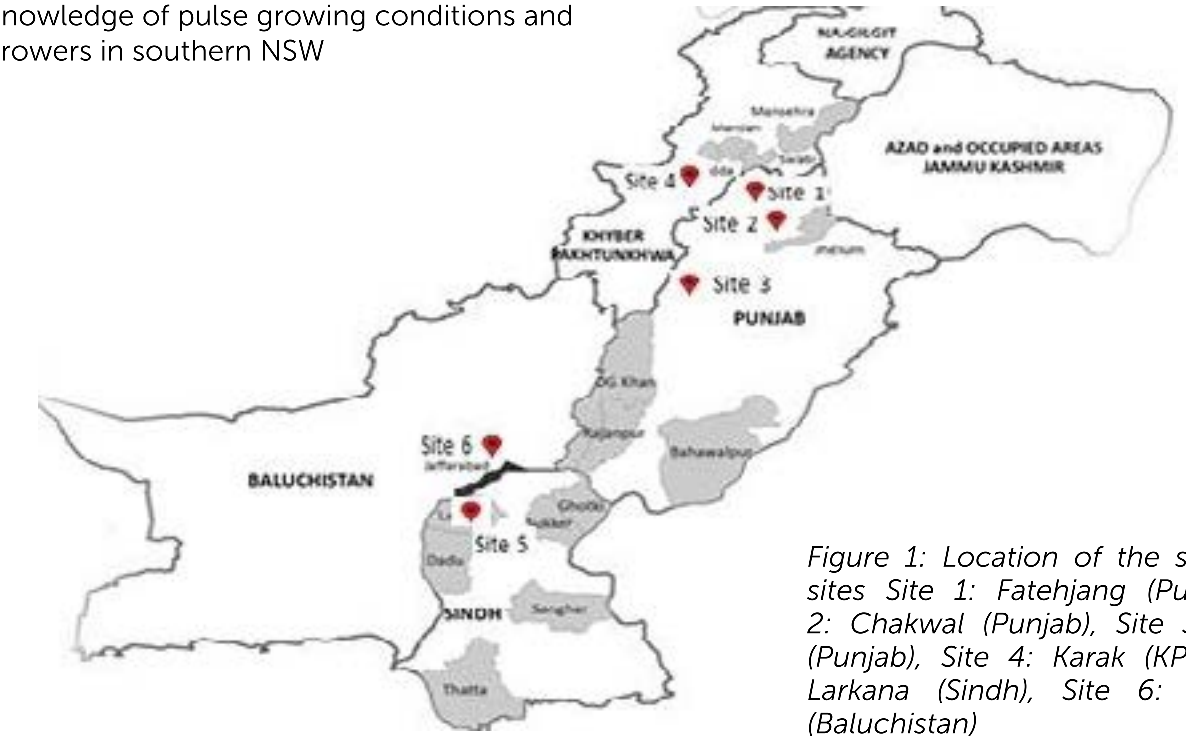


Figure 1: Location of the site project sites Site 1: Fatehjang (Punjab), Site 2: Chakwal (Punjab), Site 3: Bhakkar (Punjab), Site 4: Karak (KPK), Site 5: Larkana (Sindh), Site 6: Jafferabad (Baluchistan)

Pictured during the Pakistan project leader visit to Temora Agricultural Innovation Centre in February were (l-r) Lyndon McNab, Tehreem Javaid, Penny Heuston, Israr Hussain, Helen Burns, Abdul Manan, Phil Bowden, and Deirdre Lemerle.

Project leader Australian Visit February 2018

A program of visits was conducted over two weeks in February 2018 (see Table 1) for the Pakistan based project leaders. FarmLink hosted the group to provide an introduction and overview of Australian farming and the pulse industry in southern NSW. A focus of the tour was to also understand the FarmLink model for farmer led agricultural innovation.

	Program
Mon 5th Feb	The program team met with their Australian counterparts at Charles Sturt University and the Functional Grains Centre. The focus of these two days is to undertake detailed project planning to ensure delivery of project objectives and to build team dynamics
Tues 6th Feb	
Wed 7th Feb	FarmLink hosted the project team on a local tour taking them to visit with FarmLink members involved in pulse production and supply – Visit 1 - Ben Langtry, "Glenelg", Marrar Crop rotations, farm scale and pulse marketing options locally Visit 2 - Daniel Fox, "Five Oaks", Old Junee Farm system – moisture conservation with stubble retention, disc seeding and summer weed control. Visit 3 – Rob Hart – Hart Bros Seeds, Old Junee Seed production and cleaning.
Thurs 8th Feb	FarmLink hosted the project team at Temora Agricultural Innovation Centre, inviting farmers, researchers and advisors to participate in providing an overview of the Australian grains industry, Australian pulse industry, the role of different RD&E investors and providers, and the structure and function of FarmLink as a means of farmer led RD&E. Participants included Phil Bowden, Pulse Australia; Helen Burns, NSWDPI; Penny Heuston, Agronomist; Deirdre Lemerle, Graham Centre; Cindy Cassidy, FarmLink; Kylie Dunstan, FarmLink; Lisa Anderson, Elwood Pastoral; Lyndon McNab, "Oori" Quandialla
Fri 9th Feb	FarmLink hosted the project team on a visit to the Conqueror Milling Company at Cootamundra, a subsidiary of Croker Grain involved in trading and value adding a range of pulses locally. Understanding the role that value adding can play in increasing returns to the industry but also in buffering price volatility.
Mon 12th Feb	The project team met with ACIAR, Functional Grains Centre and CSU representatives to discuss progress of the project and define next steps.
Tues 13th Feb	The project team joined local farmers, advisors and researchers at the GRDC Update Wagga Wagga
Wed 14th Feb	

Figure 2: Pakistani farmers discussing constraints on pulse production as part of the situational analysis, November 2017

Results

Situational Analysis 2017

The situational analysis identified the following issues common across sites in Pakistan –

- Reduced chickpea production area due to disease (mainly Ascochyta blight)
- cereals and oils seeds more profitable/ productive
- limited inoculum and/or fungicide seed treatment
- Weed control options predominantly manual
- Farmer saved seed is the primary seed source and there is often a lack of varietal purity
- Limited to no soil sampling and testing being conducted
- Pests including pod borer and termites reducing production
- Average farm is small, typically 1-10ha, but up to 160ha
- Low rainfall and/or limited access to irrigation
- Limited internet access
- Limited finance available to support investment in agronomic or other technologies

Project leader Australian Visit February 2018

Marked differences in Pakistani and Australian farming, RD&E systems and value chains were noted over the course of the visit. These included scale, mechanisation, access to finance, access to advice and information, road and rail infrastructure, storage and processing capacity, industry representation and collaboration, RD&E strategy and investment as well as farming practice. Similarities were observed in the agronomic challenges (pests, disease, weeds), low rainfall conditions and the need for soil moisture conservation and water use efficiency, variety development, supply chain constraints and market volatility.

Observations about the quality of Australian pulses and a preference amongst Pakistani consumers for homegrown product based on 'better flavour' was shared and is worth further investigation.

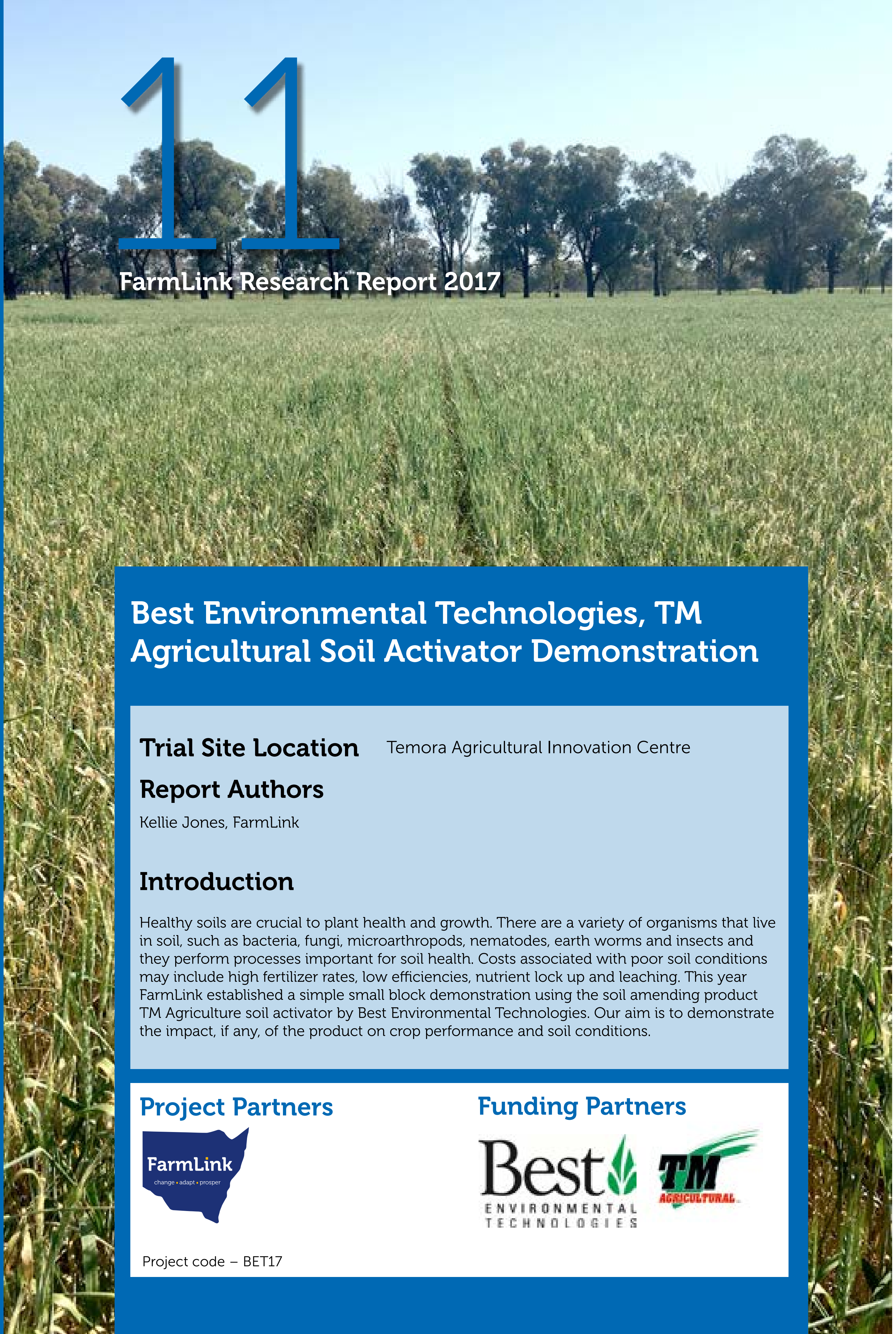
Discussion

Figure 3: Australian farmers and researchers discussing lentil production, Hart Bros September 2017

Outcomes of the situational analysis highlight the subsistence nature of much of the agriculture in Pakistan. Landholdings are small, access to technology is limited and there are generally, low levels of mechanisation resulting in a heavy dependence on manual labour for sowing, harvest and in crop activities like weed control. Due to the poor relative returns of pulses compared to cereals and oilseeds, pulse production has been pushed to the more marginal farm land compounding the issues. The baseline information highlights immediate opportunities for improvement in weed, disease and pest control as well as in soil and fertility management based on our understanding of available control measures and pulse agronomy. Even the questions related to variety development and seed purity appear, on the surface, to be relatively easy to address immediately through landrace selection and quality systems to retain purity. However, several of the findings around reliance on manual labour, limited access to finance and limited internet access are indicative of other structural issues that may impede or at very least hinder farmers as they look to adopt new farming practices. These outcomes were supported by the observations coming out of the Australian visit.

This project has been designed to identify and overcome the barriers inhibiting adoption of more profitable and productive pulse farming in Pakistan using a farmer led approach. Looking at the system beyond the farm gate that impacts on production decisions and capacity will be critical in achieving success. Interestingly, similar conclusions could be reached in relation to the further development of the pulse industry in southern NSW, where production constraints (variety and soil suitability, agronomic packages etc), storage, logistics and marketing limitations as well as market volatility, appear to be working in combination to limit production growth despite increasing farmer interest in pulses. An opportunity exists to look at pre and post farm gate innovations together to achieve growth in pulses in SNSW eg solving supply chain constraints supports production of new varieties as they become available; developing agronomic packages supports production of pulses when the processing sector signals that there is a secure, stable market for them.

Recognising that expansion of a new crop or suite of crops in this region requires a coordinated response is perhaps the first step in growth of the pulse industry here and in Pakistan.



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FarmLink Research Report 2017

Best Environmental Technologies, TM Agricultural Soil Activator Demonstration

Trial Site Location Temora Agricultural Innovation Centre

Report Authors

Kellie Jones, FarmLink

Introduction

Healthy soils are crucial to plant health and growth. There are a variety of organisms that live in soil, such as bacteria, fungi, microarthropods, nematodes, earth worms and insects and they perform processes important for soil health. Costs associated with poor soil conditions may include high fertilizer rates, low efficiencies, nutrient lock up and leaching. This year FarmLink established a simple small block demonstration using the soil amending product TM Agriculture soil activator by Best Environmental Technologies. Our aim is to demonstrate the impact, if any, of the product on crop performance and soil conditions.

Project Partners

Funding Partners

Project code – BET17

Objective

To establish a product display at the Temora Agricultural Innovation Centre on behalf of Best Environmental Technologies, TM Agricultural Soil Activator.

Method

Establish a 3 year rotation Canola, Wheat, Pulse in a 3ha demonstration plot.

In 2017, 3 crop types (canola, wheat, lentils) were planted with two treatments each -

- Applied: - 250ml/ha Best Environmental Technologies TM Agricultural Soil Activator pre-sowing
    - 250ml/ha Best Environmental Technologies TM Agricultural Soil Activator between post-emergence and pre-flowering
    - sowing fertilizer reduced by 20%, which is standard practice when using the soil activator
- Not applied: - no product application
    - standard fertilizer application (see appendix)

Soil sampling is undertaken prior to trial establishment and pre-sowing each year. This demonstration is located on a yellow brown/red brown medium clay.

Production costs were the same across treatments, except -

- TM Agricultural Soil Activator costs $25/ha
- 20% saving in fertiliser equivalent to $12.13/ha
- The net difference in production cost is that the applied treatment cost an additional $12.87/ha

Results

Soil nitrogen and organic carbon results are provided in Figure 1 (wheat), Figure 2 (lentils) and Figure 3 (canola).

For wheat, soil nitrogen decreased in both treatments. Both strips began the trial with a soil nitrogen of 31 mg/kg, the treated strip dropped by 16 mg/kg, the untreated strip dropped by 21 mg/kg. The organic carbon decreased only slightly for both treatments.

