FarmLink

change ▪ adapt ▪ prosper

2016 Research Report

FarmLink 2016 Research Report
Published by FarmLink Research Limited
www.farmlink.com.au

FarmLink Research Limited
PO Box 521
361 Trungley Hall Rd Temora NSW 2666
P: (02) 6980 1333 F: (02) 6978 1290
E: farmlink@farmlink.com.au
www.farmlink.com.au

Published by FarmLink Research Limited (FarmLink), a not for profit agricultural research and extension organisation coordinating research and development activities in the FarmLink region.

ACKNOWLEDGEMENTS
DESIGN: Blair Doherty - Snap Wagga Wagga
PHOTOGRAPHY: FarmLink Image Library
PRINTING: Snap Wagga Wagga

FarmLink gratefully acknowledges the contributions of all project collaborators to this report and for the time and effort they have invested in ensuring the success of FarmLink.

Contents

Silver Partner

CommonwealthBank

BAYER

Bayer CropScience

Bronze Partner

AGT

AWB

DOW Dow AgroSciences

Best Environmental Technologies

HP Hutcheon & Pearce

Grain Growers

TTTS Temora Truck & Tractor Service PTY LTD

New Holland Agriculture

Croplands

Intersales Temora Leeton

Corporate Members

Pacific Seeds

agribusiness nab

Suncorp Bank Agribusiness

RMS Agricultural Consultants

Pioneer. Brand • Seeds

Rabobank

Legal advice generously provided by

TressCox Lawyers

A Word from the Chairman & CEO

Dear Members

It is with pleasure that we present you with the 2016 FarmLink Annual Research Report. 2016 has been a year of consolidation and stabilisation. The FarmLink team has focussed on delivering high quality R&D activities as well as hosting a range of events that have both entertained and informed.

We would like to take this opportunity to thank our major funding and project partners – GRDC, Riverina LLS, CSIRO, NSWDPI, ClearView Consulting, Bayer, Charles Sturt University, AGT, Kalyx, BCG, Dow Agroscience and CropFacts. Without their recognition of the value that FarmLink creates and the importance of RD&E to the future of farming in southern NSW, none of the work of FarmLink would be possible. We also acknowledge our other Partner organisations, Commonwealth Bank, Hutcheon and Pearce, AWB, Best Technologies, Grain Growers, Intersales, Temora Truck and Tractor whose involvement with FarmLink creates enormous benefits for members and the organisation. We hope that your support of them continues.

We would also thank our volunteer Board members, who often go unnoticed, and who are contributing significantly with their time, expertise and passion to the success of FarmLink.

A significant highlight for the year was our Open Day, held in September at Temora Agricultural Innovation Centre, and attended by 250 people. Combined with the presenters and companies' hosting trade displays there was quite a crowd – even with the torrential rain! Attendees were from all over southern NSW and included members and non-members alike, a demonstration of the value that FarmLink creates and shares with farmers across southern NSW.

Professor Chris Blanchard of the Functional Grains Centre, launched the Open Day and spoke about the International Year ofv Pulse and opportunities to value add Australia grain to deliver greater returns for Australian farmers, two topics close to our hearts.

A feature of the Open Day, and in fact the FarmLink program in 2016 and going forward, is the renewed focus on livestock in the mixed farming context and as standalone enterprises. This year we will commence an MLA project designed to deliver RD and A priorities in mixed farming.

Looking forward, our livestock program will continue with Murray Long hosting a Satellite Flock under the Meat and Livestock Australia (MLA) Resource Flock Database, collecting data on DNA predictions, at TAIC. We are also hosting the Federal Department of Agriculture funded, CSIRO project looking to develop an online system for estimating current and future soil water storage at the field scale using satellite and field-based measurement systems and simulation models. CSIRO will investigate the use of local automated and telemetered climate data stations to improve farmers' knowledge of the often large differences in conditions between their paddocks, and to develop a tool to assist in understanding the benefits and risks of fertiliser application at various crop stages. Also continuing in 2017 are two sites in the Galong and Harden areas with trials investigating amelioration of sub soil acidity and management of weeds seeds at harvest. Both of these projects are GRDC funded and we have partnered with NSWDPI and Southern Farming Systems respectively to deliver them.

We look forward to seeing you through 2017 and beyond, as we all strive to Change, Adapt and Prosper.

Darryl Harper

Chair

Cindy Cassidy

CEO

A proven partner to New South Wales Agriculture.

At Commonwealth Bank, we have been supporting regional communities and the agribusiness sector for over 100 years, and our track record is one of genuine commitment and long term partnership with customers.

We understand the industry and the community, because we're part of it.

We recognise that doing business means riding out the cycles of good times and tougher times, particularly in the farming sector.

The needs of our customers are at the centre of everything we do, from specialised financial solutions to accessible branches and staff.

Our regional and agribusiness customers have access to our financial strength, economic insights and technology. Most importantly, they also have access to a team of people who are passionate about regional Australia, and committed to securing and enhancing the financial wellbeing of people, business and communities.

We're proud to be the bank of choice for many of Australia's leading agribusinesses.

From lines of credit, asset finance and award-winning online banking, to a wide range of hedging products, we're determined to enable your business with the tools it needs to innovate and grow.

Talk to your local New South Wales agribusiness specialists today.

Kym Hampton 0455 059 648
Executive Manager Riverina

Your local Wagga Wagga Agribusiness Executives

Leigh Schneider	0428 836 169
Jonathan Uphill	0428 432 801
Angas Swann	0476 849 574
Andrew Schmetzer	0478 322 920
Lawrence Graham	0475 989 836

CAN

The 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 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, Cootamundra Shire Council, Hilltops Shire Council, Wagga Wagga City Council, Cowra Shire Council, 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, UA, Bayer, DAFF, Dow AgroSciences, AGT, Best Environmental Technologies, Hutcheon & Pearce, Landmark, MLA, Environmental Trust, CSU, 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, strategic tillage, crop sequences and early sowing.

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 as well as gaining access to 4th year and PhD students working and located within the FarmLink business.

01

Maintaining profitable farming systems with retained stubble across various rainfall environments in SA, Victoria and central and southern NSW

GRDC Project codes – GRDC CSP00174, EPF00001, BWD00024, YCR00003, MFM00006, CWF00018, RPI00009, LEA00002 plus collaboration with SFS00032 & DAS00160

Project Partners

FarmLink change • adapt • prosper

CSIRO

Funding Partners

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Trial Site Location

5 km SSE of Temora

Report Authors

Tony Swan, Clive Kirkby, Brad Rheinheimer (CSIRO Agriculture), Paul Breust (SFS), Claire Brown (BCG), James Hunt (CSIRO Agriculture, (La Trobe University (current address)), Kellie Jones (FarmLink Research), Helen McMillian (CWFS), Sarah Noack (Hart Field Site Group), Trent Potter (Yeruga Crop Research), Cassandra Schefe (Riverine Plains), Amanda Cook, Blake Gontar, Michael Nash, Naomi Scholz (SARDI), Felicity Turner (MFMG) and John Kirkegaard (CSIRO Agriculture)

Introduction

Following a GRDC review that identified gaps regarding the impact of stubble retention in southern cropping systems, a five year program was initiated by GRDC in 2014. Ten projects comprising 16 farming systems groups and research organisations which include FarmLink Research, BCG, CSIRO, CWFS, EPARF, Hart Field Site group, ICC, LEADA, MFMG, MSF, Riverine Plains, SARDI, UNFS, VNTFA, Yeruga Crop Research are currently involved in exploring the issues that impact on the profitability of retaining stubbles across a range of environments in southern Australia with the aim of developing regional guidelines and recommendations that assist growers and advisors to consistently retain stubbles profitably.

Take home messages

- In 2017, don't let stubble compromise the big things (weeds, disease, timeliness)
- If the intent is to retain stubble:
- Pro-actively manage the stubble for your seeding system
- Diversify (add legumes to rotation), deep band N and manage invertebrates. Mice could also be a major problem
- For tined seeders, reduce stubble load by mulching, incorporation + nutrients, baling, grazing and consider sowing at 15-19 degree angle to previous sown row
- If stubbles are too thick to sow through, consider strategic late burn, especially before second wheat crop or if sowing canola into large stubbles
- Early monitoring is essential to see how effective actions are to allow for re-planning

Report One

Stubble management options

Background

In 2016, grain yields were high across most of southern and south-eastern Australia, with many cereal crops yielding ≥ 5t/ha and often up to 8t/ha which indicates there will be a residual stubble load of 7.5-12 t/ha. This paper examines two main management options to deal with high stubble loads (≥ 5t/ha) in 2017, and incorporates many of the main findings from the stubble initiative to date.

Option 1: How to manage stubble if you plan to retain the stubble at all costs

- Tine seeder options

1. Harvest high (≥30cm) and mulch or incorporate

2. Harvest low (≤ 20cm), use chopper/power spreader to smash and spread straw evenly across swath at harvest or soon afterwards

- Disc seeder

Stripper fronts/harvest high, good diverse rotation

Option 2: How to manage stubble if you have a flexible approach to retaining stubble

Harvest big crops high, graze, burn, bale straw as necessary to reduce stubble to amounts that sowing equipment can manage. Focus on reducing stubble in paddocks where the stubble is likely to impact the 2017 crop yield e.g. wheat on wheat paddocks.

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 1,2,3,4,5,6). During these periods, a series of questions (some outlined below) will need to be addressed by farmers to successfully establish a crop (ref 4).

- 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 in 2017?
- 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 to the 2017 crop?
- Am I likely to encounter a pest problem in 2017: 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. The GRDC Project YCR00003 is developing an App to assist farmers and consultants. 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, 6).

Remember, 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.

Option 1: How to manage stubble if you plan to retain the stubble at all costs

A recent survey was undertaken in the Yorke Peninsula and Mid-North of SA which showed that 82% of farmers use tined seeders, with the remaining 18% using discs (Yeruga Crop Research).

About 21% of farmers were totally committed to retaining stubbles at all costs while about 79% would consider burning stubbles if absolutely necessary.

In relation to establishing a crop in stubble retained systems, the following issues were extremely important -

- Herbicide efficacy was extremely important (80+% in both tine and disc);
- Managing weeds (approx. 65% both tine and disc);
- Managing slugs and snails (> 50% in tine and disc);
- Efficiency and ease of sowing (82% in tine and 58% in disc);

The following were more important at seeding -

- Straw length (70% tine)
- Chaff fraction (50% disc)
- Hair pinning (15% tine, 84% disc)

Stubble 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 1). As a general rule, there is a 10% reduction in harvest speed for each 10cm reduction in harvest height (Tables 1 and 2, ref 4, 5, 8). 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 1.

However, there are some negatives to retaining tall wheat stubble, with several groups in the initiative finding that wheat sown into taller wheat stubble (45cm cf 15cm) received less radiation and were exposed to cooler temperatures. This can reduce early growth and significantly reduce tiller numbers. In a Riverine Plains experiment in 2014, there was a significant reduction in grain yield (4.98t/ha cf 5.66t/ha with lsd @ P<0.05 = 0.45t/ha) in tall compared to short stubble. In 2015 the group found no difference in grain yield. In 2016, significantly less tillers were found in several trials in tall stubble, however in all of these trials, this did not result in any difference in grain yield.

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

Table 1: 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)	Harvest efficiency (t/hr)	Grain Yield (t/ha)	Cost $/ha	Cost $/ton
40cm	12.0	8.5	6.6	45	3.8	$50.0	$13.5
15cm	7.5	6.0	10.6	30	3.9	$80.0	$20.2
% Change to 15cm	-38%	-29%	+61%	-33%	ns	+37%	+33%

Table 2: Harvesting wheat low or high using a Case 8230 combine with a 13m front in 2015 (ref 7). Ground speed was altered to achieve similar level of rotor losses at both harvest heights. Operating costs determined at $600/hr.

(ns = no significant difference)

In 2016 like many previous years, herbicide resistant weeds, especially annual rye grass (ARG) continue to be a problem. 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. HWSC requires crops to be harvested low in order for weed seeds to be captured in the chaff fraction from the combine, and if practised, 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 4km/hr to compare the efficiency and cost with non-weed seed destruction methods (Table 3). The three large scale field trials in both states are being monitored for changes in annual ryegrass populations before and after sowing between 2015 and 2018.

In 2016 there has been less opportunity to harvest cereal crops very high in many areas due to lodged or leaning crops, and variable head heights. Cereal crops such as Compass barley often lodged badly resulting in the need to harvest very low.

A full report on the Harvest Weed Seed Control in the Southern Region project appears in this Research Report.

	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	5.7	6.2	6.2	9.6	$105.3	$50.1
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 15cm				+9%	+11%	+11%
% change to iHSD				+33%	+37%	+40%

Table 3: A Case 9120 harvesting wheat conventionally at 30cm, harvesting at 15cm for baling or narrow windrow burning and harvesting at 15cm with a prototype iHSD at Furner, SA in 2016. (Data supplied by GRDC project SFS00032)

MULCH and incorporate

Lightly incorporating the stubble into the surface soil using a disc chain or disc machine (i.e. Speed Tiller, Grizzly, Amazone Cattross, Vaderstad Topdown or Lemken Heliodor) soon after harvest while the stubble is higher in nutritional value is another option for farmers wanting to maintain all of their stubble, especially where a tined seeder is the primary sowing implement, or where lime and stubble needs to be incorporated into the soil in a disc-seeding system. On the lighter sandier soils in SA, the recommendation would be to delay incorporation until 3-4 weeks before seeding as these soils are more prone to wind and water erosion. Mulching and incorporation requires soil moisture, warm soil temperature, soil/stubble contact and nutrients to convert a carbon rich feed source into the humus fraction. Early mulching and incorporation allows time for the stubble to decompose and immobilise N well before sowing, reducing the likelihood of reduced N availability.

When trying to decompose a large quantity of stubble in a short period of time (i.e. to convert stubble into humus), it may be beneficial to add some nutrients to the stubble prior to incorporation. To assist in minimising the amount of fertiliser required to add to the stubble, determining the concentration of the nutrients in the stubble is important. As humus is so nutrient rich and the stubble residues are relatively nutrient poor, only a small proportion of the total carbon in the crop residues can be converted into humus. Dr Clive Kirkby has found that a maximum of 30% of the total carbon from stubble residues could be converted to humus, so recommends lowering the humification rate to 20% rather than 30%. In our example (Table 4), the quantity of fertiliser (sulphate of ammonia) that would need to be applied to the 10t/ha residual cereal stubble load where the stubble had a nutrient concentration of 0.7%N, 0.1%P and 0.1%S and the farmer wanted a humification rate of 20% would

Stubble Nutrient Humification Calculator		C	N	P	S
Stubble load (kg/ha)	10000				
Humification required (%)	20				
Stubble nutrient concentration (%)		45.0	0.700	0.100	0.100
Nutrients already in stubble (kg/ha)		4500	70	10	10
Carbon to be humified & nutrients required (kg)		900	77.0	9.2	11.7
Carbon remaining (kg)		3600			
Extra nutrients required (kg/ha)			7.0	-0.8	1.7
1. Fertiliser type and Nutrient concentration (%)	SOA		21.0		24.0
2. Fertiliser type and Nutrient concentration (%)					
Fertiliser required to supply exact nutrients (kg/ha)			33		7
Fertiliser cost ($/ha)			$14.9		
Fertiliser and spreading cost ($/ha)			$23.4		

(Financial support provided by NIEI, EH Graham Centre, CSIRO and GRDC project DAN00152)

be 33.1kg/ha of nitrogen and 7kg/ha of sulphur at an estimated cost of $14.90/ha for nutrients only. In contrast, if a farmer was trying to build up their organic carbon concentration in the soil from this stubble residue to the maximum possible amount (30% humification rate), the quantity of nutrients required increases to 45.4kgN/ha, 3.8kgP/ha and 7.6kgS/ha, at a cost of $74.40 for nutrients (Table 5). The nutrients applied are not lost, but should form a source of slow release nutrition to the following crop while avoiding "nutrient tie-up" caused by late incorporation of nutrient poor residues. Thus, later inputs could potentially be reduced if costs were of concern.

In an experiment at Harden, NSW between 2008 and 2011, Dr Kirkby incorporated between 8.7 and 10.6 t/ha of cereal or canola stubble without nutrients or with nutrients at a humification rate of 30%. In May 2009, following the incorporation of 8.7t/ha wheat stubble in February 2009, they measured the quantity of wheat stubble that had broken down and found that only 24% of the stubble remained where nutrients had been added whereas 88% remained where the stubble had been incorporated only (Kirkby et al. 2016). A couple of groups (Riverine Plains, MFMG) have included light incorporation (+/-) nutrients in their treatment mixes. Although no group specifically examined residue breakdown, they found that the cultivated (+ nutrient) treatment often yielded the same or more than cultivated (no added nutrient) treatment (i.e. Wheat grain at Yarrawonga January 2017 in Cultivate +40kgN/ha = 6.7t/ha compared to Cultivate only = 5.9t/ha, lsd = 0.58).

Stubble Nutrient Humification Calculator		C	N	P	S
Stubble load (kg/ha)	10000				
Humification required (%)	30				
Stubble nutrient concentration (%)		45.0	0.700	0.100	0.100
Nutrients already in stubble (kg/ha)		4500	70	10	10
Carbon to be humified & nutrients required (kg)		1350	115.4	13.8	17.6
Carbon remaining (kg)		3150			
Extra nutrients required (kg/ha)			45.4	3.8	7.6
1. Fertiliser type and Nutrient concentration (%)	Urea		46.0		
2. Fertiliser type and Nutrient concentration (%)	Single super			8.8	11.0
Fertiliser required to supply exact nutrients (kg/ha)			99	43	69
Fertiliser cost ($/ha)				$74.4	
Fertiliser and spreading cost ($/ha)				$82.9	

(Financial support provided by NIEI, EH Graham Centre, CSIRO and GRDC project DAN00152)

Cropping system	Crop Type	Average Total Cost 2014-16	Average Net Margin 2014-16	Average 3yr Profit: Cost ratio
		($/ha/yr)	($/ha/yr)	($/ha/yr)
Aggressive	Canola RR	$524	$722	1.4
Aggressive	Wheat (yr 1)	$525	$378	($/ha/yr)
Aggressive	Wheat (yr 2)	$504	$394	1.4
Conservative	Canola TT	$452	$694	2.26
Conservative	Wheat (yr 1)	$415	$289	+9%
Conservative	Wheat (yr 2)	$419	$261	1.5
Sustainable	Vetch (Hay)	$463	$416	
Sustainable	Canola TT	$426	$769	1.5
Sustainable	Wheat	$492	$422	
Sustainable	Barley	$478	$441	0.6
SYSTEM AVERAGES				0.9
Aggressive		$517	$498	1.8
Conservative		$429	$415	0.9
Sustainable		$465	$512	1.0

Table 6: Average net margins (EBIT) – effect of crop strategy at Temora, NSW, 2014-2016

Diverse cropping sequence

A diverse cropping sequence provides many benefits for farmers wanting to retain all their stubble annually. Diversity allows each crop to be sown into a less antagonistic stubble by reducing physical, disease, pest and weed constraints.

A fully phased systems experiment was established in Temora in 2014 at a site with high levels of Group B resistant ARG to examine if a diverse crop rotation ('sustainable' - vetch hay-TT canola-wheat-barley) could improve the profitability of stubble retained no-till (Flexi-Coil tine seeder with Stiletto knife points and deep banding and splitting boots) and zero-till (Excel single-disc seeder with Arricks' wheel) systems. Three cropping systems (aggressive, conservative and sustainable) were compared with the rotations for each as aggressive (RR canola-wheat-wheat), conservative (TT canola-wheat-wheat) and sustainable (as above). In the cereal crops in the aggressive and sustainable system, new-generation pre-emergent herbicides (Sakura® and Boxer Gold®) were used for grass weed control. In the conservative system, trifluralin and diuron were used for grass weed control in the tine system, and diuron alone in the disc system.

The introduction of diversity in the sustainable system has allowed it to achieve a net margin ($512/ha/year) which is higher than in the aggressive systems ($498/ha/year) and at lower cost ($465 cf $517/ha/year) and thus higher profit:cost ratio ($1.12 cf $0.98) (Table 6). The reduced costs in the sustainable system are driven by lower fertiliser N inputs from the inclusion of vetch hay, which requires no fertiliser N itself and provides residual N for subsequent crops. The barley phase of the sustainable system has also been more profitable than the second wheat crop in either the aggressive or conservative system (Table 6), despite record low barley prices in this 2016/17 season.

The Riverine Plains group compared a wheat-faba bean-wheat rotation against a wheat-wheat-wheat (+/- burning) and found there was no significant difference in wheat yield following wheat stubble that was retained or burnt (average 3.42t/ha), but there was a 2t/ha increase in wheat yield following faba beans. The wheat stubble also acted as a trellis assisting to keep the beans off the ground and improve airflow and the higher nitrogen concentration following the bean crop combined with the increased decomposition of the wheat stubble resulted in the bean crop "resetting" the system and burning was not required. Similar findings have been observed by the Hart Field Site group in relation to lentils using the wheat stubble as a trellis. Earlier maturing varieties such as Blitz were found to be taller with increasing stubble height (30 and 60cm stubble height cf 15cm or baled). They also found that the type of stubble was important for the following crop, with wheat maintaining its supportive structure better than barley.

Margin	Net Margins 2014 ($/ha)		Net Margins 2015 ($/ha)		Net Margins 2016 ($/ha)		Average Net Margins 2014-2016 ($/ha/yr)		Profit:Cost ratio 2014-2016	
Seeder	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 7: Average net margins across all crop types for each crop system by opener type between 2014 and 2016 at Temora, NSW.

Establishing crops with disc and tined seeders

It has been well documented that a disc seeder can handle higher stubble loads in comparison to a tined seeder, have less variability in seeding depth and higher sowing efficiencies than a tined seeder. Over the three year trial at Temora, there has been little difference in the net margin of either the disc or tine openers where ARG was effectively controlled by pre-emergent herbicides in the aggressive and sustainable cropping systems. However, in the conservative system, the combination of trifluralin and diuron were able to achieve a reasonable ARG control in the tined system, but diuron alone was largely ineffective in the disc system, and this has reduced yields and profit in this system (Table 7).

Southern Farming Systems have been comparing the advantages of establishing crops with a disc and tined seeder over the past 3 years. They found that although there was no significant difference in wheat yield at the 95% confidence level (0.5 t/ha increase in yield at the 90% confidence level), there were significant improvements in efficiencies in the disc system with quicker sowing, quicker harvesting (harvest high) and fuel savings in 2015 (Table 8). It must be remembered that both types of seeders have advantages and disadvantages in different circumstances and the main aim is to establish seed reliably in a wide range of sowing conditions!

	Sowing	Harvest time	Fuel Usage
Disc vs tine	4.8km/hr faster*	1.81 ha/hr faster#	2.11 L/ha##
Value of difference	$2.10	+$13.23	$2.53

Table 8: Cost calculations for sowing efficiency, harvest efficiency and fuel usage in a Southern Farming Systems disc vs tine trial in Victorian HRZ in 2015.

Deep banding vs surface applied Nitrogen at sowing

One mechanism by which large amounts of retained cereal stubble can reduce yields in subsequent crops is through immobilization of N. Banding N fertiliser either at sowing using a deep, side or mid-row banders or in-crop using mid-row banders is a way of separating fertiliser N from high carbon stubble that microbes use as an energy source when immobilising N. In 2016, an experiment was established at Temora on 5.1 t/ha of retained wheat stubble where 122 kg/ha N as urea was either banded beside and below wheat seed using Stiletto splitting boots, or spread on the soil surface before sowing with the same boots. Starting soil mineral nitrogen concentration was 58 kg/ha N (0-150cm) and no additional nitrogen was applied. By Z30 more nitrogen had been taken up by the plant where the N was deep banded (4.3% cf 3.8%), a pattern which continued with greater plant dry matter and nitrogen uptake at anthesis and higher grain yield (Table 9). However, there was no significant interaction with the presence/absence of stubble, indicating that banding N may improve N use efficiency in all systems (with or without stubble).

		GS30	GS30	GS30	Anthesis	Anthesis	
Pre-sowing Nitrogen Application	Emergence	Plant Dry Matter	Plant Nitrogen	Nitrogen uptake	Plant Dry Matter	Nitrogen uptake	Grain Yield
	Plants/m^2	(t/ha)	(%N)	(kgN/ha)	(t/ha)	(kgN/ha)	(t/ha)
Deep	132	1.4	4.3	60.0	9.2	136.4	5.2
Surface	137	1.4	3.8	51.6	7.9	102.5	4.1
P value (interaction)	0.257	0.570	0.016	0.074	<0.001	0.007	0.001
lsd (P<0.05)	ns	ns	0.394	ns (9.58)	0.3	17%	0.43

Table 9: Wheat (Lancer) emergence, dry matter, % nitrogen in the tissue, nitrogen uptake and grain yield where 122kgN/ha was applied at sowing either below the seed using stiletto points or on the surface pre-sowing into either 5.1t/ha of wheat stubble or where stubble was removed at Temora in 2016.

Option 2: How to manage stubble if you have a flexible approach to retaining stubble

There are many reasons why a flexible approach to retaining stubble may be required as 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 is managed

A flexible approach to manage stubble means crops can be harvested high or low depending on the season and situation, stubbles can then be grazed with considerable economic advantage, or straw baled and sold, or burnt.

Grazing

For mixed farmers, the option to graze the stubble soon after harvest can be quite profitable. In a long term no-till controlled traffic grazing experiment in Temora between 2010-2015 with crop rotation of canola-wheat-wheat, four treatments were compared including a full stubble retention system (nil graze, stubble retain) and a post-harvest grazing of the stubble (stubble graze, stubble retain). Each of these were split to accommodate a late burn pre-sowing (i.e. nil graze, stubble burn and stubble graze, stubble burn) (Table 10). All plots were inter-row sown with deep knife points and machinery operations conducted using controlled traffic. Stubble grazed plots were grazed within 2-3 weeks of harvest at approx. 300 DSE/ha for five days ensuring > 3t/ha remained for soil protection and water retention. All plots were sown, fertilised and kept weed free such that weeds, disease and nutrients did not limit yield. Over seven years, the experiment has shown that there is a $44/ha increase in gross income where sheep were used to graze the stubbles compared to nil grazing if no grazing value was assumed. This increase was related to higher yields and grain quality in subsequent crops driven by greater N availability in the grazed stubble. There was a $159/ha increase if a grazing value for the stubble was assumed (see GRDC paper 2015 Hunt et al. for details).

Graze treatment	Stubble treatment	Gross income ($/ha/year)	
Nil graze	Retain	$1,153	$1,153
	Burn	$1,179	$1,179
Stubble graze	Retain	$1,197	$1,312
	Burn	$1,193	$1,307

Table 10: Gross income per year averaged across two phases where stubble was either grazed post-harvest or not, and either burnt just before sowing or retained, 2010-2015 at Temora, NSW.

		Grain Yield 2009-2016							
Phase	Stubble Treatment	2009	2010	2011	2012	2013	2014	2015	2016
1	Retain	1.7	4.2	4.6	**4.4**	0.7	3.8	**4.1**	3.2
1	Burn	1.7	4.0	4.6	**5.0**	1.0	3.8	**4.6**	3.2
2	Retain		6.3	3.4	4.5	**2.0**	2.0	5.5	**5.2**
2	Burn		6.2	3.5	4.8	**3.4**	2.0	5.3	**5.7**
	Red = Canola crops					frost			

Table 11: Grain yield of wheat and canola sown using deep knife points in two phases between 2009 and 2016 where stubble was either retained or burnt (pre-sowing) at an experiment in Temora, NSW.

Similar results were observed in a crop systems experiment where wheat (first wheat) was either sown into canola stubble or into 7.2 t/ha wheat stubble (second wheat) in April 2016. The wheat was deep banded with 40kgN/ha at sowing in both treatments to assist in supplying N to the crop, however, there was a 0.6-0.8t/ha reduction in wheat yield in the second wheat crop (Table 12). Many farmers in the south west slopes also observed decreases in the grain yield of their second consecutive wheat crop compared to wheat sown after canola in 2016 in stubble retained systems.

Cropping system	Crop	2016 Disc	2016 Tine
Aggressive	Wheat (yr 1)	5.5	6.0
Aggressive	Wheat (yr 2)	4.9	5.3
P value = <0.001	lsd (P<0.05)	0.54	

Table 12: Wheat grain yield in crop following canola (wheat yr 1) compared to second wheat crop at crop systems experiment at Temora, NSW 2014-2016 in disc and tines x systems

Computer applications (Apps) for stubble management

GRDC Project YCR00003, led by Yeruga Crop Research is finalising a computer/smart phone application (App) which may be of great benefit to farmers and consultants. It provides a quick and efficient method to indicate what the benefit or cost could be for different stubble management decisions such as narrow windrow burning, burning or baling a crop to reduce stubble. A couple of examples are highlighted below for narrow windrow burning (Figure 1) and baling (Figure 2) the stubble from a 5t/ha wheat grain crop.

For more information, contact Yeruga Crop Research. The tool was developed by Stefan Schmitt in conjunction with Bill Long, Mick Faulkner, Jeff Braun and Trent Potter.

Narrow windrow burning (NWB): NWB has been practiced for several years now and has proven to be an effective tool in reducing weed seeds. One advantage of NWB compared to entire paddock burn is the reduction in nutrients lost from the stubble residue. The stubble management optimiser indicates that approximately $22.60/ha is lost from the paddock if NWB compared to approximately $76/ha if the entire paddock is burnt (Figure 1). One constraint with narrow windrow burning as AHRI indicated, would be the increased risk if the wheat grain yield was greater than 2.5t/ha (> 4t/ha stubble residue). In 20114/15 NWB was successfully undertaken in wheat crops between 3-3.75t/ha with an estimated stubble load of 4.5-6t/ha in the Riverina, NSW (Grassroots Agronomy 2014). Due to the high stubble loads in 2016/17, narrow windrow burning may be restricted to canola stubbles and other lower DM crops. It must be acknowledged that a wet cool autumn can severely reduce the efficiency of burns leading to weed strips in the paddock.

Baling: In many areas across southern Australia, a significant area of stubble has been baled in 2016/17 season. Baling allows the farmer to harvest high and efficiently (use stripper front if possible), and reduce the stubble load in the paddock to minimise problems at sowing. One of the negatives of baling stubble is the loss of nutrients from the paddock. The stubble management optimiser shows the farmer the cost to make hay including the cost of nutrient loss (Figure 2).

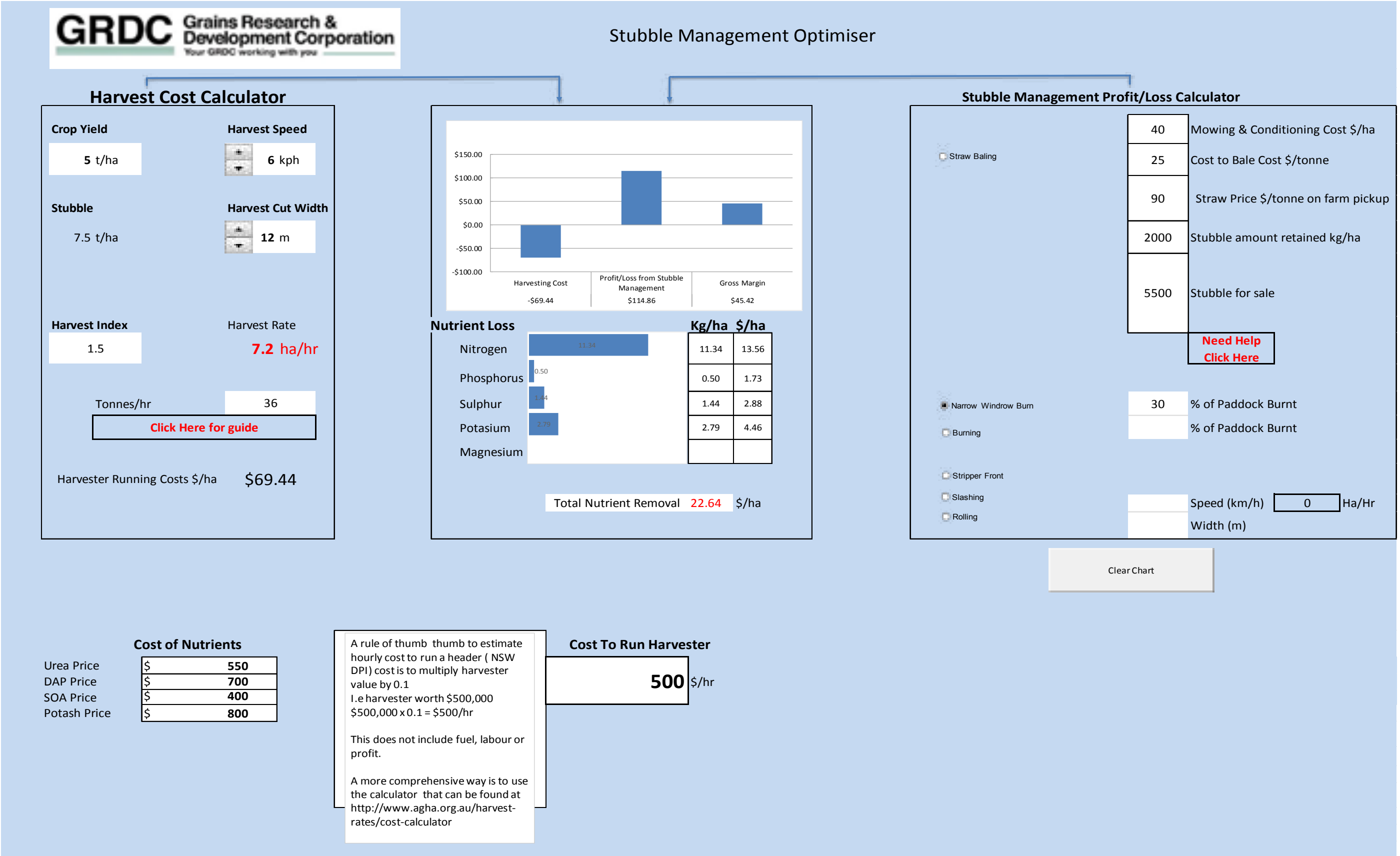


Figure 1: The estimated effect on profit from harvesting a 5t/ha wheat yield with 7.5t/ha stubble load remaining that is narrow windrow burnt, valuing the loss of nutrients.

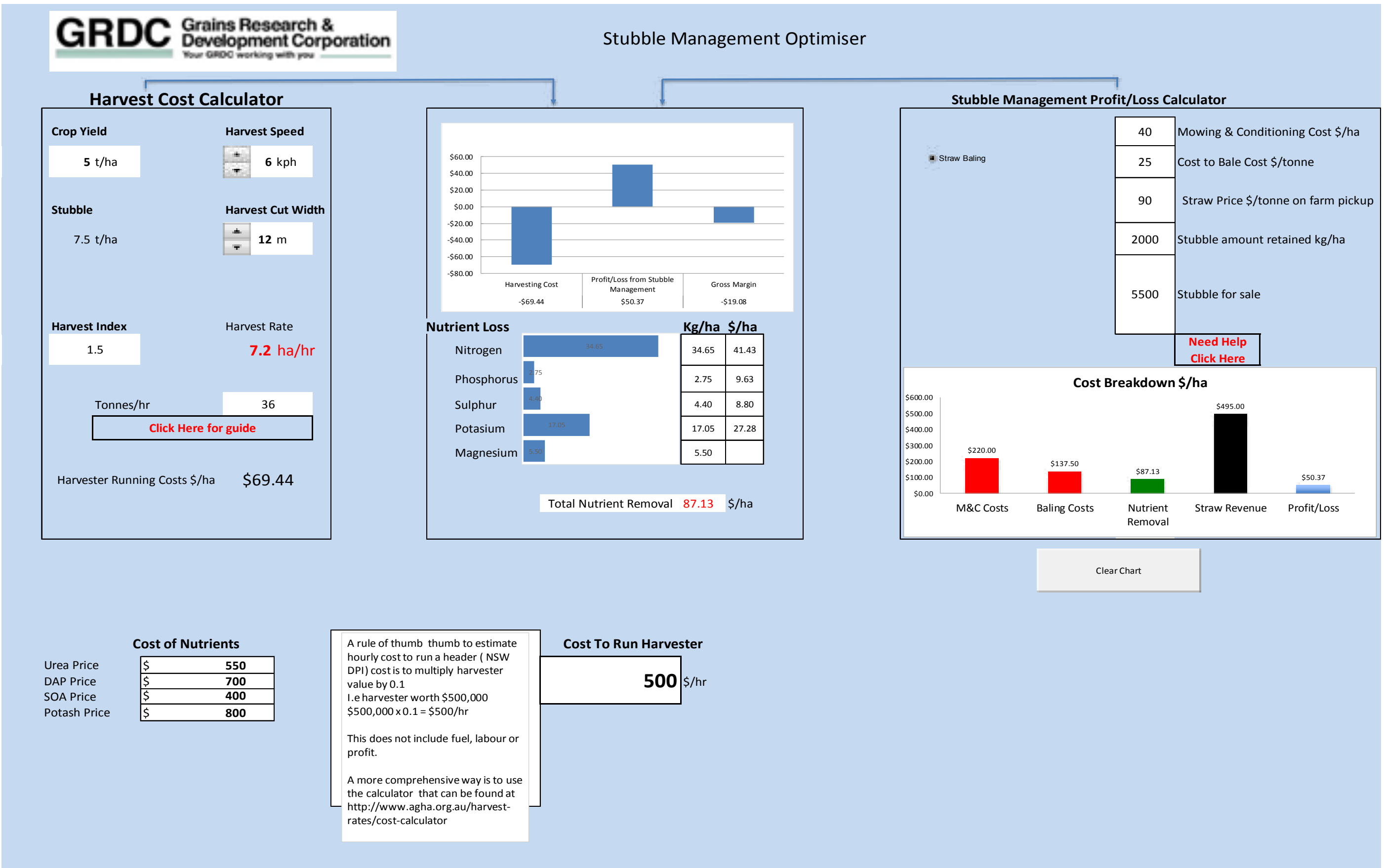


Figure 2: The estimated effect on profit from harvesting a 5t/ha wheat yield with 5.5t/ha of the remaining 7.5t/ha stubble load being baled and sold (valuing the loss of nutrients).

Pests

Invertebrate and vertebrate pests will potentially be a major problem in 2017, and may in some cases provide justification for strategic burning and tillage. Snails, slugs, mice and other insect numbers are currently being monitored and the cool wet spring has provided excellent conditions for increased numbers. The large stubble loads and plentiful grain on the ground from shedding and harvest losses is providing an excellent environment for breeding, so this needs to be factored into the equation if retaining stubble in 2017. Monitor mice numbers after harvest and bait as required.

The wet cool spring in the Victorian HRZ has resulted in an increase in the population of slugs and earwigs pre-harvest. The populations of slugs (Figure 3) and earwigs are expected to pose a greater threat to establishing crops in 2017 (Figure 3). Plan to roll then bait at sowing for slugs, monitoring problem areas and keep baiting if using cheap bran based baits. More information on slug and snail baits may be found at: http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/286735/Snail_and_slug_baiting_guidelines.pdf

Snails: A field trial on the Lower Eyre Peninsula, SA demonstrated the benefits of using mechanical snail control methods over retaining tall standing stubble – either light tillage or heavy (ribbed) rolling – in conjunction with a baiting strategy (Figure 4). Carried out under optimal conditions (late February, 35°C + and low humidity) the mechanical treatments proved effective to reduce snail numbers initially, whilst also appearing to improve the accessibility of baits applied in March.

This project demonstrated a number of key points for the coming growing season. Mechanical rolling, light tillage or cabling in the right conditions (hot and dry) is an effective action which can reduce the breeding population before a crop is present when there is less time pressure from other tasks (Figure 4). Baiting efficacy after this mechanical strategy is likely to be improved, as snails will find the baits easier in a rolled/tilled surface, rather than where tall stubbles remain, providing "bridges" for snails over and around baits.

Baiting should not be applied during the same hot, dry conditions as cultural controls. Baiting should commence during moist, cool conditions. The same field trial incorporated time lapse video and micro weather station monitoring to monitor snail activity and found high levels of night time activity where RH went above 85-90 %, and feeding during wet periods in early March. The key with

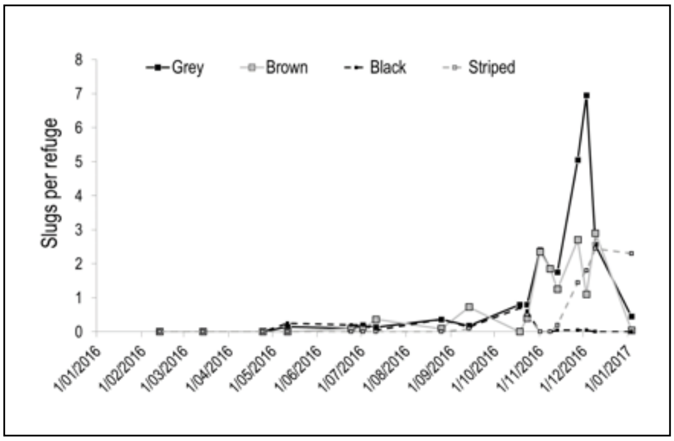


Figure 3: The change in population of four slug species between May 2016 and January 2017 at one site in south west Victorian (GRDC slug ecology project DAS00160)

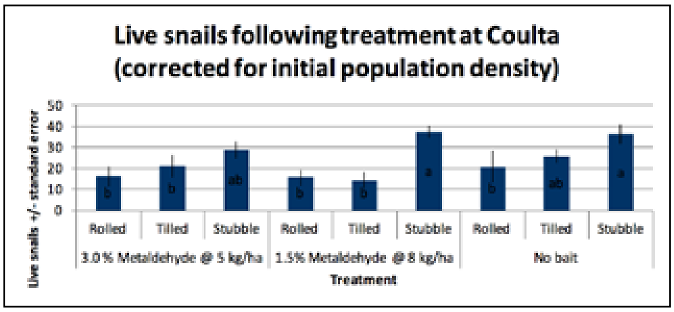


Figure 4: Mechanical treatment by baiting experiment in canola stubble at Coulta, Lower Eyre Peninsula, SA

all management strategies is to try to reduce the breeding population prior to reproduction. This research showed snails feeding and increasing sexual maturity during March with egg laying taking place April 21st – prior to the break of season and seeding. Baiting at seeding may be too late where snails have already laid eggs. For further information http://www.pir.sa.gov.au/research/services/reports_and_newsletters/pestfacts_newsletter/pestfacts_issue_15_2016/summer_snail_activity_and_control

It is also important to consider using insecticide seed treatments in canola and legumes with to supress or control early seedling pests including earwigs, slaters, aphids, millipedes and earth mites (always adhere to label guidelines).

Herbicide efficiency in retained/burnt stubble systems

Two separate experiements were setup in the EP and LowerEP to compare the effectiveness of pre-emergent herbicides in stubble retained systems

Water Rate (L/ha)	Reduction in ryegrass numbers compared to control (%)
50	52a
100	73b
150	75b

Table 13: The reduction in ryegrass populations with increasing water rate in the LEP in 2015

compared with burnt stubble in 2015. In both experiments, cereal crops were harvested low with straw spread evenly across the swath and either retained or burnt late pre-sowing. Standing stubble was also compared at one experiment. Residual stubble load was between 5 to 6.9t/ha. In both experiments there was no significant difference in the effectiveness of Sakura ®, Avadex Xtra ®, or Boxer Gold ® on the emergence of ryegrass post sowing where the spraying water application rates was 100L/ha or higher. An important finding was that a spray water volumn of 100L/ha was required to improve the effectivness of the herbicides, but this must be put in context with spray quality and nozzle type (Table 13).

The wet season in 2016 throughout much of south-eastern Australia resulted in farmers not being able to manage weeds to their normal high standard. The combination of high annual weed populations in large cereal stubble residues may mean that farmers may need to consider burning problem paddocks in 2017 to reduce weed populations and improve herbicide effectiveness where stubble loads and ground cover percentage is high. The higher the percentage of ground covered by residue, the higher the percentage of herbicide captured by the stubble (Shaner 2013).

Burning

Burning is an effective, inexpensive method of removing stubble, assisting in reducing disease carryover, reducing certain seedling pests and weed populations and if using a flexible managament approach should be considered in strategic situations. With careful planning and diverse management, burning can be kept for those occassions 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 in 2017. In a long term experiment at Harden in NSW, burning late just prior to sowing is still producing some of the highest grain yields after 28 years of continuous cropping, which would indicate that a single strategic burn to re-set the sequence may do little damage. In general, late burning resulted in the largest yield benefits in wetter years, and had little impact in other years. Across a number of trials in the Riverine Plains, Victorian HRZ and those conducted by the MacKillop Farm Management group, the comparision between burning or stubble retain treatments has resulted in variable results. More often than not, there was no significant difference in grain yield between the burn and stubble retain treatment in 2014-15. However, in some years the burn treatment has resulted in good early crop vigor, more early biomass and the crop has become moisture stressed with reduced grain yield where there has been an early end to the season with a hot and dry spring.

Some 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 six people, two 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

This paper has outlined many of the overall findings from the "Stubble Initiative" project to date and incorporated these into a series of regional guidelines to assist farmers deal with the high stubble loads from the 2016/17 harvest.

It is extremely important for farmers to NOT compromise managing weeds, disease or being able to sow their crop in 2017 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 in 2017 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 mulching, baling, grazing and if sowing with a tined seeder, sowing at 15-19 degrees from the previous direction, that it is easier to manage stubble without the need to burn. 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. In a year where stubble residue loads are greater than ever before experienced, it is also important that as new techniques are tried, to keep monitoring the results early to see how effective the actions have been.

References

1. GRDC Stubble Management Fact Sheet, March 2011: Strategies to manage winter crop stubbles without reaching for the matches

2. GRDC Managing Stubble Booklet, May 2012: https://grdc.com.au/~/media/2B5EFD71C2D04212827E2E045E022DE6.pd.

3. Mallee Sustainable Farming Inc: Stubble Management – A guide for Mallee farmers (2013)

4. Farmlink Guideline No 3. "What sort of stubble? It all begins at harvest" http://www.farmlink.com.au/project/maintaining-profitable-farming-systems-with-retained-stubble. GRDC Project 000174 - Maintaining profitable farming systems with retained stubble in NSW SW slopes and Riverina.

5. Riverine plains Stubble management guideline No 1. "Managing stubble at harvest improves sowing success" –. GRDC project RPI00009 - Maintaining profitable farming systems with retained stubble in Riverina Plains region.

6. Stubble management – an integrated approach (2010): EH Graham Centre for Agricultural innovation

7. Farmlink Guideline No 4. "Contractors and stubble. Engaging contractors with equipment suitable for stubble retention" http://www.farmlink.com.au/project/maintaining-profitable-farming-systems-with-retained-stubble. GRDC Project 000174 - Maintaining profitable farming systems with retained stubble in NSW SW slopes and Riverina.

8. Efficacy of harvest weed seed control techniques in Southern Victorian HRZ – Southern Farming Systems.

Grassroots Agronomy and GRDC extension notes. "Narrow windrow burning in southern NSW … the good the bad and the ugly"

Hunt J, Swan T, Pratt T, Rheinheimer B, Goward L, Jones K, Kirkegaard J (2015) The effect of grazing and burning stubbles on grain yield and quality in no-till and zero-till controlled traffic farming systems in SNSW. GRDC Updates Adelaide and Wagga.

Kirkby C A, Richardson A E, Wade L J, Conyers M, Kirkegaard J A (2016). Inorganic nutrient increase humification efficiency and C-sequestration in and annually cropped soil. PLOS ONE DOI: 10.1371/journal.pone.0153698 May4, 2016.

Shaner, D (2013). Interactions of herbicides with crop residue. GRDC Advisor Update, Goondiwindi.

Acknowlegements

I would like to acknowledge all the collaborating scientists, technicians, staff, farmers and consultants from all of the organisations and groups who have contributed significantly in terms of their time and research capability to each farming systems group to ensure the project in their region is producing the highest quality of work. To keep the list of co-authors to one cricket team (rather than many), only one person from each group was included as authors.

Contact Details

Tony Swan

Business Address: CSIRO Agriculture and Food, GPO Box 1700, Canberra ACT 2601

Phone: 0428145085

Email: tony.swan@csiro.au

Report Two

Opportunities and challenges for continuous cropping systems

Authors - John Kirkegaard, James Hunt (Latrobe University (current address)) , Mark Peoples, Rick Llewellyn, John Angus, Tony Swan, Clive Kirkby (CSIRO Agriculture and Food), Tony Pratt, Kellie Jones (FarmLink Research),

Project Codes - GRDC CSP00146; CSP00174; CSP00186; DAN00152; MSF00003; CSA00025

Take Home Messages

- Continuous cropping can be sustained for decades, but requires careful management.
- A larger proportion of N supply as fertiliser will be required over time even when grain legumes are included in crop sequences.
- Herbicide resistance develops faster under continuous cropping. Integrated management to keep key weed populations at very low levels is essential for long-term viability.
- Suitably diverse crop and end-use portfolios and flexible management help build resilience to climate and crop price shocks.

Background

Australian broad-acre farms have intensified crop area. In the two decades from the mid-1980s crop area doubled and sheep numbers halved (Kirkegaard et al., 2011). Many farms, or parts of farms are continuously cropped. The reasons for intensification (e.g. social, financial, logistic, biophysical) vary with individual businesses. In this paper, our aim is not to focus on the "pros and cons" of mixed vs crop-only systems. Rather we seek to highlight the main challenges faced in continuous cropping systems, and provide some recent research outcomes on best-bet management to sustain profitable continuous cropping with current and foreseeable technologies. The major challenges we foresee are (1) maintaining soil fertility (2) managing weeds and diseases and (3) managing economic risk and resilience.

Managing soil fertility

Q1. Are you mining, maintaining or manufacturing soil fertility, and at what cost to your business?

Organic matter, soil structure and fertility

Pasture phases are the most effective way to build stable soil organic matter (humus), N fertility and structure - so maintaining these assets under continuous cropping systems is a challenge (Angus and Peoples 2012). Conservation cropping systems (no-till, stubble retention) can certainly build coarse soil organic matter (i.e. plant residues), maintain cover, protect soil structure and reduce erosion but at best only maintain, rather than build stable soil organic matter. Maintaining adequate levels of humus is essential to ensure the structural stability of soils, and for the provision of nutrients (soil fertility), which will be soil type (texture) specific. Recent studies indicate that the failure to maintain or build humus may be due to a lack of sufficient nutrients (N, P, S) rather than a lack of carbon under continuous cropping systems (Kirkby et al., 2016). For example, to sequester one tonne of soil carbon as humus requires 83 kg/ha N, 20 kg P and 14 kg S. Using this knowledge, the long-term decline in soil carbon was reversed in a continuously cropped (28-year) field by adding supplementary nutrients to incorporated crop residues – because nutrient input, and not carbon input was limiting. Modern farming systems focussed on "nutrient use efficiency" (i.e. kg grain per kg fertiliser applied) may not account for the nutrients required to maintain or build the soil microbes that generate stable organic matter. As the levels of organic fertility declines, the supply of plant-available nutrients such as N from the soil will also decrease over time. Consequently there will be a requirement for progressively more fertiliser to support increases in crop yields.

Nitrogen fertility

Humus is the primary source of mineralised organic N for crops, and organic N in southern Australian soil declines at around 2-3% per year in cropped soils with a "half-life" of 34 to 23 years. In the absence of legume-based pastures, mineral N from native organic matter or pasture residue declines, and must be replaced with other legume or fertiliser N sources. Farm N budgets based on different farming system scenarios can predict the likely increase in the fertiliser needs required (Table 1).

Year	N from mineralisation (kg/ha)	Fertiliser N requirement (kg/ha)
2013	108	80
2033	54	134
2053	17	161

Table 1. Source of N for a typical 4 t/ha wheat crop in southern NSW assuming continuous cropping (Angus and Peoples, 2012).

Soil	Nil N	9 kg/ha	40 kg/ha (9+31)	1-year Pasture then 9 kg/ha N
Swale	-210a	-156c	-61a	-102b
Mid-slope	-102b	-81b	10a	-92b
Dune	-64c	-15b	60a	-21b

Table 2. Calculated N balance for different soil types under different N management during a 5-year cereal phase at Mallee Sustainable Farming Karoonda field site (from McBeath et. al., 2015).

For example in southern NSW, with 4.0 t/ha average wheat yields, a 60:40 crop:pasture ratio can maintain N balance, while continuous cropping will increasingly rely on N inputs, potentially eroding the initial economic advantage (Angus and Peoples, 2012).

The trend towards lower mineral N levels in pre-sowing tests over recent years provides evidence of diminishing organic N levels, as pasture area declines and long crop sequences with low legume frequency are not balanced with equivalent increased fertiliser N. In southern NSW, the number of pre-sowing deep soil mineral-N tests that measured <30kg/ha Min-N doubled between the periods 2008-2010 and 2013-2015, while those >120 kg/ha have halved (Jim Laycock pers. Comm., 2017). This "mining" may make sound economic sense initially, but if yield and quality levels are to be maintained or increased in the medium to long-term, improved nutrient balance must be achieved. The data for a variable soil site at Karoonda in SA Mallee (Table 2) shows how significantly more N than the current district practice of 9 to 20 kg/ha N annually is required to maintain N balance in the cereal phase.

The cost and risk of supplying an increasing proportion of N as fertiliser to support crop yield on N-depleted soils may become prohibitive. Current N prices are relatively low compared with long-term average or peak N prices, and N prices are likely to rise in future as the efficiency of production facilities reaches a peak. There are numerous strategies available to maintain N fertility and profitability under continuous cropping.

Improved efficiencies of fertiliser N use

Good agronomy and following the 4R mantra of IPNI (Right product, Right rate, Right place, Right time) are important for the provision of sufficient quantities of all plant nutrients, including N, in all farming systems - but strategies to improve fertilizer-use efficiency become critical in continuous cropping systems as the original soil organic matter levels and pools of pasture-derived N diminish. The adoption of precision agriculture techniques and variable rate technologies in broad-acre agriculture is increasing steadily in Australia, with typical economic gains estimated of around $40/ha for N-related applications. On variable soils such as in the Mallee, significant improvements in overall productivity, water-use efficiency and profit along with reduced risk can be achieved over traditional flat-rate applications by increasing N rates on sand hills and reducing N rates on flats. An example is found at Karoonda SA, where profitable responsiveness to N fertiliser

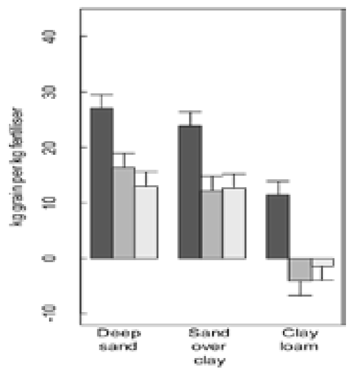


Figure 1. Grain yield responsiveness (kg/ha) per kg/ha N input on the deep sand, sand over clay and clay loam soil types across the 2010 (dark bars), 2011 (medium bars), 2012 (light bars). Data from McBeath et al., (2015) https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/Managing-the-profit-and-risk-of-fertiliser-nitrogen-investment-in-sandy-soils

Treatments	Z30			Anthesis			Grain Yield (t/ha)
	t/ha	N%	N-up (kg/ha)	t/ha	N%	N-up (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*

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

is reliably achieved on the sandier soils but was profitable only in the extremely wet year of 2010 on the heavier flat soils (Figure 1).

As soil N fertility slowly declines under continuous cropping, more fertiliser may be required at sowing to ensure adequate N to achieve crop yield potential. In stubble-retained systems, surface applied N is more prone to immobilisation and the amount that can be drilled with the seed is limited. Banding N fertiliser below or beside seed rows at sowing can improve the efficiency of N uptake in crops by making more available to the plant, reducing the competition for N with soil microbes (immobilisation), and reduce leaching or denitrification losses prior to plant uptake by slowing the rate of nitrification. In an experiment at Temora in 2016, the amount of applied N captured by wheat crops was improved by deep banding N below seed in the presence or absence of stubble (Table 3).

Greater N-use efficiency of in-crop N applications may also be achieved by top-dressing just prior to rainfall during the peak period of crop demand after stem elongation or by mid-row banding equipment which has been adopted by some farmers and is being evaluated by researchers from Agriculture Victoria and NSW DPI. Banding urea between every second row (mid-row banding) may have advantages over banding under every row because the concentration of ammonium is doubled and the fertiliser remains longer in this form before its conversion to nitrate. Mid-row banded urea is effectively a slow-release fertiliser that prevents excessive vegetative growth. The ammonium it forms in soil is less prone to loss than nitrate (Angus et. al., 2014).

Slow-release fertiliser products (urease inhibitors, nitrification inhibitors and polymer coated urea) to better match N supply to crop demand are also available but currently these products may be too expensive for many broad-acre grain applications (Angus et. al., 2014). As new polymers and products become available they may have specific applications, especially in the higher rainfall zones on soils prone to leaching.

Increasing the efficiency of fertiliser use by improving the synchrony of N supply with crop N demand to reduce unnecessary losses of mineral N (leaching, denitrification, run-off) and converting those to plant uptake makes economic and environmental sense. But paradoxically, pushing for higher N efficiency by avoiding N immobilisation can lead to a heavier reliance on mineralisation to supply crops, and represents an increased net loss of organic N. Ultimately the requirement for N fertiliser will increase at a faster rate assuming crop yields (i.e. N removal) continue to improve. The total N decline can only be slowed if additional "new" sources of N enter the system to balance product removal and losses.

Integrating legumes in the system

In the absence of legume-based pasture phases, other ways to incorporate legumes into the crop system will help to maintain a better organic N balance. Legumes frequently fix around 20 kg/ha N per tonne of shoot biomass grown, but there is enormous variability in fixed and net N inputs of different end-uses, though harvested grain legumes rarely match those achieved by well-managed, legume-based grazed pastures (Table 4).

System	N fixed (kg/ha)	Net N input (kg/ha)
Grain legumes (harvested)	134 (65 to 310)	45 (-40 to 96)
Grain legumes (brown manured)	144 (86 to 246)	144 (86 to 246)
Pastures	174 (102 to 256)	132 (70 to 199)

Table 4: Average and range of N fixed and Net N input for crop legumes (harvested for grain or brown manured) and pasture systems (Data courtesy Mark Peoples, collated from field experiments during 2011-2015 GRDC Crop Sequence Initiative CSP00146)

Incorporating legumes into a farming system also reduces the financial risk associated with large N fertiliser inputs, as no N is applied to the legume, and less is usually required for the following cereal crops. In the experiments reported in Table 3, the amount of extra mineral N available to crops at sowing following legumes compared to cereals is variable (5 to 92 kg/ha; median 33 kg/ha) but some simple rules of thumb can assist in predicting the likely amounts as follows (Peoples 2016);

- 0.13 kg extra Min-N/ha per mm fallow rainfall
- 9 kg extra Min-N/ha per tonne of shoot residue N
- 15 kg extra Min-N/ha per tonne legume grain harvest

The amount of mineral N supplied by legumes tends to be higher in equi-seasonal areas of NSW than in winter dominant and summer dominant rainfall areas, and tended to be higher for faba bean, and lower for lentil and vetch. We estimate that the first wheat crop can recover the equivalent of ~30% of the N in legume stubble and root residues, with <10% being taken up by the second crop grown after a legume. This compares to a 50-60% apparent uptake of top-dressed fertiliser N applied to wheat at Z30.

Higher value grain legumes such as chickpea and lentil can provide a highly profitable option as a regular part of a continuous crop sequence in suitable environments, although net removal of N by high-yielding grain legumes is common. The area sown to these grain legumes is expanding with improved varieties and agronomic packages, however variable prices and marketing issues can increase the economic risks from year to year. Meanwhile the halving in the area of lupins, in the last decade or so means that legume crop area in 2015 was no greater than in the 1990s (htttp://www.pulseaus.com.au/storage/app/media/industry/AU-lentil-area.pdf).

Legumes with lower grain value (e.g. lupin, pea, vetch) can provide a range of other flexible and diverse end-uses in continuous crop sequences such as grazing, hay or brown-manure where the N benefits combine with weed control and water conservation to reduce production risk and input costs, and provide a significant benefit to the overall crop sequence (Table 5). In this example from a fully-phased experiment at Temora (2014-2016), compares a typical C-W-W sequence, with a sequence that includes vetch hay, the major difference in the total costs incurred was the savings in N application to the canola following the vetch hay.

The income from hay combined with highly effective non-chemical weed control (see later) and water conservation, especially preceding higher value and risky crops such as canola, can make this a good option. The N inputs and soil cover are reduced in the hay option compared with brown manuring, and low cover can also be an issue with low biomass grain legumes on erosion-prone areas. Brown manuring of grain legumes (or long fallow) is less economic in more reliable rainfall areas because of the income forgone in the year it is used, but along with hay may be viable in lower rainfall areas (Kirkegaard et al., 2014), or in areas as part of a "double-break" where it precedes a higher value but riskier crop such as canola (see later in Weed section).

Legume intercrops (where more than one crop species are grown together) are common in subsistence and organic agriculture or where labour costs are low (e.g. China), and frequently demonstrate "over-yielding" where the mixture is more productive then the monocrops due to biological synergies (typically by a factor of 1.2). Mixtures of legume and non-legume crops to date have been used less in broad-acre, mechanised agriculture. A recent review by Fletcher et al., (2016) suggests there may be potential for some promising mixtures (e.g. Peaola) with Australian experiments finding productivity increases by a factor of 1.5 compared to monocultures. Commercial peaola crops have been grown in this way for more than 10 years on some Canadian farms where growers have innovated to overcome the main practical issues. An excellent interview

System	Average N costs ($/ha/yr)	Average total costs ($/ha/yr)	EBIT ($/ha/yr)
Aggressive (C-W-W)	**$109**	$515	$508
Sustainable (Vetch-C-W-B)	$70	$464	$520

Table 5. Comparison of N input costs, total inputs costs and profit of two systems in a phased experiment at Temora (2014-2016) demonstrating that a more diverse ('Sustainable') cropping systems including a vetch hay crop can be as profitable with less N input cost. Data courtesy CSIRO and FarmLink Research Stubble Initiative "Sequences for Seeders" Project CSP00174.

with one of the key growers (Colin Rosengren) can be found here https://www.realagriculture.com/2014/07/agronomy-geeks-west-ep-15-ins-outs-intercropping/

Phosphorus

Phosphorus is a significant input cost and crop recoveries are commonly poor so improved efficiencies should always be sought (Peoples et. al., 2014). Though "peak phosphorus" concerns have generally abated, the depletion of subsoil P (mostly in northern regions) where it may be hard to replace, and the stratification of P in long-term no-till soils, where the P becomes concentrated in the surface layers and unavailable to plants when the soil dries remain important issues. Strategic tillage provides a suitable option to deal with stratification, and deeper banding of P can provide another solution. Novel products that are more mobile in soil, techniques for deep placement and novel root P foraging traits are all areas of current research interest.

*Though N and P have been singled out for discussion, continuously cropped soils can clearly be depleted in any of the essential nutrients - but few would threaten any business where regular monitoring of soil and plant fertility is conducted and relevant action taken.

Acidity

Crop production primarily acidifies soil by removal of alkalinity in grain and hay. Leaching of nitrate along with associated cations down the soil profile will also acidify soils, but this has become less common as soil N levels decline and agronomy of crops and pastures improves. It is still an issue on lighter soil types in higher rainfall regions more prone to leaching. Leaching of nitrate may in fact be lower under continuous cropping than in annual legume pastures.

Acid soils remain an issue in many Australian grain-growing areas, but with an estimated 300+ years of available lime reserves and a long history of well-researched and widely available liming strategies, it should theoretically not be an insurmountable problem with best management practices. The main challenge is to deal with acid, or acidifying subsoils, which become difficult to treat due to the immobility of lime in soil. Once again strategic tillage and regular lime application at adequate levels will ensure that the lime moves to depth rather than remain in surface layers. In naturally acid deep sandy soils such as in WA, deep placement of lime using specially designed machinery, or even carefully timed mouldboard ploughing (every 10 years) are approaches that have been used successfully.

The search for genetic tolerance to soil acidity and the aluminium toxicity it induces is ongoing as the mechanisms and the genes responsible for tolerance in wheat have been identified and moved into barley. Research into tolerance in other sensitive crops is underway (Peoples et al., 2014). Genetic tolerance will continue to be of greater importance in low rainfall regions where yield responses to liming are uneconomic.

Weed, disease and pest management

Continuous cropping can lead to greater weed and pest pressures such as herbicide resistance, and increasing weeds that are favoured by modern, no-till cropping systems (e.g. brome grass). Well-managed pasture phases provide excellent opportunities to control most biotic threats to crop production, but a range of integrated weed, pest and disease management approaches are available for application in continuous cropping systems. A diverse cropping sequence (i.e. a sequence of different crop species and end-uses) provides the most cost-effective defence against most of these threats.

Herbicide resistant weeds

A key challenge and a major cost to continuous cropping systems that are primarily reliant on herbicides for weed control is the development of herbicide resistance. Maintaining a diversity of crops, control practices and herbicides is the key to staying ahead of this problem. The number of weed individuals to which a given mode of action is exposed, and how often, determines the speed at which resistance develops. Therefore, development of resistance is slowed by maintaining weed populations at very low levels, and preventing seed set in individuals that have survived chemical control. Keeping weed populations at very low levels by a variety of complimentary practices forms the basis of integrated weed management, which is essential to ensure the sustainability of continuous cropping systems. The large areas sown under continuous cropping has contributed to increasing use of dry seeding which, in the absence of knockdown herbicides, can place increasing reliance on selective herbicides if weed seed banks are not kept low.

Rotate & Mix Herbicides

Maintaining adequate diversity in crops and their end-uses provides the best opportunity to rotate and mix herbicides with different modes of action to slow the development of herbicide resistance.

Under continuous cropping, greater application of herbicides in summer also increases the risk of herbicide residues in soil causing crop damage. The increasing use of more sensitive crops such as pulses in alkaline low rainfall areas on sands with low biological activity adds to these concerns. Herbicide residues from Group B chemistry can commonly limit crop choice but a range of other residues are also being investigated for their potential impact and careful management requirements (https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Herbicide-residues-in-soils-are-they-an-issue). Different crop types allow the use of different chemical and non-chemical control measures e.g. crop-topping in legume crops and narrow windrow burning (usually more effective in canola and grain legumes than in cereals). Maintaining low weed levels also provides an opportunity to use cheaper herbicide options where possible to reduce input costs.