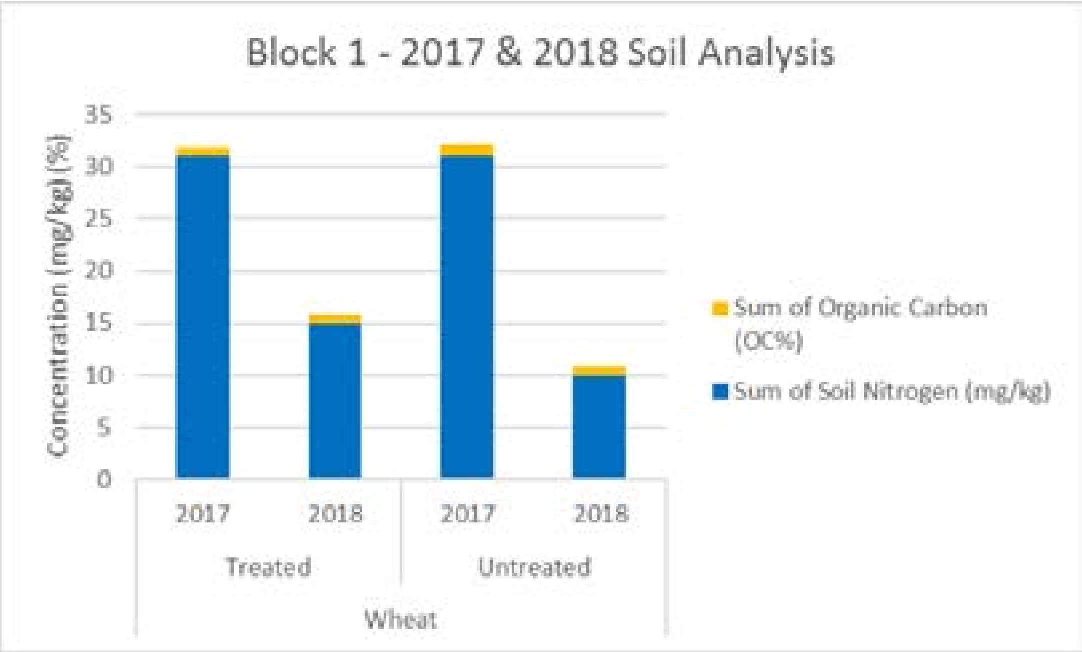


Figure 1. Block 1 2017 and 2018 pre-sowing soil results, organic carbon and soil nitrogen comparison. Condo wheat sown over the 2017 season.

For lentils, soil nitrogen in the treated strips decreased by 5mg/kg, while the soil nitrogen increased in the untreated strips by 10mg/kg over the 2017 season. The untreated strip was the only strip to also increase its organic carbon percent (+0.05%), all the other strips decreased.

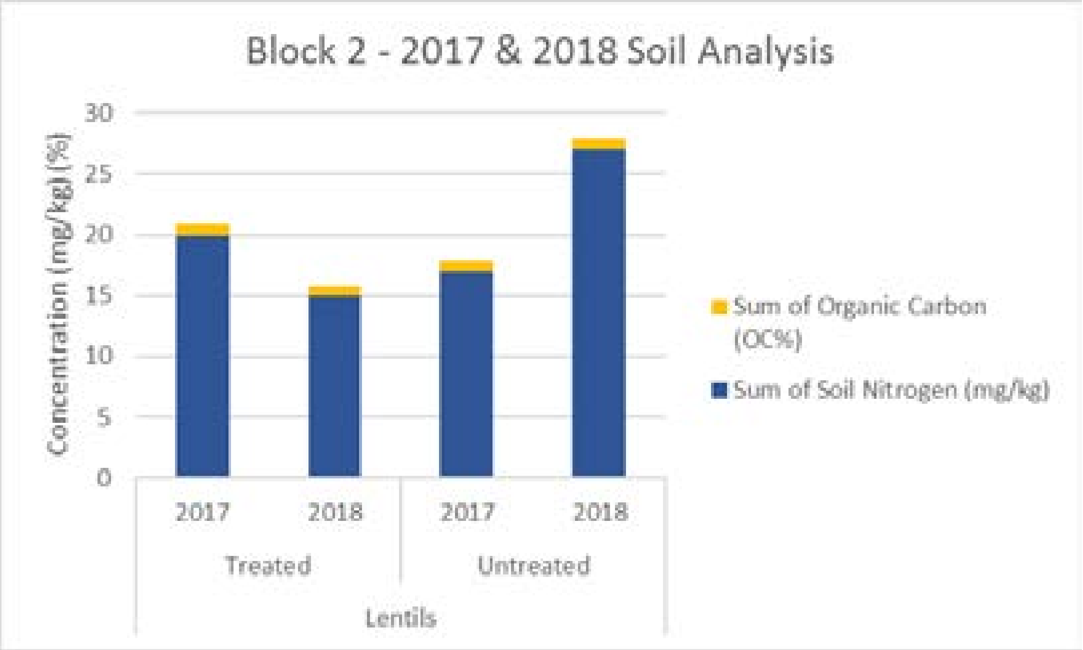


Figure 2. Block 2 2017 and 2018 pre-sowing soil results, organic carbon and soil nitrogen comparison. Hurricane lentils sown over the 2017 season.

For canola, the soil nitrogen decreased in both treatments over the 2017 season (figure 3). The untreated strip had a larger decrease of 5mg/kg, the treated strip decreased by 2mg/kg. The organic carbon decreased slightly in both treatments.

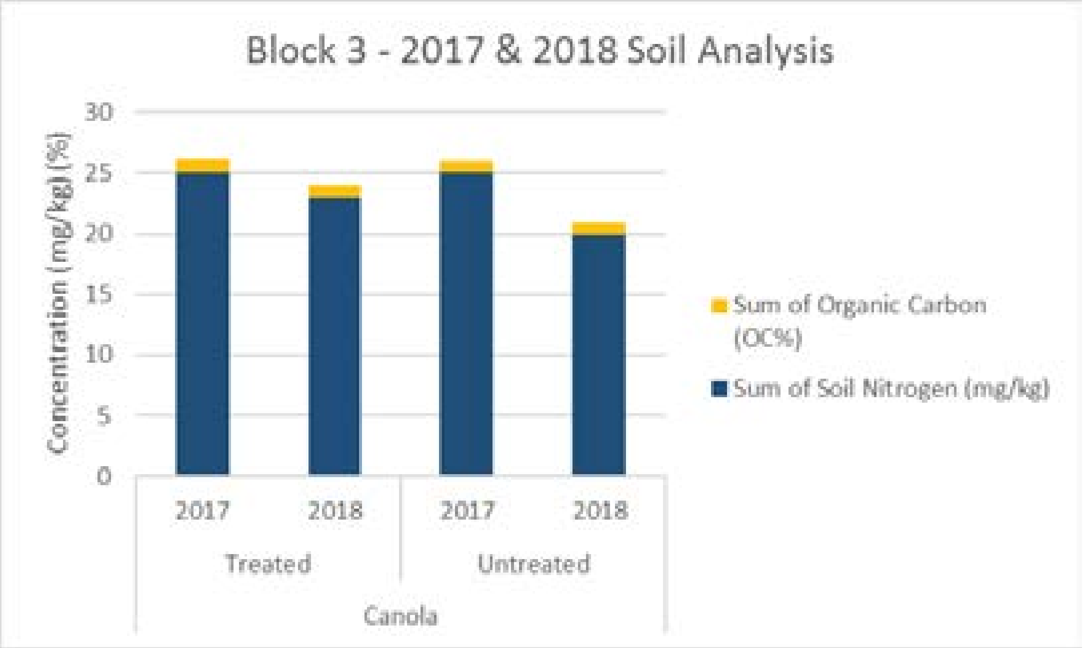


Figure 3. Block 3 2017 and 2018 pre-sowing soil results, organic carbon and soil nitrogen comparison. Bonito canola sown over the 2017 season.

Table 1 shows the treated canola and lentil strips yielded more that the untreated strips. However, the untreated wheat strip out-yielded the treated strip by over half a tonne. The number of plants per square metre had no effect on yield, in fact, the strips that had a smaller plant population yielded better – a factor likely driven by the dry season.

Table 2 shows very little difference between treatments in the wheat protein results. There was a difference of 1.21% in oil content between the canola treatments with the treated strip having higher oil percentage. Due to harvest difficulties, the lentils were unable to be tested for quality.

Table 1. Plant numbers per square metre and grain yield (tonne/hectare). Results obtained from hand harvest cuts.

Strip	Plant Density (plant/m^2)	Grain Yield (t/ha)
Block 1 - Wheat		
Treated	104.0	3.11
Untreated	80.7	3.69
Block 2 - Lentils		
Treated	104.0	1.12
Untreated	123.3	1.00
Block 3 - Canola		
Treated	60.7	1.05
Untreated	60.0	0.54

Table 2. Grain quality comparison and grain price (December 2017).

Strip	Protein	Oil (%)	Grain Price ($/t)
Block 1 - Wheat			
Untreated	16.00%	-	$263.00
Treated	16.20%	-	$263.00
Block 2 - Lentils			
Untreated	-	-	$360.00
Treated	-	-	$360.00
Block 3 - Canola			
Untreated	27.95%	32.84%	$464.94
Treated	28.38%	34.05%	$474.72

Table 3 captures the difference in input costs across the applied and not applied treatments and highlights the potential to offset the additional cost of the soil activator through reduction in fertiliser inputs and/or yield increases.

Table 3. Cost analysis for the three crop types and treatments. Fertilizer prices used in analysis were taken from local price lists at time of sowing, May 2017.

Strip	TM Agricultural Product Price ($/ha)	Fertilizer Reduction ($/ha)	Addition to Production ($/ha)	Yield (t/ha)	Grain sales $/ha
Block 1 - Wheat					
Untreated	$ 0.00	$ 0.00	$ 0.00	3.69	970
Treated	$ 25.00	-$ 12.13	$ 12.87	3.11	817
Block 2 - Lentils					
Untreated	$ 0.00	$ 0.00	$ 0.00	1.00	360
Treated	$ 25.00	-$ 12.13	$ 12.87	1.12	403
Block 3 - Canola					
Untreated	$ 0.00	$ 0.00	$ 0.00	0.54	251
Treated	$ 25.00	-$ 12.13	$ 12.87	1.05	498

Discussion

This demonstration is not replicated and is a single season and so there are no conclusions to be drawn. Our discussion captures observations form 2017.

Overall season

2017 was the driest year since 2006 for New South Wales (Australian Government BOM 2017a). Rainfall was 18% below average. December was the only month with above average rainfall. Growing season rainfall for the Temora demonstration site was 243mm (Figure A2) and 491mm for the whole year. The clear nights meant cooler than average minimum temperatures during winter. The mean minimum temperature for winter for NSW was the lowest since 1997

(Australian Government BOM 2017a). Temora had 65 nights of 0°C or below temperatures, and 4 nights of below -5°C during the growing season (Australian Government BOM 2017b) (Figure A3). The climate throughout 2017 undoubtedly had the greatest impact on yields, grain quality and changes in soil characteristics than any other variable.

Block 1- Wheat

The soil nitrogen in both the treated and untreated wheat strips declined over the 2017 season (Figure 1). The untreated soil nitrogen levels decreased more than the treated strip. The wheat in the untreated strip yielded 0.58t/ha more than the treated strip, contributing to the reduction in soil nitrogen. It is noted that the treated strip had 20% less urea and MAP fertilizer at sowing.

The treated strip had 23.3plants/m2 more than the untreated strip (Table 2) and the higher water use early in the season by the high plant population may have resulted in reduced soil water availability later in the season contributing to the yield reduction. There was no real difference in grain quality between the treatments

In Table 2, the grain quality in both the treated and untreated strip samples was very similar and both samples were graded H2, earning $263/t (Grain Corp CropConnect 2017b).

Block 2 – Lentils

The soil results for the lentils don't follow the same trend as the wheat and canola. The soil nitrogen and organic carbon decreased for the treated strip, and they increased in the untreated strip. The untreated strip nitrogen increased by 10mg/kg and the organic carbon increased by 0.05mg/ha. As this is not a replicated trial, it is impossible to know if this anomaly is due to treatment or spatial variability. Further research over the next two years is required to see if this trend continues.

The treated strip had a plant density of approximately 19 less plants than the untreated strip (Table 1), however, it yielded 0.12t/ha more than the untreated strip. The lower plant density numbers would have assisted in obtaining a higher yield due to reduced competition for moisture in the dry season. Higher plant numbers mean the soil water is likely to have depleted earlier in the season, causing moisture stress later on. This stress may also have made the plants more susceptible to damages such as frost and disease.

Block 3 - Canola

The soil nitrogen in the canola block decreased for both treatments (Figure 3), with a greater reduction in the untreated strip. In spite of this the treated strip yielded more than double the untreated strip (Table 1). It is noted that the treated strip received less urea and MAP at sowing. There was a small difference in oil between treatments, with the treated strip having slightly higher oil.

Conclusion

Interesting observations were captured in 2017 and further analysis and observations will add to these outcomes. Blocks will continue to be analysed separately due to the product having diverse effects on different crop types and soil. Going forward into 2018, the fertiliser will be reduced a further 20% for the treated strips, being reduced a total of 40%. The top-dressed urea will also be reduced. This is a demonstration only, if you would like to view more in-depth data, please visit https://bestenvirotech.com.au/

References

Grain Corp CropConnect 2017a, the marketplace, all bids and pools, viewed 15 January 2017, https://cropconnect.com.au/cc/market/bids

Grain Corp CropConnect 2017b, the marketplace, overview, viewed 15 January 2017, https://cropconnect.com.au/cc/market/overview

Australian Government Bureau of Meteorology 2017a, New South Wales in 2017: warmest on record, Annual Climate Summary for New South Wales, Australian Government, Bureau of Meteorology, viewed 15 January 2017, http://www.bom.gov.au/climate/current/annual/nsw/summary.shtml

Australian Government Bureau of Meteorology 2017b, Temora, New South Wales 2017 daily temperature data set, Temora, New South Wales 2017 daily weather observations data set, Australian Government, Bureau of Meteorology, viewed 5 January 2017, http://www.bom.gov.au/climate/dwo/201704/html/IDCJDW2130.201704.shtml

Appendix

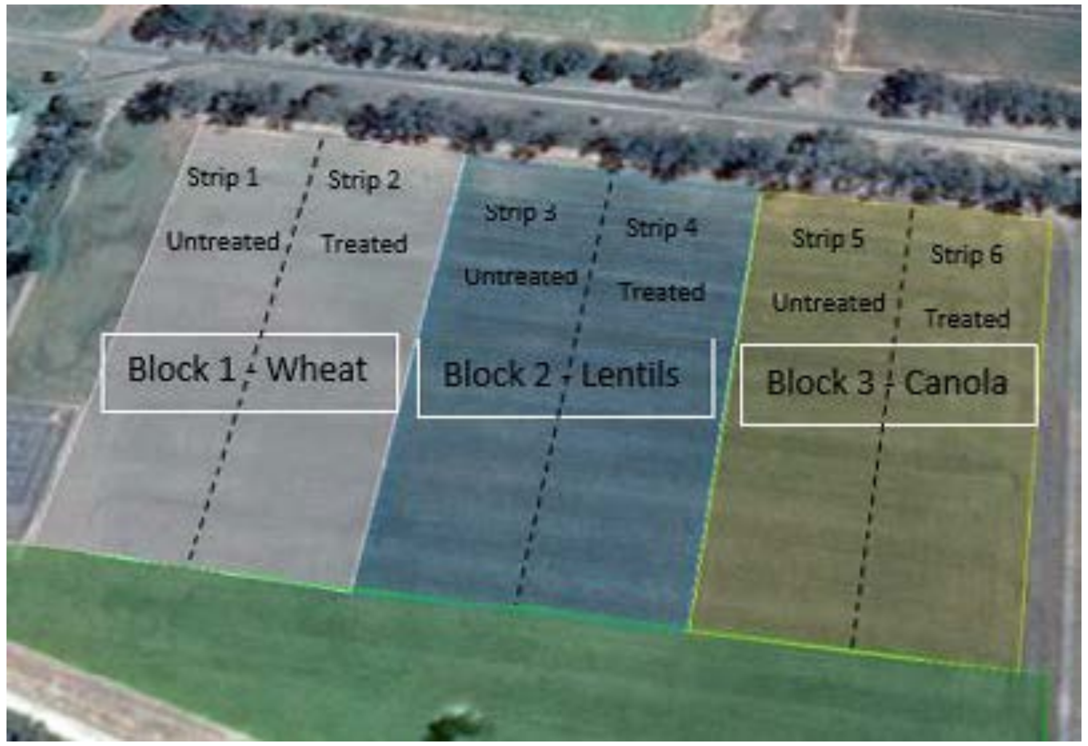


Figure A1. 2017 demonstration layout at the Temora Agricultural Innovation Centre.