Recent experiments in fields with high levels of multiple post-emergent herbicide resistant annual ryegrass (HRARG) have shown that it is difficult to reduce weed seed banks without adequate crop diversity, even with the use of expensive herbicides (Table 6). The experiments show that although high yielding and profitable intensive wheat sequences can be managed in the medium term, considerable weed populations are maintained, which are able to develop resistance to further modes of action as they are exposed to them. Round-up ready (RR) canola followed by wheat with high gross margins provided the highest gross margin, but was less effective at reducing the seed bank than most of the double-break options. Sequences that involved either canola or a spray-topped lupin grain crop in year 1 followed by cereal hay or RR canola in year 2 provided high gross margin with the most effective weed control.

In addition to diverse crop species, including fallow or different end-uses such as hay or brown-manure also provided opportunities to drastically reduce seed set using non-selective herbicides with different modes of action (e.g. glyphosate and paraquat) in tandem ('double knocking'). Brown-manure crops have the disadvantage of providing no income in the year they are grown, so that the residual water, N and weed control benefits must compensate for lost income, and the extent to which this is possible varies for specific circumstances, but have been demonstrated to be economic at farm level https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02. In severely infested fields it may take a "double-break" (two years with very high levels of weed control) to reduce weed seed banks to manageable levels.

Competitive Crops

Competition from crop plants can be very effective at reducing weed seed production, and is a vital component of integrated weed management. The aim of crop competition is to reduce the amount of light that gets to weeds in the crop canopy,

Break Type	Crop x Input Year 1 (2013)	Crop x Input Year 2 (2014)	Crop x Input Year 3 (2015)	ARG Seedbank Year 4 (2015) (seeds/m^2)	Average Annual 3yr Gross Margin ($/ha/yr)
Double	Fallow	RR Canola	Wheat (H)	56	$603
Double	Lupin grain	RR Canola	Wheat (H)	63	$790
Double	Lupin BM	RR Canola	Wheat (H)	110	$552
Double	RR Canola	Wheat (Hay)	Wheat (H)	122	$834
Single	Lupin grain	Wheat (H)	Wheat (H)	142	$757
Single	Pea BM	Wheat (H)	Wheat (H)	162	$486
Single	RR Canola	Wheat (H)	Wheat (H)	219	$883
Nil	Wheat (H)	Wheat (H)	Wheat (H)	366	$585
Single	RR Canola	Wheat (L)	Wheat (H)	2387	$845
Single	Pea BM	Wheat (L)	Wheat (H)	3118	$397
Nil	Wheat (L)	Wheat (L)	Wheat (H)	3140	$388

Table 6. Average annual 3-year gross margin and annual ryegrass (ARG) seedbank following 3 years of various crop sequence and input strategies at Eurongilly, NSW (2013 to 2015). Sequences included double- and single breaks of pulses (grain or brown manure - BM), canola, fallow and cereal hay and wheat with high or low (H, L) N and herbicide input costs. Initial ARG seedbank in 2012 was 1815 seeds/m2. (Data source, Swan et al., 2015).

particularly those that emerge after knockdown herbicides have been applied and residual activity from pre-emergent herbicides has ceased. There are four main components to crop competition;

- Row spacing. Crops on narrow rows (<250 mm) cover the ground faster, let less light through the canopy to weeds and reduce seed set (Borger et al. 2016a) and crop yields can be higher on narrow rows, particularly in high yielding environments (Scott et al. 2013). Operational benefits of wider rows (>250 mm) include better stubble handling (including the ability to inter-row sow), lower cost of machinery, lower draught and horsepower requirement, and greater crop safety for pre-emergent herbicides. Row spacing is thus a trade-off between these factors and higher yields and crop competition. The need for vigorous and competitive crop canopies has seen a recent trend back to narrower rows on some continuous cropping farms, particularly those in higher rainfall areas.
- Row orientation. Crop rows that are sown east-west shade the inter-row more effectively than when sown north south. This helps the crop be more competitive with weeds growing in the inter-row, and has been shown to reduce seed set in ryegrass by about 50% (http://ahri.uwa.edu.au/sow-west-young-man/). Paddocks should be set up with east-west seeding runs where it is efficient to do so. Row orientation becomes increasingly critical on wider row spacing.
- Plant density. Crops are able to compete more effectively with weeds when they are planted at higher density, as there are less gaps in the crop and the canopy closes over faster.
- Vigorous crops. Maintaining healthy and vigorous crops assists with crop competition (e.g. early sowing into warmer soils, liming to adequate pH, good nutrition and disease management). Crop species vary in their ability to compete (oats and barley > wheat; canola > pulses) and crop varieties also vary (hybrid canola > OP canola > TT canola). New wheat germplasm has been selected for early vigour, and has levels similar to barley, and these have been shown to have much better weed competitive ability.

Harvest Weed-Seed Control

Numerous methods have been developed and tested in recent years to collect and destroy weeds that have escaped in-crop control (Borger et. al., 2016b). These options include narrow windrow burning, chaff carts, chaff lining, mechanical seed destruction and direct bailing. These tend to be more effective in controlling some weeds (e.g. ryegrass) more than other early shedding weeds (e.g. barley grass). Some form of harvest weed seed control is essential in continuous cropping systems situations, particularly those that do not have hay crops or a high frequency of crops that can be crop-topped in their crop sequence. Together with sustaining new herbicide technology, further increases in the extent of use of weed seed control options is likely to be a key factor in sustaining continuous cropping.

New Developments

Increasingly sophisticated seeding systems including precision row and seed placement are likely to bring further benefits for weed control and crop performance in intensively cropped environments (better establishment in difficult conditions, greater early vigour and targeted disturbance and nutrition to benefit crops over weeds. New forms of novel, non-chemical control are also under development (mechanical, microwave, steam, compressed air) and may provide options to reduce the pressure on herbicide usage if affordable options for broad-acre applications emerge.

Disease and pest control

Maintaining a diversity of crops and practices is also the key to managing pests and diseases in continuous cropping systems. Particular attention must be paid to diseases and pests that:

- Develop resistance to available fungicides or pesticides (e.g. Green Peach Aphid)
- Overcome genetic resistance that was once reliable (e.g. Blackleg in canola)
- Infect a wide host range, so less controlled by diversity (e.g. Rhizoctonia, Pratylenchus, Sclerotinia)
- Are exacerbated by current agronomic practice (e.g. Crown rot, slugs and snails under no-till)
- Are novel or exotic pests not previously encountered (e.g. Russian Wheat Aphid, WSMV)
- Become expanded in severity or range by climate change (e.g. Clubroot in canola)

An assessment of the relative risk posed by these threats within continuous cropping systems is needed to develop the most cost-effective and sustainable way to avoid economic loss. Sensible, flexible and pragmatic approaches to soil and crop management will be necessary in circumstances where diverse crop sequences alone are inadequate to manage pest damage.

System	Mean Yields (t/ha)	3 Yr System Financials				2016* ARG (seeds/m^2)
		Input cost ($/ha/yr)	Total cost ($/ha/yr)	EBIT ($/ha/yr)	Profit/Cost ratio	
Aggressive (C-W-W)	2.3, 4.1, 3.9	354	515	508	0.98	442
Conservative (C-W-W)	2.5, 3.6, 3.3	289	439	506	1.14	2772
Sustainable (Vetch-C-W-B)	3.9, 2.4, 4.1, 5.2	254	464	520	1.14	482

Table 7. Comparison of 3 cropping systems in a phased experiment at Temora (2014-2016) demonstrating that a more diverse ('sustainable') cropping systems can be as profitable with less cost and risk while achieving similar control of annual ryegrass as more conventional high input approaches (Note: initial ARG seedbank in March 2014, 1864 pl/m2). In the 'aggressive' system, ARG control is based on hybrid RoundUp Ready® canola followed by Sakura® and Boxer Gold® in subsequent wheat crops. In the 'conservative' system, ARG control is based on open pollinated TT canola, and trifluralin in subsequent wheat crops. In the 'sustainable' system, ARG control is based on hay-cutting and double-knocking in vetch, open pollinated TT canola followed by Sakura in wheat and Boxer Gold plus crop competition in barley.

Economic resilience

Q. Productivity, profitability and peace of mind

The recent, medium-term (3-5 year) farming systems experiments such as those reported here (in Tables 4 and 5) can carefully account for the variable input costs to provide useful information on the likely economic impact of different management strategies. They also support the value of maintaining diversity in species and end-use to not only maintain profitability and the biophysical assets of the farm (N fertility and weed seed burden) but to do so while reducing financial risk, in this case the profit to cost ratio (Table 7).

However, medium-term, small-plot experiments while valuable, cannot adequately account for the broader economic and logistical issues that are encountered at farm-scale. Often these issues can dominate financial planning and relate to labour, equity, debt levels and farm size. These considerations can dictate what is feasible in implementing the advice arising at experimental scales.

Several recent studies of real farm businesses have emphasised the dramatic changes in the economics and risk of grain farming in recent years as cropping intensity has increased. As farm size, cropped area and land values increased, so too have debt levels, machinery costs and total interest so that despite improvements in productivity, farm income to cost ratios have decreased significantly. For the Victorian Mallee farmers in the example below (Figure 2), a net farm income of around $100K involved costs of around $400K in early 2000s, but that has doubled to $800K today.

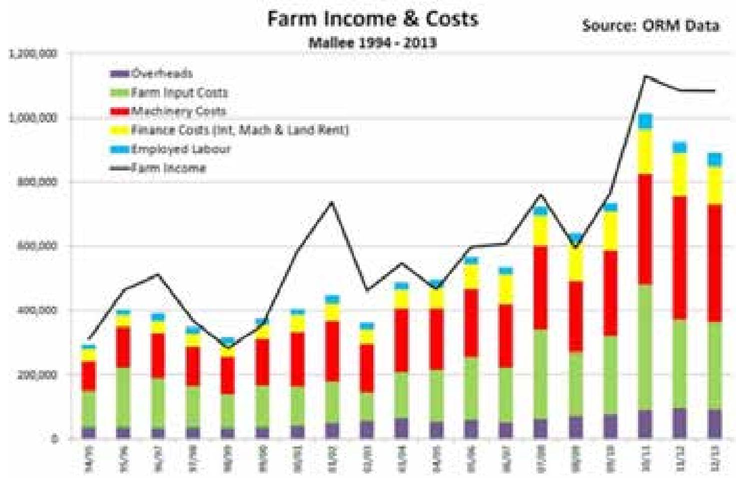
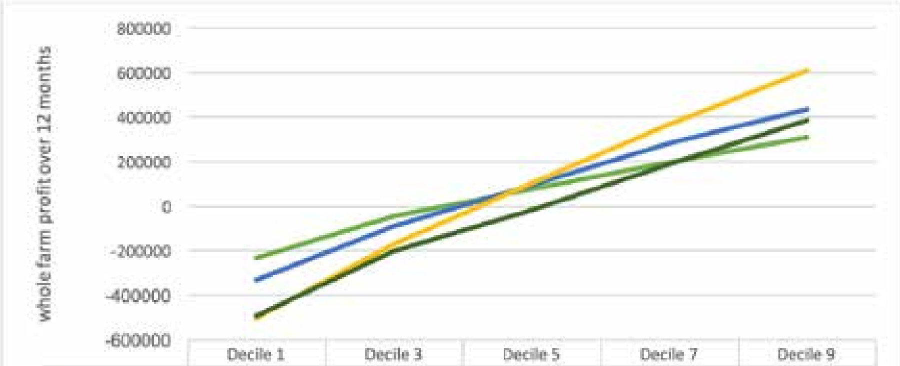


Figure 2. Average annual farm income and costs for 12 Mallee farms 1994 to 2013. As reported in van Rees et al., (2015) and by Ed Hunt (2015). Data source, ORM Pty Ltd.



	Decile 1	Decile 3	Decile 5	Decile 7	Decile 9
50%	-232000	-42000	76000	196000	308000
70%	-331000	-89000	94000	281000	435000
100%	-501000	-171000	102000	366000	608000
100% cereal	-493000	-199000	-17000	190000	384000

Figure 3. Average whole farm profit for typical farms at Karoonda (2,400 ha) assuming 80% equity. The numbers represent whole-farm profit predicted under different seasonal conditions (Decile 1=driest 10% of years, Decile 9 = wettest 10% of years, Decile 5 = Average year) and are graphed for ease of comparison (Data courtesy: Ed Hunt, Michael Moodie and Mallee Sustainable Farming).

Subsequent economic modelling to compare continuous cropping and mixed farms in this and other regions have demonstrated that it is very important to consider economic outcomes on actual yields over a number of years, rather than using long-term averages. Such analyses revealed that while continuously cropped farms (100%) and mixed farms may have similar profitability in average seasons, the continuously cropped farm was able to better capitalise in good seasons but was at greater risk in poor seasons (Fig 3). The study also demonstrated that the less diverse, continuously cropped farm (100% cereal) had the lowest economic performance in all but the very best of seasons, supporting much of the experimental data related to the benefits of diversity.

Though the absolute numbers shown above will change across different locations, the general trends will be consistent and the best strategies will be dependent on physical (soil type, rainfall), economic (equity, debt), and social (labour, skill levels, family circumstances) situations on individual farms. In riskier, low rainfall environments profits in high rainfall seasons are constrained by a (sensible) unwillingness to fertilise to levels required, increasing the need for legume nitrogen sources. As has been demonstrated above, reliance on increasingly expensive herbicide bills to maintain productivity also becomes a problem. In the absence of pasture phases with livestock, other ways to reduce risk must be sought including finding greater off-farm income, maintaining higher levels of equity, more consideration of machinery investments, use of contract services, or value adding.

Studies in other areas of intense cropping using real farm data support these findings. Lawes and Kingwell (2012) conducted a study of the economic resilience of 123 farms in the intensively cropped northern wheat belt of WA during the years 2004 to 2009 which included a period of significant drought. Indicators included business equity, operating profits, return on capital and debt to income ratio. Business equity declined on 60% of farms during the period, but the other indicators varied over time with no trends. The most resilient farms had the following features; (i) cropped more than 50% of the farm, (ii) were prudent with expenditure, (iii) maintained enterprise diversity, and (iv) grew wheat yields that were close to potential. Interestingly there was no impact of farm size which averaged 3200 ha.

In relation to mixed vs continuous cropping, most consultants agree that "it is not what you do, but how well you do it" that defines the success of the farm business, whether a mixed farm or continuously cropped (Kirkegaard et al., 2011). However with the biological and economic buffer of the pasture phase absent, a consistent message in studies of successful intensively cropped farms (in addition to sound financial management) is the importance of more frequent monitoring and measurement to assist in management decisions, and timeliness in implementing them. The fact that the top 25% of grain specialists make double the return on capital (8.8%) as the other 75% (4.5%) (ABARES 2015) emphasises that point.

As researchers and agronomists our challenge is to test and develop innovations that can continue to increase production efficiency, decrease costs and reduce risk in the face of the biological, climatic and economic challenges that we have discussed here.

Conclusion

Based on currently available technologies and price relativities, it is likely that continuous cropping can be sustained over many decades. However, in order for these systems to be sustainable, careful attention to key aspects of the farm is required, particularly control and provision of N and weeds. Under continuous cropping it becomes necessary to provide a greater proportion of crop N supply as fertiliser, and expend greater resources in maintaining low weed populations. As a result, production costs usually rise, and risk of substantial economic loss following price or climate shocks needs to be managed. Maintaining diverse crop species and end-uses forms the foundation of the solution to many of the biophysical as well as economic challenges faced in continuous cropping systems.

Useful Resources

http://www.farmlink.com.au/project/crop-sequencing

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/09/Farming-Systems-Managing-Profitability-and-Risk-in-SA-Grain-Business

http://www.agronomy2015.com.au/papers/agronomy2015final00274.pdf

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Leading-farmers-have-closed-the-yield-gap

References

Angus JF, Peoples MB (2012) Nitrogen from Australian dryland pastures. Crop & Pasture Science 63, 746-758.

Angus JF, et. al. (2014) Effects of banded ammonia and urea fertiliser on soil and the growth and yield of wheat. Crop and Pasture Science 65, 337-352.

Borger, CPD et. al., (2016a). Eleven years of integrated weed management: long-term impacts of row spacing and harvest weed seed destruction on Lolium rigidum control. Weed Research doi: 10.1111/wre.12220

Borger CPD, Riethmuller GP (2016b) Long-term impact of harvest weed seed destruction on annual ryegrass. 20th Australasian Weeds Conference. http://caws.org.au/awc/2016/awc201610311.pdf

Fletcher AL et. al., (2016) Prospects to utilise intercrops and crop variety mixtures in mechanised, rain-fed, temperate cropping systems. Crop and Pasture Science http://dx.doi.org/10.1071/CP16211

Kirkby CA et. al., (2016) Inorganic nutrients Increase humification efficiency and C-Sequestration in an annually cropped soil. PLOS ONE DOI:10.1371/journal.pone.0153698

Kirkegaard JA et. al., (2011) Diversity and evolution of rain-fed farming systems in southern Australia. In 'Rainfed Farming Systems' (Eds P Tow, I Cooper, I Partridge, and C Birch) pp. 715-754, Springer, Dordrecht, Netherlands.

Kirkegaard JA et. al., (2014) Improving water productivity in the Australian Grains industry—a nationally coordinated approach. Crop and Pasture Science 65, 583-601.

Lawes RA, Kingwell RS (2012) A longitudinal examination of business performance indicators for drought-affected farms. Agricultural Systems 106, 94-101.

McBeath T, et. al., (2015) Managing nitrogen nutrition under intensive cropping in low rainfall environments. http://www.agronomy2015.com.au/papers/agronomy2015final00260.pdf

Peoples MB et. al., (2014) Soil: Nutrient Cycling. In: Neal Van Alfen, (Ed-in Chief), Encyclopedia of Agriculture and Food Systems, Vol. 5, San Diego: Elsevier; 2014. pp. 197-210.

Peoples MB et. al., (2016) Soil mineral nitrogen benefits derived from legumes and comparisons of the subsequent apparent recovery of legume or fertiliser nitrogen by wheat.

Scott et. al., (2013) Developments in stubble retention in cropping systems of southern Australia. https://www.csu.edu.au/__data/assets/pdf_file/0009/922725/Developments-in-Stubble-Retention-in-Cropping-Systems-in-Southern-Australia-11Dec2013.pdf

Swan T et. al., (2015) Profitable crop sequences to reduce ryegrass seed bank where herbicide resistant ryegrass is a major constraint to the sustainability of cropping systems. Proc. 17th ASA Conference Hobart www.agronomy2015.com.au.

van Rees H et. al., (2014) Leading farmers in South East Australia have closed the exploitable wheat yield gap: prospects for further improvement. Field Crops Research 164: 1-11.

Zerner MC et al., (2016) Genotypic stability of weed competitive ability for bread

wheat (Triticum aestivum) genotypes in multiple environments. Crop and Pasture Science 67, 695-702.

Acknowledgements

The authors would like to acknowledge the collaborative partnerships in farming systems research with FarmLink Research, Mallee Sustainable Farming and Birchip Cropping that have contributed to published and unpublished data presented here, and to the useful discussions with numerous consultants including Greg Condon, Tim Condon, Chris Duff, Kate Burke, Alan McKay, Matt McCallum and Michael Moodie. We acknowledge the technical teams behind the research and GRDC funding support.

Contact Details

Name: John Kirkegaard

Business Address: CSIRO Agriculture and Food, GPO Box 1700, Canberra ACT 2601

Phone: 0458354630

Email: John.Kirkegaard@csiro.au

Sheep grazing on crop residues increase soil mineral N and grain N uptake in subsequent wheat crops

Authors - James R Hunt (CSIRO Agriculture, La Trobe University (current address)), Paul D Breust (FarmLink Research, Southern Farming Systems (current address)), Antony D Swan, Mark B Peoples, John A Kirkegaard (CSIRO Agriculture)

Abstract

In southern Australia, the majority of farms combine a sheep enterprise with cropping to form a mixed farming business. Crops are grown in sequence with pastures, and sheep graze crop stubble residues after harvest. Recently, growers practicing no-till, controlled traffic cropping, became concerned that grazing livestock would damage soil and reduce soil water capture, crop yield and profitability. Sheep grazing on stubbles remove residue cover and compact surface soil, but there is little published research on potential impacts on subsequent crop performance. A long-term experiment was established in 2009 to quantify trade-offs between grazing stubbles, resource capture and subsequent crop performance. Here we report effects on soil mineral nitrogen (N) accumulation and grain N uptake due to stubble grazing in the seven phase years of the experiment in which wheat crops were grown. Grazing wheat and canola stubbles on average increased mineral N prior to sowing of the subsequent wheat crop by 19 kg/ha, and grain N uptake by 7 kg/ha N. This could have arisen from 1) rapid mineralisation of N in livestock excreta, and/or 2) the reduction in stubble carbon inputs to soil due to grazing lowering rates of N immobilisation. Further research is necessary to confirm the relative importance of these processes, and to explore how they could be exploited to greater advantage to manage soil N availability in mixed farming systems.

Introduction

A livestock enterprise, particularly sheep, in conjunction with a wheat-based cropping has long formed the basis of mixed farming systems in southern Australia (Kirkegaard et al. 2011). In southern New South Wales (NSW) where livestock often comprise 50% of farm enterprise by area, rainfall is equi-seasonal, but crops are grown only during the cool half of the year from April to December. During summer, cropping land is left fallow and sheep graze stubble residues and weeds that germinate in response to summer rain. Recent research has re-evaluated the contribution that summer fallow rain makes to winter crop yield (Hunt and Kirkegaard 2011) versus grazing value of summer weeds (Moore and Hunt 2012) and weeds growing on fallows are now predominantly controlled with herbicide to allow accumulation of soil water and mineral nitrogen (N) for use by subsequent crops (Hunt et al. 2013). However, crop residues are still a highly valuable feed source and stock are grazed on them in situ following chemical control of summer fallow weeds. This is somewhat different to other regions of the world where sheep are grazed on fallows specifically to control fallow weeds (e.g. Hatfield et al. 2007; Sainju et al. 2014).

Previous studies have speculated that increased mineral N is a possible benefit from grazed crop fallows (Hatfield et al. 2007), but in practice few have demonstrated it. Sainju et al. (2014) reported significantly lower soil nitrate in grazed fallows compared to tilled or chemical fallow, and Allan et al. (2016) report inconsistent responses in levels of soil mineral N to grazing. However, the above studies focused on or retained fallow weeds as a treatment effect, and summer fallow weeds are known to greatly reduce levels of soil mineral N available prior to the planting of subsequent crops (Hunt et al. 2013) and grazing them is unlikely to substantially reduce water or N use (Fischer 1987). Further research into the effect of grazing crop residues on the N availability to crops could potentially be rewarding given the economic and environmental imperative to improve the nutrient use efficiency of cropping systems.

A long-term field experiment was established to determine the impact of sheep grazing on stubbles during the summer fallow period on soil properties, crop resources and growth under no-till, controlled traffic cropping with strict weed control. Here we describe the effects of grazing on soil mineral N and grain N uptake using the seven phase years of the experiment in which wheat was grown.

Methods

The experiment was located on a red chromosol soil with surface pH of 4.7 (CaCl2) and little slope 5 km SSE of the township of Temora in SE NSW (S 34.49°, E 147.51°, 299 m ASL). The experiment consisted of three grazing treatments (nil graze – NG, stubble graze – SG, winter and stubble graze – WSG) applied in a factorial randomised complete block design with two stubble management treatments (stubble burn – SB, stubble retain – SR) and four replicates. Treatments were applied in two different phases in adjoining areas of a farmer's 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 16.00 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.

All crops were inter-row sown using a plot seeder equipped with contemporary no-till seeding equipment.

Crops were sown in mid-late April in all years of the experiment, and both crop phases were kept in a rotation of canola (Brassica napus)-wheat-wheat. Only results for years in which wheat was grown are reported here. Following harvest in each year (late November-early December), weaner ewes grazed stubbles in SG and WSG treatments (average 2263 sheep/ha.days). The stubble burn treatments were applied in mid- to late-March of each year. 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. Synthetic fertilisers were applied as required such that nutrient deficiency did not limit yield.

Prior to seeding each year two soil cores (42 mm diameter) were taken per plot to a depth of 1.6 m and segmented into 0-0.1, 0.1-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, 0.8-1.0, 1.0-1.3, 1.3-1.6 m. Six additional cores were taken for 0-0.1 m depth, and cores were bulked according to depths. Soil from each depth increment was analysed for mineral N (NH4 and NO3). 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. Wheat grain protein was estimated by NIR, and grain N content calculated by dividing protein content by 5.75. Wheat grain N uptake was calculated by multiplying grain N content by grain yield. Amount of residue returned to plots prior to grazing was measured by hand harvesting large areas (>1.0 m^2) of crop and threshing and weighing grain and subtracting from total weight. Crude protein content of stubble was estimated by NIR, and stubble N content calculated by dividing protein content by 5.75 for wheat and 6.25 for canola. The amount of stubble present in plots was measured after grazing to calculate how much sheep had consumed.

Soil mineral N and grain N uptake were analysed using a three-way analysis of variance (ANOVA) in randomised blocks with grazing, stubble treatment and phase year as factors 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 test calculated at the 95% confidence level.

Results

The amount of stubble that was grazed prior to the years in the study in which wheat was grown varied seasonally, but averaged 3.3 t/ha (Table 1). The N content of the stubble varied with crop type and averaged 1.2% for canola and 0.7% for wheat. The average N in grazed stubble varied from 3 to 68 kg/ha, but averaged 33 kg/ha.

Phase year & crop type	Mean stubble grazed (t/ha)	Mean stubble N content (%)	Mean N in grazed stubble (kg/ha)
Ph 1 2010 Canola	2.9	1.5	45
Ph 1 2011 Wheat	5.7	0.8	44
Ph 1 2013 Canola	3.5	1.0	34
Ph 1 2014 Wheat	1.6	0.7	11
Ph 2 2011 Canola	4.9	1.4	68
Ph 2 2012 Wheat	3.9	0.7	27
Ph 2 2014 Canola	0.3	0.8	3
Mean	3.3	1.0	33

Table 1. Mean amount and N content of stubble grazed for the years preceding the seven phase years in which wheat crops were grown.

Averaged across all phase years, grazing stubble increased mineral N prior to sowing from 102 to 121 kg/ha N (P<0.001). There was a significant interaction between phase year and grazing, with positive effects of grazing in Phase 1 in 2011, 2012 and 2015 and in Phase 2 only in 2015 (Table 2). There was no significant main effect of burning stubble on soil mineral N (P=0.911), or interaction with either grazing (P=0.389) or phase year (P=0.617) (data not shown).

As a main effect, grazing stubble increased wheat grain N uptake from 85 to 92 kg/ha N (P<0.001) reflecting the observed increase in soil mineral N prior to sowing. However, there was a significant three-way interaction with phase year, grazing, and burning (Table 3). Grazing significantly increasing grain N uptake in the SR treatment in Phase 1 in 2012 and 2015, and in Phase 2 in 2013. Grazing increased N uptake in the SB treatment in Phase 1 in 2014 and Phase 2 in 2015.

Phase year	Nil graze	Stubble graze
Phase 1 2011	79	107
Phase 1 2012	99	127
Phase 1 2014	132	121
Phase 1 2015	90	145
Phase 2 2012	73	81
Phase 2 2013	93	94
Phase 2 2015	145	170
P-value **LSD (P=0.05)**	**0.018** **26**	

Table 2. Soil mineral N (NO3 + NH4, kg/ha N) sampled to 1.6 m depth prior to sowing for the two grazing treatments and seven phase years at the site in which wheat was grown. P-value and LSD are for the graze x phase year interaction.

Phase year	Graze treatment	Stubble management	
		Stubble burn	**Stubble retain**
Phase 1 2011	Nil	107	108
	Stubble	111	110
Phase 1 2012	Nil	92	79
	Stubble	89	92
Phase 1 2014	Nil	99	112
	Stubble	109	106
Phase 1 2015	Nil	63	61
	Stubble	77	84
Phase 2 2012	Nil	88	81
	Stubble	86	86
Phase 2 2013	Nil	77	51
	Stubble	79	73
Phase 2 2015	Nil	81	88
	Stubble	92	94
P-value **LSD (p=0.05)**		**<0.001** **8**	

Table 3. Wheat grain N uptake (kg/ha N) for the two grazing treatments and stubble management treatments and seven phase years in which wheat was grown. P-value and LSD are for the graze x phase year x stubble management interaction.

Discussion

Grazing stubbles significantly increased accumulation of soil mineral N during the summer fallow in four of seven phase years. Averaged across all seven phase years the mean increase was 19 kg/ha N, but the highest observed was 55 kg/ha. There are several mechanisms that could collectively be responsible for this effect. The first is more rapid cycling of organic N in stubble residues into mineral forms by animal digestion. The majority of the N in crop residues consumed by sheep (59%, Freer et al. 1997) is returned to the soil as urea in urine, which under warm summer temperatures would rapidly hydrolyse to ammonia before nitrifying (Haynes and Williams 1993) resulting in elevated levels of soil mineral N. By contrast the organic N in stubble (C:N ratio ~40-80) is likely to be immobilised by decomposing microbes in NG treatments (Kumar and Goh 1999). Based on the mean N content (1.0%) in stubbles grazed in this experiment, and amount of stubble consumed (3.3 t/ha), cycling by animals could on average provide an additional 19 kg/ha of N in mineral form, up to 25% of which could have been lost as ammonia prior to soil sampling (Haynes and Williams 1993).

The second likely mechanism is reduced immobilisation of N in the grazed treatments due to the reduced input of high C:N crop residues compared with ungrazed treatments. The majority of carbon (C) in plant residues consumed by animals is emitted in gaseous form (58%=CO2, 4%=CH4) and lost from the system, or separately excreted to plots as faeces (37%) with a C:N ratio of 25 (Freer et al. 1997). Carbon in stubble will immobilise N at a ratio of 25:1 (Kumar and Goh 1999), meaning that in faeces will not immobilise any more N other than that contained in the faeces itself. Therefore, in this experiment grazing on average either removed C from the system or neutralised C with potential immobilising power of 52 kg/ha N. Immobilisation would be spread over several years as under the no-till management practised at this site residues take numerous years to fully decompose.

Conclusion

Grazing crop stubbles makes more mineral N available to crops which increases grain N uptake and is perhaps an overlooked benefit of keeping livestock in stubble-retained farming systems. There are two mechanisms that are likely to be responsible for this 1) more rapid mineralisation of N in livestock excreta, and 2) a reduction in stubble C inputs into soil that encourage N immobilisation. Further research is necessary to confirm the mechanisms and their relative importance, and to explore how they could be exploited to greater advantage to manage nitrogen in mixed farming systems in the longer term.

References

Allan, CJ, Jones, B, Falkiner, S, Nicholson, C, Hyde, S, Mauchline, S, Ferrier, D-A, Ward, P, Siddique, KHM, Flower, KC (2016) Light grazing of crop residues by sheep in a Mediterranean-typeenvironment has little impact on following no-tillage crops. European Journal of Agronomy 77, 70-80.

Fischer, RA (1987) Responses of soil and crop water relations to tillage. In 'Tillage.' (Eds PS Cornish, JE Pratley.) pp. 194-221. (Inkata Press: Melbourne)

Freer, M, Moore, AD, Donnelly, JR (1997) GRAZPLAN: Decision support systems for Australian grazing enterprises—II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS. Agricultural Systems 54, 77-126.

Hatfield, PG, Goosey, HB, Spezzano, TM, Blodgett, SL, Lenssen, AW, Kott, RW, Marlow, CB (2007) Incorporating sheep into dryland grain production systems: III. Impact on changes in soil bulk density and soil nutrient profiles. Small Ruminant Research 67, 222-231.

Haynes, RJ, Williams, PH (1993) Nutrient Cycling and Soil Fertility in the Grazed Pasture Ecosystem. In 'Advances in Agronomy.' (Ed. LS Donald.) Vol. 49 pp. 119-199. (Academic Press:

Hunt, JR, Browne, C, McBeath, T, Verburg, K, Craig, S, Whitbread, AM (2013) Summer fallow weed control and residue management impacts on winter crop yield through soil water and N accumulation in a winter-dominant, low rainfall region of southern Australia. Crop & Pasture Science 64, 922-934.

Hunt, JR, Kirkegaard, JA (2011) Re-evaluating the contribution of summer fallow rain to wheat yield in southern Australia. Crop & Pasture Science 62, 915-929.

Kirkegaard, JA, Peoples, M, Angus, JF, Unkovich, M (2011) Diversity and evolution of rainfed farming systems in southern Australia. In 'Rainfed farming systems.' (Eds P Tow, I Cooper, I Partridge, C Birch.) pp. 715-754. (Springer: Dordrecht, Netherlands)

Kumar, K, Goh, KM (1999) Crop Residues and Management Practices: Effects on Soil Quality, Soil Nitrogen Dynamics, Crop Yield, and Nitrogen Recovery. In 'Advances in Agronomy.' (Ed. LS

Donald.) Vol. Volume 68 pp. 197-319. (Academic Press:

Moore, AD, Hunt, JR (2012) Does control of summer fallow weeds improve whole-farm productivity in both Mediterranean and temperate environments? In 'Capturing Opportunities and Overcoming Obstacles in Australian Agronomy: 16th Australian Society of Agronomy Conference. Armidale, Australia', 14-18 October. (Australian Society of Agronomy. Available at http://www.regional.org.au/au/asa/2012/soil-water-management/8145_mooread.htm [Accessed accessed 21 December 2012].

Sainju, UM, Barsotti, JL, Lenssen, AW, Hatfield, PG (2014) Particulate and active soil nitrogen fractions are reduced by sheep grazing in dryland cropping systems. Nutrient Cycling in Agroecosystems 99, 79-93.

Contribution of sheep in no-till and zero-till systems

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

GRDC Project Code - CSP00174

Take Home Messages

- Grazing stubble 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 seven year experiment, grazing and retaining stubble has been the most profitable treatment, with an annual Gross Income 172 higher than un-grazed, stubble retain (assuming a grazing value of the stubble) or $55 higher if no grazing value assumed.
- Over the seven years, there was on average a 0.5 t/ha reduction in wheat grain yield in the 2nd wheat crop where stubble was retained and not burnt – mostly related to N tie-up.

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 by-products from cropping (crop residues, weather damaged and spilt grain, early vegetative crop growth) whilst the legume-based pastures used for sheep production spell paddocks from crop production, increase soil nitrogen and reduce crop weed and disease burden. The presence of both livestock and crops also diversifies the farm business, offsetting climate 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 cropping country, removing residue and trampling soils. However, there is little contemporary research evidence to support this view. We report results from a long-term experiment (established in 2009) testing the impact of sheep grazing no-till and zero-till farming systems on soil conditions and 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 2013-2015 were presented in the FarmLink 2016 annual report. This paper updates the results with 2016 data including a summary of grain yield and gross income from continuously cropped treatments between 2010 and 2016.

Methodology

The experiments 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 2016 these treatments were also 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 treatments were applied in two different phases in adjoining areas of a farmer's paddock which had been in 4 years of 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. 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 which followed a canola-wheat-wheat sequence.

In 2016, phase 1 was sown to Hyola 650TT canola on the 27th April at 3.1kg/ha with MAP & impact @ 40kg/ha, following pre-emergent application of propyzamide @ 1L/ha, Dual Gold ® @ 250ml/ha, Lorsban ® @ 1L/ha and Fast-tac Duo ® @ 150ml/ha. In-crop herbicides included Atrazine 900WG @ 1.1kg/ha, Lorsban @ 1L/ha and Venom @ 200ml/ha. Phase 2 was sown to Lancer wheat at 80kg/ha with MAP & impact @ 40kg/ha, following pre-emergent applications of Sakura ® @ 118g/ha, Avadex Xtra ® @ 2L/ha, Lorsban ® @ 1L/ha and Fast-tac Duo ® @ 150ml/ha.

From late June to mid-July each year, large weaner ewes grazed in treatment 3 (winter and stubble graze - WGSG). The amount of plant dry matter was assessed pre and post grazing. In 2016, the wheat treatment was grazed between Z29-31 and the canola between 6 leaf and bud emerged on wet soil (not saturated) for the equivalent of between 500-700 DSE/ha/days (7-8 sheep for 15-21 hours).

In 2016 in phase 1, Prosaro® was applied at 450ml/ha with Transform® @ 100ml/ha at 20% flowering with a 2nd application of Prosaro® @ 450ml/ha on the 20th September. In phase 2, broadleaf weeds were sprayed with a mix of Paridgm® @ 25ml/ha, Ally® @ 5g/ha, MCPA lve @ 500ml/ha and Lontrel Advance® @ 75ml/ha after grazing. Prosaro® was sprayed @ 300ml/ha with Transform® @ 100ml/ha on the 23rd August. Nitrogen was top-dressed on both phase 1 and 2 as urea at 100kg/ha on the 29th June and 120kg/ha on the 29th July.

Grain yields were measured using a plot header harvesting only the inside 4 rows only of each seeder 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 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 2016 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 (SG and WGSG treatments) for an average period of 2263 DSE/ha/days. In 2016-17, four medium sized weaners (55kg) grazed the canola stubble and five weaners grazed the wheat stubble for 4.5days (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 burn treatments were applied in mid- to late-March of each year. Summer weeds that emerged at the site were promptly controlled with herbicides.

Results 2016

In 2016 there was 103mm of summer rainfall (Dec 2015-March 2016), 591mm growing season rainfall (April-Oct inclusive) and a total annual rainfall of 704mm. Between the 30th April and the 9th May, 65mm of rain fell resulting in an even germination and good incorporation of the pre-emergent herbicides. In May 2016, the average canola plant population was 34 plants/m2 across all treatments with fewer plants established using the disc opener and where the stubble was burnt (Table 1). The reduction in canola emergence in the disc and burn treatments may have been due a combination of herbicide damage, Dual Gold ® washing into the sown row in treatments where there was little or no stubble. There was also some effect from insects in the burn treatments, primarily from pasture cockchafers and bronze field beetles. However, in all treatments there were sufficient plant numbers for maximum grain yield.

Opener	Canola emergence (plants/m2)	Stubble treatment	Canola emergence (plants/m2)
Disc	30	**Burn**	29
Knife	38	**Retain**	39
Spear	34		
LSD (p=0.05)	**5**		**6.5**

Table 1: Canola plant populations (m^2) across all grazing treatments for each opener type and for each stubble type in May 2016.

There was no effect of grazing and stubble on wheat emergence in May 2016 (mean population 143 plants/m2). However, there were more plants emerged with the disc seeder (Table 2), but with slower emergence and reduced early vigour (data not shown).

Opener	Wheat emergence (plants/m2)
Disc	154
Knife	136
Spear	139
LSD (p=0.05)	**8.1**

Table 2: Wheat plant populations (m^2) across all grazing treatments for each opener type in May 2016.

The treatments influenced soil mineral nitrogen (kgN/ha) in both phase 1 and 2 in March 2016. The NG treatment had less mineral N (phase 1 @ 90 kg/ha or phase 2 @ 87 kg/ha) compared to either the SG or WGSG treatments @ 120 to 144kgN/ha (Table 3). Thus retaining stubble reduced Min-N available at sowing by 30-50 kg/ha.

Graze treatment	Stubble treatment	Phase 1- Canola 2016 Soil mineral N (kg/ha) Graze x stubble Graze treat		Phase 2- Wheat 2016 Soil mineral N (kg/ha) Graze x stubble Graze treat	
Nil graze (NG)	**Retain**	96	90	75	87
	Burn	83		100	
Stubble graze (SG)	**Retain**	104	120	125	134
	Burn	136		144	
Winter & Stubble	**Retain**	149	144	130	132
(WGSG)	**Burn**	139		134	
LSD (p=0.05)		No interaction	26	No interaction	26

Table 3: Soil mineral N (kgN/ha) in phase 1 (canola) and phase 2 (wheat) between 0-175cm in March 2016.

By the 14th July, across all treatments, there was approximately 1.1t/ha of wheat or canola DM. The sheep in the WGSG treatments removed between 450 to 500kg/ha of plant dry matter in both phases 1 and 2 (canola and wheat), but grazed the disc treatment more heavily in phase 1. The sheep had also removed approx. 20% of the buds from the canola plants and had trampled both the wheat and canola plots (Figure 1).

Figure 1: Pre and post winter graze in phase 2 in July 2016.

At anthesis in phase 1, the average canola DM yield was 5.1t/ha. There was no significant difference in canola plant DM between grazing treatments except in the WGSG disc treatment which had reduced biomass (3.8t/ha cf 5t/ha; data not shown). In phase 2, there was no difference in wheat DM between openers, but wheat DM was reduced in both the NG stubble retain and SG stubble retain treatments and increased in the WGSG treatment compared to the NG stubble burn treatments (Table 4).

There was no difference in canola grain yield, oil content or gross income between any of the treatments (Table 5) or between opener types (Table 7).

Graze Treatment	Stubble Treatment	
	Burn	Retain
Nil graze (NG)	9.0	7.9
Stubble graze (SG)	9.3	8.3
Winter and stubble graze (WGSG)	9.9	10.2
LSD (P=0.05)	0.85	

Table 4: Wheat dry matter (t/ha) at anthesis (28th September - 5th October) in the graze and stubble treatments in phase 2 across all opener types.

Graze treatment	Stubble treatment	Grain yield (t/ha)	Oil (%)	Gross Income ($/ha)
Nil graze (NG)	Retain	3.2	49.1	$1775
	Burn	3.3	49.2	$1805
Stubble graze (SG)	Retain	3.4	48.7	$1873
	Burn	3.1	49.0	$1708
Winter & Stubble graze (WGSG)	Retain	3.4	49.1	$1865
	Burn	3.1	49.0	$1694
LSD (p=0.05)		ns	ns	ns

Table 5: Canola grain yield, oil % and gross income from phase 1 in 2016.

However, where the 2nd wheat crop was sown in phase 2 in 2016, there was significantly more wheat grain yield in both the NG burn and the SG burn treatments compared to all other treatments which translated to higher gross incomes (Table 6). The average wheat grain protein concentration across the entire experiment was 8.5% with no significant difference between openers, however, the protein concentration in the WGSG treatment was significantly lower than the NG and SG burn treatments (Table 7). Wheat protein concentrations in all treatments were low, indicating that the crop was nitrogen limited in this wet year. The wheat grain yield was slightly higher when sown with the knife opener compared to the disc (Table 7).

Graze treatment	Stubble treatment	Grain yield (t/ha)	Protein (%)	Gross Income ($/ha)
Nil graze (NG)	Retain	5.3	8.7	$899
	Burn	5.8	8.7	$980
Stubble graze (SG)	Retain	5.5	8.5	$934
	Burn	6.0	8.6	$1024
Winter & Stubble graze (WGSG)	Retain	5.3	8.4	$891
	Burn	5.2	8.3	$876
LSD (p=0.05)		0.3	0.26	$49

Table 6: Wheat grain yield, protein % and n the wheat in phase 2 in 2016.

Opener	Wheat Grain Yield (t/ha)	Canola Grain Yield (t/ha)	Wheat Gross Income ($/ha)	Canola Gross Income ($/ha)
Disc	5.4	3.1	$916	$1721
Knife	5.6	3.2	$951	$1762
Spear	5.5	3.4	$934	$1876
LSD (p=0.05)	0.14	ns	$23	ns

Table 7: Grain Yield and Gross Income across all treatments by opener type in 2016

Results for 2010-2016

Across the seven years of the experiment in both phases, there has been a significant decrease in wheat grain yield (~0.5 t/ha) when stubble was retained rather than burnt in the nil graze treatments. (Tables 8 and 9). In 2012, 2015 and 2016, this resulted in a 0.5t/ha reduction in grain yield and was associated with lower soil N concentrations and presumably increased N tie-up by the retained stubble (Table 8). The soil mineral N concentration was always 15 to 20 kgN/ha lower in March of each year in the NG stubble retain compared to the NG stubble burn treatment (data not shown). The combined effect of lower soil mineral N concentrations and lower air temperatures (i.e. frost) in 2013 in NG stubble retained treatment resulted in a 1.6t/ha decrease in wheat grain yield in phase 2 compared to the NG stubble burn treatments (Table 9). The 0.6t/ha decrease in grain yield in the SG stubble retain compared to the SG stubble burn treatment was also due to frost (Table 9).

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

Table 8: Grain yield between 2010 and 2016 in Phase 1 sown with knife point.

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

Table 9: Grain yield between 2010 and 2016 in Phase 2 sown with knife point.

In most cases, (2012, 2013, 2015), the wheat grain yield in the 2nd wheat crop in the SG stubble retain treatment has been significantly higher than in the NG stubble retain treatment (Tables 8 and 9). Grazing stubble increased the soil mineral N available prior to sowing and in 2015 phase 1, it was almost doubled. This result was verified by surface N measurements taken immediately before and immediately after stubble grazing, which showed that mineral N in the SG stubble retain treatment was twice that in the NG stubble retain treatment, an effect that persisted through the summer fallow.

Gross Incomes

Averaged across both phases for the seven years of this experiment, grazing and then retaining the stubble generated the highest gross income (Table 10). 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.

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
Winter Graze	Retain	$1170	$1287
	Burn	$1196	$1313

Table 10: Gross income per year averaged across both phases for all years (2010-2016) of the experiment

**Grazing value of the summer stubble only in both SG and WGSG treatments. No grazing value was calculated for the grazing in winter.*

Conclusion

In 2016, the average canola grain yield was 3.1t/ha with an oil content of 49% and a gross income of $1787, with no significant difference between treatments or openers. In 2016, wheat grain yield and gross income was higher in both the nil graze and stubble graze treatments where stubble was burnt than where stubble was retained.

02

FarmLink Research Report 2016

The Strategic Use of Tillage Within Conservation Farming

GRDC Project code – DAN00152

Project Partners

FarmLink change • adapt • prosper

NSW Government Department of Primary Industries

Funding Partners

GRDC Grains Research & Development Corporation

Trial Site Location

Harden (CSIRO long term trial), Cootamundra (Byrne Bros), Young (Chris Holland), Corowa (Andrew Simpson).

Report Author

Mark Conyers

Introduction

Tillage can do damage to soil structural stability as measured by Wet Aggregate Stability (WAS): the damage is generally small, a 5-10% loss of macro-aggregates, but can exceed 15% loss of macro-aggregates in the instance of rotary hoeing.

Recovery time for WAS ranged from 1 to >4 years depending on the severity of the tillage (scarifying was mild) and the rotation and stubble management that followed (pasture phases are ideal for recovery).

There is little to be concerned about from implementing a strategic tillage provided:

- That it is not frequent, say less frequent than once every five years based on data to be outlined.
- That we consider the well-known risks for erosion such as slope, groundcover, and current weather, and the considerations for tillage, such as the soil moisture at the time of the proposed tillage. Hence, we suggest leaving the tillage as late as possible to avoid the chance of erosive rainfall between tillage and crop establishment.

Background

There are obvious problems and contradictions associated with the adoption of complete zero tillage, which have been well documented. Briefly:

- Limestone applied to correct pH has to be incorporated into the soil or else it does little to ameliorate acidity.
- A lack of tillage causes nutrients such as Nitrogen and Phosphorous from plant residues to accumulate in a relatively shallow soil surface
- Zero tillage can favour diseases such as Rhizoctonia and Pseudomonads
- Conventional tillage has been found to suppress plant parasitic nematode populations compared with direct drilling.
- Tillage can be used to help lower numbers of snails and slugs prior to canola crops, and to lower mice numbers
- Integrated weed management might require the use of strategic tillage to manage herbicide resistance.
- In a mixed farming system, infiltration of rain can be poor following compaction by livestock in wet weather.
- Deep ripping is used to remove hard pans, while spading and delving are used to put clay into the surface.

How do we reconcile the philosophy of zero tillage (disc sowing), or even minimum tillage (knife points), with what is actually happening in practice? We asked ourselves one simple question:

How much damage is done to soil by occasional tillage, strategically applied, in an otherwise direct drilled system?

Methods

We selected three contrasting sites where some form of cultivation made sense; following limestone application within a cropping phase, following a five year pasture phase and before canola, and following a green manure crop. The sites were at Thuddungra between Young and Grenfell, Berthong near Cootamundra, and Daysdale near Corowa. A fourth site was the CSIRO long term trial at Harden which had 20 years of contrasting tillage and stubble management.

We measured a range of chemical, physical, and at two sites, biological properties of the soils to assess what effects the implementation of tillage had on the soil. We also measured a range of agronomic variables to assess impacts on plant production. We followed these soil properties and plant yield variables over three to five years to measure the changes in time following tillage. For example, if there were detrimental effects from tillage, how long does it take for the soil to 'recover'?

In this report, we document the soil physical property known as Wet Aggregate Stability (WAS). This is a measure of the soil's structural stability; in particular how it behaves as it wets up following rain or irrigation. Macro-aggregates are defined as being bigger than 250 micron diameter and a high proportion of these is considered desirable. Micro-aggregates are defined as being less than 50 micron diameter and are not considered desirable (effectively dust).

Here, we show the results from one on-farm site (Daysdale) and from the CSIRO long term trial at Harden, which represent contrasting results.

Results and Discussion

Daysdale

The design at Daysdale involved three tillage treatments: on-going direct drilling (DD), one pass with a scarifier (Scar) or one pass with offset discs (Offs). Each tillage was applied in 2012 and again in another set of plots in 2013, with the tillage treatments for both years randomly distributed within the trial area so that we could assess any effect of the year of tillage. There were therefore six treatments: three different tillage operations by the two years of tillage, each with four replicates. We measured the wet aggregate stability (%WAS) of the soil in each plot at two depths; 0-5 and 5-10 cm.

The statistical analysis showed very few significant effects at this site (Figure 1). The macro-aggregates (>250 μm) at 0-5 cm depth showed lots of variability and no significant differences amongst the 6 treatments over the years. The micro-aggregates (<50 μm) at 0-5 cm depth showed one anomalous effect in April 2013 where offset discing produced a significantly (P=0.03) lower % of micro-aggregates (less dust) than ongoing direct drilling or scarifying. It was accompanied by a higher % of macro-aggregates but which failed to reach statistical significance. From 2014 to 2015 the use of offset discs in 2012 tended to produce a lower % of macro-aggregates and a higher % of micro-aggregates. Although not significant because of the variability in the data, the trend serves as a caution that small detrimental effects from the use of offset discs might have occurred.

At 5-10 cm depth there were three statistically significant differences amongst the six treatments over the period 2012-2015. There were no differences between the six treatments at 5-10 cm depth from July 2013 to April 2015, indicating that any of these minor effects of tillage on WAS had been overcome within 12 months.

Overall the effects of tillage on WAS at this site were minor and short lived, indicating that there were no detrimental effects of tillage to WAS that are likely to be of practical relevance.

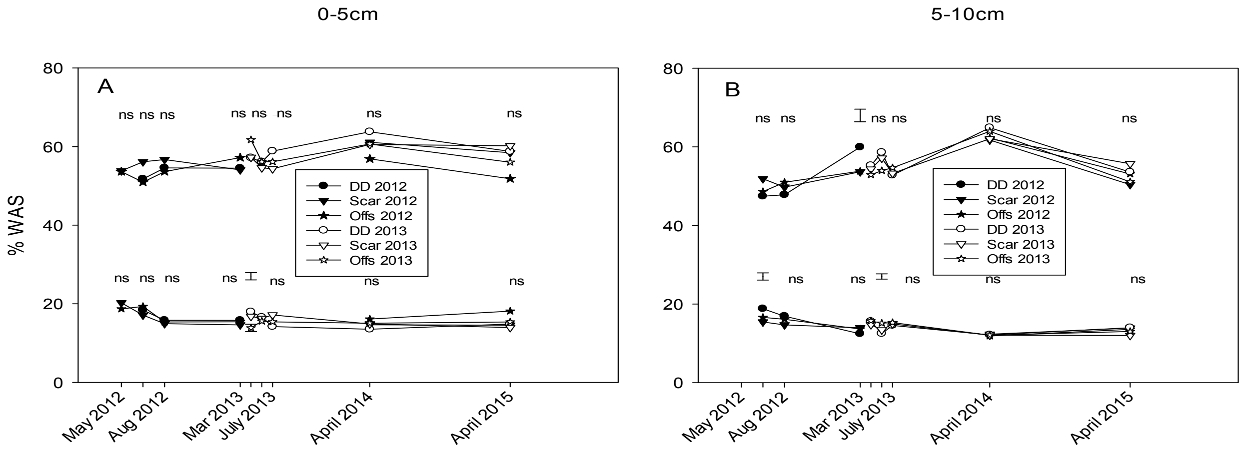


Figure 1: Change in Wet Aggregate Stability over three years at two depths at the Daysdale site.

The upper lines and symbols in each graph describe the macro-aggregate data while the lower lines and symbols describe the micro-aggregate data. The treatment key is given on each graph; filled symbols describe the 2012 site and hollow symbols the 2013 site. Error bars are for tillage main effects.

Harden Long Term Site

The CSIRO Long Term Experiment at Harden contained treatments that had been under direct drilling for 20 years, with stubble that had been either burnt or mulched. We split the plots and tilled half of each with a rotary hoe. This gave us four treatments, a two by two factorial: direct drilling with stubble retained (DD SR) or with stubble burnt (DD SB), and a single cultivation by rotary hoe with either stubble retained (RH SR) or stubble burnt (RH SB). In addition, we undertook measurements on two test strips; one strip under a double rotary hoeing, which we then sowed to pasture (ryegrass – subclover) and the other under a five-year-old pasture (phalaris) across the trial fence in the farmer's paddock.

Where the soil had been under DD SR for over 20 years, about 70% of the surface soil (0-5 cm depth) was in stable macro-aggregates (Figure 2). The five-year-old pasture in the farmer's paddock had a similar proportion of macro-aggregates. However, when the soil received two passes of a rotary hoe, the soil's macro-aggregation decreased to ~50%WAS, indicating a large increase in susceptibility to erosion. However, after two years of pasture the soil recovered from this loss of aggregate stability. Conversely the increased micro-aggregation (dust) due to rotary hoeing was rectified after 12 months. Hence the damage caused by a severe cultivation was rectified in 12 to 24 months where a pasture was grown after the cultivation.

Under continuous cropping the recovery of the soil from cultivation was not so clear (Figure 3). The treatments were all previously under DD but were split for a single pass of a rotary hoe, not two passes as in Figure 2. The damage from the single pass was not so large, averaging about an 8% decrease in macro-aggregate stability. The DD SR treatment maintained the best macro-aggregate stability for stability of the soil's macro-aggregates, as is well known. The RH SB treatment produced the lowest macro-aggregate stability as expected, at about 60%. After two years (2011 to 2013) only the DD SR treatment was significantly better than the other treatments, though tillage and stubble effects re-emerged in 2014 only to disappear again in 2015. From a practical perspective the DD SR treatment maintained better soil structure in the surface soil over the four years of the trial while the other 3 treatments converged to a lower value of %WAS over two to four years.

Figure 3B shows the macro-aggregate stability at 5-10cm depth for the same four treatments. Here the macro-aggregate stability of the soil under DD was less than for the cultivated treatments. This indicates that some of the "damage" caused by tillage was simply due to mixing of the 0-5 and

5-10 cm layers of soil by tillage. Again, by two years there was no significant difference between treatments.

Given that macro-aggregate stability is most important for the surface soil, as protection from erosion, Figure 3A indicates the need for caution when contemplating tillage. The impact of a single rotary hoeing on the surface soil caused an increased susceptibility to erosion, albeit only a 5-10% increase in risk on this soil.

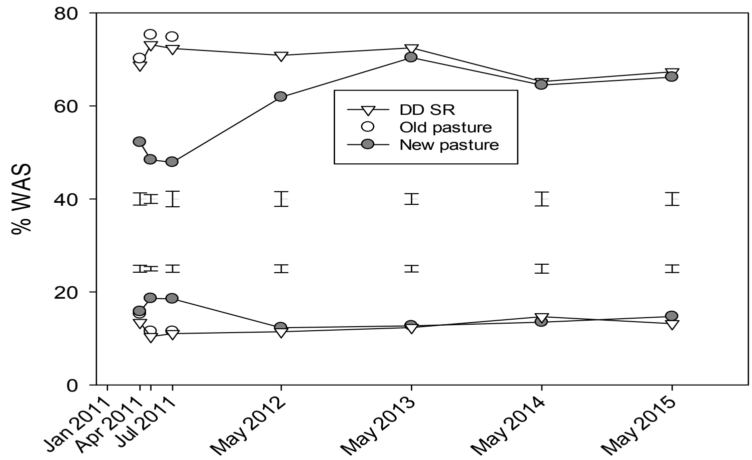


Figure 2: The wet aggregate stability (%WAS) of the pasture soils at Harden over 4 years (2011-2015).

The upper two lines represent macro-aggregates (> 250 µm) whist the lower two lines represent micro-aggregates(< 50 µm). The error bars are for the stubble by tillage interaction.

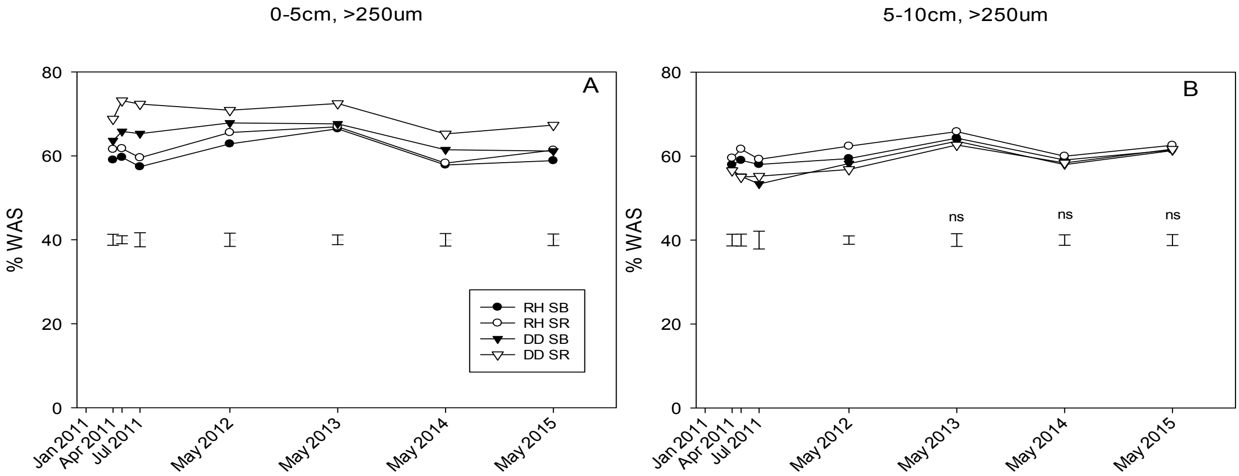


Figure 3: The wet aggregate stability (%WAS) of macro-aggregates (>250 µm) for the cropped soils at Harden over 4 years (2011-2015).

The error bars are for the stubble by tillage interaction at each depth.

Brief comment on the other sites

The Berthong site, like the Harden site, showed some longer term detriment from tillage to macro-aggregation in the surface 0-5cm when tilled in 2013 but not when tilled in 2012. The Thuddungra site showed some initial damage to soil structure at 0-5cm depth from off-set discs but recovery occurred within two years.

Conclusions from the data

Tillage can do damage to soil structural stability: the damage is generally small, 5-10% in terms of WAS, but can exceed 15% loss of WAS in the instance of rotary hoeing.

Recovery time for WAS ranged from one to >4 years depending on the severity of the tillage and the rotation & stubble management that followed. Including a pasture phase in the farming system is likely to repair any damage to soil structure resulting from strategic tillage during the cropping phase.

Practical Message

There is little to be concerned about from implementing a strategic tillage provided:

- That it is not frequent, say less frequent than once every five years based on the above.
- That we consider the well-known risks for erosion such as slope, groundcover, and current weather, and the soil moisture at the time of the proposed tillage. Hence, we suggest leaving the tillage as late as possible so as to avoid the chance of erosive rainfall between tillage and crop establishment.

Useful Resources

https://indd.adobe.com/view/d0d69075-611d-45eb-a24c-67c2efb94003

Acknowledgements

The Advisory Committee (in alphabetical order by surname): Sandy Biddulph (Biddulph Rural Consulting), Greg Hunt (Rural Management Strategies), Peter McInerney (3D -Ag).

The Research team (in alphabetical order):

CSIRO – John Graham, Clive Kirkby, John Kirkegaard, Tony Swan

FarmLink – Cindy Cassidy, Kylie Dunstan

NSW DPI – Albert Oates, Graeme Poile, Vince van der Rijt. Kurt Lindbeck assisted with pathology.

The Co-operators (in alphabetical order):

Byrne Bros (Geoff, John and Scott), Berthong near Cootamundra

Chris Holland, Thuddungra between Young and Grenfell

O'Connor Bros, Harden

Andrew Simpson, Daysdale near Corowa

Contact Details

Mark Conyers, mconyers@bigpond.net.au

6931-3272 (home)

03

FarmLink Research Report 2016

Facilitating increased on-farm adoption of broadleaf species in crop sequences to improve grain production and profitability

GRDC Project code – CSP00146

Project Partners

A collaboration between CSIRO, NSW Department of Primary Industries (NSW DPI), the Victorian Department of Economic Development, Jobs, Transport and Resources (ECODEV; previously Vic DEPI, or Vic DPI) and leading Grower Groups in the Southern Region based in either the lower rainfall (Birchip Cropping Group [BCG], Central West Farming Systems [CWFS]), medium-high (FarmLink, Riverine Plains), or high rainfall zone (Southern Farming Systems [SFS], MacKillop Farm Management Group [MFMG]), or have a focus on irrigated systems (Irrigated Cropping Council [ICC]).

Funding Partners

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Introduction

The Grains Research & Development Corporation (GRDC) Crop Sequence Initiative was established to address concerns within the grains industry at the intensification of cereal cropping that occurred during the millennium drought. Continuous wheat had become increasingly common in many grain production areas, despite a wide range of other crop options being available. In part, the preference of wheat over other crops were based on the perception that cereals were less risky and more profitable; especially in the face of variable climatic conditions. However, in most areas there were growers who ran profitable farming systems that challenged this perception as they actively embraced broadleaf break crops such as canola and legume pulse crops, or routinely included a legume-dominant pasture phase as part of their cropping sequence.

The project aimed to generate new information on how crop choice and sequence could affect grain productivity and profitability, and to give growers necessary knowledge and confidence to appropriately and profitably integrate a greater range of crops into their system. Much of the experimentation and on-farm trials were designed to answer one or more of the following questions:

1. Can a break crop be as profitable as wheat?
2. Are sequences that include break crops more profitable than continuous wheat?
3. Can a weed problem be managed more cost effectively with a break crop than in a continuous cereal system?
4. What effects do break crops have on soil nitrogen availability?
5. What break crop should I grow?

Report One

Profitable Break Crops

Report author/s – Laura Goward, Antony D Swan and Mark B Peoples (CSIRO Agriculture and Food, Canberra, ACT)

What is meant by the term 'crop sequence'?

Growing different crop types in a rotation is not a new concept. The context of the use of the term crop sequence here is to specifically avoid implying the more traditional and rigid rotational pattern where one specific crop type always follows another. We are advocating a much more flexible approach where the choice of crop is made in response to the need to address agronomic issues, market and seasonal needs and opportunities.

Why did we need to reconsider the management of break crops in crop sequences?

Many grain growers acknowledge that they are likely to suffer some yield penalty by more intensive cereal cropping. However, their perception of the possible size of yield losses in the order of 10-15% (based on 2008 grower and agribusiness survey results collated by John Kirkegaard and Michelle Watt of CSIRO) underestimates the true value of break crops. Data collated from many research trials from Australia and around the world indicate average yield improvements of 20-50% equivalent to 1.1-1.8 tonnes of grain by wheat grown following a legume in the absence of N fertiliser and 0.8 additional tonnes of grain per ha if wheat is grown after canola compared to wheat on wheat (see Figures 1 and 2 below).

Much of the project's experimental and communications program was based on the assumption that in the absence of high grain prices for canola or pulses, growers are most likely to want to sow broadleaf break crops to address specific agronomic problems when growing cereals associated with evidence of reduced crop performance due to: (a) difficult to manage grass weeds, (b) low soil N fertility, or (c) disease.

The project examined the productivity and financial implications of growing legumes or canola in various genotype x environment x management (GxExM) and end-use (grain, brown manure, hay, forage) combinations in cereal-based systems, to re-evaluate the full value of integrating broadleaf species in a cropping sequence.

Full details of the research undertaken and the results can be found on the FarmLink website link to the Break Crop Management Guide (BCMG) - http://www.farmlink.com.au/project/crop-sequencing

Break crops for Profit – a single year comparison

Short-term profitability of grain production of any given crop at a paddock level is determined by the price received for the grain, its yield and the input costs incurred to grow it. One of the key considerations when choosing a canola or legume break crop is: can it be as profitable as a cereal in its own right?

All the experimental trials used continuous wheat as a biophysical and economic benchmark against which the performance of break crops (and their impact on following crops) were compared. Several studies included wheat treatments grown with low inputs to minimise production costs, as well as high inputs to target ambitious, but potentially achievable, grain yields for the district.

In summary, the results from all the plot trials and farmer case studies undertaken between 2010 and 2015 in high, medium and low rainfall environments indicated that there was at least one break crop option that could be as profitable, if not more profitable than wheat.

Canola was shown to be the most widely adapted break crop and returned higher gross margins than wheat in the majority of trials across the rainfall zones and years. Results from trials at Junee Reefs and Eurongilly NSW (Junee Reefs and Eurongilly Exp 1 (BCMG), are examples of where canola was much more profitable than wheat most of the time (by between $522-$1009/ha). Lupins grown for grain in low and medium rainfall areas were more profitable than various wheat treatments in a number of experiments (eg Chinkapook, Junee Reefs, Eurongilly Exp 1 and Eurongilly Exp

2 (BCMG). Faba beans or sub-clover cut for hay were more profitable options for the medium-high rainfall areas or under irrigation (eg Yarrawonga, Naracoorte and Kerang Q1 (BCMG)). Whilst field peas, chickpeas and lentils were shown to be more profitable options (up to $100/ha per year over 4 years) on certain soil types in low rainfall areas (eg Mildura (BCMG)).

Once you access the BCMG on the FarmLink website (http://www.farmlink.com.au/project/crop-sequencing) reference the Table of Contents for regional specific trial results relating to single year break crop profitability.