Table A1. Crop sowing rates and fertilizer inputs for each crop type and treatment in 2017.

Treatment	Description
Wheat	- 60kg/ha Condo wheat
	- 60kg/ha MAP at sowing for untreated plots
	- 48kg/ha MAP at sowing for treated plots
	- 40kg/ha urea at sowing for untreated plots
	- 32kg/ha urea at sowing for treated plots
	- 80kg/ha top dress for both treatments
Lentils	- 60kg/ha Hurricane lentils
	- 60kg/ha MAP at sowing for untreated plots
	- 48kg/ha MAP at sowing for treated plots
	- 40kg/ha urea at sowing for untreated plots
	- 32kg/ha urea at sowing for treated plots
Canola	- 2.5kg/ha Bonito canola
	- 60kg/ha MAP at sowing for untreated plots
	- 48kg/ha MAP at sowing for treated plots
	- 40kg/ha urea at sowing for untreated plots
	- 32kg/ha urea at sowing for treated plots
	- 150kg/ha top dress for both treatments

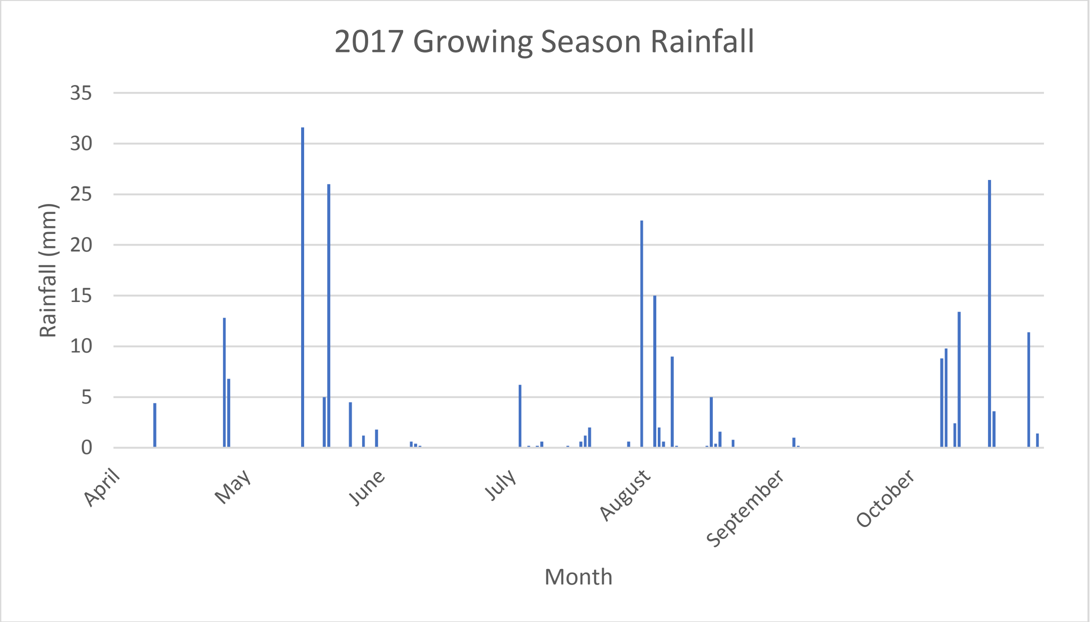


Figure A2. Temora 2017 growing season rainfall.

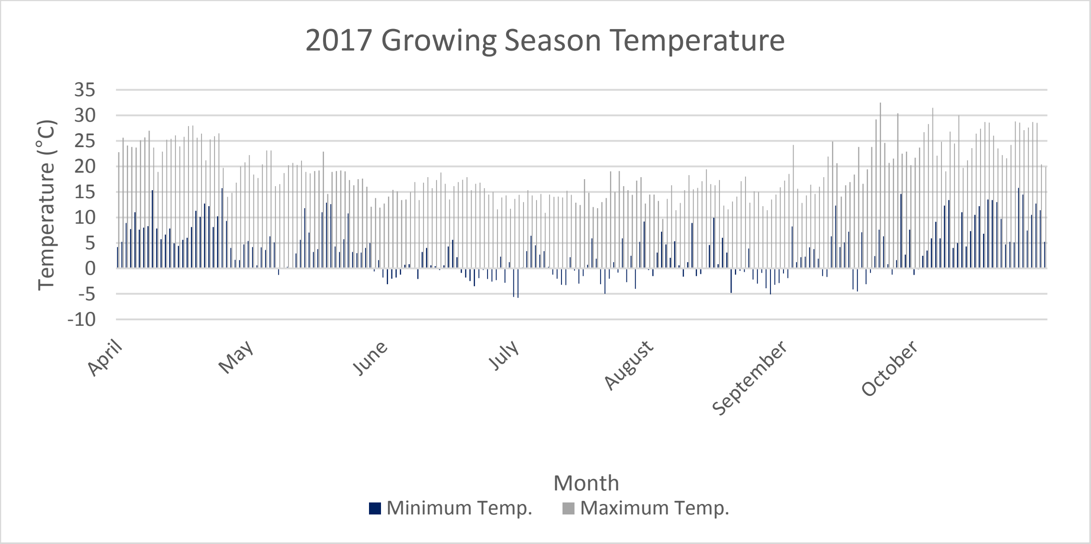
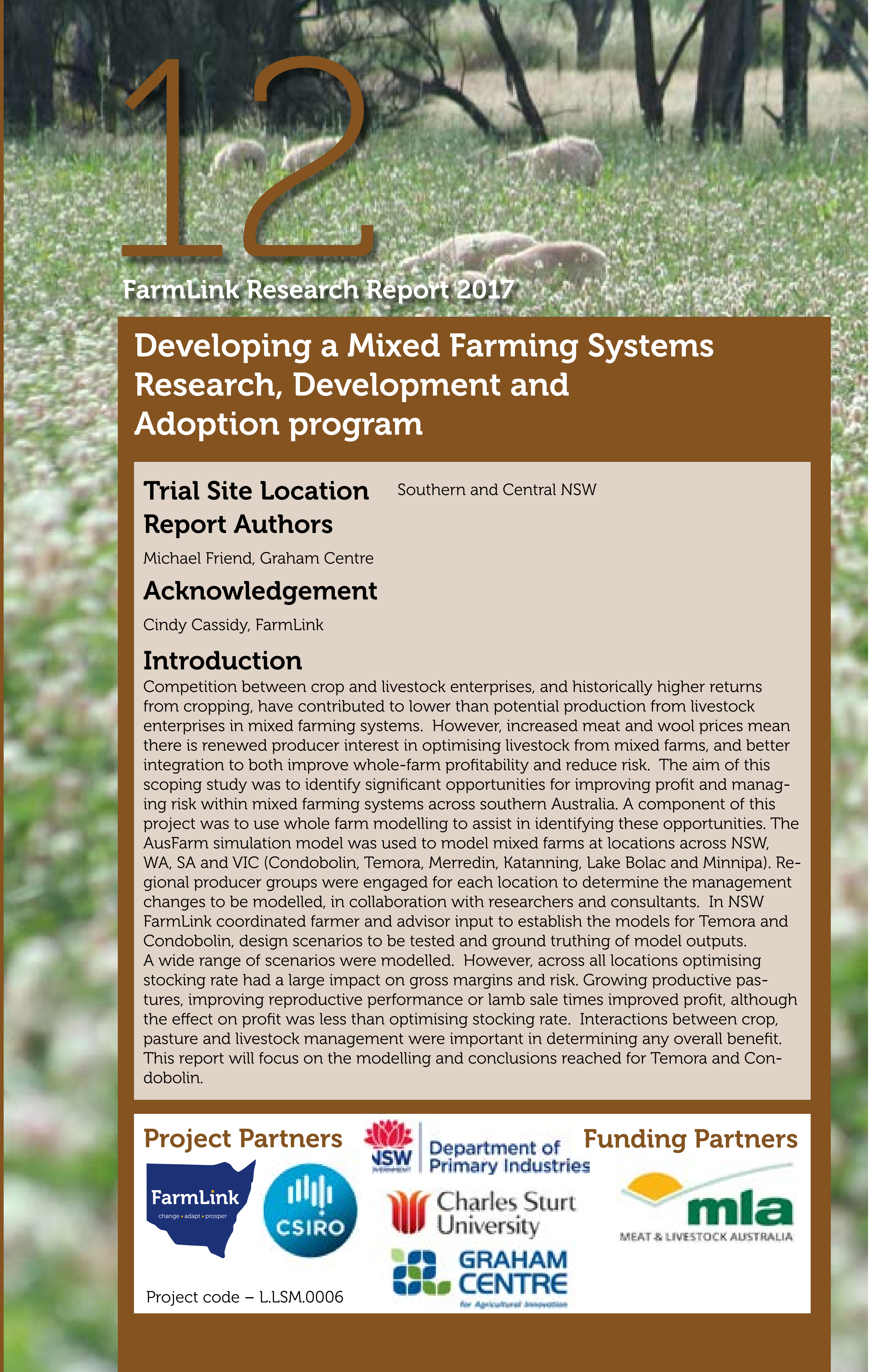


Figure A3. Temora 2017 growing season temperature (Australian Government BOM 2017b).

Figure A4. Wilted canola plants from the untreated strip after a frost event (top). Wilted canola plants from the treated strip after a frost event (bottom).



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FarmLink Research Report 2017

Developing a Mixed Farming Systems Research, Development and Adoption program

Trial Site Location

Southern and Central NSW

Report Authors

Michael Friend, Graham Centre

Acknowledgement

Cindy Cassidy, FarmLink

Introduction

Competition between crop and livestock enterprises, and historically higher returns from cropping, have contributed to lower than potential production from livestock enterprises in mixed farming systems. However, increased meat and wool prices mean there is renewed producer interest in optimising livestock from mixed farms, and better integration to both improve whole-farm profitability and reduce risk. The aim of this scoping study was to identify significant opportunities for improving profit and managing risk within mixed farming systems across southern Australia. A component of this project was to use whole farm modelling to assist in identifying these opportunities. The AusFarm simulation model was used to model mixed farms at locations across NSW, WA, SA and VIC (Condobolin, Temora, Merredin, Katanning, Lake Bolac and Minnipa). Regional producer groups were engaged for each location to determine the management changes to be modelled, in collaboration with researchers and consultants. In NSW FarmLink coordinated farmer and advisor input to establish the models for Temora and Condobolin, design scenarios to be tested and ground truthing of model outputs. A wide range of scenarios were modelled. However, across all locations optimising stocking rate had a large impact on gross margins and risk. Growing productive pastures, improving reproductive performance or lamb sale times improved profit, although the effect on profit was less than optimising stocking rate. Interactions between crop, pasture and livestock management were important in determining any overall benefit. This report will focus on the modelling and conclusions reached for Temora and Condobolin.

Project Partners

Funding Partners

Project code – L.LSM.0006

Background

The overall project was established to develop a business case for possible MLA investment in a mixed farming systems Research, Development and Adoption (RD&A) program. The business case aims to identify what activities MLA could invest in to make a significant impact in the profit and risk profile of mixed farming businesses. A key deliverable of the project was whole farm modelling using AusFarm at six locations across southern Australia (two in NSW, two in WA, and one each in Victoria and SA), covering high and low rainfall zones suited to crop-livestock integration, that considers various pasture, cropping and livestock options. The purpose of the modelling was to identify opportunities to increase farm business performance (profit and risk). The relevant options tested were determined in consultation with regional producer groups, and the outputs tested with these groups to identify best-bet opportunities for RD&A. This report details the modelling and outputs of the two sites in NSW – Temora and Condobolin.

Objective

To identify regionally-relevant cost-effective opportunities for enhanced integration of crops and livestock practices to reduce the cost of production by 1.5% in real terms by 2020 ($/kg lwt) and improve the resilience of mixed farming businesses; as well as informing future R&D priorities.to reduce cost of production by 5% in real terms by 2030. Using the AusFarm model and producer/advisor input for Temora and Condobolin sites suited to crop-livestock integration to consider various cropping, pasture and livestock options in order to identify opportunities to increase farm business performance (profit and risk).

Method

The NSW component identified regional priorities to investigate using simulation modelling through consultation with producer groups (FarmLink, Central West Farming Systems), consultants and researchers. The priority areas for NSW are listed below:

Priority 1: Enterprise mix, grain production for feed only, 100% grain vs 100% sheep

Does varying the proportion of farm used for crop vs grazing alter sheep production, profit and risk?

Does any impact of percentage of farm cropped vary with crop potential?

Does the proportion of wheat area as grazing wheat increase farm profit? Does the benefit vary with good or poor pastures?

Priority 2: Grazing efficiency, feed utilisation, cropping efficiency

What is the impact of time of spraying out of pastures on whole-farm profit?

What is the optimal percentage of lucerne area of pasture area, if annual pastures are good rather than poor?

Priority 3: Tactical management on feed budgeting

Priority 4: Use of existing technologies

When is pregnancy scanning profitable?

The questions modelled were further prioritised on both the ability of the model to provide reasonable results, and time limitations.

The decision support tool AusFarm was used, including the most current parameter sets for crop, pasture and livestock. Simulations were conducted from 1 January 1964 to 31 December 2015, with only 1970 to 2015 data reported, to allow for model initialisation. Base models were provided by Andrew Moore (CSIRO) and adjusted to represent a typical farm at two sites, Condobolin and Temora. Varying management was applied to the base models to allow whole-farm comparison of production, profit (gross margins) and risk.

Financial values used in the model were mostly obtained from the RSA livestock and crop gross margin guides, although 5-year average (2012-2016) meat values were sourced from MLA (www.statistics.mla.com.au; downloaded 24/05/17), and grain values (average 2012-2016) were sourced from ABARE, because complete lists were not available from the gross margin guides. The values used for sheep are shown in Table 1, and for cropping in Table 2. Lime was applied to cropped area at a rate of 1T/ha every 8 years at Condobolin, and 2T/ha every 10 years at Temora. Pastures on cropped area were established by under sowing the last phase of crop at both sites, with these costs included in cropping. Where gross margins are reported for sheep and cropping enterprises separately, the cost of fertiliser for pastures and spray-cleaning, but not spray-out, of pastures was included in sheep gross margins. In this case, the cost of lime was not attributed to either enterprise as it benefits both. Gross margins were calculated on a January to December basis.

Description of base models

Condobolin

The base farm comprised 4000 ha, consisting of 17 paddocks and 3 land management units.

Red calcarosol (ApSoil 690), 40% of farm area, with rotation: Lucerne, Lucerne, Lucerne, Lucerne, long fallow, wheat, wheat, oats (under sown)

Red calcarosol (ApSoil 690), 40% of farm area, with rotation: Lucerne, Lucerne, Lucerne, Lucerne, long fallow, canola, wheat, barley (under sown)

Sandy clay over medium clay (ApSoil 688), 20% of farm area, permanent pasture (annual grass early, Paraggio medic and Dalkeith subclover)

Crops were sown with 23.5 kg urea, and top dressed in late July with 80 kg/ha urea only if rainfall 1 March to 30 June exceeded decile 5.