Profitability of break crop sequences

Longer-term profitability is dependent on how a crop sequence contributes to the income of the whole farming system. In which case, it is important to consider the trade-offs between the cost of production (risk) and potential profit (reward) of different break crop options and end-uses. This will be largely influenced by local factors such as: rainfall, timing of the autumn 'break', soil type, soil water and soil N availability, herbicide history, weed dynamics and the risk profile for any given grower. Break crops have been shown to reduce costs associated with managing weeds and disease and improving N supply for following wheat crops. The versatility of break crops for different end uses (e.g. grain, hay/silage, brown manure and grazing) can also allow for better seasonal risk management.

Crops grown after break crops are consistently higher yielding than continuous wheat and require lower input costs; consequently, cumulative economic returns for sequences that include break crops tend to be greater over a 3-5 year timeframe.

Figure 1 summarises data collated 180 comparisons of canola-wheat versus wheat-wheat sequences and almost all experiments demonstrated a yield benefit (i.e. data points for yield after canola were above the 1:1 dashed line) which represented an average 0.8 t/ha additional grain for wheat grown following canola.

Figure 2 summarises data accumulated from 300 experiments which included legume-wheat and wheat-wheat sequence comparisons. The results from these studies suggested that on average an additional 0.7 to 1.6 t/ha of wheat grain was harvest after a legume crop depending upon the species.

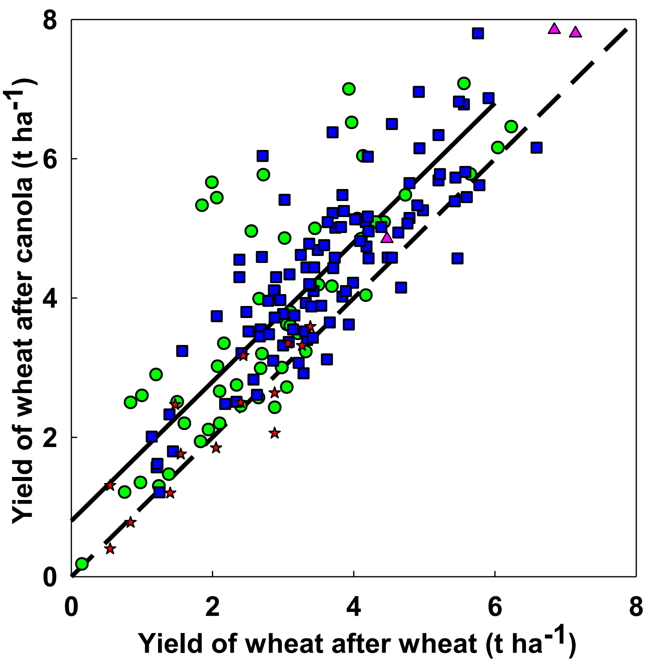


Figure 1. Yield of wheat after canola compared with wheat after wheat growing in the same experiments. Symbol colours represent experimental locations. ●, Australia; ■, Sweden; ▲, Other Europe; ★ North America.

The 1:1 dashed line represents equal yield (Angus et al. 2015).

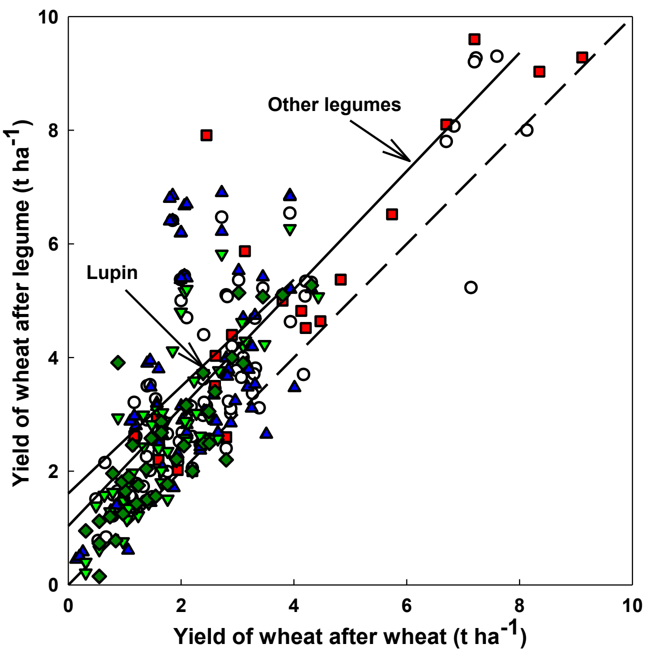


Figure 2. Yield of wheat after grain legumes compared with wheat after wheat growing in the same experiments. The dashed lines represent equal yields and the solid lines represent fitted equations. Symbols represent field pea, O; faba bean,■; lupin, ▲; chickpea, ▼; lentil, ◆ (Angus et al. 2015).

Some of the observed increases in wheat yields after canola or legumes may be derived from providing a range of weed contol options, the breaking of cereal disease cycles, changes in soil structural characteristics that encourage a deeper rooting depth by following crops, or the carry-over of residual soil water. In the case of legumes, the effects on soil biology and increased availability of N and other nutrients can also be very important components of the yield benefits. In some instance these benefits have been demonstrated to last for several subsequent cereal crops.

The cumulative gross margins over multiple years of a crop sequence is one useful measure for determining the profitability of break crops in a farming system. In most instances, it can be found that the most profitable sequences involving three years or greater contain at least one break crop. In the presence of a major constraint to wheat production such as a high weed burden, sequences involving 'double breaks' can be the most profitable (eg Eurongilly Q2 (BCMG)).

Environmental suitability of different species will be a key determinant in deciding on which break crop to grow where. What will grow well and provide the most profitable break in the Western Districts of Victoria is likely to differ from the best option available in the Central West region of NSW. Growing break crops for maximum profit requires careful management and consideration of both environmental factors such as rainfall and soil type along with recent paddock fertiliser and herbicide histories. Growers should always consult their advisors and local agronomists, but decision-trees such as that developed by BCG for the southern Mallee (Appendix A BCMG) or the break crop checklist (Appendix B BCMG) can provide a starting point when choosing break crop suitability. Matching legumes to a well suited environment is particularly important as individual species are generally less well adapted to the range of environments than canola and the potential break crop benefit could be greater.

Managing weeds with break crops

There is growing evidence that the number of populations of grass weeds (particularly annual ryegrass) around Australia are now resistant to many of the common herbicides used in cereal production. Difficult to manage weeds reduce the productivity and profitability of cereals by competing for light, soil water and nutrients. For instance, on-farm experimentation undertaken in southern NSW indicated that for every additional tonne of ryegrass dry matter present at spring within a wheat crop, there was grain yield penalty of around 0.5 t/ha (eg Eurongilly Q3 (BCMG)). The rotation of chemical groups that is possible with break crops through the use of alternate pre-emergent and post-emergent grass selective herbicides, spray-topping, hay or silage cutting and brown manuring all help to reduce seedbanks, and therefore decrease the incidence of herbicide resistant (and susceptible) weed populations.

A number of trials were established in southern NSW in conjunction with FarmLink (eg Eurongilly and Wagga Wagga Q3 (BCMG)), and Victoria (Lake Bolac and Inverleigh Q3 (BCMG)) to address the questions 'can ryegrass populations be managed cost-effectively under break crops?' and 'can you buy your way out of needing a break crop?' As part of these field trials, weed seedbanks, spring weed and crop dry matter and final panicle numbers were all measured.

It was found that the greatest reduction in weed pressure could be achieved by applying a range of control strategies to a break crop or fallow rather than attempting to continue to manage the problem within wheat. The latest management options available to control grass weeds in wheat (pre- and post-emergent herbicides, high plant populations and high nutrient supply to increase wheat's ability to compete with weeds) were less effective and cost twice as much as those used in most break crops ($142/ha cf $56/ha) (eg Eurongilly Q1 (BCMG)).

In the presence of a high density of herbicide resistant ryegrass it was also found that 'single breaks' were not adequate to reduce weed seedbanks and in-crop weed competition in wheat that they needed to be used in conjunction with costly inputs as described above during the wheat phase to achieve some measure of control. 'Double breaks' (two broad leaf break crops or cereal hay grown in sequence) were shown to be a better option for reducing ryegrass seedbank numbers and were amongst the most profitable 3-year sequences.

Once you access the BCMG on the FarmLink website (http://www.farmlink.com.au/project/crop-sequencing) reference the Table of Contents for regional specific trial results relating to weeds.

Managing nitrogen with break crops

Many experimental trials have demonstrated that there is commonly a close relationship between soil mineral N and wheat yield across a range of environments in eastern Australia (Figure 3). Figure 3 also indicates that both soil mineral N and wheat yields are generally lower following wheat crops and highest following legumes. The amount of N mineralised from legume residues that becomes available for a subsequent crop can be influenced by legume species and its end use (ie. whether it is grown for grain or brown manured, grazed or cut for hay), and the amount of rainfall over the summer fallow between crops.

Cost-effective supply of legume N is dependent on productive and efficient biological N2 fixation (Please refer to Appendix C BCMG for a summary of key findings arising from the GRDC-funded project experimentation, including on-farm measures of N2 fixation from commercial pulse crops and pastures). Matching species choice to the environment was the primary factor that impacted the total amount of N2 fixed (kg N/ha). The more dry matter (DM) that a legume can produce, the greater the potential for N2 fixation. Where a species is well suited and doesn't have any obvious constraints to N2 fixation (e.g. herbicide residues, low soil pH, no or failed rhizobial inoculation, or soil mineral N concentrations greater than 100 kg N/ha) it is likely legumes will be deriving more than half of their N requirements for growth from N2 fixation. Under these conditions it is common for around 15-20 kg shoot N to be fixed per ha on average for every tonne of legume shoot DM that is accumulated during the growing season. An easy way for growers to estimate the likely amounts of N2 fixed being achieved in their own crop is to take advantage of the observation that the harvest index (proportion of above-ground biomass partitioned in grain) of crop legumes is often 30-35%. Therefore, the total shoot dry matter accumulated by a pulse crop would approximate 3 x the weight of legume grain harvested (t/ha). Consequently the amounts of shoot N fixed (kg N /ha) would equate to approximately 60 x harvested legume grain yield (t/ha).

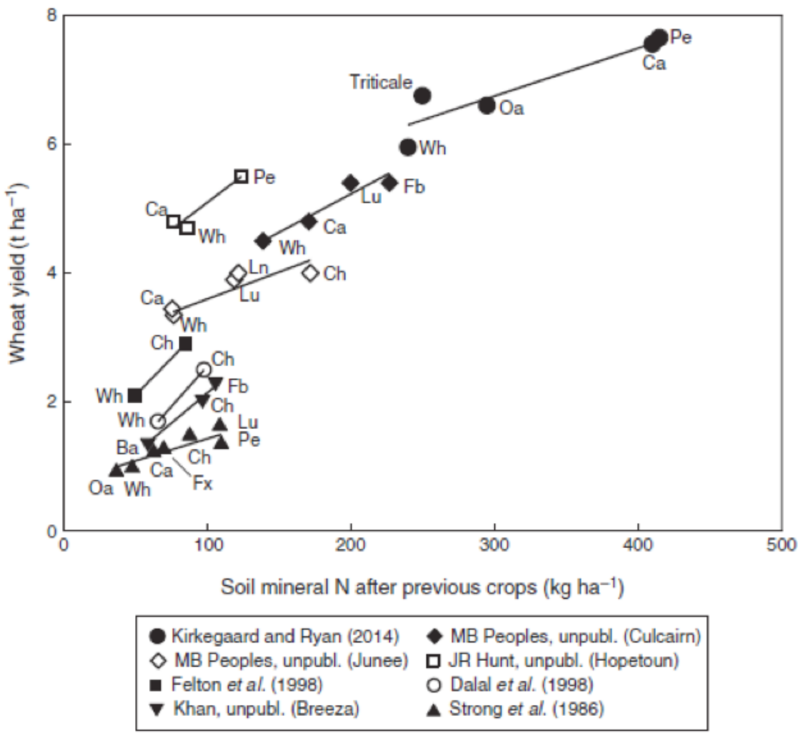


Figure 3 Relationship between residual soil mineral N in the root-zone (_0.9 m) after different crops and grain yield of the following wheat crop. Each set of symbols and the fitted line is from a different field experiment. Wh, Wheat; Ba, barley; Oa, oats; Ca, canola; Fx, flax; Pe, field peas; Ln, lentils; Ch, chickpeas; Fb, faba beans; Lu, lupins; Fa, fallow (Angus et al 2015).

A healthy, productive legume crop sourcing its N requirements predominately from the atmosphere will be well positioned to provide a net contribution of N for the benefit of subsequent crops. In short, when choosing a legume break crop "grow what you can and grow it well" for maximum input of N into the cropping sequence.

Individual studies have explored the various constraints to effective rhizobia nodulation to allow for efficient N2 fixation. There are no native rhizobia naturally present in Australian soils that are capable of forming root nodules on agriculturally important legumes. Consequently no nodules will be formed and N2 can be fixed when a new legume crop or pasture species is grown for the first time unless the seed or soil is inoculated with the correct strain of rhizobia (note: different legumes often require different specific rhizobial strains to form functional root nodules – this can be determined by digging up some root systems and slicing nodules in half with a knife or razor; effective N2-fixing nodules will appear red inside). There is currently not a commercially available test for measuring background rhizobia, so it is not possible to determine whether sufficient numbers of the right rhizobia will have survived in the soil since the last time the same legume had been grown to adequately nodulate the coming season's crop. Poor nodulation can result in depressed crop growth, low inputs of fixed N, and up to 1 t/ha lower grain yields (eg Culcairn trial (BCMG)). At the current cost of peat inoculants it is regarded as cheap insurance to always inoculate legume seed (eg Watchupga East inoculation x N experiment Q4 (BCMG)). Other trials have investigated the impact of certain herbicide applications and residues on N2 fixation, for instance Group A chemicals on vetch growth at Boree Creek NSW (2012) and Group B herbicides in lentils at Rupanyup Vic (2011). Adhering to label recommendations, in particular plant-back periods is important for maximising N2 fixation.

Profitable N management in crop sequences can be improved with the use of budgeting tools, including 'rules of thumb' (Appendix E BCMG), that factor for starting soil mineral N, N mineralisation, and potential yield as determined by crop water use and supply. Water and N are often the key yield drivers in wheat dominant farming systems. Nitrogen availability to wheat crops is increased from the mineralisation of N contained in legume residues or the addition of synthetic fertiliser ('bagged N'). There are good opportunities for the use of both sources of N, for instance whilst legume N can be a low risk option as it can be largely 'free', the use of fertiliser N in canola in a year of good canola prices can result in good gross margins. Mineralisation rates and timing is largely determined by rainfall, but can be heavily influenced by previous crop choice and management. For example, studies undertaken by Alan Mayfield in SA some years ago (unpublished data) demonstrated that incorporation of legume residues prior to the summer fallow can significantly increase levels of soil mineral N. However, other more recent trials have failed to show such a large effect (eg Lockhart and Ariah Park Case Studies (BCMG)).

Ultimately how well N is managed will determine input costs and will have implications for both short and long-term profits.

The end-use of a crop (cut for silage/hay, grazed, harvested for grain or brown manured) is a management decision that has the potential to impact both soil water and soil N. For example, brown manured crop or pasture legumes have been shown to have higher starting soil mineral N and soil water for a subsequent crop than a legume harvested for grain. However, where a subsequent wheat crop does not receive enough rainfall there can be too much N and this can result in 'haying off' as occurred in a vetch termination trial at Birchip in 2013 (eg Birchip Q4 (BCMG)).

Clearly soil water reserves and rainfall will be critical factors determining potential biomass production by wheat and/or grain yield. The most notable management decisions to impact on soil water availability for wheat were either fallow the soil in the previous year, or the timing of termination of the preceding break crop or pasture. Well managed long fallows left behind the greatest residual soil water, followed by where crops or pastures had been brown manured, cut for hay or grazed. The least amount of water was left behind when break crops were harvested for grain. Whether differences in soil water established at the end of a growing season were subsequently maintained for the benefit of the next crop sown in the following autumn was largely influenced by summer rainfall.

Fallow management can also impact on N mineralisation. Experiments in the GRDC Water Use Efficiency initiative demonstrated that if summer fallow weeds are allowed to grow, they reduce mineral N available to the next crop by 1.5 kg N/ha for every 1 mm of water they use (Hunt et al. 2013). Therefore, a well-managed fallow can improve both soil water and N availability.

Once you access the BCMG on the FarmLink website (http://www.farmlink.com.au/project/crop-sequencing) reference the Table of Contents for regional specific trial results relating to nitrogen management.

Managing disease with break crops

Diverse crop sequences are needed to reduce the risk of root and foliar crop disease incidence. PreDicta B tests can be used to measure the presence of soil borne pathogens that can damage wheat. Seasonal conditions will determine whether these pathogens build up to high enough numbers to be for disease to be expressed. For example, from 2010-2015, of more than 25 break crop trials, only two trials had detectable disease incidence. One was the irrigated trial at Kerang, Vic which had crown rot. In this case, it took only one break crop to control the disease. The other was at Mildura where Rhizoctonia was present. In this case, disease inoculum was seen to increase once the rotation was returned to the wheat phase; inoculum levels were lowest after canola treatments. Crop rotation is equally important for break crop species and where seasonal conditions are conducive to disease it is important that preventative strategies (e.g. application of fungicides) are put in place to minimise crop biomass and yield loss.

Take Home Messages

The results from experimental comparisons of crop sequences of at least two and three years' length undertaken over the last five years in the SE Australian cropping belt were consistent with findings from previous local and global research that has demonstrated that sequences including break crops tend to be more productive than continuous wheat.

Due to the rising populations of herbicide resistant weeds, the potential break crop benefit is becoming increasingly important as the cost of controlling these weeds in cereals is progressively becoming more expensive and less effective over time. However, the flexibility of break crops extends beyond herbicide use, and includes an array of possible end uses. This allows for greater versatility in a range of season types with varying rainfall.

Key conclusions derived from five years of study were:

1. Given the grain prices and growing seasons experienced between 2010 and 2015, break crops were as profitable, and in many cases more profitable, than wheat.

2. Cropping sequences that include at least one break crop tend to be more productive and profitable than continuous wheat when using best management practices.

3. Controlling herbicide-resistant grass weeds in continuous cereal crops was more expensive and less effective than alternative options available in break crops.

4. Wheat grain yield can be expected to be reduced by around 0.5 t/ha for every tonne of in-crop grass dry matter present in spring.

5. In the presence of a high density of herbicide resistant ryegrass a 'single break' was not adequate to reduce weed seedbanks and subsequent in-crop weed competition. 'Double breaks' (two broad leaf break crops, or break crop - cereal hay sequence) reduced ryegrass seedbank numbers to manageable levels and were amongst the most profitable sequences.

6. Legumes commonly fix between 15-20 kg shoot N/ha for every tonne of shoot dry matter grown.

7. Net inputs of fixed N (i.e. total amounts of N fixed – N removed or lost) tended to be greater for brown manure crops and pasture legumes than pulses grown for grain because of the large amounts of N exported from the paddock in high-protein grain.

8. Around 20% of commercial pulse crops and pastures may be experiencing constraints to N fixation.

9. Soil mineral N measured in April tended to be similar following wheat and canola crops, but could be 40 or 90 kg N/ha greater than after wheat where a legume had been grown for grain or brown manure; respectively.

10. Estimates of apparent net mineralisation over the summer fallow represented on average the equivalent of 0.13 kg N/ha per mm rainfall, 9 kg N per tonne stubble residue dry matter (DM), or 28% of the total N estimated to be remaining in above- and below-ground legume residues at the end of the previous growing season.

11. The efficiency of recovery of residual legume N by wheat (around 30%) tended to be lower than top-dressed fertiliser N applied at stem elongation just prior to the peak period of crop N demand (60%), increased soil N availability can persist for several years after a legume, and since less legume N is lost from the system, legumes ultimately contribute to the long-term organic fertility of soils.

12. The flexibility of break crops extends beyond herbicide use, and includes an array of possible

end uses. This allows for great versatility under a range of season types with varying rainfall.

13. Break crops can reduce the cost and risk of cereal production.

Unfortunately, no firm conclusions could be drawn on the use of break crops as a strategy to control cereal diseases since disease was evident in only two of the 25 experiments and on-farm trials undertaken during the project.

Acknowledgements

We thank GRDC for financial support to undertake the collaboration with FarmLink. We are indebted to members of FarmLink and key local agribusiness consultants for their input into project experimentation. All farmers who provided land for trials are gratefully acknowledged.

Cited Publications

Angus JF, Kirkegaard JA, Hunt JR, Ryan MH, Ohlander L, Peoples MB (2015) Break crops and rotations for wheat. Crop & Pasture Science 66: 523-552.

Hunt JR, Browne C, McBeath TM, Verburg K, Craig S, Whitbread A M (2013). "Summer fallow weed control and residue management impacts on winter crop yield through soil water and N accumulation in a winter-dominant, low rainfall region of southern Australia." Crop & Pasture Science 64: 922-934.

Report Two

Break crop research with FarmLink to manage grass weeds

Report author/s – Antony D Swan, Laura Goward and Mark B Peoples (CSIRO Agriculture and Food, Canberra, ACT); Tony Pratt and Kellie Jones (FarmLink), GRDC Project - CSP00146

Introduction

There is substantial evidence indicating wide-spread resistance or partial resistance of annual ryegrass (ARG; Lolium rigidum Gaudin) to a wide range of herbicide groups across south eastern Australia. Consultation with FarmLink members and agribusiness collaborators identified difficulties in managing grass weeds as a major constraint to wheat production, and the primary driver of decisions to grow broadleaf break crops.

Can a break crop be as profitable as a cereal?

Eurongilly Exp 1

In 2012, an on-farm break crop experiment was established in a paddock near Eurongilly that had been identified as having a herbicide-resistant ARG population. The most profitable crops were RR and TT canola which returned grain yields and gross margins of 3.5t/ha (GM =$1259/ha) and 3t/ha (GM = $1166/ha), respectively. The next most profitable crops were lupins (grown for grain) @ $683/ha (yield = 3.1t/ha), wheat (High input) @ $257/ha (yield = 3.2t/ha), wheat (Low input) @ $250/ha (yield = 2.0 t/ha), with the brown manure or fallow treatments having negative returns (-$45 to -$250/ha). It was shown that in the presence of a high weed burden, there were multiple broadleaf options that were more profitable than wheat in a single year.

This experiment, also aimed to test whether or not you can 'buy your way out of needing a break crop' in the presence of a high weed burden. In addition to the standard herbide treatments used to control grasses in wheat (nominated as 'low' input), a 'high' input wheat treatment was included in the design along with various broadleaf crops grown for grain or brown manure (Bm), and a fallow treatment. It was found that using the latest and most effective ryegrass control options in wheat was very expensive relative to those used in the other treatments. See Table 1 below to compare the costs of the herbicides alone used to control ryegrass.

Eurongilly Experiment 2

In 2013 a second trial was established on another farm with a herbicide-resistant AGR population. The wheat yield in high input treatment represented about twice the canola yield, but was considerably lower in the wheat low input treatment due to competition with ARG. The lupin-grain crop proved to be the most profitable crop with a profit/cost ratio of 2.5 (profit of $2.50 for each $1 spent). Nitrogen was applied to the wheat at rates of 174 and 49 kgN/ha (high and low inputs; respectively) and to the canola at 196 and 98 kgN/ha (high and low inputs; respectively). The high rates of N reduced the gross margin in both the canola and wheat high input treatments compared to lupin in Experiment 2, or the canola and wheat treatments

Crop & Input - Year 1	Ryegrass Control Costs ($/ha)
Wheat (Low)	$56
Wheat (High)	$142
Lupin (Grain)	$65
TT Canola (Grain)	$62
RR Canola (Grain)	$46
Pea Bm	$66
Fallow	$35

Table 1: Ryegrass Herbicide Costs at Eurongilly Exp 1 in 2012

described above in Experiment 1. As the canola price was similar between 2012 and 2013 ($490/t and $476/t), the main difference in gross margin related to a lower crop yield in Experiment 2. In this case, the break crop (lupins) was still more profitable than wheat.

Crop & input	Grain yield 2013 (t/ha)	Gross income[a] 2013 (t/ha)	Variable costs 2013 (t/ha)	Gross margin 2013 (t/ha)	Profit / cost ratio
Lupin - grain	2.6	$1040	$299	$741	2.5
Wheat - high	4.0 (14.5)	$1110	$756	$354	0.5
Canola - low	1.6	$781	$442	$339	0.8
Wheat - low	2.2 (12.2)	$556	$289	$300	1.1
Canola - high	1.9	$872	$711	$161	0.2
Fallow	0	$0	$72	-$72	-1.0
Peas Bm	0	$0	$204	-$204	-1.0

Table 2: Comparisons of grain yield, income, variable costs, and gross margins of wheat and break crops grown for grain or brown manure (Bm) or fallow from Year 1 of Eurongilly Expt 2. Crops arranged in order of descending gross margin. [a] Note: Grain prices used in the calculations were current at the around the time of harvest and assumed delivery to Junee except RR canola to Stockinbingal (extra freight cost = $5/t). () brackets indicate grain % protein.

Are sequences that include break crops more profitable than continuous wheat?

Eurongilly Exp 1

In the presence of a high weed burden herbicide-resistant annual ryegrass (ARG), sequence profitability was closely related to the efficacy of weed control. Herbicides used to control the ryegrass population were a major input cost and the effectiveness of the management decisions used for the different sequences impacted the year-to-year profitability.

Break Type	Crop x Input 2012	Crop x Input 2013	Grain Yield 2012	Gross Margin 2012	Grain Yield 2013	Gross Margin 2013	Grain Yield 2014	Gross Margin 2014	Avg 3 yr Gross Margin
			(t/ha)	($/ha)	(t/ha)	($/ha)	(t/ha)	($/ha)	($/ha/yr)
S	RR Canola	Wheat (H)	3.5	$1,259	4.7	$533	4.5	$858	$883
S	RR Canola	Wheat (L)	3.5	$1,259	2.8	$489	4.1	$788	$845
S	TT Canola	Wheat (L)	3.0	$1,166	4.7	$537	3.8	$828	$844
D	RR Canola	Wheat (Hay)	3.5	$1,259	7.4DM	$533	3.7	$709	$834
D	Lupin grain	RR Canola	3.1	$683	3.2	$967	4.1	$721	$790
S	Lupin grain	Wheat (H)	3.1	$683	5.1	$726	3.9	$863	$757
D	Fallow	RR Canola	nil	-$45	3.6	$1,159	3.7	$696	$603
Nil	Wheat (H)	Wheat (H)	3.2	$257	5.0	$642	4.2	$855	$585
D	Lupin Bm	RR Canola	nil	-169	3.6	$1,146	4.1	$680	$552
S	Pea Bm	Wheat (H)	5.2DM	-$160	5.0	$707	4.3	$911	$486
S	Pea Bm	Wheat (L)	5.2DM	-$160	3.0	$525	3.8	$826	$397
Nil	Wheat (L)	Wheat (L)	2.0	$250	1.5	$170	3.3	$745	$388

Table 3: Grain yield, annual Gross Margin and 3-year average Gross Margin at Eurongilly Exp 1.

In year 1 the most profitable crops were RR and TT canola which returned gross margins of =$1259/ha (yield = 3.5t/ha), and $1166/ha (3t/ha), respectively. The next most profitable crops were lupins at $683/ha (3.1t/ha), high input wheat at $257/ha (3.2t/ha), the low input wheat at $250/ha (2.0 t/ha), with the brown manure or fallow treatments all having negative returns (-$45 to -$250/ha).

In year 2, the treatments with the highest gross margin were canola following fallow or brown manure treatments (> $1000/ha, grain yield avg = 3.5t/ha) with canola following wheat (H) or lupins returning ~$900/ha (3.2t/ha). Over the 3 years, the most profitable sequence was RR canola - wheat (H) - wheat, with an average GM of $883/ha/yr. Sequences with the highest average annual gross margins >$800/ha/yr were treatments that had canola (RR or TT) in year 1, with the next most profitable group having grain lupins in year 1 or canola year 2 (> $600/ha). The third group included the use of fallow, with the final group involving sequences with Bm crops followed by wheat (H or L).

Overall it was found that sequences that involved either canola or a spray topped lupin grain crop in year 1 followed by cereal hay or RoundupReady (RR) canola in year 2 provided the highest gross margins and significantly reduced ARG seed bank over the 3 year crop sequence. Cheaper double break combinations using a fallow or pulse Bm in year 1 followed by RR canola in year 2 resulted in lower gross margins, but were the most effective in reducing the seed bank. Continous low input wheat had the lowest gross margin and the least ryegrass control.

Eurongilly Exp 2

The lupin grain yield in 2013 of 2.6/ha resulted in the highest gross margin with a profit: cost ratio of 2.5:1. The wheat (H) grain yield in 2013 was approximately double the wheat (L) yields due to reduced competition from ARG and also double the canola (H) grain yield. However, the wheat (H) and canola (H) grain yields were lower than expected due to the dry October (14mm) and November (7mm) rainfall and high nitrogen inputs. These lower yields combined with the high inputs of nitrogen of 196kgN/ha in both the wheat (H) and canola (H) significantly reduced their respective gross margins in 2013.

The wheat-hay treatment was significantly the most profitable in 2014 with gross margins being two to three times higher than any other treatment. Wheat yield in both the high and low treatments in 2014 were similar at 2.7 and 2.6 t/ha respectively but the protein concentrations were significantly higher in the wheat (H) treatment, 16.4% compared to 14.8% in the wheat (L).

Wheat yields were significantly lower than observed in Exp 1 in 2013. The low wheat yields and high protein concentrations were due to the crop suffering from stem frost (40% stems affected) and head frost (10%), which reduced water and carbohydrate transportation and reduced the plant's ability to fill grain. This resulted in screenings of between 14% to 19% in the wheat (L) and wheat (H) treatments respectively. This had a significant negative effect on the wheat gross margins in 2014, especially in the wheat (H) treatment due to the high nitrogen inputs. The RR canola grain yields in 2014 were also lower than in Exp 1 in 2013 (1.7-1.9t/ha c.f. 3t/ha in Exp 1) resulting in low gross margins due to high input costs of herbicides and nitrogen.

At Eurongilly Exp 2, the top six sequences in terms of average annual 3 year gross margins included either the hay treatment in 2014 or lupin-grain in 2013 (due to their yearly high gross margins). If we compare the average three year gross margin in experiment 1 and 2, the first main difference is that the canola grain yields and associated gross margins were significantly lower in both the first and second year in crop sequences at Eurongilly experiment 2. The second difference is that the average 3 year gross margin in any sequence that included a wheat (H) treatment, especially in 2014 was very unprofitable. The performance of the low input wheat sequence (Wheat (L) – Wheat (L)) relative to the other sequences in experiment 2 was due to the high costs associated with unused N fertiliser used in high input wheat and canola treatments. The brown manure treatments followed by wheat (H) were the least profitable sequences in both experiments.

Crop x Input 2013	Crop x Input 2014	Grain yield 2013	Gross Margin 2013	Grain yield 2014	Gross Margin 2014	Grain yield 2015	Gross Margin 2015	Average 3 yr GM
		(t/ha)	($/ha)	(t/ha)	($/ha)	(t/ha)	($/ha)	($/ha/yr)
TT canola	Hay	1.6	$348	7.9	$933	3.7	$638	**$640**
RT canola	Hay	1.6	$40	8.1	$962	3.9	$708	**$568**
RR canola	Hay	1.9	$171	7.9	$937	4.3	$587	**$564**
Lupins	Wheat (L)	2.6	$724	2.1	$222	3.4	$696	**$550**
Lupins	Canola	2.6	$724	1.7	$157	4.6	$753	**$543**
Lupins	Wheat (H)	2.6	$724	2.6	$42	4.1	$697	**$487**
Wheat (H)	Wheat (L)	4.0	$359	2.7	$369	3.9	$631	**$455**
TT canola	Wheat (L)	1.6	$348	2.5	$274	4.0	$605	**$408**
Wheat (H)	Canola	4.0	$359	1.7	$163	4.1	$663	**$393**
Wheat (H)	Wheat (H)	4.0	$359	2.8	$118	4.3	$612	**$362**
RT canola	Wheat (L)	1.6	$40	2.5	$307	4.2	$733	**$362**
TT canola	Wheat (H)	1.6	$348	2.7	$23	4.4	$681	**$351**
RR canola	Wheat (L)	1.9	$171	2.5	$309	4.5	$566	**$350**
Wheat (L)	Wheat (L)	2.2	$318	2.1	$129	4.1	$547	**$331**
Wheat (L)	Canola	2.2	$318	1.7	$82	4.4	$550	**$316**
Fallow	Canola	Nil DM	-$72	1.9	$285	4.8	$705	**$305**
Pea Bm	Wheat (L)	5.7DM	-$204	2.9	$421	3.9	$695	**$305**
Fallow	Wheat (L)	Nil DM	-$72	3.0	$442	4.3	$519	**$298**
Wheat (L)	Wheat (H)	2.2	$318	2.7	-$18	3.6	$586	**$297**
RT canola	Wheat (H)	1.6	$40	2.7	$53	4.5	$745	**$279**
RR canola	Wheat (H)	1.9	$171	2.6	$36	4.1	$609	**$271**
Fallow	Wheat (H)	Nil DM	-$72	2.7	$115	4.0	$715	**$253**
Pea Bm	Canola	5.7DM	-$204	1.9	$242	4.7	$634	**$223**
Pea Bm	Wheat (H)	5.7DM	-$204	2.8	$114	4.2	$654	**$188**

Table 4: Grain yield, annual gross margin and Average 3 year Gross Margin 2013-15 at Eurongilly Exp 2.

Can a weed problem be managed more cost effectively with break crops than in a continuous cereal system?

Eurongilly Exp 1

This section describes the effectiveness at reducing seed banks of herbicide resistant annual ryegrass (ARG) through the use of different inputs and herbicides applied to canola, pulse legumes, or wheat crops.

ARG panicles per m2 in the spring year 1 in untreated areas were 1,042 (with each panicle containing in the order of 30 seeds), significantly more than the low input wheat with 534 panicles/m2. By the autumn of year 2, there was a significant three-fold increase in ARG seed bank populations (5492 seeds/m2) following low input wheat (L) and by autumn year 3 a further significant 2.5 fold increase (13148 seed/m2) after a second wheat (L) treatment. The expensive herbicide costs ($142/ha) associated with consecutive high input wheat treatments resulted in a significant reduction in seed bank by November 2014 (366 plants/m2), but was not as effective as sequences involving break crops or a fallow. The most effective ARG control was achieved by fallow, pulse Bm or RR canola (see Table below). By spring in year 2, there were significant differences in panicles/m2 with four distinct categories (0-8, 14-71, 192-388 & >643 panicles/m2). Main year 2 treatment effects continued into year 3 with panicles numbers from fewest to most in order of: canola < hay = wheat (H) < wheat (L), and year 1 effects: fallow < pulses < canola = wheat (H) < wheat (L). Interactions were categorised into groups of (0-30, 60-166, 199-370, >536 panicles/m2). Generally, double break sequences or those where high input (H) wheat treatments were grown following treatments with bare soil or less stubble from year 1 had significantly

Crop x Input 2012	Crop x Input 2013	Ryegrass panicles Nov 2012	SEEDBANK March 2013	Ryegrass panicles Nov 2013	SEEDBANK March 2014	Ryegrass panicles Nov 2014	SEEDBANK March 2015	Average Annual 3yr GM
(Year 1)	**(Year 2)**	**(panicles/m^2)**	**(seeds/m^2)**	**(panicles/m^2)**	**(seeds/m^2)**	**(panicles/m^2)**	**(seeds/m^2)**	**($/ha/yr)**
Fallow	Canola	0 (NM)^	290	0	NM	2	56	$603
Lupin grain	Canola	43*	748	0	196	6	63	$790
Lupin BM	Canola	0 (NM)^	152	0	NM	1	110	$552
Fallow	Wheat (H)	0 (NM)^	290	2	NM	10	118	$539
RR Canola	Wheat (Hay)	0	208	0 (537)^	124	23	122	$834
Pea BM	Canola	0 (NM)^	464	0	210	4	142	$513
Lupin grain	Wheat (H)	43*	748	8	312	19	148	$757
Pea BM	Wheat (H)	0 (NM)^	464	2	496	14	162	$486
RR Canola	Wheat (H)	0	208	15	381	29	219	$883
TT Canola	Wheat (H)	32	505	14	NM	82	252	$844
Wheat (H)	Canola	78	777	0	259	20	267	$636
Lupin BM	Wheat (H)	0 (NM)	152	2	NM	11	279	$463
TT Canola	Wheat (Hay)	32	505	0 (790)^	NM	23	300	$844
Wheat (L)	Canola	504	5492	0	797	22	332	$582
Wheat (H)	Wheat (H)	78	777	29	1379	60	366	$585
Wheat (L)	Wheat (H)	504	5492	71	3412	121	523	$537
Fallow	Wheat (L)	0 (NM)^	290	56	NM	100	970	$530
Lupin BM	Wheat (L)	0 (NM)^	152	192	NM	308	1105	$419
Lupin grain	Wheat (L)	43*	748	200	6614	122	1167	$715
Wheat (H)	Wheat (L)	78	777	294	5508	147	2158	$513
TT Canola	Wheat (L)	32	505	383	NM	229	2222	$800
RR Canola	Wheat (L)	0	208	388	7770	200	2387	$845
Pea BM	Wheat (L)	0 (NM)^	464	237	7413	157	3118	$397
Wheat (L)	Wheat (L)	504	5492	898	13148	943	3140	$388
P value (2012)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
P value (2013)			NA	<0.001	<0.001	<0.001	<0.001	
P value (interaction)			NA	0.004	0.105	<0.001	0.699	

Table 5: Average annual gross margin over 3 years compared to ryegrass seedbank (April 2013, 2014, 2015) and ryegrass panicle number (November 2012-2014) in Exp 1 at Eurongilly, NSW.

Crop 2012 pre-treatments are arranged in order of descending SEEDBANK March 2015 seed counts.

**Lupins spray topped in Nov 2012 prior to ryegrass seed maturity. ^Ryegrass panicles estimated at zero in 2012 and 2013 due to either spraying or cutting of hay prior to seed set*

NM Not measured

fewer panicles.

In the presence of a high population of herbicide-resistant ARG, sequences that included a break crop were more profitable compared to continuous wheat (H or L). Canola was consistently the most profitable break crop, largely due to the high returns from canola itself, but legume grain crops were profitable and provided additional N for crops in year 2. Although the TT canola / wheat (H) sequence was profitable, it was not as effective at reducing the ARG seed bank and any sequence with wheat (L) resulted in an increase in ryegrass numbers. Break crops or fallow provided cheaper and more effective ARG control options. Two consecutive years of complete ARG control were required to reduce seed banks to managable levels. The most profitable double break sequences were RR canola followed by a cereal hay or grain lupins followed by RR canola with these sequences also very effective at reducing the seed bank. Sequences involving fallows and brown manures reduced production risk in subsequent years due to enhanced yield in the following wheat crops, but were not as profitable as continuous cropping.

Crop x Input 2013	Crop x Input 2014	Seedbank March 2013	Ryegrass panicles Nov 2013	Seedbank March 2014	Ryegrass panicles Nov 2014	Seedbank March 2015	Ryegrass panicles Nov 2015	Seedbank Feb 2016
Year 1	Year 2	seeds/m^2	panicles/m^2	seeds/m^2	panicles/m^2	seeds/m^2	panicles/m^2	seeds/m^2
Fallow	Canola	2775	0	649	1	408	22	37
RT Canola	Wheat (H)	2775	0	900	2	375	4	58
RR Canola	Wheat (H)	2775	1	670	2	350	3	59
Peas Bm	Canola	2775	108*	897	1	104	10	106
Wheat (H)	Canola	2775	30	1337	1	212	5	115
RR Canola	Hay	2775	1	670	99^	457	15	132
RT Canola	Hay	2775	0	900	78^	197	11	145
Peas Bm	Wheat (H)	2775	108*	897	3	309	8	218
Fallow	Wheat (H)	2775	0	649	2	226	5	223
TT Canola	Hay	2775	193	3358	631^	1004	47	347
Wheat (H)	Wheat (H)	2775	30	1337	6	593	23	363
Peas Bm	Wheat (L)	2775	108*	897	52	729	26	437
RT Canola	Wheat (L)	2775	0	900	23	593	20	520
RR Canola	Wheat (L)	2775	1	670	20	819	10	597
Lupins	Canola	2775	462	4505	1	892	46	638
Fallow	Wheat (L)	2775	0	649	44	1112	39	653
Lupins	Wheat (H)	2775	462	4505	47	1129	61	711
TT Canola	Wheat (H)	2775	193	3358	70	1019	51	826
Wheat (H)	Wheat (L)	2775	30	1337	173	2722	104	1316
Wheat (H)	Canola	2775	534	6748	1	1507	133	1477
Wheat (H)	Wheat (H)	2775	534	6748	130	3216	126	1567
Wheat (L)	Wheat (L)	2775	534	6748	532	4930	167	1693
TT Canola	Wheat (L)	2775	193	3358	166	3415	108	1720
Lupins	Wheat (L)	2775	462	4505	537	4251	152	1951
P value (2013)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P value (2014)			NA	NA	<0.001	<0.001	<0.001	<0.001
P value (interaction)			NA	NA	<0.001	0.025	0.037	0.005

* Brown manure treatment was killed prior to ARG setting seed. Effectively zero ryegrass seedset.

^ Hay treatment was cut for hay prior to ARG setting seed. Followup spray with glyphosate.

Lupins were not spray topped in 2013

Table 6: Average annual ryegrass seedbank (March 2013, 2014, 2015, Feb 2016) and ryegrass panicles (Nov 2013, 23014, 2015)

In both Eurongilly Experiments in 2013, pre- and post-emergent herbicide treatments combined with higher N and P nutrition and increased wheat density (150 plants/m2 cf 75 plants/m2) in the high input wheat treatments resulted in good control of the annual ryegrass compared to the low input wheat treatment (30 panicles/m2 cf 534 panicles/m2 and 0.1 t/ha cf 3.5 t/ha ryegrass DM). The effect of the high and low input treatments on ryegrass control and ultimately wheat grain yield can be seen in the following Figure. The high input treatment (open symbols) significantly reduced ryegrass DM and increased wheat grain yield. By contrast there was higher ryegrass DM under the low input treatments (closed symbols) resulting in a reduction in wheat grain yield of 450 kg/ha for every 1 t/ha of ryegrass DM regardless of whether the 2013 wheat followed a break crop, brown manure, fallow or wheat in 2012 (see also weeds rules-of-thumb in Appendix E in BCMG).

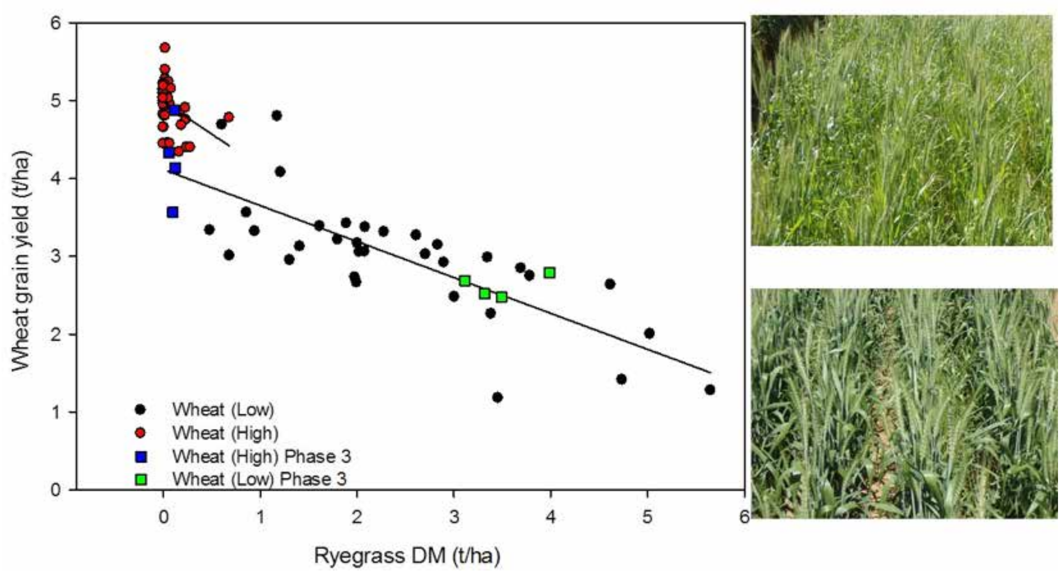


Figure 1. Relationship between ryegrass dry matter (DM) and wheat grain yield following high and low input treatments in wheat at two locations at Eurongilly, NSW

Take Home Messages

1. Wheat grain yield can be expected to be reduced by around 0.5 t/ha for every tonne of in-crop grass weed dry matter present in spring.

2. Wheat following break crops were consistently more profitable than wheat on wheat. This in part reflected the relatively low wheat grain prices experienced during experimentation, and the high returns for canola, but was also related to the efficacy and costs of ryegrass control.

3. Growing pulses for brown manure (Bm) lost money in the year that they were grown, but achieved excellent weed control, provided high inputs of N and a residual carry-over of soil water, and more ground cover than if they had been cut for hay.

4. In the presence of a high density of herbicide resistant ryegrass a 'single break' was not adequate to reduce weed seedbanks and subsequent in-crop weed competition. 'Double breaks' (two broad leaf break crops, or break crop - cereal hay sequence) reduced ryegrass seedbank numbers to manageable levels and were amongst the most profitable sequences.

5. Break crop choice and selection should be based on individual farm management and ability to manage the various break crops options in the rotation. If growers remain flexible in break crop and end-use decisions, and make suitable choices, risks associated with producing them can be greatly reduced.

6. A cropping program that includes break crops is likely to be more sustainable in terms of N inputs and risk of build-up of root diseases than continuous wheat, and provided cheaper, more effective strategies for controlling herbicide resistant grass weeds.

Acknowledgements

We thank GRDC for financial support to undertake the collaboration with FarmLink. We are indebted to members of FarmLink and key local agribusiness consultants for their input into project experimentation. All farmers who provided land for trials are gratefully acknowledged.

04

FarmLink Research Report 2016

Satellite Flock at TAIC

Project Partners

FarmLink, MLA, Sheep CRC, Clear View Consulting

Funding Partners

MLA

Trial Site Location

Temora Agricultural Innovation Centre

Report Author

Murray Long

Introduction

The Australian sheep industry today is vastly different to the one we all remember 20 years ago. The use of technology and genetic benchmarking has made extensive contributions into both lamb production and processing resulting in the industry leading the world in genetic gains. The use of DNA in predicting a whole range of traits; some we have previously been able to measure, some we have previously not be able to evaluate, has been instrumental in achieving this status through the findings from the Sheep CRC research program. The recent granting of a contract to run a Satellite Flock at TAIC is crucial in ensuring the ongoing relevance of these findings.

The use of DNA to predict an individual animal's performance and Meat Eating Quality (MEQ) traits has been developed through the generation of massive amounts of data from seven resource flock sites around Australia. (This has now been reduced to just two main sites, Katanning in Western Australia and Kirby at Armidale, New South Wales). The cost to maintain this reference population to continually update the genomic correlations has been a main concern for most within industry. The development of the Satellite Flock at TAIC is the next step in ensuring that the gains made over the past nine years continue to provide accurate genomic information to the sheep industry and a blueprint for future flocks.

The flock at TAIC is much more than just another sheep flock producing lambs. It will provide a template as to how the industry continues to validate the information developed to date and ensure that the Australian sheep industry continues to lead the globe in genetic gains.

Late in 2015, the contract was awarded to run an MLA Satellite Flock at TAIC which involved the artificial insemination of 200 ewes to 61 sires comprising of predominately Poll Dorset and White Suffolk genetics with a few Southdown and Suffolk sires. These ewes lambed early July which initiated a whole range of measurements and data recording on each lamb including collection of DNA which was then analysed against recorded data. When the lightest lambs reached saleable weights, they were sent as an entire group to JBS Bordertown where further measurements relating to carcase specifications were conducted including the collection of loin samples for the calculation of MEQ traits such as intra muscular fat and tenderness as well as Iron, omega 3 and Zinc levels. These lambs were also evaluated with the use of a machine (DEXA) to measure in-line the intra muscular fat content and lean meat yield of the lamb carcase. The cost to gather this level of information is high but essential if the relationships between DNA and the measured traits are to be maintained.

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 SNPs. In simple terms, the presence or absence of these SNPs determines the effect those SNPs have on the expression of that trait. DNA is collected on a blood card and sent to laboratories in America 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 Australian Sheep Breeding Values (ASBVs) are expressed.

The process of constantly re-evaluating the DNA correlations is essential as they begin to lose accuracy after 2-3 generations due to the introduction of new genetic lines and they cannot be cross-referenced across breeds. The flock at TAIC is the first prototype of how we may continue to update the database into the future. Dedicated seedstock producers already provide much of the information needed through DNA testing their sires and collecting a lot of phenotypic information such as wool measurements, weights, muscle and fat scan information and reproduction data. The need for a specialist flock such as the satellite flock is required to collect additional information on the hard to measure traits such as MEQ and Lean Meat Yield (LMY) and provide a central point where a large number of sires can be evaluated under the same conditions. Not only will the flock at TAIC provide the necessary genomic information, but allow an evaluation of how to manage and make best use of smaller flocks to ensure maximum gain from what is essentially a commercial operation. The flocks at Katanning and Kirby are much larger and specialist research flocks designed to provide the bulk of the information; going forward can satellite flocks either supplement or potentially replace the need for expensive larger flocks. As the processing of the lamb carcase samples are the main expense, how can we make best use of available resources into the future?

Results

Scanning of the ewes in April showed a conception rate of around 60% for the AI program close to average for a typical insemination program on White Suffolk ewes. The lambs were dropped in early July, the middle of the wettest period for the year and despite the cold miserable conditions, lamb survival was acceptable leading to 165 lambs born from the 119 ewes scanned in lamb. Embryo loss between scanning and lambing was at the higher end of what is usually expected with 18.7% of scanned embryos lost before lambing. Industry average is around 15%. Due to the wet weather and the expected problems, a few losses were incurred at lambing resulting in 140 lambs making it through to weaning.

These lambs were grown in Lucerne pasture at TAIC and achieved average growth rates above 400 Gms/day from birth to four months of age, plateauing in the fifth month just prior to sale time.

	28th Aug	16th Oct	10th Nov	5th Dec
Average Weight (Kg)	26.1	44.8	55.4	63.3
Growth Rate (Gms/day)	407	443	425	316

Weight Class Summary		LMB		
	Range	Bodies	%	Tot Wgt
	16-17.99kg	2.0	1.4	33.9
	18-19.99kg	4.0	2.8	78.8
	20-21.99kg	7.0	5.0	144.8
	22-23.99kg	8.0	5.7	185.6
	24-25.99kg	14.0	10.1	351.4
	26-29.99kg	48.0	34.7	1347.3
	30-31.99kg	16.0	11.5	498.1
	32kg&Over	39.0	28.8	1360.1
	Total:	**138.0**	**100.0**	**4000.0**
Fat Class Summary		**LMB**		
	Range	**Bodies**	**%**	**Tot Wgt**
	Fat Class 2	30.0	21.7	674.6
	Fat Class 3	54.0	39.1	1529.5
	Fat Class 4	33.0	23.9	1050.4
	Fat Class 5	21.0	15.3	745.5
	Total:	**138.0**	**100.0**	**4000.0**

Obviously as a prime lamb producer, many of these lambs would have been sold prior to reaching close to 40Kg dressed weight but as the processor was located at Bordertown and being a research flock, it was an distinct advantage to have all lambs slaughtered at the one time. These were the heaviest and fastest growing lambs ever recorded at any of the reference flock sites, consequently creating a lot of interest at many levels of research. Due to the fast growth rates achieved, there is interest as to whether the usual relationships with IMF will change as IMF also has an age component to its development. Younger animals usually do not have as much IMF but are usually more tender. Will the correlation between IMF and tenderness be altered due to the fast growth rates achieved?

The heaviest lambs at sale time were close to 80Kg at five months of age with almost all exceeding the 40Kg liveweight level. Only at the heaviest carcase weights were there any Fat Score 5 lambs. Muscle and fat scanning conducted just prior to sale will allow an accurate level of performance to be calculated and given the ewes have full pedigree and performance records, this data can be evaluated against the DNA collected and analysed for each lamb.

In 2017, 300 ewes will be inseminated using the same mix of breeds plus some Dorper and White Dorper genetics to allow industry to build a Genomic data base for those breeds. Once again a vast range of measurements will be conducted on the progeny to allow accurate analysis of genomic information against actual recorded performance. Depending on the results from this year's analysis, slaughter timing may be modified this year to avoid very heavy lambs.

Discussion

So why is the information so valuable to the average lamb producer?

There is little doubt the genetic gains we have made in a relatively short time have changed the suitability to market of the sheep we are now breeding. From the 16-20 Kg lambs, fat score five lambs that our parents produced, we are now able to turn off lambs at much higher carcase weights with lower fat score values, a result of focussing on specific selection for individual traits. The same applies to the wool industry where the relationship between micron and fleece weight has been broken to allow increasing fleece weights without sacrificing micron. As we have increased growth rates across all breeds, we have been able to control the expected increase in birth weights to ensure our animal welfare and management issues are not compromised. All this, and much more, has been a result of the use of performance benchmarking through the use of ASBVs generated by Sheep Genetics.

However, the generation of these ASBVs has been limited to those traits that breeders can realistically measure and record. The investigation of using DNA technology by the Sheep CRC has transformed not only the accuracy of the breeding values but enabled the evaluation of a whole new range of traits that previously have not been able to be measured or have been difficult to evaluate. The area of MEQ is the one area that has been the main focus and there are others that will come into relevance as further investigation continues. The industry push for higher growth rates, leaner genetics, more muscle and/or increased fleece weights has compromised MEQ so as an industry we need to ensure eating quality is at least maintained at the current level.

No longer are we resigned to taking the word of a ram supplier as to the merit of the sheep we are considering as replacement sires. There is now the technology through both ASBVs and DNA (Genomics) to accurately predict the performance and genetic merit of almost all sheep from every breed in the Australian Sheep industry. Sheep producers can now select, with confidence, replacement sires for traits that are specific to their improving production within their enterprise.

There is also a new area of whole flock genomic profiling that will enable commercial producers to evaluate the current performance of their flock simply by testing a sub sample (20) of the ewes using Genomics. This will enable better matching of sires to ensure that any areas where performance requires change can be addressed by selection of specific sires to increase performance in the desired traits.

The use of Genomics has fast tracked the genetic gains the Australian sheep industry has been making and in the area of meat eating quality (MEQ), both processors and retailers are watching closely and developing strategies to cater for the opportunity to grade lamb carcases for MEQ. The importance of continually updating the correlations between the actual performance or MEQ and the prediction derived from the DNA is crucial in ensuring that what we predict from the Genomic prediction is accurate. For most traits, such as growth etc., the genomic data is combined with the actual measured phenotypic data to generate an ASBV, for traits such a MEQ it relies much heavier on the actual DNA prediction with some influence from correlated traits to generate the ASBV. Flocks such as the satellite flock at TAIC will play a vital role in not only maintaining the correlations between DNA and measured traits but also, give industry direction as to how best to continue to manage these satellite flocks into the future.

05

FarmLink Research Report 2016

Impact of Condition Score on Artificial Insemination Success in White Suffolk Ewes

Project Partners

FarmLink change • adapt • prosper

mla MEAT & LIVESTOCK AUSTRALIA

SHEEPCRC

CLEAR VIEW CONSULTING

Funding Partners

mla MEAT & LIVESTOCK AUSTRALIA

Trial Site Location

Temora Agricultural Innovation Centre

Report Author

Murray Long

Introduction

The advantages of using artificial insemination (AI) to increase the genetic merit of sheep flocks is now well entrenched as the standard for many sheep producers and not restricted to just seedstock producers. The use of laparoscopic techniques has greatly increased the success of AI and therefore the economic benefits of this technology. Despite many years of understanding the processes involved, there still remains the unpredictability of the final result; that being good conception rates. A forum conducted at the 2009 White Suffolk Annual Conference in Albury, NSW, (AWSA, 2009) determined that the results gained from an AI program were as varied as the procedures that may producers employed, and what works for one program or producer, doesn't necessarily work for another. The general recommendation given is to maintain ewes in moderate condition scores (CS) and on a rising plane of nutrition both through the AI program and post AI making sure to avoid any stress on the inseminated ewes. However, there are plenty of reports where conception rates well below 50% (AWSA pers. communication) are achieved following these recommendations making the cost per lamb a significant consideration and questioning the benefits of using AI for some producers.

Method

As part of the Meat and Livestock Australia (MLA) resource flock running at the Temora Agricultural Innovation Centre (TAIC), 200 mixed age White Suffolk ewes were programmed and inseminated using laparoscopic Artificial Insemination (AI) on February 4, 2016. These ewes were programmed using CIDRs and given 2ml PMSG (Serum Gonadotrophin) after CIDR removal which was staggered to eliminate any timing effects. The ewes were assessed for condition score and weighed prior to being programmed, flushed on Lucerne for the 12 days after CIDR insertion and once inseminated, returned to a fresh stubble paddock containing self-sown, actively growing barley. Backup rams were introduced 13 days after AI.

The ewes were again assessed for condition score and body weight at pregnancy scanning (day 69 post AI). Pregnancy scanning identified foetus number (single, twin, triplet) and differentiated between those ewes pregnant to the AI program and those that failed to conceive to AI.

Results

This AI program resulted in conception rates of 60% (industry average 60-65%) and of those that conceived, 167% lambs in utero. The effect that condition score had across the whole range of criteria in determining what would be considered a successful program was substantial and surprisingly consistent across the range of condition scores measured. Given the recommendations to limit condition score to average levels leading up to AI, the results shown in Figure 1 seem to challenge the theory that high condition score ewes are counterproductive to good conception rates. There was a gradual increase in conception rates as CS values increased from CS 2-3 (57.1%) up to CS 4-5 (62.7%).

Figure 1. Influence of Condition Score on AI Conception rate.

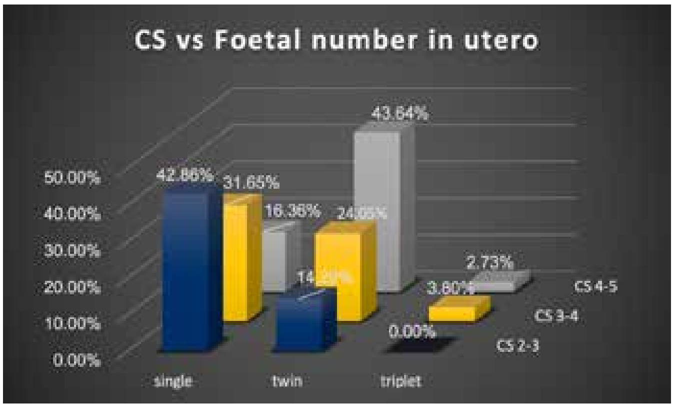


Figure 2. Influence of Condition Score on Foetal number in utero

Given that the differences in conception rates between CS 2-3 and CS 4-5 is around 5.6%, this would not be enough to recommend a shift to higher condition scores pre-AI, however it is the effect of condition score on foetal number and on consequently lambs in utero that is noteworthy as seen in Figure 2 and Figure 3.

Figure 2 indicates that as condition scores increase from CS 2-3 through to CS 4-5, the percentage of singles decreases at similar rates to the increase in percentage of twin lambs in utero. No triplets were recorded at CS 2-3. This translates to an increase in lambs in utero from 125 % (CS 2-3) to 178% (CS4-5), an additional 53% more lambs at the higher condition scores as seen in Figure 3.

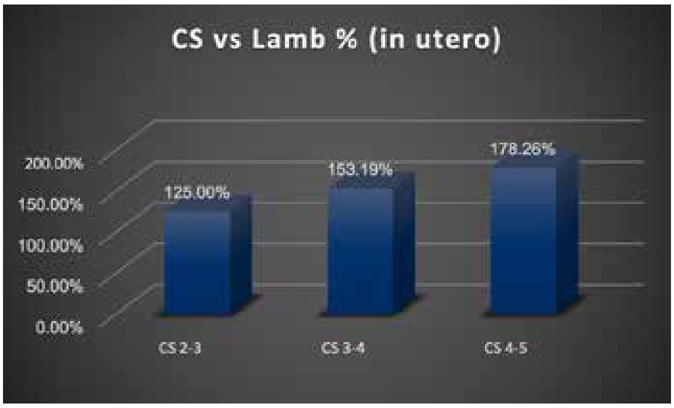


Figure 3. Influence of condition score on percentage lambs in utero

Discussion

The outcomes of this analysis only serve to add to the ambiguities surrounding the results obtained from many laparoscopic AI programs. Suggestions from the findings of the survey conducted by the South Australian Stud Merino Breeders Association (2013) indicated that CS 3-3.5 was ideal to achieving best results indicating overfat ewes ran the risk of poorer conception as a result of poor synchronisation through absorption of progesterone from the pessary by body fat. This is the same recommendation from most AI technicians and veterinarians regarding preparation of ewes for AI. The discussion around ideal condition score for AI programs is also confounded by the recommendation for natural joining to have ewes in as good a condition score as possible to achieve best results. Results from a previous trial conducted by Long (2015) found that the best results for foetal number in the same White Suffolk ewes was at CS 3-3.5 indicating a disparity between recommendations and subsequent results for the totally different conception methods. The programming of ewes for AI is markedly different to the natural mating process and therefore not surprising that there is a difference in responses to condition score.

The range of factors that can affect AI conception include maintaining body CS and weight immediately following insemination. In this trial, average CS and body weight were relatively unchanged from insemination to pregnancy scanning, CS 4.0 / 84Kg and CS 3.9 / 80Kg respectively. While there was a general correlation between CS and body weight as seen in Figure 4, there was insufficient indication that heavier ewes achieved better conception rates or more foetuses than lighter ewes. Figure 4 indicates that, for a majority of body weights, the full range of condition scores assessments are covered. Condition score, not body weight is the ideal assessment to monitor ewe condition prior to and during any AI program.

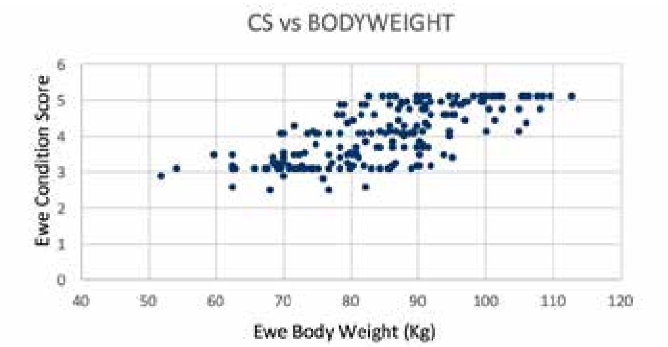


Figure 4. Relationship between condition score and body weight

The results of this trial indicate that higher condition scores resulted in better conception rates, higher percentages of multiple foetuses and consequently higher percentages of lambs in utero. However, having ewes at high condition scores can lead to difficulties for some producers in maintaining critical recommendations such as low stress levels and maintaining body weight and condition score post AI. Fatter ewes are more difficult to manage to maintain weight and condition score and if the weather turns hot, they are more likely to suffer higher levels of stress. In this trial, maximum temperatures following AI were not at extreme levels usually associated with February and all conditions regarding feed availability, shade and weather were favourable for good results. It could be argued that the safest level to have ewes would be in the CS 3-4 range and aim to maintain or increase condition score after insemination, however the results from this analysis indicate that gains in fecundity can potentially be achieved by aiming for higher condition scores leading into an AI program.

It is widely accepted that higher body condition score leads to potentially more lambs (Lifetime Wool) and the response achieved in this program fits well into their predictions. The 'trick' with AI programs is to retain the foetuses post AI, not getting the eggs fertilised. Technically all ewes are in lamb post AI given correct programming and good semen quality, it is those embryos that actually 'stick' that determines the success of the program. Potentially, ewes that are fatter create a greater risk of embryo loss and are harder to manage, especially given that most AI programs are carried out in the summer months when heat and feed shortages are more likely. Any loss of body condition produces breakdown of fat which releases ketones into the system which are detrimental to embryo survival. Reports of ketone damage has been observed in over fat ewes just through the overnight yarding of ewes prior to an AI program (pers. comm. with AI Vet.). The use of pastures such as Lucerne or high protein feeds to maintain weight causes problems with embryo retention due to ammonia in the circulatory system. The consumption of high energy feed in early pregnancy is also detrimental to embryo survival resulting in a 20% drop in pregnancy conception when compared to a maintenance ration (Parr et al, 1987). Given these scenarios, it is more likely to be management post-AI that determines the ultimate success of the program and management to achieve maximum embryo retention becomes more achievable for many producers with more moderately conditioned ewes. However, there are plenty of seedstock producers who have consistently inseminated high condition score ewes for many years with outstanding conception results.

The flushing of the ewes for a short time prior to AI has the impact of increasing potential number of multiple foetuses and is common practice in many AI programs. The report from the AWSA (2009) stated that this effect works better on ewes with lower condition score and not as effective on better conditioned ewes therefore adding some significance to the results observed in this analysis.

The variability of results across many artificial insemination programs both within and across various breeding operations however should provide a warning that a different season or different flocks provide a totally different result. The same practice across different seasons can produce totally different results for no explicable reason. In this assessment, higher condition scores delivered higher numbers of lambs and better conception rates. Experience indicates that a totally different result is possible given another set of circumstances and the best advice for any producer would be to follow the directions provided by the AI veterinarian and work within the constraints of the prospective management and climatic circumstances that are likely to occur. Don't change what is already working!

Additional Information - Analysis at Lambing

The actual number of lambs born compared to the number of foetuses scanned indicated slightly above average embryo losses between scanning and birth. Average embryo losses of around 15% between scanning and birth can be experienced in commercial flocks (pers. comm. LTEM) whereas in this program, 18.7% (203 scanned, 165 born) of foetuses were lost post scanning. Analysis of embryo loss against ewe condition score showed a marginally higher risk of loss with higher condition score but this was more than likely due to the higher incidence of multiples with higher condition scores. Of the ewes that lost embryos, there was a high proportion of total embryo loss with 50% of the ewes losing all scanned embryos. Once again there was no relationship between total embryo loss and ewe condition score.

It would therefore seem that given good post AI nutrition and management, high ewe condition score does not adversely affect embryo survival.

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.