The sheep flock comprised a self-replacing Merino flock, of large frame (60 kg):

Breeding ewes/pasture ha: 1.4
Join start: 1 Dec
CFA sold: 30 Sep, after-shearing
Young culls sold: 28 Sep
Wether weaners sold: 26 Jan
Ewes shorn: 15 Sep
Ewe lambs shorn: 1 Oct

Sheep were allowed to graze wedgetail wheat if biomass exceeded 400kg DM/ha and were removed on 31 July.

Temora

The base farm comprised 2000 ha, consisting of 21 paddocks, and 3 land management units:

1. Hill, red chromosol (based on ApSoil 913), 10% of farm area, permanent pasture (annual grass early, Seaton Park subclover)
2. Light red soil (based on ApSoil 913), 30% of farm area
3. Red/brown earth (based on ApSoil 179-YP), 60% of farm area

The last two soil types used the same pasture base - annual ryegrass, Seaton Park subclover, and winter active lucerne, and the same rotation: Lucerne, Lucerne, Lucerne, Lucerne, canola, wheat, wheat, canola, wheat, barley (under sown) Crops were sown with 25 kg urea, and top dressed in late July with 80 kg/ha urea.

The sheep flock comprised a Merino ewe flock, of large frame (60 kg), joined to a terminal ram breed, with replacement ewes purchased.:
Breeding ewes/pasture ha: 3.5
Join start: 1 Jan
CFA sold: 30 Sep (after shearing)
All weaners sold: 1 Nov
Ewes shorn: 27 Sep

Sheep were allowed to graze wedgetail wheat if biomass exceeded 400kg DM/ha and were removed on 31 July.

Table 1. Value of products used for sheep in the Temora and Condobolin analyses.

Sheep	units	Value ($)
shearing	$/hd	6.06
crutching	$/hd	0.85
purchase young Merino ewes	$/hd	180
purchase rams	$/hd	1000
lamb husbandry M	$/hd	4.18
lamb husbandry XB	$/hd	2.59
ewe husbandry	$/hd	2.11
preg scan	$/hd	1.1
feed ewes	$/t	200
feed lambs	$/t	300
sell young Merino ewes	c/kg	432
Cast For Age ewes	c/kg	298
CFA rams	$/hd	50
XB trade+heavy lamb 42 kg live +	c/kg carcase weight	493
restocker lamb < 42 kg live	c/kg carcase weight	461
Merino lamb	c/kg carcase weight	432
skin values lambs		9
skin ewes		0
freight selling sheep	$/hd	4
sale costs	% of value	5.5
Wool	**units**	**Value ($)**
micron		
17	c/kg clean	1463
18	c/kg clean	1375
19	c/kg clean	1305
20	c/kg clean	1250
21	c/kg clean	1235
22	c/kg clean	1212
23	c/kg clean	1186
24	c/kg clean	1092
Adjustment for oddment lines	% of value	-10
Wool levy	% of value	2
Wool sale costs	% of value	4

Table 2. Values used for cropping and pastures in the Temora and Condobolin analyses.

Grain prices	Unit	$
APW wheat	$/t at port	275
canola	$/t at port	522
malt barley	$/t at port	256
lupin	$/t at port	303
oats	$/t at port	237
levy	% of value	1
Sowing costs	$/ha	
wheat	$/ha	132.52
barley	$/ha	146.35
oats	$/ha	72.4
canola	$/ha	203.82
lupin	$/ha	132.12
wheat (undersown)	$/ha	110.82
barley (undersown)	$/ha	110.82
oats (undersown)	$/ha	96.42
post-sowing sprays		
wheat	total $/ha	32.42
barley	total $/ha	37.41
oats	total $/ha	11.46
canola	total $/ha	19.09
lupin	total $/ha	20.19
wheat (undersown)	total $/ha	51.7
barley (undersown)	total $/ha	51.7
oats (undersown)	total $/ha	50.3
urea spreading (all crops) (contract)	$/ha	8.5
urea	$/t	440
pod-fill insecticide	$/ha	
canola	$/ha	39.2
lupin	$/ha	16.78
windrow canola (contract)	$/ha	35
harvest (all crops)	$/ha	11.25
harvest freight (all crops)	$/t	20
lime	$/t delivered	80
lime spreading	$/ha	14
summer spray weeds	$/ha (per occasion)	10
spray out pasture and fallow	$/ha	10
grass-clean lucerne	$/ha	13.2
pasture fertiliser (single super)	$/t	350

Results

Condobolin

Does varying the proportion of farm used for cropping alter production, profit and risk?

Any benefit from altering enterprise mix (sheep vs cropping) depended on the relative profitability of each, as well as interactions between the enterprises. The same enterprise could have widely varying profitability depending on its level of performance relative to its potential performance. To consider any benefit to change in percentage cropping, the level of performance of the sheep enterprise was altered by changing stocking rate and level of pasture production.

Crop yields are shown in Table 3. The rotation was changed between different proportions of crop, and this may alter the result. Crops after long fallow appeared to have higher yields than if placed later in a rotation. Topdressing with urea was required to prevent large declines in yields with successive cropping.

The base level of pasture growth for Condobolin is shown in Fig. 1. Pasture growth rate was reduced by approximately 50% for the low pasture simulation. This was achieved by reducing the fertility scalars, but in practice may result from causes such as low soil fertility (or fertiliser usage), overgrazing, or herbicide effects. Pasture production for a year at decile 1, 5 and 9 was 2207, 4806 and 7521 kg DM/ha at the base level, and 1202, 2441, and 3856 at the low pasture level.

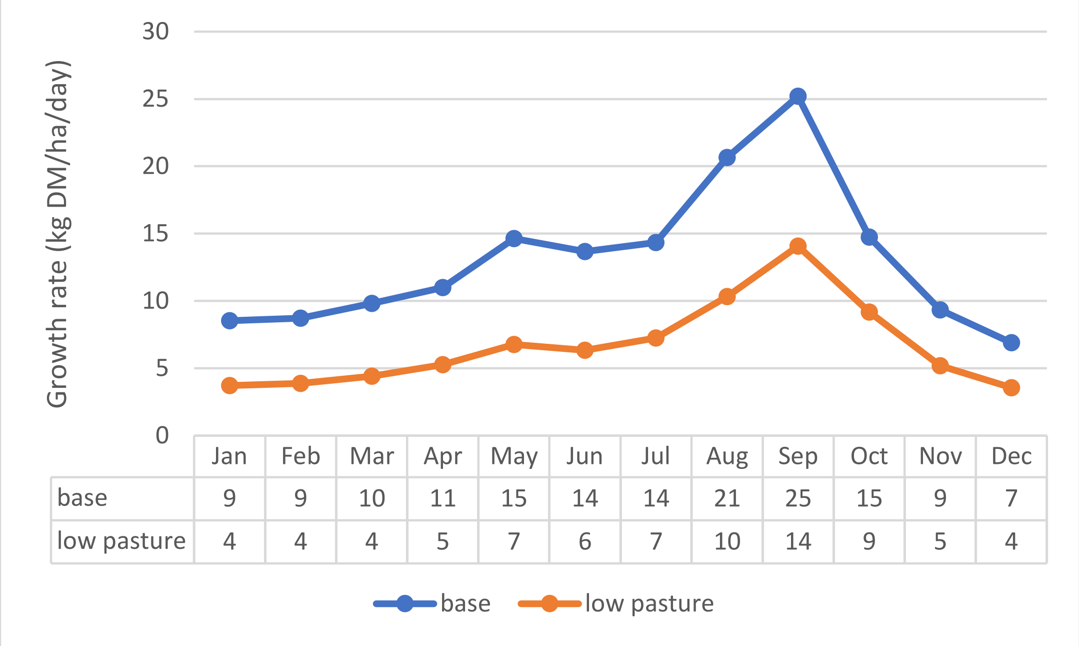


Fig. 1. Monthly pasture growth rates at Condobolin for base and low pasture simulations (1970-2015).

Table 3. Crop yields (kg/ha ± sd) by land management unit (LMU) and rotation for 40% crop (base), 60% crop and 90% crop simulations for Condobolin (1970-2015). Oats and barley were undersown with Lucerne.

40% crop (Base)	Crop yield	60% crop	Crop yield	90% crop	Crop yield
LMU1		*LMU1*		*LMU1*	
Lucerne		Lucerne		Canola	1707 ± 502
Lucerne		Lucerne		Wheat	2035 ± 1001
Lucerne		Long fallow		Long fallow	
Lucerne		Wheat	3382 ± 1420	Wheat	3074 ± 1208
Long fallow		Canola	1601 ± 503	Canola	1497 ± 410
Wheat	3446 ± 1570	Wheat	2356 ± 1037	Wheat	2311 ± 1076
Wheat	2684 ± 1261	Wheat	2482 ± 1099	Wheat	2531 ± 1058
Oats-U	766 ± 347	Oats-U	775 ± 362	Oats-U	1793 ± 754
LMU2		*LMU2*		*LMU2*	
Lucerne		Lucerne		Canola	1944 ± 453
Lucerne		Lucerne		Wheat	2020 ± 1042
Lucerne		Long fallow		Long fallow	
Lucerne		Wheat	2998 ± 1531	Wheat	2955 ± 1368
Long fallow		Canola	1951 ± 577	Canola	1768 ± 453
Canola	2778 ± 791	Wheat	2076 ± 1036	Wheat	2264 ± 1143
Wheat	2115 ± 1232	Wheat	2409 ± 1308	Wheat	2463 ± 1201
Barley-U	1371 ± 814	Barley-U	1980 ± 766	Barley-U	2243 ± 1101

Per hectare sheep production was increased at higher stocking rates above the base (Table 4), but there was a very high risk of sheep being fed large quantities of supplement. The risk of feeding was excessive at all stocking rates for the low pasture, and sheep production levels at the base stocking rate (2.1 sheep/ha) were 10 to 20% lower than for the standard pasture.

Table 4. Sheep production at stocking rates of 2.1 (base), 4.1, 6.1 and 8.1 sheep/pasture ha for Condobolin (1270-2015).

	Base				**Low pasture**		
Sheep/ha	2.1	4.1	6.1	8.1	2.1	4.1	6.1
Breeding ewes/ha	1.3	2.7	4.0	5.4	1.4	2.8	4.2
Farm clean wool shorn (tonnes)	26.0	48.1	66.2	77.0	21.9	35.8	45.2
Farm stock weight sold (tonnes)	223	402	536	602	180	286	336
Clean fleece weight adults (kg)	4.7	4.6	4.3	3.9	4.2	3.7	3.2
Sale weight wethers (kg)	62.7	58.3	52.4	45.9	52.6	43.6	36.8
Lambs marked/ewe joined (%)	113	110	106	102	106	101	97
Supplement/ewe (kg)	50	93	137	171	137	186	217
Years fed> 30 kg/ewe*(%)	39	57	76	85	80	98	100
Farm ground cover (%)	61	57	53	48	50	47	46

**Includes feed to weaners*

Total farm mean gross margins increased from stocking rates of 2.1 to 6.1, but the standard deviation also increased, indicating higher risk. Mean farm gross margin declined at 8.1 sheep/ha. While the gross margin for sheep increased with stocking rate up to 6.1 sheep/ha, the gross margin for cropping declined above 2.1 sheep/ha (Fig. 2), due to a 5% decline in wheat yields.

Increasing the proportion of farm cropped from 40 to 60% only increased mean gross margin if the stocking rate was 2.1 sheep/ha, or if pasture production was low (Fig. 3). Increased cropping increased the standard deviation of gross margins. Increasing to 90% cropping only increased gross margins if pasture production was low. The reduction in gross margin for 4.1 sheep/ha on base pasture with 90% cropping should be interpreted with caution, as sheep died and the model needs to be checked for an error.

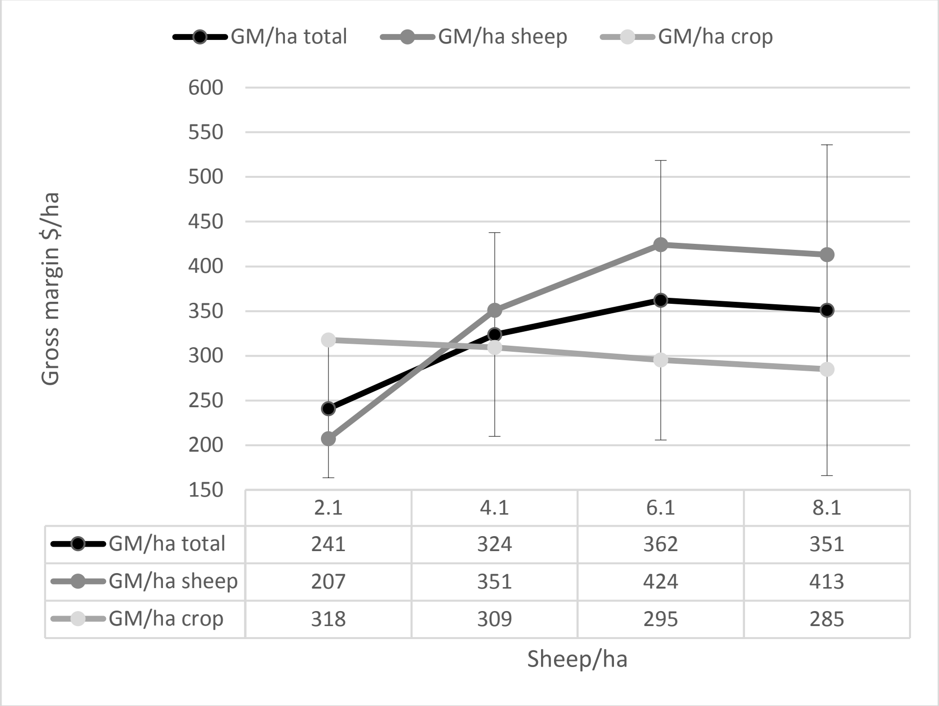
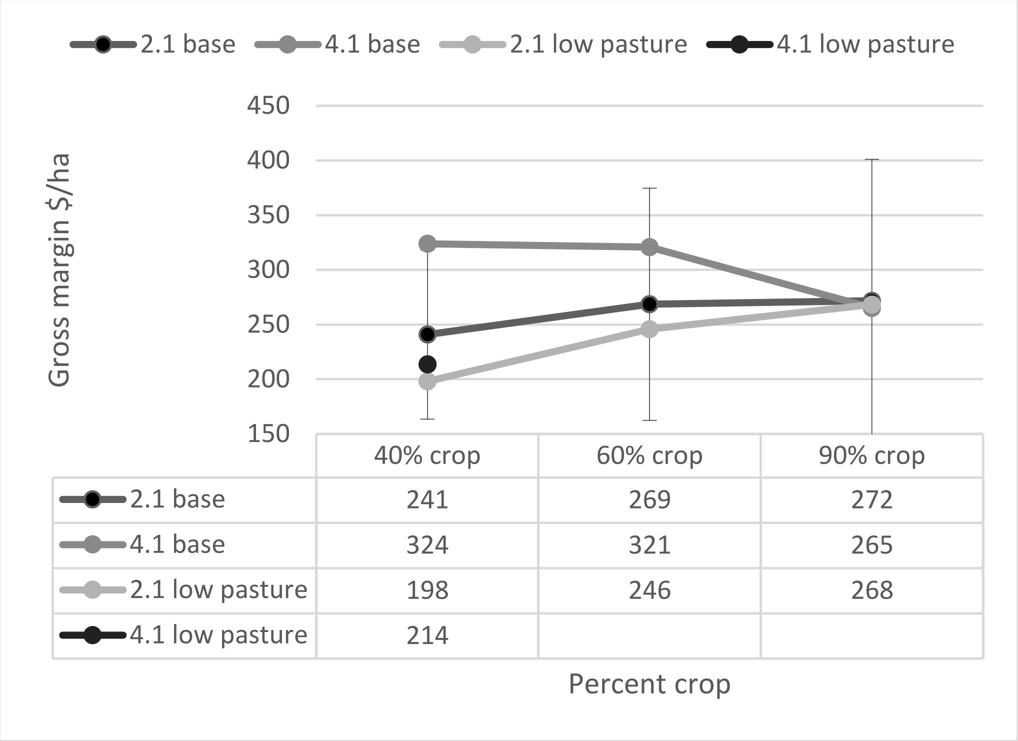