06

FarmLink Research Report 2016

Influence of Loose Lick Supplement on the Growth Rate of Lambs Grazing Stubbles

Project & Funding Partners

FarmLink change • adapt • prosper

Clear View Consulting

Trial Site Location

Temora Agricultural Innovation Centre

Report Author

Murray Long

Introduction

The opportunity to graze stubbles after harvest plays an important role in mixed farming operations for both the livestock and cropping sections of the enterprise. However, the nutritional value and window for maximum benefit is dependent upon a number of factors, with weather being a major consideration in management of these stubbles. The role of mineral supplements has previously been shown to provide significant benefit to lambs grazing lucerne (Long and Duddy, 2015), but what role do they have on the growth rates of lambs grazing stubbles given that these can vary from dry feed with a grain component to stubbles with either actively growing or stressed volunteer plants?

Methods

The 63 lambs used for the initial part of this trial were September drop, White Suffolk lambs averaging 37kg that had been raised and weaned on lucerne at the Temora Agriculture Innovation Centre (TAIC). They were vaccinated and drenched at weaning and three weeks later, split into two groups and rotated through the available stubbles at TAIC across the summer. Half the lambs were provided with loose lick supplement ad-lib (Supplement) and half had no supplement (Control) with the weights of each group monitored before moving to a fresh stubble.

The supplement provided was a commercially available product (Fabstock™ Stubble Mix)

The cereal stubble treatments (barley and wheat) were conducted on identical paddocks with the same paddock history, size and management. The Canola stubbles used in this trial were not identical in size and variety sown but similar in management and paddock history.

Recorded rainfall at Temora over the trial period was 66mm from nine separate rainfall events, with one major storm event making up half the total. This provided a scenario that would be common in a mixed farming enterprise where volunteer plants appear after a rain event only to be 'burnt off' by subsequent hot weather. The sequence of events and management of lambs in this trial was kept as close as to what would be typical in a commercial enterprise over the summer months following harvest.

The sequence of grazing rotations was as follows -

1. Day 0-20 - Lambs were provided barley stubble containing 2010kg dry matter/ha (stubble), with 47kg/ha grain on the ground. There were 73 volunteer barley plants/m2 in this stubble (2-3 leaf stage).

2. Day 21-34 - Canola stubble with volunteer plants under the windrows at an average density of 28.6 plants/m2, stage 4-5 leaves. These plants were actively growing following a heavy storm prior to the lambs entering the paddock.

3. Day 35-46 – Unharvested trial wheat crop that had been slashed with volunteer wheat at 104 plants/m2 (leaf stage 3-4 leaf) plus some hairy panic growing. Still an amount of grain in the ground; 245kg/ha. Estimated vegetative grazing available was 550 kg green DM/ha

Following the removal of lambs from the wheat stubble (day 46), an additional 92 September drop White Suffolk lambs that had been on lucerne pasture for six weeks were weighed and divided into four groups. Two of these were added to the existing treatment groups and placed on lucerne for three days prior to being allocated to canola stubbles, one group with supplement, one without. The remainder of the lambs were grazed on either wheat stubble that had been sprayed out or remained on the lucerne pasture, both without supplement. The purpose of this treatment was to further determine the effect supplement was having in relation to the growth rate of lambs when grazing volunteer canola with different previous grazing histories. The canola at this stage was severely moisture stressed and around 50% of the plants had flowered, the density of the volunteer plants was as recorded previously. The lambs remained on these treatments for a further 17 days.

Results

The growth rates of lambs on cereal stubbles provided with supplement exhibited a considerable advantage over those without supplement as shown in Figure 1.

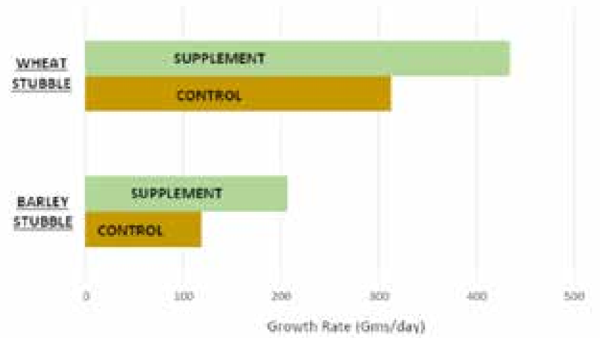


Figure 1. Comparison of growth rates of lambs on cereal stubbles with and without supplement

The lambs on barley stubble with supplement exhibited growth rates 87gms/head/day greater than those without supplement which was equal to a 74% increase in growth rate above the above the control group. The visual differences in the paddocks following the removal of the lambs revealed that the lambs on supplement had consumed all the grain and young plants whereas the control group had not been so efficient. This confirms information provided by Queensland Business and Industry (2013) suggesting an increase in dietary intake by sheep provided supplement and would explain to some degree the increase in growth rates of the lambs on supplement. It was noted that in the days following the introduction of the lambs to their treatments, several of the lambs on supplement scoured in a manner consistent with consumption of grain when not accustomed to it. No noticeable discomfort was observed in the scouring lambs and it corrected itself within a few days. The control lambs at no stage exhibited any signs of scouring.

The amount of feed on offer to the lambs on the slashed wheat crop was substantially greater which was reflected in the higher growth rates achieved by both groups of lambs. The lambs on supplement grew 122.1gms/head/day faster than the control group which was an increase in growth rate of close to 40%. There was a high level of both dry matter and grain available to these lambs with again an apparent difference in level of grain consumption with supplemented lambs consuming slightly more grain. The volunteer plants and weeds present were suffering from a degree of moisture stress during the trial making the grain easier to source for both groups. No scouring was observed in either group.

The consumption of loose mix supplement was similar across the barley and wheat treatments at an average of 49.7 gms/head/day, much less than the average consumption of lambs involved in the previous trial on Lucerne (Long and Duddy, 2015

Growth Rates on Canola stubble

When the lambs were shifted to a canola stubble with volunteer plants actively growing following a recent rain event, some unexpected results occurred as seen in Figure 2.

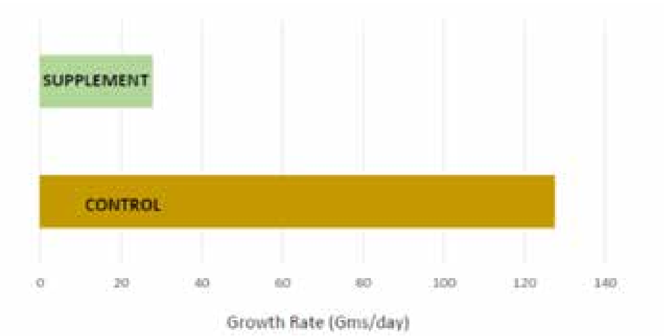


Figure 2. Growth rates of lambs with and without supplement grazing on volunteer canola

The lambs grazing canola with supplement seemed more stubborn to shift to the yards for weighing than the control mob, a characteristic that didn't raise any alarms until the weight data was analysed. As the level of supplement consumption had decreased to just 21.5gms/head/day and the weight gains between treatments were so different, there was sufficient concerns to re-run the trial after a short period of readjustment for the lambs.

The addition of a fresh group of lambs that had been grazing lucerne for six weeks provided an opportunity to test the suspicion of sub-clinical nitrate poisoning given the recommendation that animals can adapt to high nitrate feeds lowering the risk of nitrate poisoning (Robson, 2007). This would suggest that the lambs from lucerne would not be at high risk from nitrate poisoning and would respond accordingly. There was a difference in the growth rates of these lambs between the treatments when placed on canola with the lambs from lucerne with supplement growing at faster rates than those without supplement. Once again there was a slight reduction in growth rates of lambs with supplement compared to those without supplement from the lambs not accustomed to high nitrate feed (original mob). Figure 3 shows the results of lambs from the four grazing treatments with the effect of previous grazing history (adjustment) showing an effect on weight gain when grazing canola.

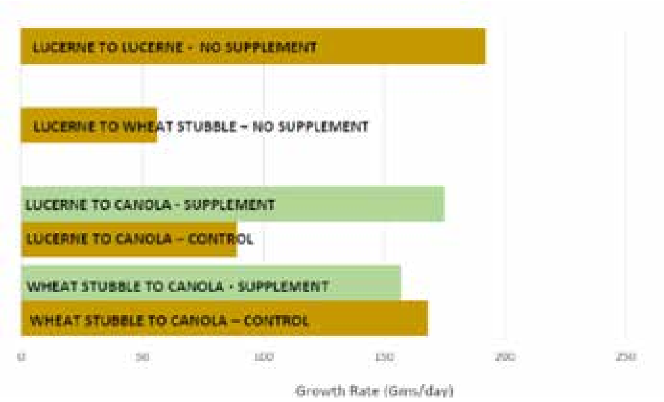


Figure 3 Effect of pre-grazing treatment on response to supplement when grazing canola

The value of all stubbles at this stage was beginning to diminish as the canola was drying off and the wheat stubble had very little to offer store lambs. The lucerne pasture was also showing signs of moisture stress. The growth rates of lambs left on lucerne exceeded lambs on all other treatments whereas those on depleted wheat stubble struggled to maintain acceptable growth rates.

Discussion

The growth rate response to supplements on cereal stubbles is clear and decisive. Lambs grazing on cereal stubbles achieve higher growth rates when given access to loose lick supplements than those grazing on stubbles without supplement. This more than likely occurs for a number of reasons. Firstly, the loose lick provides supplementation of essential minerals missing in the available feed within the stubbles such as calcium and sodium and as most stubbles are low in crude protein (2-4%) (Agriculture Victoria, 2016), supplements provide some additional benefit through additional protein in the form of protein meal and urea. The second area where supplements assist is by increasing appetite and dietary intake (Queensland Business and Industry, 2013) therefore increasing potential for increased growth rates.

Lambs on barley stubble with supplement achieved growth rates 74% higher than those without supplement and the difference in the amount of both grain and volunteer plants consumed was clearly evident. No grain or barley plants remained in the stubble running the supplemented lambs whereas the control lambs still had an estimated 27Kg/ha of grain and 19.7 plants/m2 not consumed in the paddock. The lower consumption in lambs not offered supplement would account for a proportion of the weight large gain differences as it has long been recommended that increased appetite is one of the benefits of mineral supplements as well as providing additional protein and minerals. The initial, short term scouring of the lambs on supplement could have been due to the increased consumption of spilt grain within the stubble due to the effect of the supplement plus the concentration of components within the loose lick.

With the relative low value of feed on offer in the barley stubble, the inclusion of loose lick supplements was critical in achieving growth rates of just over 200gms/head/day, however once the grain and volunteer plants were consumed, this growth rate would not be sustained had the lambs remained on this stubble and supplementation of their diet with cereal grain and/or lupins would have been required to maintain weight gain.

The wheat stubble provided a different situation, with high levels of grain and dry matter available to the lambs. This provided a much higher daily growth rate (434 and 312 gms/day) across both the supplemented and control lambs respectively. Even with higher nutritive value within the stubbles, the inclusion of a loose lick supplement still provided a daily growth advantage of close to 40% when compared to the control treatment. The level of volunteer wheat and some weed species, coupled with grain on the ground provided an ideal finishing opportunity for lambs with growth rates from both groups more than acceptable. However, the provision of supplement was still a favourable economic decision with an additional $3.35 carcase value for a cost of supplement around $0.60/lamb for the short period of the trial. This figure approaches the financial returns (600%) gained from using supplement on high value Lucerne pasture by Long & Duddy (2015).

The effect of supplement on the growth rates of lambs grazing volunteer canola was totally different and provided some interesting results. The advantages that loose licks provide to lambs grazing cereals such as mineral supplementation and protein addition to the diet, do not apply to canola stubbles with volunteer plants. Canola stubbles with volunteer plants do not have the same requirement for mineral supplements due to a much higher sodium (Dove, 2014) and magnesium content (Frischke and McMillan, 2012) and the average value of 12-14% crude protein (Schroder 2008) present in canola plants. The effect of creating greater appetite may not be a factor but if it is, only serves to amplify the warnings that go with grazing canola. These include potential problems due to high levels of nitrate up to 4000ppm (Frischke and McMillan, 2012) and high levels of sulphur (0.5 – 1.3%) (Schroeder, 2008) and the fact that these issues become more critical just after rainfall or as plants become moisture stressed. The reasons that supplements work in cereals are identical to the ones that potentially cause problems when grazing canola stubbles where volunteer plants are actively growing. When nitrate levels approach 4000ppm, nitrate poisoning becomes a real consideration. Sulphur consumption should not exceed 0.4% on a dry matter basis (Schroeder,2008), and the fact that the supplement contained around 3.3% sulphur and levels of nitrates through the use of urea and canola meal, potentially creates issues when both the plants and supplement are consumed. However, generally, sulphur is essential in maintaining rumen efficiency and a ratio of 10:1, Nitrogen:Sulphur is considered the right level to achieve maximum utilisation of feed and production (Breytenbach, 1999, Merck Vet. Manual, 2014), especially in Merinos.

The first trial where the lambs on canola with supplement showed a large reduction in growth rate when compared to the lambs without supplement was potentially a subclinical case of nitrate poisoning. Actively growing canola plants, higher susceptibility of young animals (Undersander et.al, Crowley (1985)) and lack of alternative grazing plants all point to a high risk of nitrate poisoning. The addition of a loose lick may have contributed to this condition although no lambs showed the advanced signs of poisoning and lethargic behaviour was the only sign apart from markedly lower weight gains.

The subsequent trial using canola stubble attempted to explain some of the differences in the initial trial. There are many references to conditioning animals to high levels of nitrates in feed and with lucerne typically containing moderate to high levels of nitrate between 1760 – 4000ppm, (Undersander et.al, Healthy Soils Inc (2012)), lambs coming off lucerne pasture should have some level of adjustment to potentially higher nitrate levels in canola plants. The lambs that had been on lucerne pasture for six weeks did show the typical response to supplement that had been witnessed in the previous trials on cereal stubble and lucerne (Long & Duddy, 2015) with the supplemented lambs increasing growth rate by 86gms/head/day above the control; almost double the growth rate. As in the initial trial on canola stubble, supplemented lambs coming off cereal stubble onto canola stubble exhibited lower growth rates than the control but not to the same extend as in the initial trial; 157 compared to 168gms/head/day respectively. Interestingly the growth rates of all the groups except the lucerne to canola control lambs were similar (175, 157 & 168gms/head/day) raising a further question as to why the large drop in growth rate attributable to lambs coming from Lucerne to canola when no supplement was available or conversely, why didn't we get a similar response on those lambs that had been on wheat stubble. It also raises the suspicions that even the control lambs in the first trial were suffering some small degree of nitrate poisoning as the growth rates of these lambs averaged 128gms/head/day, much lower than the growth rates of the same lambs (168gms/head/day) in the second trial, despite having access to canola plants that were more actively growing and more palatable in the first trial.

Part of the answer to the results in the second part of the trial may lie in the fact that the canola plants within the stubble were severely stressed and at a much later maturity stage than the initial trial. Not only would the nutritive value have been much less, but the potential for any degree of nitrate poisoning would have been considerably diminished. This is confirmed with the growth rates of the lambs remaining on lucerne averaging 30-40gms/head/day above those on canola with supplement. It is the altered responses of the two groups of lambs from different pre-treatment grazing history's (cereal vs lucerne) that creates questions as to what factors are causing this result. Future trials using actively growing canola need to be conducted to validate the initial trial results and also clarify the effect that changing feed types may have on potential growth rates in lambs. The adjustment of gut microflora to different feed types and the effect it has on growth rate is one area that needs further investigation. In the time frame of these trials, the gut microflora would not have had sufficient time to fully adjust.

Nonetheless, the decision to use supplements on canola stubbles is not as straight forward as the decisions on cereal stubble or lucerne pasture.

When grazing lambs on cereal stubbles the use of loose lick supplements provides clear benefits in increasing lamb growth rates. The financial returns provided by supplements are evident as well as better utilisation of stubbles through increased dietary intake. When faced with the opportunity to use canola stubbles, consideration to the potential risk of nitrate poisoning must be given regardless of whether you are considering the addition of a supplement or not. The use of a supplement may actually compound the potential risks across a number of areas especially by increasing nitrate and sulphur intake.

Footnote: The reduction in growth rate of lambs on canola provided with supplement has since been confirmed by Hugh Dove, CSIRO

07

FarmLink Research Report 2016

Innovative Approaches to Managing Subsoil Acidity in the Southern Grain Region

GRDC Project code – DAN00206

Project Partners

FarmLink change • adapt • prosper

NSW Government Department of Primary Industries

Holbrook Landcare Network

Charles Sturt University

CSIRO

RiverinePlains

La Trobe University

SFS

Funding Partners

GRDC Grains Research & Development Corporation

Trial Site Location

Rob McColl, 'Fairview', Binalong, NSW

Report Author

Kellie Jones (FarmLink)

Introduction

The project targets the high rainfall zone (500-800mm) South-Eastern region of Australia 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, lime moves very slowly down through the soil profile so the subsoil acidity won't be ameliorated until years after the surface application. There is also the problem of most of the added alkalinity being consumed in the topsoil prior to reaching the subsoil to neutralize the acidity.

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 these new innovative subsoil acidity management techniques.

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

The first of the large-scale on-farm experimental sites was established in February 2016 at Binalong NSW, in the east of the FarmLink region. The site was located in the high rainfall zone (HRZ), with an average annual rainfall of 647mm. The paddock had a high acidity and high exchangeable aluminium, fitting the trial site selection criteria perfectly.

Characteristics	Target Site	Actual Site
0-10cm: pHCa (CaCl2)	pHCa (CaCl2) 4.0-4.5. If limed, preferring <5.0	pHCa (CaCl2) 5.75
10-20cm: pHCa (CaCl2)	pHCa (CaCl2) < 4.3, exchangeable Al% >20%	pHCa (CaCl2) 4.24, 18.83%
20-30cm: pHCa (CaCl2)	pHCa (CaCl2) pHCa < 4.6, exchangeable Al% >10	pHCa (CaCl2) 4.26, 13.29%
Annual Rainfall	>500mm	647mm
Rotation	Cropped for 3 consecutive years	Canola, TBA, TBA

Table 1. Target trial site characteristics vs actual.

	Treatments	Description
1	Surface liming	The site received 3.5t/ha of lime in 2015. The pH at 0-10cm was 5.75 in 2016 as shown in table 3. Therefore, no additional lime was added.
2	Deep ripping only	Ripping occurred at a depth of 30cm and at width 50 cm between ripping lines. Once again, the surface was not limed due to liming in 2015.
3	Deep ripping + lime	For this treatment, 2.6 t/ha of lime was placed at 10-30cm to target the subsoil acidity.
4	Deep ripping + organic amendment	As above with organic amendment, lucerne pellets at 15t/ha.

Table 2. treatments and descriptions for 2016 Binalong site

The trial included four treatments, replicated three times. The four treatments were 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 2 for a more detailed description of the treatments.

The treatments were implemented using a duel 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. Using his own equipment, the grower planted 970CL grazing canola at 3kg/ha on 300mm spacings at a 45° angle to the deep ripping lines (Figure 1 right). This was to ensure uniform performance of crop to the treatments. Ideally, the crop should be sown each side of the ripping line using a seeder with 250mm row spacing to maximise treatment effect (Figure 1 left). However, the farmer's equipment was set to 300mm spacings so the alternate plan was implemented.

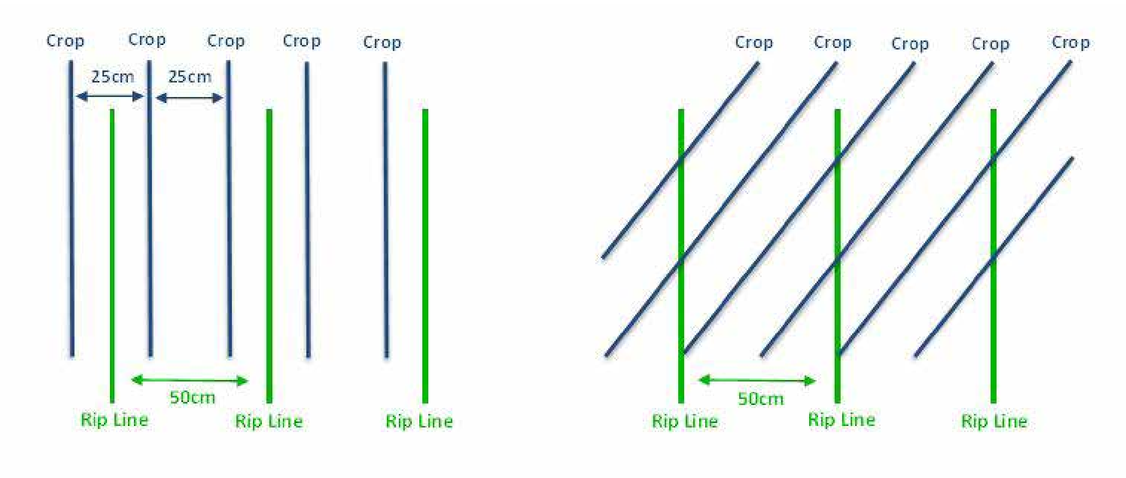


Figure 1. Initial crop sowing plan (left) vs new plan (right)

Following crop emergence and throughout the season data collected included - emergence counts, anthesis and harvest dry matter cuts, header yield data, grain quality testing and initial and final soil sampling. Another farm scale site will be set up in February 2017. The site will have the same selection criteria, treatments and assessments.

NB: these parameters will be assessed at this site for the next two years.

Results 2016

Initial soil samples were taken prior to the treatments being implemented (Table 2). At the end of the experiment, in the third year, final soil samples will be taken to compare the pH and exchangeable aluminium percent at depths from 0-100cm. Results from initial soil samples showed that the exchangeable aluminium and acidity spikes greatly in the 10-30cm profile and begins to increase downwards from 30cm.

During emergence, it appeared that the surface liming treatment had the highest emergence count of 32.6 plants/m2, while the deep organic amendment treatment had the lowest with an emergence count of 18.5 plants/m2. This equates to a difference of 14 plants/m2.

The harvest dry matter cuts follow a different trend when compared to the emergence counts. The deep organic amendment treatment had the highest dry matter cut weight just prior to windrowing, with a weight of 22.9 t/ha. The surface liming treatment had the lowest dry matter weight of 17.6 t/ha, even though it had the highest emergence counts. That's a dry matter weight difference of 5.3 t/ha between the surface liming and deep organic amendment treatment.

	0-10cm	10-20cm	20-30cm	30-40cm	40-60cm	60-80cm	80-100cm
pH (CaCl2)	5.75	4.24	4.26	5.02	5.74	5.96	5.97
Exchangeable Aluminium %	0.70	18.83	13.29	0.94	0.27	0.19	0.20

Table 3. pH (CaCl2) and exchangeable aluminium percentage from the initial soil samples

Treatment	Emergence Counts (Plants/m2)	Harvest DM Cuts (t/ha)	Quad Harvest Yield (t/ha)
Surface Liming	32.6	17.6	3.6
Deep Ripping	21.5	18.4	4.0
Deep Liming	24.4	21.3	4.7
Deep Organic Amendment	18.5	22.9	4.7

Table 4. treatment averages of assessments taken throughout the year

The deep liming and deep organic amendment treatments had the highest quad cut harvest yield, with both treatments bringing in 4.66 t/ha. The surface liming treatment had the lowest yield. There was a 1.1 t/ha difference between the highest and lowest yield.

Discussion

During emergence, surface liming had a substantially higher emergence rate when compared to the other treatments. This may be the result of the canola seed not having a good seed-to-soil contact in the other treatments. It is likely that air pockets were formed when the deep ripper loosened the soil, causing the small canola seed to be unable to absorb enough moisture at germination. Canola should be placed into a seedbed that is firm, level and moist (GRDC, 2009). The GRDC canola best practice management guide states that sowing into loose or 'fluffy' soil should be avoided (GRDC, 2009). Observations during emergence found that although the surface liming treatments had high plant populations, the plants seemed to be less mature.

This immaturity followed through to anthesis where it was observed that the surface limed treatments continued with the high plant density, but had thin stems, while the other treatments, although plant density was lower, seemed to have thicker stems. Where plant populations are low, plants compensate by producing extra branches (GRDC, 2009). The ability for the canola to compensate for poor emergence was so good that the deep ripped plots had a higher dry matter weight just prior to windrowing. Other variables may have contributed to the differences in weight between the three deep ripped treatments, such as the lime or lucerne pellets distributed at depth. The plots with the lucerne pellets at depth were slightly taller than the other treatments, which may be due to the breakdown of the lucerne pellets into plant available nutrients.

The quadrant cut yields were measured by cutting three one metre square quadrants out of each strip; threshing and calculating an average yield for each treatment. Hand harvest yield follows the same trend as the harvest dry matter cuts, surface liming had the lowest yield and lucerne pellets having one of the highest. However, lime at depth also had the highest yield results, even though the dry matter cuts were lower, meaning that the harvest index (yield/dry matter=HI) for this treatment is higher.

This trial is a large-scale experiment, the data collected provides an indication of treatment effects and demonstrates benefits and pitfalls of adopting these subsoil acidity management methods on a large-scale. The small plot trials are more accurate and provided detailed statistical analysis of the impact of different treatments. Further years of research and analysis from this site and other sites will confirm these findings.

References

Grains Research Development Corporation. (2009). Canola best practice management guide for south-eastern Australia. Melbourne: Coretext

INTERSALES

08

FarmLink Research Report 2016

Soil Moisture Education for Landowners to Avoid Erosion and Achieve Productivity Outcomes

Funding Partner

The project is supported by funding from the Australian Government

Report Author

Kellie Jones (FarmLink)

Introduction

The project was designed to improve landholder understanding of soil moisture conditions through the use of raw data, the establishment of yield modelling and data analysis and interpretation. This information was communicated to landholders at a workshop, and via the Weather or Not newsletter, to support the development of seasonally appropriate management strategies that will optimise agricultural productivity and reduce environmental risks associated with erosion and waterlogging.

Method

1. FarmLink soil moisture probes network used to generate raw data
2. Subset of sites selected to implement automated weather stations and to establish yield modelling
3. Analyse and interpret the soil moisture, weather conditions and yield forecast data
4. Facilitate a workshop with landholders to educate them on data analysis & interpretation, strategies to maintain ground cover & optimise agricultural productivity/profitability.
5. Communicate key messages to landholders via monthly publications during the growing season

The project, conducted by FarmLink funded by a grant under the National Landcare Programme Sustainable Agriculture Small Grants Round 2015-16 had a focus on education in soil moisture management to reduce erosion risks across farming operations in Southern New South Wales.

The project used FarmLink's existing Weather or Not publication to deliver soil moisture information across the growing season to landholders across SNSW, paired with the inclusion of a workshop looking at soil moisture and seasonally appropriate management practices, at the annual FarmLink Open Day on September 2 at TAIC.

The 2016 season in itself presented challenges not experienced for some years in Southern New South Wales, with waterlogging and paddock inaccessibility seeing landholders faced with a different set of management issues than that of a 'typical' year.

The final report for the Weather or Not series summarised the year's activities.

To sum up 2016 it was dry, then wet, then underwater. It was a season that was frustrating, worrisome, and hard work, but, hopefully, rewarding for you all.

What did we learn?

In 2016, waterlogging 'threw a spanner into the works' disrupting what could have been a great production year. Waterlogging is difficult to overcome once it hits because it not only inhibits root growth but reduces nitrogen via denitrification when, in wet soils the oxygen concentration falls and microbes use nitrate instead of oxygen to support their growth, resulting in the production of nitrogen gasses that are lost to the atmosphere.

If you could go back in time and redo 2016, what would you do differently? What would you focus on?

Traditionally, Nitrogen (N) budgets call for how much to apply and when to apply it with a target yield and protein in mind. But to cope with a year where waterlogging is prevalent, how would you have altered the system? In hindsight, farmers may have started with a strong lead into the growing season by increased sowing rates, made sowing dates as early as possible and applied nitrogen early to promote growth.

Paddocks where waterlogging and flooding occurred can be a problem, but it also presents an opportunity to look at water diversion and soil structure strategies to better manage it in the future.

Yield Prophet - what if the yield wasn't accurate....

As previously indicated, Yield Prophet predictions don't take into account frost, disease, harvest loss and waterlogging.

Reviewing the Yield Prophet versus actual yield results can raise questions about the production of the paddock, factors affecting the accuracy of Yield Prophet and highlight future yield goals to aim for.

- What other factors could have contributed to yield loss?
- Is the soil and climate data in Yield Prophet accurate? (This can be adjusted in subsequent years)
- Is the observed paddock yield accurate?
- Was there weeds, pest pressure, storm damage or moisture stress at various times?
- And what can you do to manage these factors in the future?

The weather year that was

2016 was a dry and warm start to the growing season. Rainfall recorded at Temora Agricultural Innovation Centre showed 32 mm of rainfall for March and only 8.8mm for April. The break came in May with nearly 100mm of rainfall recorded and more across the district. Subsequently, all the paddocks in this newsletter were tracked at growing season rainfall of Decile 7 or higher.

The weather year that will be

Late summer and autumn is a difficult time to be make accurate climate predictions. The oceans surrounding Australia are 'resetting' from spring last year and are therefore generating patterns that are unreliable weather predictors. For this reason, models should not be given too much attention from now on until May. ENSO and IOD indicators are currently neutral but interestingly, the Southern Annular Mode (SAM) has been negative all summer. SAM's influence on NSW rainfall is complicated and the subject of current research, but it can influence summer rainfall. The NSW DPI Agriculture have produced an excellent clip about SAM called Climatedog: SAM. You can watch it on https://www.youtube.com/watch?v=G-S-YmE-Lkc

Looking ahead – storing soil moisture

The soil moisture probes in the featured paddocks have shown high moisture levels at the end of harvest giving confidence in good potential yields leading into sowing in 2017. One of the most effective ways to conserve your soil water is to manage your summer weeds early, so be vigilant with your monitoring and act early!

Acknowledgements

Thank you to all our paddock hosts who have willingly provided access and information when required – Paul and Linda Griffin, Sam and Matt Dart, Geoff, Liz and Adam Lane, Derek and Susan Ingold, Rob and Mandy Taylor, the Meier family and Purcell family. Thank you also to Geoff Minchin from the Riverina Local Land Services for providing local insight and information for the compilation of this newsletter.

INDIVIDUAL SITES

Ariah Park SW

In October, Yield Prophet predicted a 4.2 t/ha yield potential for this wheat crop, where actual yield was higher at 4.8 t/ha, of ASW (10.1% protein).

There were minimal external factors to influence yield apart from some waterlogging in September.

Table 1 below provides a summary of the 2016 water and nitrogen balances simulated by Yield Prophet. It highlights the high amount of moisture received during the growing season and the estimated amount lost through evaporation, run-off, drainage and transpiration.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	54.3 mm	Starting Soil Nitrogen	162 kg/ha
Rainfall (soil sampling [6-May] to Maturity)	559.2 mm	Plus applied Nitrogen	65 kg/ha
Less modelled Evaporation	177.4 mm	Plus modelled Mineralisation	15 kg/ha
Less modelled Run-off	18.3 mm	Less modelled Denitrification	12 kg/ha
Less modelled Drainage	229.1 mm	Less modelled Leaching	68 kg/ha
Less modelled Transpiration	162 mm	Crop Nitrogen Supply	162 kg/ha
Crop Water Remaining	26.6 mm	Nitrogen Remaining	24 kg/ha

Table 1. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

When this site was initially soil cored at the beginning of the 2016 season (Table 2), nitrogen levels were very high, approximately 155 kg/ha. The crop was top-dressed with urea twice throughout the year with 23 kg N/ha in June and 37 kg N/ha in August. Reaching ear emergence in late September, the crop had a predicted 90 kg N/ha in reserve, considering predicted losses through mineralisation, denitrification and leaching that left the paddock with 24 kg/ha of predicted nitrogen. The final soil tests show there is approximately 50 kg N/ha. Soil nutrient levels throughout a season can be a very hard value to predict, especially after such a rare wet season like 2016.

Soil water had an increase of 3% in the top 10cm of soil, the top soil seems to be holding its moisture well even after the hot weeks in late January and February 2017. There was no difference in soil moisture between 70 to 100cm.

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	120	20	-100
	Soil Moisture (%)	7	10	3
10-40cm	Nitrogen kg/ha	18	13	-5
	Soil Moisture (%)	9	10	1
40-70cm	Nitrogen kg/ha	10	8	-2
	Soil Moisture (%)	14	16	2
70-100cm	Nitrogen kg/ha	7	8	2
	Soil Moisture (%)	14	14	0
Total	**Nitrogen kg/ha**	**155**	**50**	**-105**

Table 2. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

Greenethorpe

This wheat crop yielded 5.7 t/ha which is lower than the Yield Prophet predicted yield potential of 7.1 t/ha.

This was likely partly due to waterlogging and Yield Prophet also recorded three mild frost events which simulated a 1 t/ha loss. The grower reported "about 10% of the paddock was waterlogged in September with very low to zero yield in the wet areas which would have affected the final yield." Yield Prophet doesn't simulate the yield effect of waterlogging but in September, it did predict a 60% probability of 5 consecutive days of waterlogging.