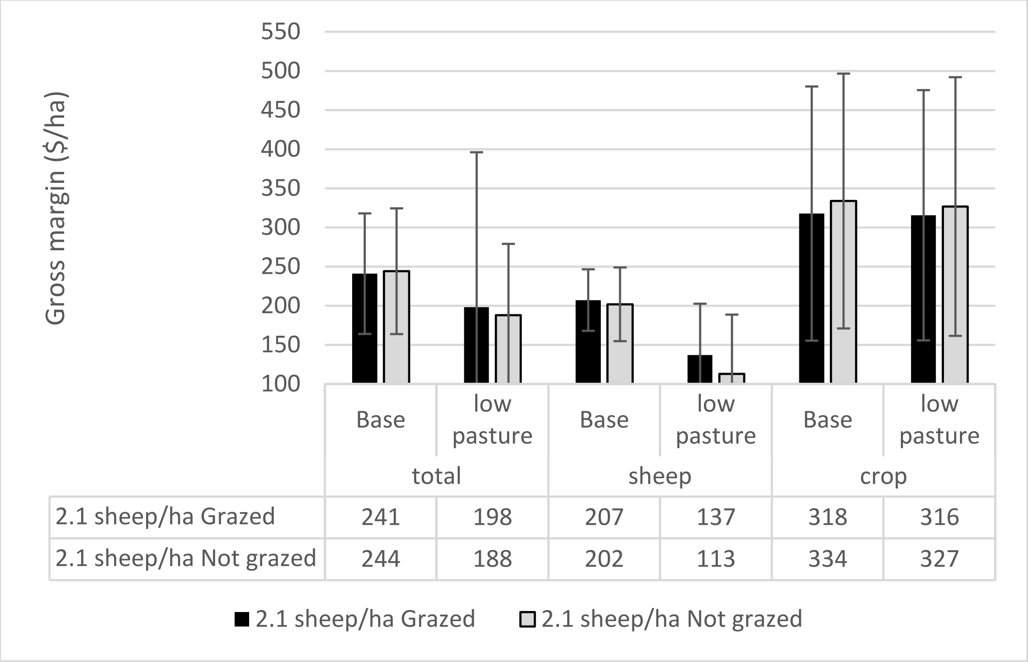
Fig. 2. Mean total (farm), sheep and cropping gross margins at stocking rates of 2.1, 4.1, 6.1 and 8.1 sheep/ha at Condobolin (1970-2015), at 40% of farm cropped. Bars are sd for total gross margin.



	40% crop	60% crop	90% crop
2.1 base	241	269	272
4.1 base	324	321	265
2.1 low pasture	198	246	268
4.1 low pasture	214		

Fig. 3. Mean total gross margin ($/ha) for stocking rates of 2.1 and 4.1 sheep/ha on base or low pastures, with 40, 60 or 90% of the farm cropped for Condobolin (1970-2015). Bars are sd for total gross margin at 2.1 sheep/ha on base pasture. GM for 4.1 base at 90% crop should be interpreted with caution due to likely error in model for this simulation.

The availability of grazing of wedgetail wheat, at the base stocking rate of 2.1 sheep/ha, did not increase total gross margins unless pasture production was low (Fig. 4). A $10/ha increase occurred when pasture production was low, and this was due to a large increase in sheep gross margins which was accompanied by a reduction in crop gross margin. At the base level of pasture, average annual dse grazing days were 2836 and 5002 at stocking rates of 2.1 and 4.1 sheep/ha. With low pasture production, annual grazing days were 3489 and 5411, respectively. This indicates wheat crops may be more heavily grazed where pastures are less productive, with potential larger reductions in grain yield. Wheat yields were reduced by grazing by 6 and 9% at the base and low levels of pasture, respectively.



	total		sheep		crop	
	Base	low pasture	Base	low pasture	Base	low pasture
2.1 sheep/ha Grazed	241	198	207	137	318	316
2.1 sheep/ha Not grazed	244	188	202	113	334	327

Fig. 4. Mean total, sheep and cropping gross margins ($/ha) for base and low pasture production levels with wedgetail wheat crop grazed or not grazed at Condobolin (1970-2015). Bars indicate sd.

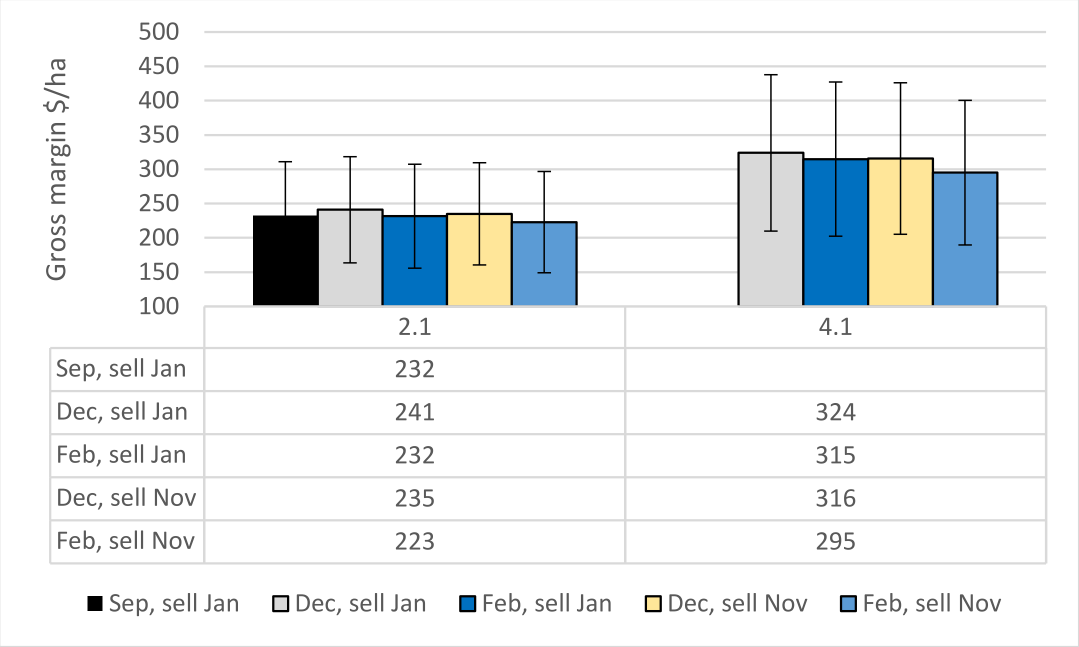
Grazing efficiency, feed utilisation and cropping efficiency

Grazing efficiency and feed utilisation were investigated at the base 40% of farm cropped, through altering stocking rate (2.1 or 4.1 sheep/ha), time of joining (1 Sep, 1 Dec or 1 Feb), and time of lamb sales (26 Jan or 1 Nov), as these are the key factors which alter feed demand.

At a stocking rate of 2.1 sheep/ha, joining in September did not increase gross margins compared with December or February joining, where lambs were sold in the same month, due to higher feed costs for ewes and a reduction in wool produced. The latter was due to cast for age ewes being sold prior to shearing changing from December to February joining slightly reduced the supplementary feed requirements of ewes, but reduced the sale weights of wether lambs (Table 5) because these were sold on the same dates. The reduction in feed requirements due to a February joining was larger at 4.1 sheep/ha, but the risk of feeding was high. At the same stocking rate, there was a small effect of changing month of joining and lamb sale date on total farm gross margins (Fig. 5). However, the effect of stocking rate was large and the reduction in feed requirements with a February joining indicate an increase in stocking rate may be possible, which is likely to increase gross margins. Investigation of varying sheep sale policies which could reduce the risk of feeding and allow higher stocking rates is warranted.

Table 5. Mean production impacts of changing stocking rate, month of joining, and lamb sale date at Condobolin (1970-2015).

	2.1 sheep/ ha					**4.1 sheep/ ha**			
Join	Sep	Dec		Feb		Dec		Feb	
Sell lambs	Jan	Nov	Jan	Nov	Jan	Nov	Jan	Nov	Jan
Breeding ewes/ ha	1.4	1.3	1.3	1.4	1.4	2.7	2.7	2.7	2.7
Lambs marked/ ewe joined (%)	99	113	113	109	109	110	110	107	106
Lamb survival (%)	95	89	89	81	81	89	89	81	81
Weaning weight wethers (kg)	25	32	32	34	34	30	30	31	31
Sale weight wethers (kg)	74	51	63	37	52	47	58	34	47
Supplement/ewe (kg)	57	39	50	33	42	75	93	64	75
Years fed> 30 kg/ ewe*(%)	39	35	39	33	37	50	57	52	48
Farm clean wool (tonnes)	20	26	26	26	26	49	48	48	48
Farm stock weight sold (tonnes)	228	202	223	173	198	366	402	312	354
Farm groundcover (%)	61	61	61	62	61	57	57	58	57



	2.1	4.1
Sep, sell Jan	232	
Dec, sell Jan	241	324
Feb, sell Jan	232	315
Dec, sell Nov	235	316
Feb, sell Nov	223	295

Fig. 5. Mean gross margin ($/ha) for September, December or February joining, with lamb sales in January of November, at 2.1 and 4.1 sheep/ha at Condobolin (1970-2015). Bars indicate sd.

Several other management changes were simulated. Spraying Lucerne pasture out in December, rather than in September, caused a minimal reduction in gross margins. Sowing crops around one month later caused a minimal increase in gross margins. A 5% increase in lamb survival increased farm gross margin by $9/ha. The key deviations from the base gross margin are shown in Fig. 6.

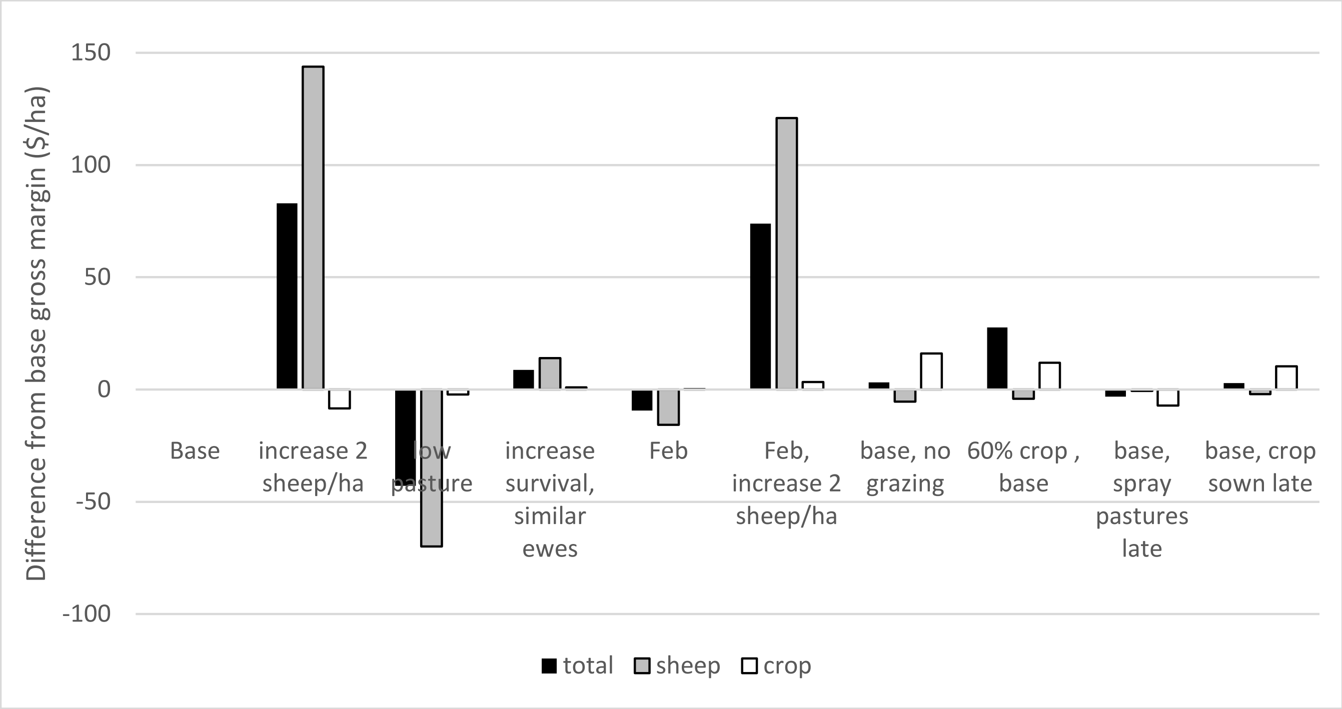


Fig. 6. Deviations from the base mean gross margin (40% crop, 2.1 sheep/ha, December joined) of a range of alternative management at Condobolin (1970-2015). Deviations are from total farm, sheep and cropping gross margins.

An error was discovered in the Condobolin simulation after the previous simulations were completed. This error affected grazing area and supplement fed. Correction of this error resulted in an $8/ha increase in mean farm gross margin using the base scenario, largely due to an increase in sheep gross margin. However, the error is unlikely to alter key trends, although the optimal stocking rate will be slightly higher than reported.

Temora

Does varying the proportion of farm used for cropping alter production, profit and risk?

Base annual pasture production at Temora averaged 5372 kg DM/ha (decile 1 was 2628 kg DM/ha and decile 9 was 8616 kg DM/ha). The low pasture averaged 2531 kg DM/ha (decile 1 was 1173 kg DM/ha and decile 9 was 3903 kg DM/ha).

Wheat yields following a pasture phase and canola averaged 3.6 t/ha (Table 6), and were 0.9, 4.1 and 5.9 t/ha at deciles 1, 5 and 9, respectively. The yields of undersown barley were higher than expected.

Crossbred lambs on average reached slaughter weights by sale on 1 November (Table 7). Increasing the stocking rate from 3.5 to 4.5 ewes per hectare had a minimal impact on lamb production, although wool production increased due to the increase in numbers. Supplement was required infrequently at these stocking rates on the base pasture, and only reached 32 kg/ewe in 39% of years at a rate of 5.5 ewes/ha. However, where pasture production was halved, both fleece weights and lamb sale weights were much reduced, and substantial levels of supplement were required at the base 3.5 ewes/ha.

Table 6. Mean crop yields (kg/ha) by for 40% crop, 60% crop (base), and 80% crop simulations for land management unit 2 for Temora (1970-2015). Barley was undersown with Lucerne.*

40 % crop	Yield (kg/ ha)	60% crop (Base)	Yield (kg/ ha)	80% crop	Yield (kg/ ha)
Lucerne		Lucerne		Lucerne	
Lucerne		Lucerne		Lucerne	
Lucerne		Lucerne		Wheat	3902
Lucerne		Lucerne		Wheat	3385
Lucerne		Canola	2031	Canola	1512
Lucerne		Wheat	3631	Wheat	3969
Canola	2067	Wheat	3392	Wheat	3500
Wheat	3619	Canola	1656	Canola	1578
Wheat	3278	Wheat	4091	Wheat	3948
Barley-U	2880	Barley-U	2991	Barley-U	3046

**Comprises 60% of farm area. Yields differed slightly on the other soil type.*

Table 7. Sheep production at stocking rates of 3.5 (base), 4.5 and 5.5 sheep/pasture ha for Temora (decile 5, 1270-2015).

	Base			Low pasture	
Sheep/ha	3.5	4.5	5.5	3.5	4.5
Breeding ewes/ha	3.5	4.5	5.5	3.5	4.5
Farm clean wool shorn (tonnes)	14	18	22	13	15
Farm stock weight sold (tonnes)	188	224	252	140	151
Clean fleece weight adults (kg)	4.7	4.6	4.5	4.0	3.8
Sale weight wethers (kg)	47	44	40	35	30
Lambs marked/ ewe joined (%)	112	110	109	106	103
Supplement/ewe (kg)	10	20	32	61	77
Years fed> 30 kg/ ewe* (%)	15	24	39	57	72
Farm ground cover (%)	75	72	70	64	61

**Includes feed to weaners*

Increasing stocking rate increased farm gross margins to a maximum at 5.5 sheep/ha, as shown in Fig. 7. While sheep gross margins showed large increases up to 5.5 sheep/ha, this was offset by a smaller reduction in crop gross margins. Low pasture production caused a large reduction in gross margins compared with base pasture, but the impact was reduced as the percentage area cropped increased (Fig. 8).

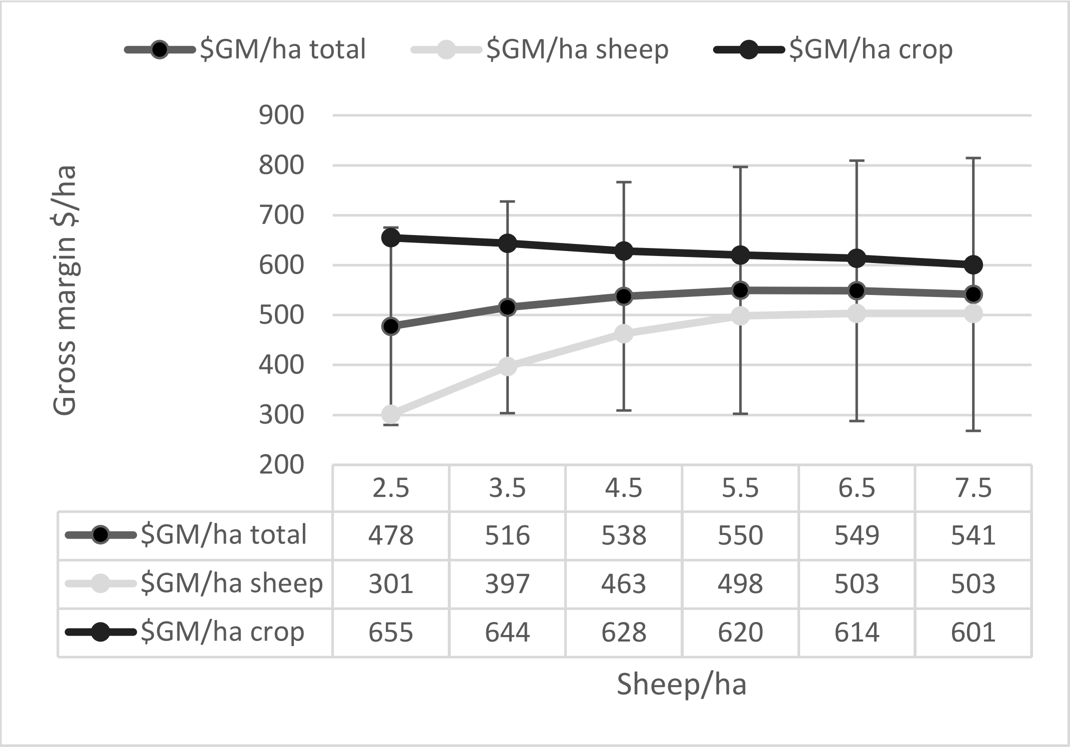


Fig. 7. Mean total (farm), sheep and cropping gross margins ($/ha) at 60% cropping at varying stocking rates at Temora (1970-2015). Bars indicate sd of total gross margin.

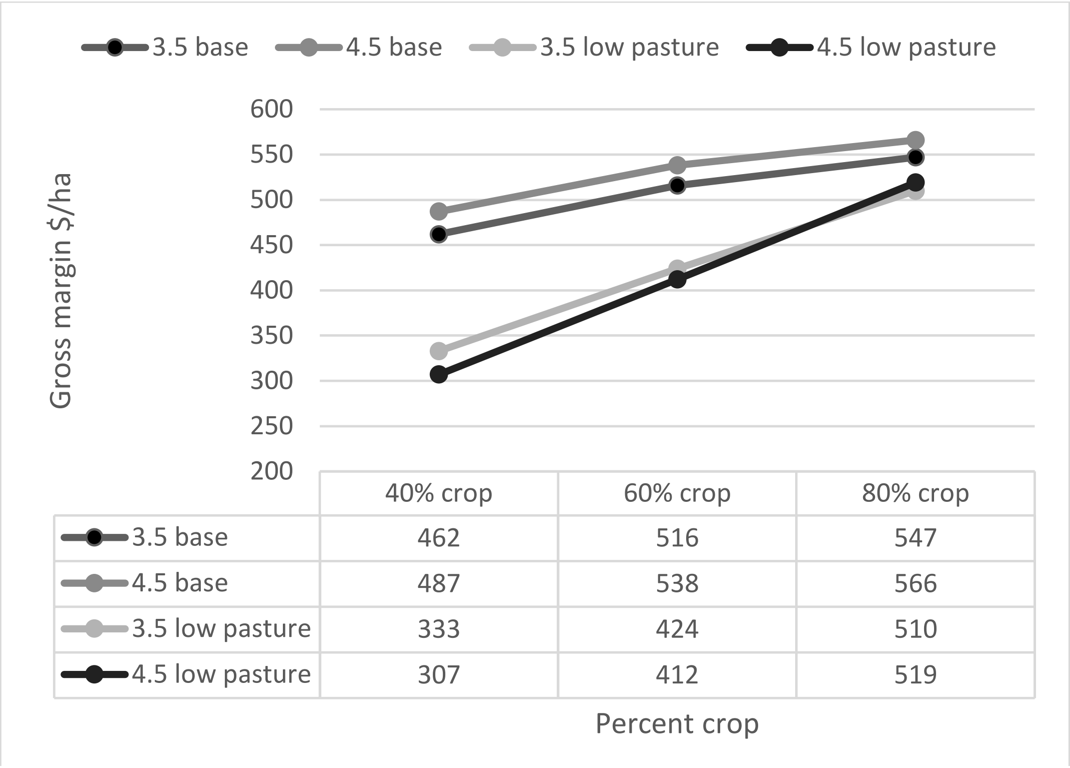


Fig. 8. Mean gross margin ($/ha) for base and low pasture simulations at 3.5 and 4.5 ewes/ha and varying cropped proportions at Temora (1970-2015).

The availability of wedgetail wheat for grazing had a minimal effect on farm gross margins. Total gross margins were similar for the base pasture level, because large gains in sheep production due to crop grazing was accompanied by similar reductions in crop gross margins. Allowing grazing of wheat until 20 August did not alter mean farm gross margin, for the same reason. There was $10/ha increase in total gross margins due to grazing of crops if pasture production was low (Fig. 9).

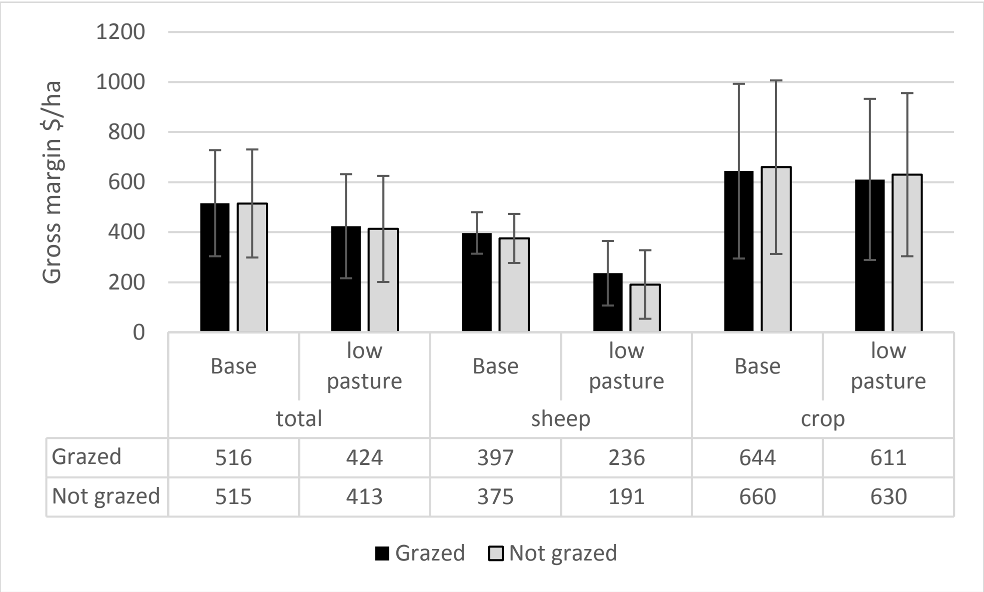


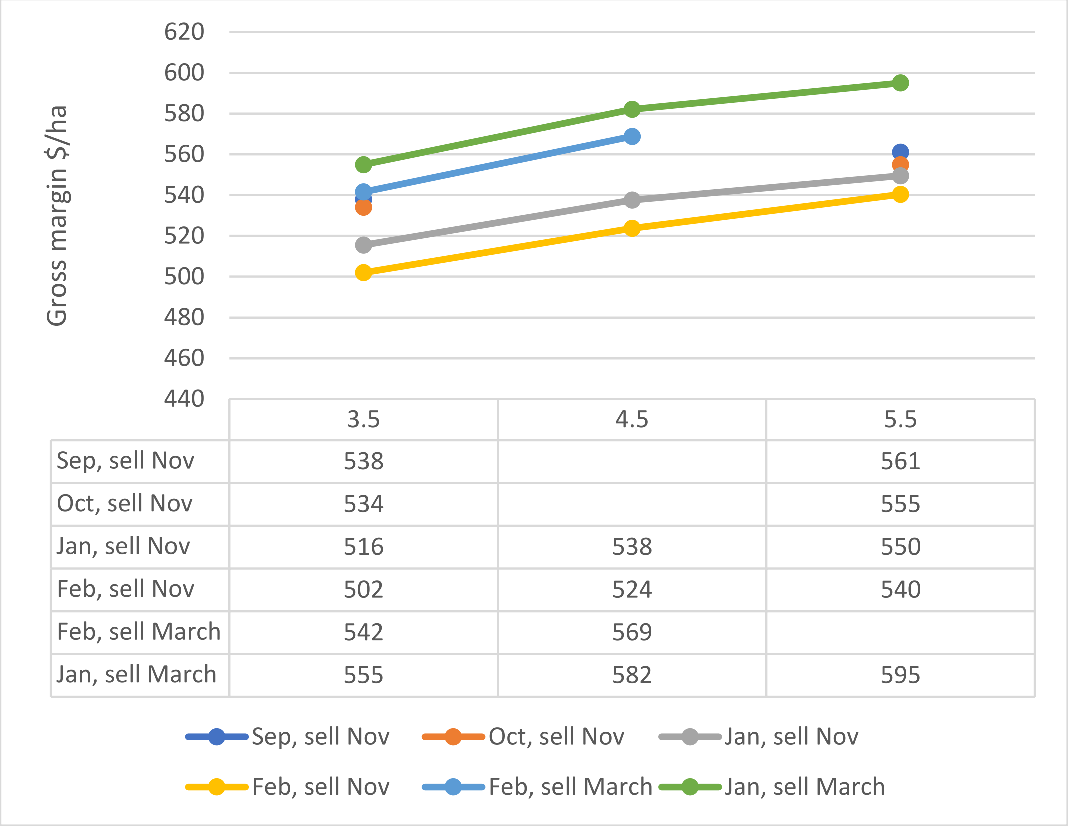
Fig. 9. Mean total (farm), sheep and cropping gross margins ($/ha) where wedgetail wheat was grazed or not grazed, at 3.5 ewes/ha at Temora (1970-2015).

Grazing efficiency, feed utilisation and cropping efficiency

Large increases in the weight of stock sold per farm were obtained if lambs were retained for longer and sold at heavier weights in March, or if stocking rates were increased from the standard 3.5 sheep/ha (Table 8). Delaying joining until February reduced gross margins if lambs were sold at the same time in November, but large increases were achieved if both time of sales was delayed, and stocking rates were increased (Fig. 10). Joining in September or October was more profitable than joining in January or February if lambs were sold in November, and stocking rates were below optimal for the later joining. This was due to earlier joining producing heavier sale weights, which was worth more than the extra supplementary feed required for autumn lambing. The risk of feeding increased with both delay in lamb sale date, and with increased stocking rate, but was low for all scenarios tested if ewes were stocked at the standard level. The risk of feeding, so differences between joining dates, is expected to vary if pasture production in summer/autumn were lower than predicted, or if different weed control policies were used on crop stubbles. Producer attitude to risk in sheep production, rather than maximum gross margin, may be a more important determinant of choice of joining/sale dates. Varying sheep management had little impact on farm ground cover, deep drainage, or crop gross margins.

Table 8. Mean production impacts of changing stocking rate, month of joining, and lamb sale date at Temora (1970-2015).

	3.5 sheep/ha				**4.5 sheep/ha**			
Join	Jan		Feb		Jan		Feb	
Sell lambs	Nov	Mar	Nov	Mar	Nov	Mar	Nov	Mar
Lambs marked/ewe joined (%)	112	110	109	108	110	109	108	106
Lamb survival (%)	85	85	81	81	85	85	80	80
Weaning weight wethers (kg)	34	33	36	35	31	30	33	33
Sale weight wethers (kg	47	65	43	58	44	60	41	54
Supplement/ewe (kg)	10	30	8	19	20	43	17	30
Years fed> 30 kg/ewe*(%)	15	26	7	11	24	37	18	28
Farm clean wool (tonnes)	14	14	14	14	18	18	18	18
Farm stock weight sold (tonnes)	188	238	175	217	224	282	210	258
Farm groundcover (%)	75	72	75	73	72	69	73	71



	3.5	4.5	5.5
Sep, sell Nov	538		561
Oct, sell Nov	534		555
Jan, sell Nov	516	538	550
Feb, sell Nov	502	524	540
Feb, sell March	542	569	
Jan, sell March	555	582	595

Fig. 10. Mean total (farm) gross margins ($/ha) for ewes joined on 1 Sep, 1 Oct, 1 Jan or 15 Feb, and lambs sold in November or March, at 3 stocking rates for Temora (1970-2015).

Several other management changes were tested. Spraying Lucerne out in November rather than mid- September had minimal impact. Increasing lamb survival by 5% improved farm gross margins by $15/ha. The difference in gross margins for the key management changes tested are shown in Fig. 11.

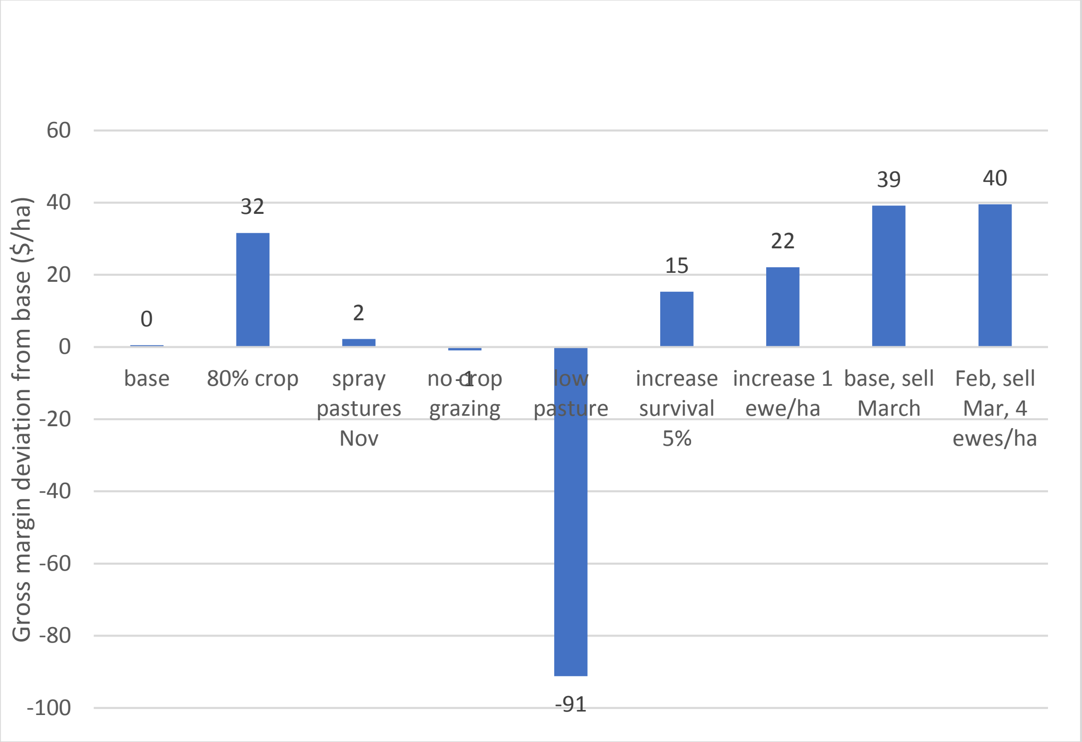


Fig. 11. Deviations from the base mean gross margin (60% crop, 3.5 sheep/ha, January joined) of a range of alternative management at Temora (1970-2015). Deviations are from total farm, sheep and cropping gross margins.

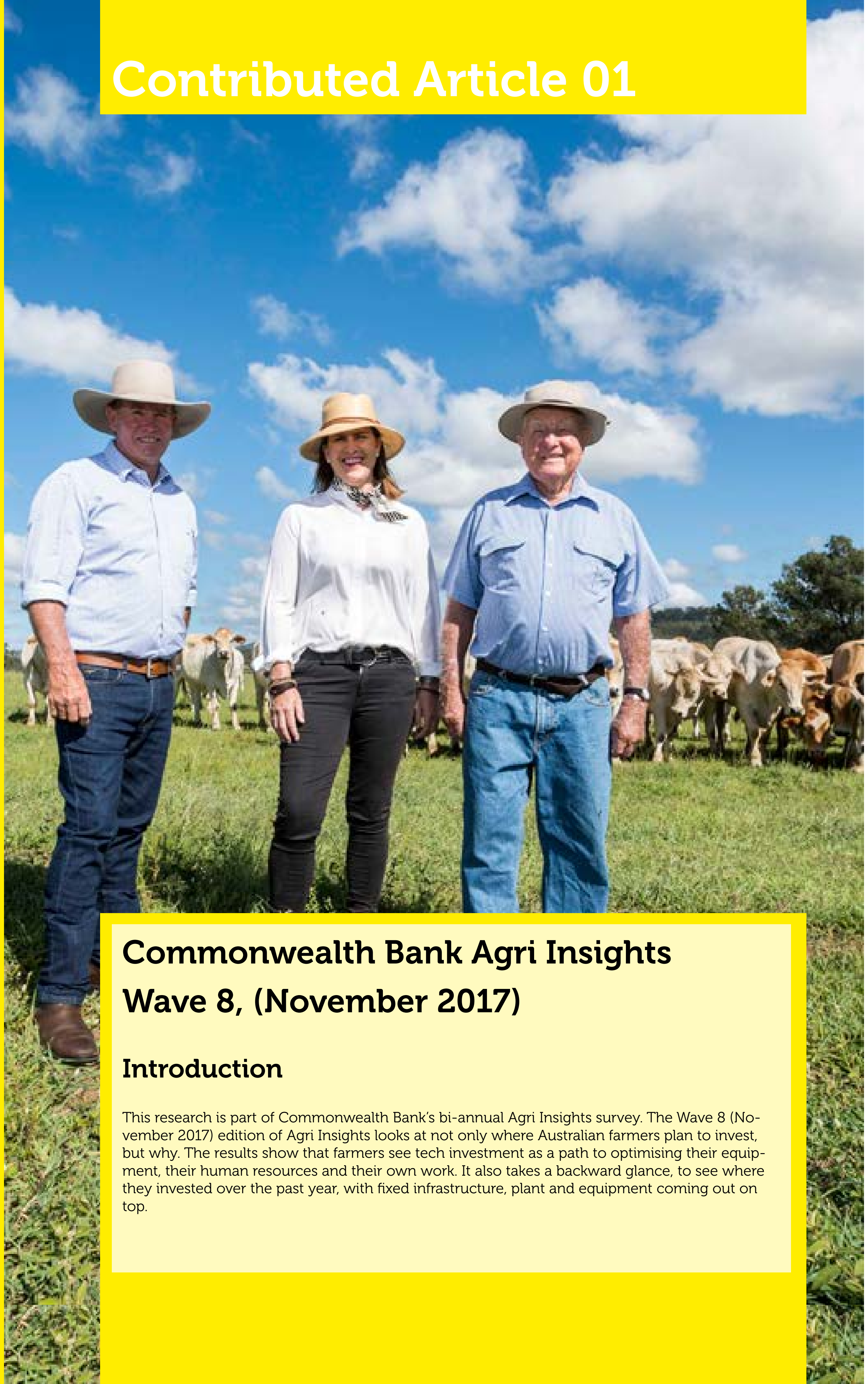
The following areas were identified as potential areas for future investment. They incorporate findings from the modelling and comments from the advisory group.

1. Ensuring pastures are productive (including novel species and filling feed gaps)
2. Increasing lamb survival – likely to have a larger effect as percentage ewes and stocking rates increase
3. Optimising sheep management for the level of pasture and crop system. While time of joining and also use of dual purpose wheat did not have as large an effect as expected, previous analyses have shown these management options can have a significant effect depending on the range of feed options available. Future work should investigate this.
4. Integration issues – weed control, nutrient cycling, parasite management, risk, cashflow etc are likely to have significant effects on system performance and sustainability. Now the models are established such effects can be investigated.

Discussion

Overall the modelling shows there are numerous management changes which could improve profit and risk on crop/livestock farms. In particular, it strongly supports the three large programs (whole farm management, profitable animal production and feed base) of activity identified through broad consultation to be a priority for future investment in a mixed farming systems RD&A program. The importance of stocking rate, in particular increases above the producer identified base scenarios (considered 'average' for the region), in increasing profit and managing risk of both the livestock enterprise and whole farm, supports investment in the 'Profitable Animal Production' theme, which seeks the outcome of producers managing livestock systems to optimise opportunities presented by mixed farming systems. The importance of feed base, in particular increases above producer identified base scenarios (generally degraded annual pastures considered 'average' for the region) to increasing profit and managing risk of both the livestock enterprise and whole farm, supports investment in the 'Feed base management' theme, which seeks the outcome of producers growing enough of the right feed at the right time to optimise their crop and livestock productivity goals. Finally, the importance of whole farm management decisions, including the relative mix between cropping and livestock, supports investment in the 'Whole Farm management' theme, which seeks the outcome of producers making informed decisions to optimise whole farm business performance.

Contributed Article 01



Commonwealth Bank Agri Insights Wave 8, (November 2017)

Introduction

This research is part of Commonwealth Bank's bi-annual Agri Insights survey. The Wave 8 (November 2017) edition of Agri Insights looks at not only where Australian farmers plan to invest, but why. The results show that farmers see tech investment as a path to optimising their equipment, their human resources and their own work. It also takes a backward glance, to see where they invested over the past year, with fixed infrastructure, plant and equipment coming out on top.

Our latest research reveals that more than a third of farmers across Australia (37 per cent) plan to increase investment in technology and innovation, versus three per cent who plan to decrease. Those who say they will increase are mainly doing it to enhance productivity and efficiency and gain greater benefits from their equipment and farm production methods.

According to the research, which surveyed 1,400 farmers on a range of business intentions, there will be a particular focus on investing in livestock production in the coming year, with solid investment intentions for wool, lamb and beef.

The survey found that 33 per cent of wool growers and 31 per cent of lamb producers are looking to expand their operations (compared to just 9 per cent of wool growers and 13 per cent of lamb producers planning to reduce). In cattle, 23 per cent of dairy farmers say they will expand their enterprise (11 per cent to reduce) and 24 per cent of beef producers plan to scale up (14 per cent to reduce).

This trend follows strong commodity investments over the past 12 months, with 10 per cent of farmers saying their biggest increases in investment were in their beef operations. Of those who invested more in livestock, many did it to make the most of strong returns.

Overall, fixed infrastructure, plant and equipment investment was the focus of the most increased investment over the past 12 months (31 per cent), and continues to present strongly for the coming year: over one third of farmers (35 per cent) are planning to increase in the coming year.

Beef

Cattle producers are back to herd rebuilding. Queensland and New South Wales pastoral regions have seen useful rainfall, whilst weather forecasters expect the northern wet season, aided by a modest La Nina event, to bring substantial rainfall. Both have bolstered producer confidence. Producers have swung from seller to buyer to boost prices sharply.

Lamb

Lamb producers are getting on with the rebuilding of Australia's flock. Agri Insights shows that almost a third of graziers are planning to expand their operations. Graziers are responding to high prices. We expect prices to stay high until next year at least, though they never stay high indefinitely – they are self-curing.

Wool

Wool prices continue to trade near 2017 highs. Supply remains on the tight side. We expect supply to remain that way for another season or so, and graziers are responding to high prices. We expect new supply to eventually, possibly in 2018, weigh on prices.

Summer Grain

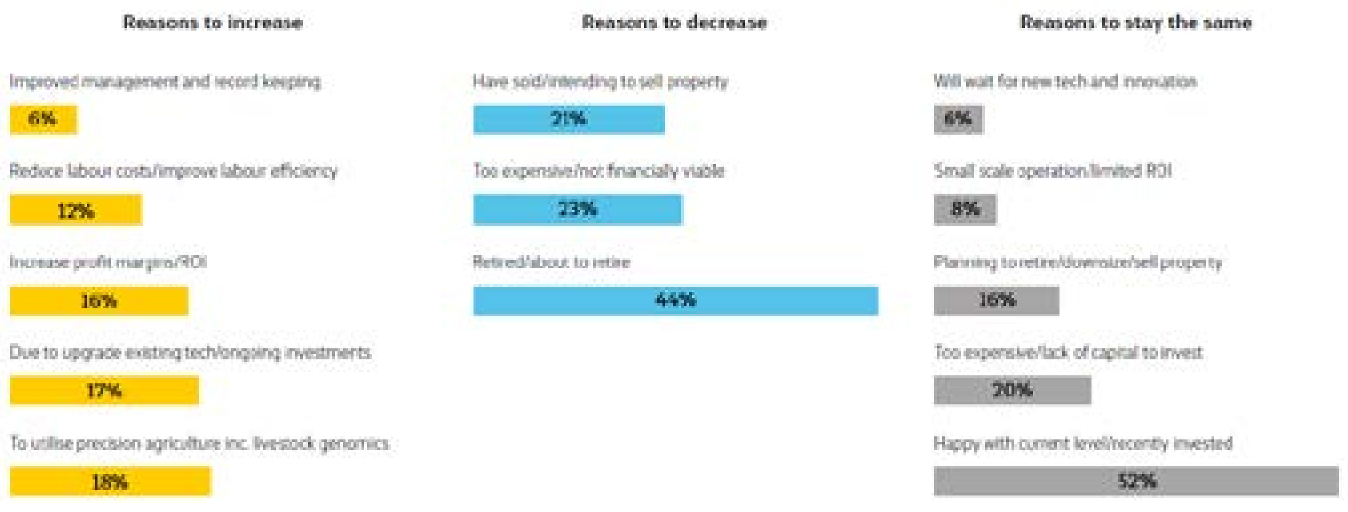
Summer croppers are looking to expand production this year. Poor previous winter and summer crops mean that feed supply is tight. Croppers are responding to high feed grain prices in and around Australia's summer crop regions. Good recent rains in the region are likely to have bolstered confidence in these plans.

Winter Grain

Winter croppers' fortunes have varied substantially in season 2017. Some regions have done well. Others though have been blighted by extended dry periods or ill-timed cold snaps. Australia's modest crop comes in the context of comfortable global supply. Modest-to-low prices thus do little to compensate for lost production.

Investment in agtech across the country

In our most recent survey, we took a deeper look at what is driving farmers' technology investment intentions. For those planning to increase investment, improving productivity and efficiency is the overall driving factor, closely followed by the need to keep up with future advancements and the latest on-farm technology. Nearing retirement was the leading reason cited by farmers who are looking to decrease their investment in this area, while just over half of those surveyed said they were happy with their current level of investment in farm technology and innovation.



*Low sample size

New South Wales

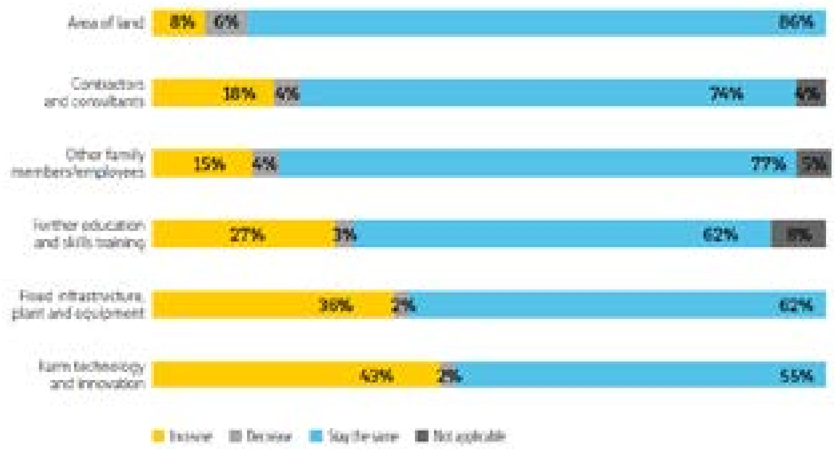
Looking forward

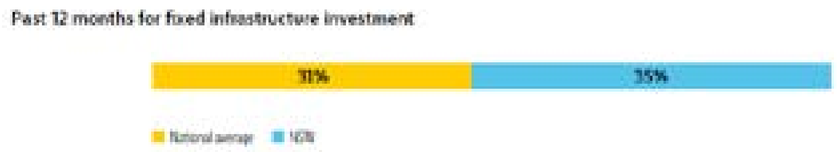
Developing the specialist skillset of the people they employ on farm is top of mind for farmers from New South Wales, who are again ahead of the national average when it comes to skills and education investment intentions.

Nearly half of New South Wales farmers plan to increase their investment in farm technology and innovation in the coming year, more than any other state and six percentage points above the national result. This is a big step up from this time 12 months ago, when only a quarter of farmers from the state said they would increase. Intentions surrounding fixed infrastructure, plant and equipment remain high for 2018 for farmers from the state.

Looking back

Over a third of New South Wales farmers stated that their greatest area of investment in their operations for the past year was in fixed infrastructure, plant and equipment. When asked why, nearly half said it was to update or upgrade their machinery for operational needs.





Contributed Article 02

Powered Farming Decisions - ProductionWise supports you through the season

Ag-technologies have enabled efficiencies, transparency of information and analytics that would otherwise seem distant without the digital age. Access to information has never been greater than today and will only improve as digital networks, infrastructure, education and technologies develop to assist the rapid expansion of data currently being generated across our farming families.

Utilising different technologies and sensors to assist our decisions is nothing new to many of us. Whether it's checking the local radar to determine forthcoming weather patterns or recognising the soil moisture status with a simple push probe, we rely on many different forms of information to influence our decisions and what to do next.

Since 2009, GrainGrowers has continued to fund the development and innovation of digital agriculture to improve efficiencies, productivity and sustainability across the Australian grains industry. Specifically, ProductionWise has improved farm level decision support and given Australian growers timely, objective and cost-effective solutions to assist with managing the risks of a modern farming enterprise.

ProductionWise – What is it?

ProductionWise is an online farm management system for broad acre cropping enterprises. The system allows mapping and management of paddock activities including tracking your stored grain and providing access to relevant soils, climate and satellite vegetation index details. Access to industry developed decision support tools powered by your very own farm management data provides ongoing paddock assessment and monitoring throughout the season. ProductionWise is also available as an app to provide in-field support when assessing paddock history, entering new activities and capturing a photo for an observation. The app is designed to work offline to give you access to information when you need it.

ProductionWise also gives growers and their advisers flexibility to communicate seamlessly through shared information whilst the added ease of recommendation reporting, planning and crop monitoring has been streamlined for improved farm efficiencies.

Price

- Grower Account $22/month*
  - Access Crop Tracker and NDVI monitoring from $4.40/month*
- Adviser Account $66/month*
  - Access Crop Tracker and NDVI monitoring from $2.20/month*

* Price includes GST

Decision Support at your fingertips

ProductionWise is not just a digital paddock recording system. The platform provides a range of decision support tools available to manage and plan activities for 12 months of the year. The location of your farm automatically enables ProductionWise to generate information specifically relevant to the farms' regional setting. The power of ProductionWise sits in the autogenerated data layers which drive many of the decision tools that most farmers would otherwise source from alternative data providers, apps or time consuming and costly analytical processes.

Weather or Not? – Plan your activities

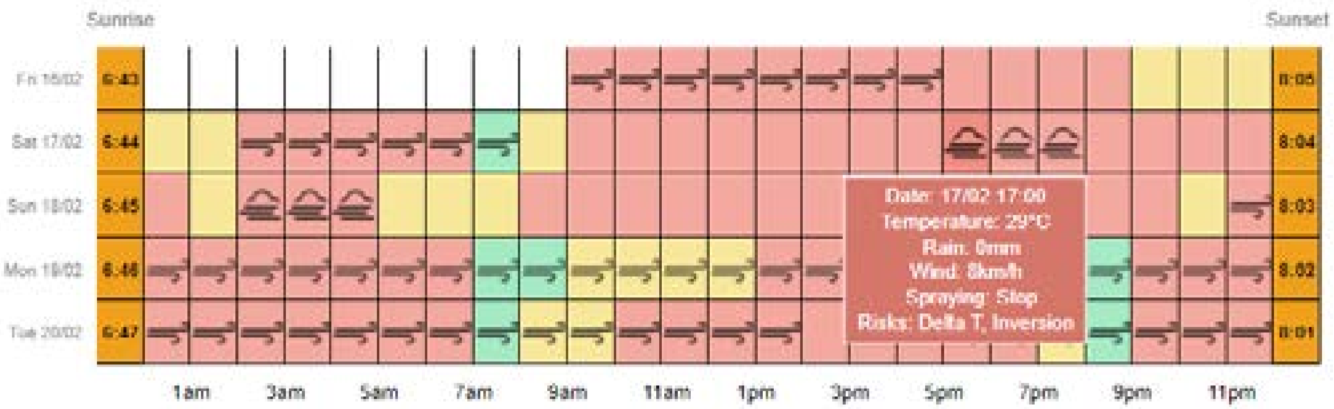
One of the key fundamental drivers that influences our day-to-day management decisions of activities is knowing what the weather forecasts are shaping up to be. More importantly, knowing the consequences of undertaking activities that are heavily influenced by adverse weather patterns could increase the risks or likelihood of ineffective crop management.

ProductionWise provides short term forecasts (updated 4 times a day) for your farm providing an assessment of the climatic conditions for the next 5 days ahead. This information gives farmers the opportunity to check conditions are suitable for paddock activities and whether your managing Delta T and inversion risk during fallow spays or top dressing to rain events, this simple farm forecast provides the foundation to plan activities accordingly. *Please note the forecasts are indicative only and conditions should always be assessed prior to high risk management activities*.

How to access these forecasts:

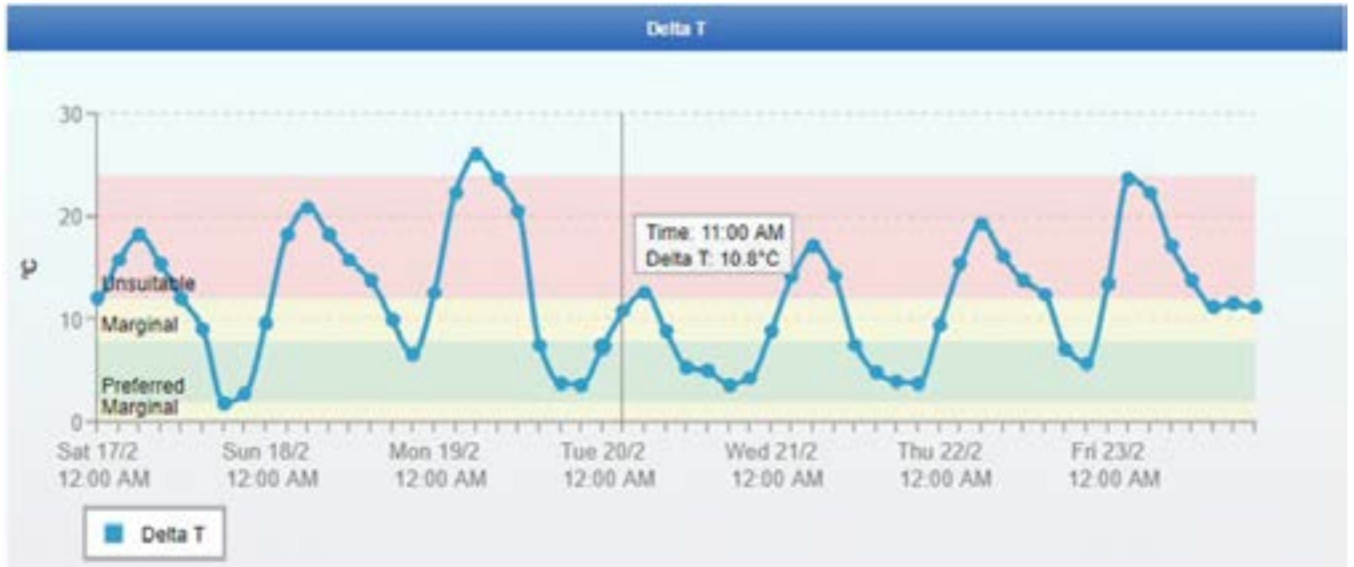
From the webpage, select your farm from the Farms page

Click the Forecast icon (top right above the map)



Date: 17/02 17:00
Temperature: 29°C
Rain: 0mm
Wind: 8km/h
Spraying: Stop
Risks: Delta T, Inversion

Forecast Planner: Provides a traffic light five-day forecast based on suitable Delta T for spraying including any risks that could potentially impact paddock management activities.



Time: 11:00 AM
Delta T: 10.8°C

Delta T Chart: Provides a seven-day Delta T forecast for your farm highlighting the temperature suitability for conditions when spraying.

Tracking Yield with Crop Tracker

Wouldn't it be handy to determine paddock yield potential as the season progresses using the information that relates to my paddock? Well... ProductionWise provides this ability on a per paddock basis using your paddock activity data. ProductionWise is the only online farm management system to have the APSIM phenology yield model integrated to provide a continuous crop assessment. Crop Tracker utilises your paddock activities entered and extracts the required information (along with automatically generated climatic data) to generate a yield prediction for each paddock. Predictions are updated every ten days as new climate data becomes available or when paddock records are updated.

Crop Tracker utilises information relating to soil type, rainfall, temperature, solar radiation and nitrogen. Many of these parameters are beyond the control of the farmer however understanding key growth periods and critical crop influences such as nutrient availability supports management decisions with regards to timing and applied rates. Understanding the cost of applications along with the potential yield gains resulting from the application are a key benefit of the Crop Tracker tool. Simply enter a planned fertiliser application with a specified rate and the model will calculate the effect the timing and rate has on the crop. This is an example of how Crop Tracker can be used to determine if top dressing is economically feasible given the status of the paddock at the time.

How to access Crop Tracker:

- *Go to the Marketplace and select a paddock(s) for monitoring yield*
- *Click Tools menu and select Crop Tracker*
- *Ensure all the key parameters are green to improve prediction capability*
- *Notional Cost: Crop Tracker for a single paddock for 8 months ~ $35 Inc. GST*

Stage - Dough Development
0.64 - Vegetation Index (NDVI)
3.49 - 80th Percentile
3.46 - Median Yield
3.37 - 20th Percentile

Crop Tracker Yield Predictions: Generates yield prediction ranges as the season occurs highlighting variability caused by abiotic factors such as soil moisture, nutrients or temperature as the crop developed.

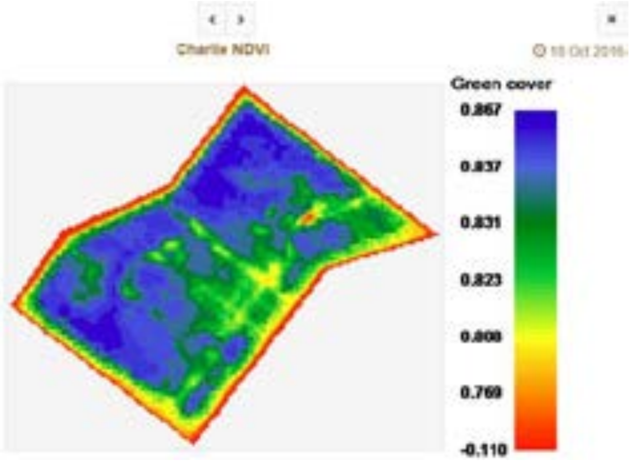
Monitoring Crops the Easy Way

With farms becoming larger these days, it makes sense to farm smarter using technologies that will provide coverage and cost savings. Satellite imagery has been available to the industry for over 40 years and access in recent times has enabled cost efficient solutions to be developed for farmers. Vegetation index or NDVI has long been regarded as an indicative measure of crop health or greenness and can be used to clearly highlight early stages of stressed vegetation that would otherwise be missed through a visual crop inspection.

ProductionWise now provides farmers the ability to order NDVI imagery on a paddock-by-paddock basis to assess crop health. Imagery can be ordered for a one-month period or up to 12 months if need be – the choice is yours. With multiple satellites available, farmers can receive at least one image per week (depending on cloud) as satellites pass over at a spatial resolution of at least 10m. Access to frequently captured NDVI data provides an invaluable support tool to monitor crop health and paddock variability as crops develop. Detecting paddock areas that appear stressed will provide a source of information to target on-ground scouting efforts and ground truthing problem areas to maximise productivity and efficiencies of valuable resources. Understanding key issues identified from scouting can enable strategic management activities to be employed such as variable rate applications.

How to access NDVI Imagery:

- *Go to the Marketplace and select a paddock(s) for monitoring NDVI*
- *An email will be received as new imagery becomes available*
- *Imagery will appear in your Paddock diary for selected paddocks*
- *COMING SOON – Viewing imagery on map as selectable layers*
- *Notional Cost: NDVI monitoring for a 50ha paddock for 8 months ~ $35 Inc. GST*



NDVI Crop Monitoring: Vegetation index (NDVI) captured by satellite is an extremely cost-effective way to monitor crop development, pinpoint problems areas for targeted ground truthing and strategic management.

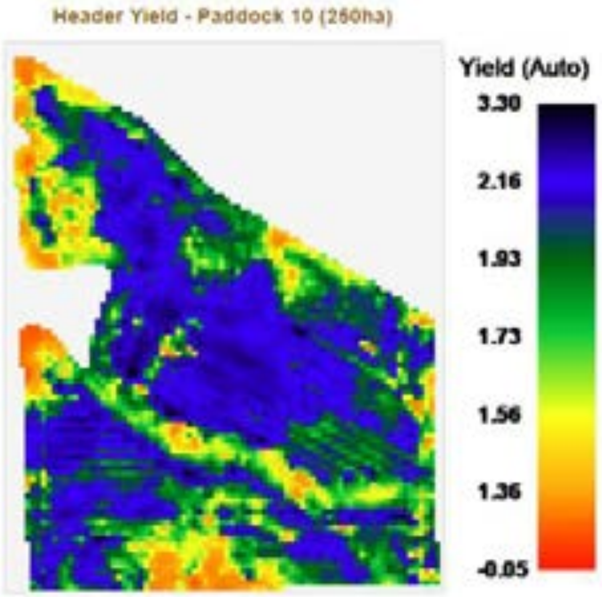
Crop Yield Data – The Next Step

With most farmers collecting yield data, the question often gets asked "How can I process or use this data?" Without teaching yourself how to use new programs or employing specialists to do this for you (and there is no harm in doing this), the process of dealing with the data can be a daunting task. Recent developments to ProductionWise provide users with the ability to upload yield data provided they have their paddock mapped and a sowing operation entered for the year the harvest data relates to… and that's it! The data is processed offsite and is returned to your paddock diary to close off the growing window for the season.

Apart from providing a visual map highlighting yield variability, this data is key for determining paddock performance especially when combined with gross margin information to determine the profitability of your paddocks. Yield maps can also support planning decisions for the following season to determine replacement phosphorus strategies if required. Whist the system at this stage only renders a yield map and production estimates for reference, the Team at ProductionWise will be further developing the use of yield data and to understand the key drivers of yield to support the needs of farmers and agronomists.

How to upload Yield Data:

- *Click Tools menu and select Yield Processing*
- *Follow the instructions to upload your zipped yield data*
- *Ensure you have sufficient sowing entries for your paddocks*
- *Notional Cost: Yield uploads are FREE for crops sown in 2017*



Harvested Yield Uploads: To bring your season paddock data to a close, ProductionWise can upload and process zipped header files.

Summary

Technology today offers a huge opportunity to understand the present day as it unfolds before us. Vast amounts of information is accessible and can be realised to the consumer with a little innovation and effort to power the decisions and support farmers to be more efficient and drive productivity throughout the farming enterprise.

ProductionWise offers a flexible month to month access and givers farmers a suite of decision support tools at an unmatched price point. The team at ProductionWise are always developing new tools and improving existing features to further support farmers and their decisions.

For further details go to www.productionwise.com.au or contact 1800 620 519