The crop made H1 classification which is excellent considering opportunities to apply N were limited due to high rainfall. The crop received a total 95 kg N/ha with 31 kg N/ha at sowing and then a 64 kg N/ha in-crop application.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	45.1 mm	Starting Soil Nitrogen	105 kg/ha
Rainfall (soil sampling [7-Apr] to Maturity)	577 mm	Plus applied Nitrogen	95 kg/ha
Less modelled Evaporation	132.2 mm	Plus modelled Mineralisation	10 kg/ha
Less modelled Run-off	38.8 mm	Less modelled Denitrification	10 kg/ha
Less modelled Drainage	179.5 mm	Less modelled Leaching	3 kg/ha
Less modelled Transpiration	222.6 mm	Crop Nitrogen Supply	196 kg/ha
Crop Water Remaining	48.9 mm	Nitrogen Remaining	14 kg/ha

Table 3. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

Table 4 shows the top 10cm of soil had a 3% increase in soil moisture, but at both 10-40cm and 40-70cm there was a reduction of 5%. The paddock started the season with approximately 99 kg/ha of nitrogen, it received 95 kg/ha during the season. Through modelled mineralisation, denitrification, leaching and removal by harvest, Yield Prophet predicted 14 kg/ha of nitrogen remaining (Table 3). The final soil analysis (Table 4) showed that there was 57kg/ha of nitrogen in the soil after the season was finished. It was predicted that 196 kg N/ha was removed from the paddock during harvest, but this was when a 7.1 t/ha yield was predicted. The paddock yielded less than that, therefore less nitrogen was removed in plant matter and more remained in the soil.

Canola is planned for this paddock in 2017.

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	57	24	-33
	Soil Moisture (%)	4	7	3
10-40cm	Nitrogen kg/ha	27	22	-5
	Soil Moisture (%)	10	5	-5
40-70cm	Nitrogen kg/ha	15	11	-4
	Soil Moisture (%)	17	12	-5
Total	**Nitrogen kg/ha**	**99**	**57**	**-42**

Table 4. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

Lockhart

This Suntop wheat crop yielded 4 t/ha and had a predicted yield of 5.1 t/ha. Yield Prophet didn't detect any frost or heat shock events so this difference could be attributed to rust disease infection detected at ear emergence and waterlogging in some parts of the paddock in September.

Table 5 provides a summary of the 2016 water and nitrogen balances simulated by Yield Prophet. It highlights the high amount of moisture received during the growing season and the estimated amount lost through evaporation, run-off, drainage and transpiration.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	[illegible] mm	Starting Soil Nitrogen	[illegible] kg/ha
Rainfall (soil sampling (25-May) to Maturity)	[illegible] mm	Plus applied Nitrogen	62 kg/ha
Less modelled Evaporation	[illegible] mm	Plus modelled Mineralisation	[illegible] kg/ha
Less modelled Run-off	[illegible] mm	Less modelled Denitrification	17 kg/ha
Less modelled Drainage	[illegible] mm	Less modelled Leaching	5 kg/ha
Less modelled Transpiration	[illegible] mm	Crop Nitrogen Supply	[illegible] kg/ha
Crop Water Remaining	[illegible] mm	Nitrogen Remaining	26 kg/ha

Table 5. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

This site started the season with approximately 155 kg N/ha and it received 62 kg N/ha during the season. Yield Prophet predicted 26 kg/ha of nitrogen remaining in the soil, and the final soil analysis shows 42 kg N/ha left in the soil.

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	50	12	-34
	Soil Moisture (%)	23	7	-16
10-40cm	Nitrogen kg/ha	63	15	-52
	Soil Moisture (%)	27	15	-12
40-70cm	Nitrogen kg/ha	25	9	-20
	Soil Moisture (%)	25	18	-7
70-100cm	Nitrogen kg/ha	17	6	8
	Soil Moisture (%)	21	20	-1
Total	**Nitrogen kg/ha**	**155**	**42**	**-98**

Table 6. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

The Lockhart moisture probe site was soil cored in May 2016, the site had received a light shower of rain a few days prior to coring, the soil was very moist at all depths. There has been a large reduction in soil moisture percentage between 2016 and 2017, a 16% decrease for depths 0-10cm and 12% decrease for 10-40cm. No other paddocks in this project had a decrease in soil moisture as high as this.

This paddock has predicted 56 mm crop water and 26 kg N/ha remaining at the end of 2016. These will be excellent for LaTrobe barley crop planned for 2017.

Grong Grong

This Bonito canola crop yielded 2.2 t/ha canola with 46 to 47% oil content and had a predicted nitrogen limited yield of 2.2 t/ha. This yield is consistent with the nitrogen limited yield prediction (Image 1), it is 0.8 t/ha lower than the nitrogen unlimited prediction.

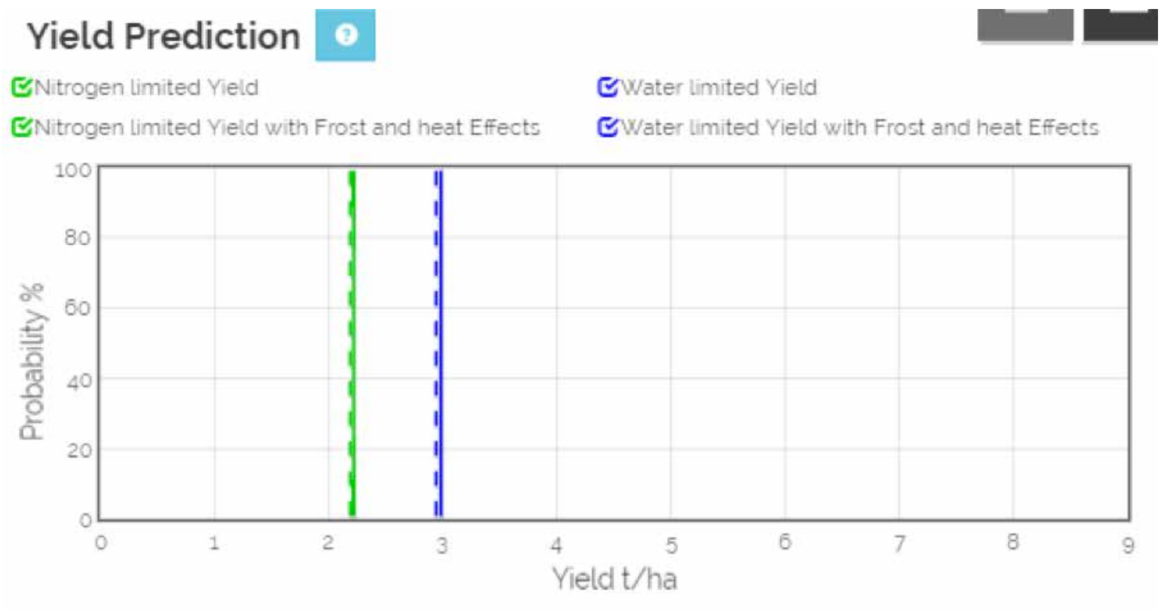


Image 1. Yield Prophet nitrogen and water limited yield prediction under frost and heat stress.

This canola crop received one in-crop application of 87 kg N/ha in early June however the grower reported excessive rainfall in September which contributed to waterlogging in the paddock and reduced access and potential yield loss. This rainfall has contributed to the estimated 70 mm water left in the soil after harvest. When comparing the initial soil moisture and actual final soil moisture, it is evident that a total of 18% of soil moisture has been lost between 0-70cm, while there was a 2% increase in moisture at 70-100cm.

There is an estimated 25 kg N/ha remaining in the soil, the final soil sample shows there is 89 kg N/ha remaining in the soil. This difference may be due to the unusual climate we experienced in the 2016 season. A wheat or oats crop is planned for this paddock in 2017.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	68.1 mm	Starting Soil Nitrogen	136 kg/ha
Rainfall (soil sampling [6-May] to Maturity)	570 mm	Plus applied Nitrogen	92 kg/ha
Less modelled Evaporation	157 mm	Plus modelled Mineralisation	23 kg/ha
Less modelled Run-off	37.1 mm	Less modelled Denitrification	12 kg/ha
Less modelled Drainage	258.2 mm	Less modelled Leaching	48 kg/ha
Less modelled Transpiration	115.5 mm	Crop Nitrogen Supply	191 kg/ha
Crop Water Remaining	70.3 mm	Nitrogen Remaining	25 kg/ha

Table 7. Predicted crop water and nitrogen starting levels, inputs and remaining levels

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	68	34	-34
	Soil Moisture (%)	9	7	-2
10-40cm	Nitrogen kg/ha	20	20	0
	Soil Moisture (%)	12	7	-5
40-70cm	Nitrogen kg/ha	27	16	-11
	Soil Moisture (%)	24	18	-6
70-100cm	Nitrogen kg/ha	19	20	0
	Soil Moisture (%)	23	25	2
Total	**Nitrogen kg/ha**	**134**	**89**	**-45**

Table 8. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

Beckom

This Condo wheat crop finished with a 4.4 t/ha yield prediction after a total 102 kg N/ha applied during the year. The actual yield was slightly higher at 4.8 t/ha and protein was 9.4%, the grower indicated there was waterlogging in some areas of the paddock.

The table below summarises the 2016 water and nitrogen balances simulated by Yield Prophet. The crop received 564 mm during the growing season and there was a good amount of water with 58 mm crop water remaining in the soil at the end of harvest.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	61.8 mm	Starting Soil Nitrogen	87 kg/ha
Rainfall (soil sampling [6-May] to Maturity)	564.7 mm	Plus applied Nitrogen	102 kg/ha
Less modelled Evaporation	188.2 mm	Plus modelled Mineralisation	29 kg/ha
Less modelled Run-off	17.8 mm	Less modelled Denitrification	14 kg/ha
Less modelled Drainage	17.7 mm	Less modelled Leaching	6 kg/ha
Less modelled Transpiration	185.6 mm	Crop Nitrogen Supply	198 kg/ha
Crop Water Remaining	57.8 mm	Nitrogen Remaining	34 kg/ha

Table 9. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

There was an estimate 34 kg N/ha remaining in (Table 9) the soil at the end of harvest (Table 9), the final soil analysis (Table 10) showed there was in fact 81 kg N/ha remaining in the soil. The 81 kg N/ha will be beneficial for the canola crop planned for 2017.

Temora Agricultural Innovation Centre

This Suntop wheat crop received 675mm of rainfall during the 2016 growing season and yielded 1.9t/ha compared to the predicted 3 t/ha nitrogen limited yield potential. This difference is likely to be due to waterlogging and the fact that only nitrogen it received was at sowing (25kg N/ha). The FarmLink team reported machinery was unable to enter the paddock through the whole growing season. "An attempt was made with a four-wheeler and urea spreader, but it was unsuccessful."

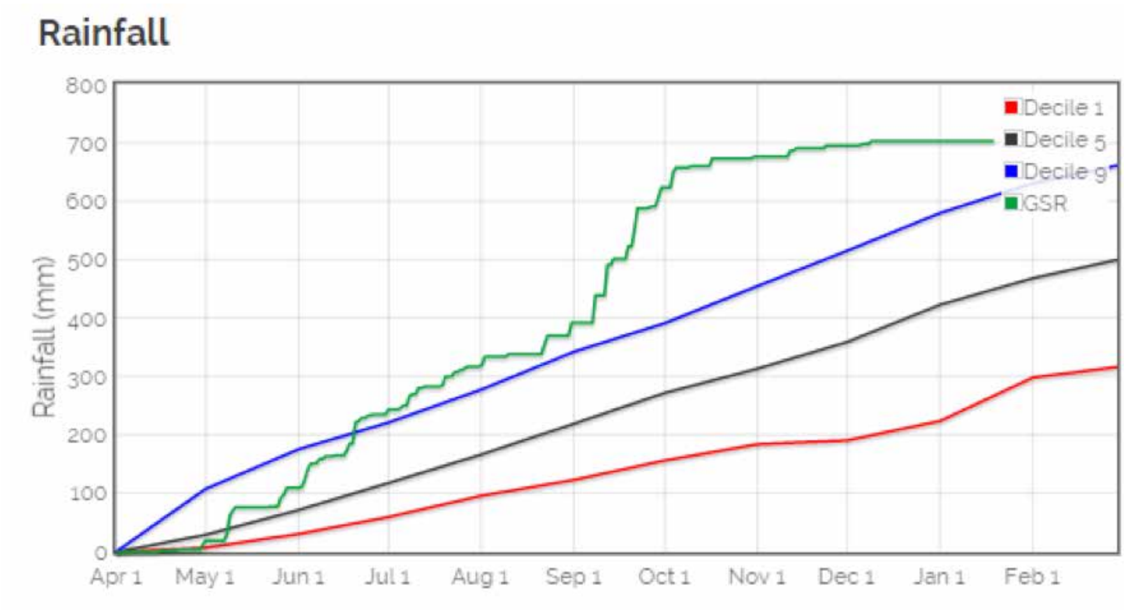


Image 2. Yield Prophet rainfall decile chart, April 2016 – February 2017

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	21.2 mm	Starting Soil Nitrogen	113 kg/ha
Rainfall (soil sampling [6-May] to Maturity)	701.7 mm	Plus applied Nitrogen	40 kg/ha
Less modelled Evaporation	191.1 mm	Plus modelled Mineralisation	10 kg/ha
Less modelled Run-off	34.2 mm	Less modelled Denitrification	5 kg/ha
Less modelled Drainage	288.3 mm	Less modelled Leaching	26 kg/ha
Less modelled Transpiration	156.5 mm	Crop Nitrogen Supply	132 kg/ha
Crop Water Remaining	52.8 mm	Nitrogen Remaining	7 kg/ha

Table 11. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

Table 11 provides a summary of the 2016 water and nitrogen balances simulated by Yield Prophet. It highlights the high amount of moisture received during the growing season and the estimated amount lost through evaporation, run-off, drainage and transpiration. This paddock has predicted 52.8mm of crop water. The final soil analysis shows that there is 3% less moisture in the top 10cm of soil, but there is an increase of 9% moisture from 20-100cm depths. Yield Prophet predicted 7kg N/ha remaining at the end of 2016, soil tests (Table 12) show that there is 81 kg N/ha remaining in the soil. Yield Prophet predicted a 1.1 t/ha higher yield than the actual yield, actual crop nitrogen supply would not have been as high as the predicted 132 kg N/ha. This would be partly the reason for the difference in remaining nitrogen.

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	78	32	-45
	Soil Moisture (%)	8	5	-3
10-40cm	Nitrogen kg/ha	15	20	5
	Soil Moisture (%)	6	7	1
40-70cm	Nitrogen kg/ha	6	15	9
	Soil Moisture (%)	14	18	4
70-100cm	Nitrogen kg/ha	6	13	8
	Soil Moisture (%)	15	19	4
Total		**104**	**81**	**-24**

Table 12. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

Dirnaseer

This Bonito canola crop had a predicted yield potential above 4 t/ha due to excellent growing season conditions including exceptional levels of soil nitrogen (405 kg/ha total) and moisture (731mm growing season rainfall which was a Decile 10 season). The crops actual yield was 2.7 t/ha with 47% oil content.

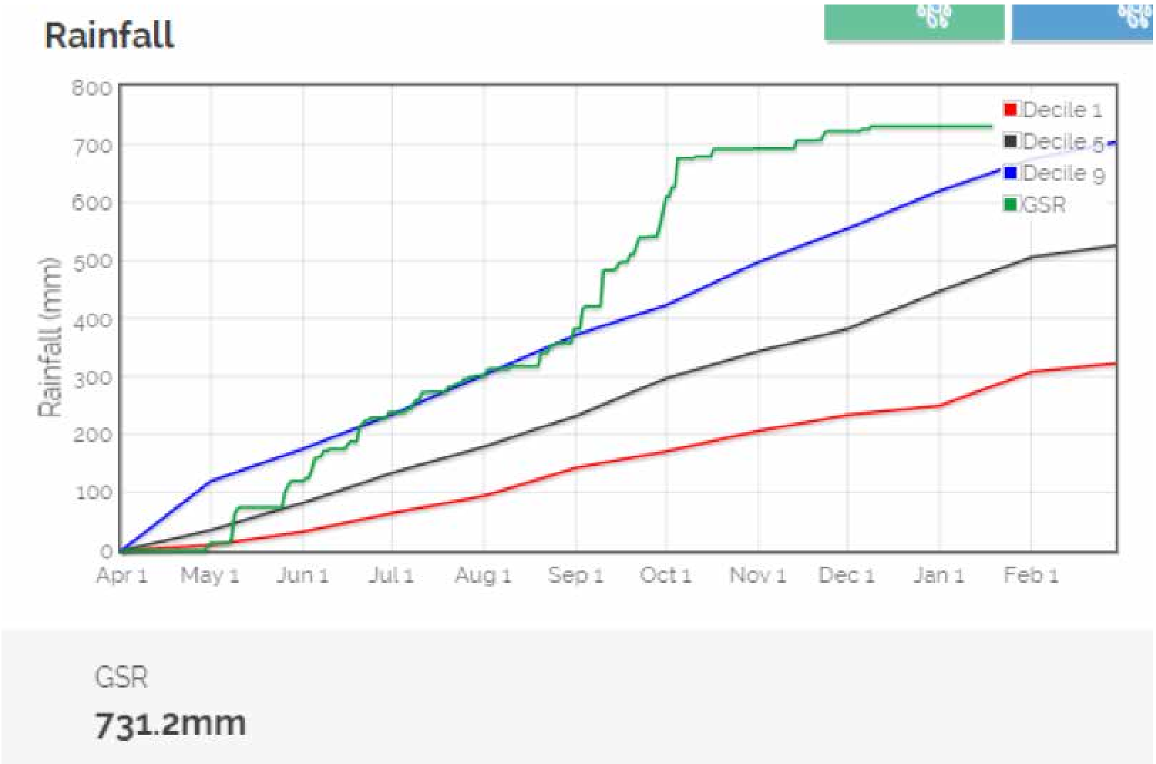


Image 3. Yield Prophet rainfall decile chart, April 2016 – February 2017

Table 13 summarises the 2016 water and nitrogen balances simulated by Yield Prophet at the end of harvest, there was 40mm of crop water and 8 kg N/ha remaining in the paddock and it is planned for a wheat crop in 2017.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	74.4 mm	Starting Soil Nitrogen	255 kg/ha
Rainfall (soil sampling [29-Apr] to Maturity)	731.2 mm	Plus applied Nitrogen	166 kg/ha
Less modelled Evaporation	228.1 mm	Plus modelled Mineralisation	44 kg/ha
Less modelled Run-off	50.7 mm	Less modelled Denitrification	35 kg/ha
Less modelled Drainage	21.7 mm	Less modelled Leaching	23 kg/ha
Less modelled Transpiration	269.6 mm	Crop Nitrogen Supply	406 kg/ha
Crop Water Remaining	40.2 mm	Nitrogen Remaining	8 kg/ha

Table 13. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

The paddock started out with approximately 249 kg/ha of nitrogen, after the season had ended, Yield Prophet predicted there was 8 kg/ha of nitrogen remaining in the soil. Table 14 shows there was 112 kg N/ha in the soil when the final soil results were taken. However, the paddock yielded 1.3 t/ha less that what Yield Prophet predicted. Therefore, less nitrogen was removed from the paddock (grain) during harvest, leaving more in the soil.

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	123	52	-71
	Soil Moisture (%)	11	10	-1
10-40cm	Nitrogen kg/ha	52	22	-30
	Soil Moisture (%)	12	12	0
40-70cm	Nitrogen kg/ha	36	12	-24
	Soil Moisture (%)	16	16	0
70-100cm	Nitrogen kg/ha	38	27	-12
	Soil Moisture (%)	16	16	0
Total	**Nitrogen kg/ha**	**249**	**112**	**-137**

Table 14. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

This paddock had very little change in soil moisture. Throughout the season the paddock received 731mm of rain. Between May, 2016, and February, 2017, only the top 10cm had a decline of 1% in soil moisture, the other depths down to 100cm had no change, even after such a wet season.

Mirrool

Yield Prophet predicted 5.2t/ha for this paddock, the paddocks actual yield was 5.3t/ha and a protein content of 10.7%. With a difference of only 0.1 t/ha, this was a very accurate prediction from Yield Prophet.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	75.9 mm	Starting Soil Nitrogen	128 kg/ha
Rainfall (soil sampling [5-May] to Maturity)	597.5 mm	Plus applied Nitrogen	134 kg/ha
Less modelled Evaporation	181.6 mm	Plus modelled Mineralisation	16 kg/ha
Less modelled Run-off	21.7 mm	Less modelled Denitrification	11 kg/ha
Less modelled Drainage	239.5 mm	Less modelled Leaching	68 kg/ha
Less modelled Transpiration	193.5 mm	Crop Nitrogen Supply	199 kg/ha
Crop Water Remaining	37.2 mm	Nitrogen Remaining	23 kg/ha

Table 15. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

The paddock started the season with approximately 123 kg/ha of nitrogen. Throughout the season the paddock received 134 kg N/ha, plus predicted mineralisation and minus predicted denitrification, leaching and removal through grain, the paddock was left with a predicted nitrogen level of 23kg/ha. The final soil test (Table 16) shows that there was a little more nitrogen left in the soil than first expected. Once again, this just shows how difficult it is to calculate inputs and outputs of a factor such as nitrogen.

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	32	42	11
	Soil Moisture (%)	9	4	-5
10-40cm				
	Nitrogen kg/ha	45	9	-36
	Soil Moisture (%)	11	7	-4
40-70cm				
	Nitrogen kg/ha	27	7	-20
	Soil Moisture (%)	16	11	-5
70-100cm				
	Nitrogen kg/ha	19	12	-8
	Soil Moisture (%)	14	13	-1
Total	**Nitrogen kg/ha**	**123**	**69**	**-53**

Table 16. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

Table 16 shows a decrease in soil moisture of approximately 5% between the 0-10cm, 10-40cm and 40-70cm layers. However, there was only a 1% decrease in soil moisture down at 70-100cm. Because this layer is so far down in the soil profile it is less effected by factors such as run off, evaporation, drainage and transpiration when compared to the other layers closer to the surface.

Ariah Park South

This crop had a 4.4 t/ha nitrogen limited yield prediction, and a 5.2 t/ha yield prediction if nitrogen was unlimited. The paddocks actual yield was 6.1 t/ha with 10.5% protein. This 1.7 t/ha yield difference may be due to incorrect soil characterisation. Soil moisture was not tested in the initial soil analysis for this paddock. This is required when choosing an accurate soil characterisation for the yield prophet site. Instead a soil characterisation was chosen using the PSA (particle size analysis) and the starting soil water was estimated. Estimating soil water in this way could introduce a high level of inaccuracy into the Yield Prophet modelling. This just shows how important it is to test for soil moisture when setting up a paddock.

Crop Water and Nitrogen Supply

Water		Nitrogen	
Starting Soil Water (PAW)	46.2 mm	Starting Soil Nitrogen	44 kg/ha
Rainfall (soil sampling [1-Jan] to Maturity)	630 mm	Plus applied Nitrogen	138 kg/ha
Less modelled Evaporation	252.5 mm	Plus modelled Mineralisation	41 kg/ha
Less modelled Run-off	3 mm	Less modelled Denitrification	1 kg/ha
Less modelled Drainage	222.5 mm	Less modelled Leaching	6 kg/ha
Less modelled Transpiration	167.2 mm	Crop Nitrogen Supply	216 kg/ha
Crop Water Remaining	31 mm	Nitrogen Remaining	33 kg/ha

Table 17. Predicted crop water and nitrogen starting levels, inputs and remaining levels.

Not having the starting soil moisture makes it hard to compare predicted (Table 17) and actual (Table 18) moisture results. Actual nitrogen results show a 5kg/ha increase and the predicted shows an 11 kg/ha decrease in nitrogen by the end of the season. This difference could also be due to poor soil characterisation. The simulation program relies greatly on accurate data being entered at the beginning and throughout the season to get accurate data at the end of the season. Please consider this when setting up a paddock in Yield Prophet in 2017.

Depth	Analysis	Initial Sample	Final Sample	Change
0-10cm	Nitrogen kg/ha	3	19	16
	Soil Moisture (%)	**NA	5	**NA
10-40cm	Nitrogen kg/ha	23	14	-9
	Soil Moisture (%)	**NA	11	**NA
40-70cm	Nitrogen kg/ha	9	5	-4
	Soil Moisture (%)	**NA	11	**NA
70-100cm	Nitrogen kg/ha	8	10	2
	Soil Moisture (%)	**NA	13	**NA
Total	**Nitrogen kg/ha**	**43**	**48**	**5**

Table 18. Actual soil moisture (%) and nitrogen starting levels, remaining levels and the difference.

Although the initial moisture levels were unknown, we can see that the top soil has 5% moisture. The moisture follows through to lower in the profile, there is 11% moisture between 10-70cm and 13% down between 70-100cm. This moisture will be useful for this year's crop.

* Please note that the actual total starting nitrogen levels are slightly different due to bulk densities used to calculate soil results from mg/kg to kg/ha. Also, the final soil samples were taken early February, 2017. Yield Prophet's predictions ended after harvest, nitrogen and soil moisture levels may differ slightly due to this time interval.

Conclusion

Although there were a few variances in predicted and actual yields, nitrogen and moisture levels, most of the predictions were within range of the actual values. Reasons for some of these discrepancies may be due to the unusually wet season we encountered in 2016. Other reasons may include spatial variability throughout the paddock. Soil test results should be interpreted as approximate values rather than exact values.

Input of accurate data is the most important point when using programs such as Yield Prophet. This includes selecting the best soil type for your paddock.

09

FarmLink Research Report 2016

What do pastures look like in the mixed farming zone?

Project Partners

FarmLink change • adapt • prosper

GRAHAM CENTRE for Agricultural Innovation

Funding Partners

GRAHAM CENTRE for Agricultural Innovation

Trial Site Location

FarmLink region

Report Author

Dr Jeff McCormick

Introduction

A pasture survey was conducted with 17 FarmLink members and comprised of 54 paddocks in total. The purpose of the survey was to determine how pastures were managed on farm and what pasture species were sown on mixed farms. An assessment of the paddock then compared the sown species to what was growing in the paddock. In total across the farms, 15 different species were sown, but lucerne and subterranean clover were the dominant species being sown in 80% of paddocks. The average frequency in which these species were found was greater than 60% but with large variation between paddocks. Sown species produced 62% of dry matter on average across all paddocks. It was determined that unless the frequency of a species in the paddock was at least 50% then the contribution to production of that species would be low (<20%). Using the frequency benchmark of 50% it could be demonstrated that pasture composition commonly includes only 2-3 of the sown species.

What was done?

Seventeen farms were visited with 54 paddocks surveyed in late spring in 2016. Interviews were conducted on each farm to determine for each paddock the species that were sown and agronomic management of the pasture. This included method of pasture establishment (straight sown vs undersown), weed management (winter cleaning/spray topping), fertiliser use and grazing management. The pasture paddocks were surveyed by walking diagonal transects across the paddock with pasture assessments occurring in 50 sampling positions that were approximately evenly spaced. At a sampling position approximately 0.25 m2 of pasture was assessed by two methods. Firstly, the frequency of the sown species was determined. This assessment simply indicated whether the sown species is present or not. Secondly, the species with the highest estimated dry matter were ranked to determine pasture composition using the dry weight rank technique.

What do our pastures look like?

Preliminary results showed that average paddock size was 38 ha with a range of 14-112 ha. Seventy one percent of paddocks were established via undersowing with the rest established either by straight sowing of autumn pasture or summer sowing hard seeded legumes. Eighty nine percent of paddocks had had some weed control by winter cleaning or spray topping during the pasture phase and top dressing with super phosphate was undertaken on 46% of paddocks. Grazing management was predominantly set stocked (83% of paddocks) from winter to harvest time.

Fifteen different species were included in pasture mixes on farm. Lucerne and subterranean clover were sown in more than 80% of paddocks. The next most common species were arrowleaf clover and medic. The number of species sown in a pasture mix ranged from one to six different species and commonly multiple cultivars of subterranean clover were included.

Species	No. of paddocks sown	Percentage paddocks sown	Frequency		Dry matter composition	
			Average	Range	Average	Range
Lucerne	47	87%	65%	0-100%	27%	0-73%
Sub clover	44	81%	64%	0-100%	20%	0-74%
Arrowleaf clover	19	35%	40%	0-94%	11%	0-44%
Medic	17	31%	15%	0-78%	3%	0-34%
Balansa clover	10	19%	82%	50-100%	30%	1-79%
Cocksfoot	9	17%	45%	0-96%	10%	0-30%
Bladder clover	8	15%	44%	0-90%	5%	0-21%
Phalaris	6	11%	44%	0-88%	18%	0-43%
Gland clover	5	9%	89%	78-96%	21%	5-35%
Biserulla	4	7%	50%	2-94%	36%	0-73%
Chicory	2	4%	12%	0-24%	2%	0-5%
Fescue	2	4%	85%	72-98%	26%	13-39%
Rose clover	2	4%	79%	70-88%	29%	6-51%
White clover	1	2%	0%	na	na	na

Table 1

The average frequency with which lucerne and subterranean clover was found in the pastures was 65% and 64% respectively although the range of frequency was from 0-100% for both species. Other species that were commonly sown including arrowleaf clover, medic and balansa clover on average had frequencies of 40%, 15% and 82% respectively, but they also had very wide ranges. Other species that had high frequencies included gland clover and tall fescue although these were taken from a much smaller number of paddocks and may not represent their average performance. On average, lucerne and subterranean clover provided 29% and 24% of the dry matter respectively with ranges from 0-74%. For other less commonly sown pastures the averages are less helpful but it can be seen other species can be highly productive under certain conditions but they could also sometimes produce very little feed. Across all paddocks sown species were shown to contribute 62% of the dry matter but this ranged from 11-89%. If the species are broken down into functional groups then perennial legume (lucerne) provided on average 29%, annual legumes 39% and perennial grasses 26% in the paddocks in which they were sown. It should be noted that included in annual legumes group was clustered clover which was very prominent in some pastures in 2016. Annual grasses formed the largest weed component of 31% while broadleaf weeds tended to be less with 5%.

What does this all mean for pasture establishment and management?

If we compared the frequency of an individual species with the contribution that it makes to dry matter for the same paddock there is a wide range of dry matter levels produced (Figure 1). It indicated that species can have a high frequency but contribute very little to production. But Figure 1 also indicated that if the frequency of a species is less than 50% there is no potential for it to make a meaningful contribution to pasture production (approx. 20%). Frequency can be very easily determined on farm by walking across the paddock and stopping multiple times. Assess the species located immediately around your feet (0.25m2) and if the species is present in less than every second stop then it is unlikely to be providing significant feed.

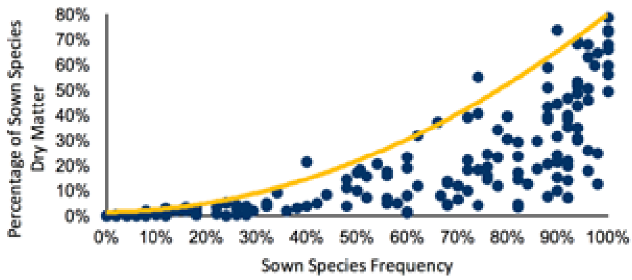


Figure 1. The effect of species frequency on dry matter production. Line plotted by eye to demonstrate upper limits of production.

In terms of the number of species sown compared to what was found in the paddock there was a small decrease in the number of species (Figure 2). If we only considered those species that had a frequency higher than 50% then the number of useful species in the pasture decreased greatly compared to the number of species sown. Figure 3 demonstrated that pastures commonly only have 2-3 species sown species that contribute significantly to pasture production. All species in the list (Table 1) can be productive in this environment (except White clover) but specific species should be sown for a purpose and managed appropriately. Only a few species will be productive out of "shotgun mixes" and reducing the number of species sown may enhance the productivity of the species that are sown.

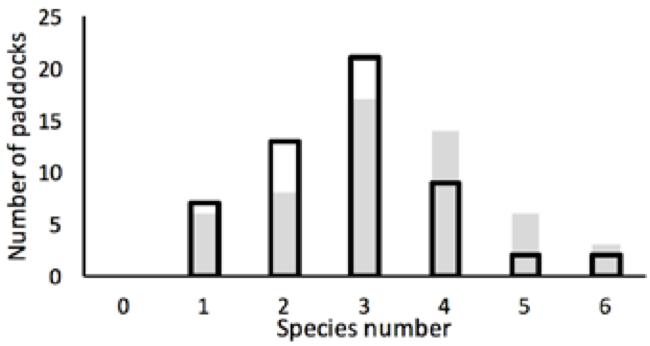


Figure 2. Comparison of number of sown species (grey bars) compared to the number of sown species found in the paddock (open bars).

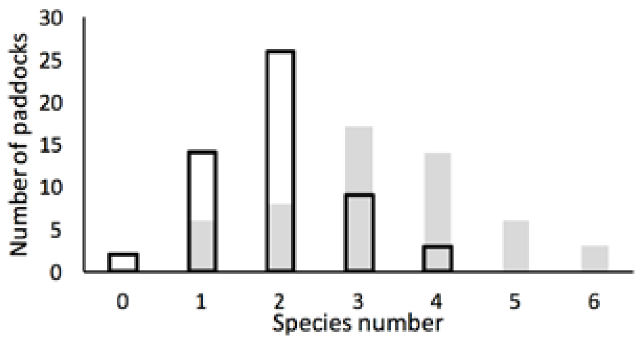


Figure 3. Comparison of number of sown species (grey bars) compared to the number of sown species with greater than 50% frequency found in the paddock (open bars).

Lucerne rightly continues to be an important species in the mixed farming zone. Interestingly only 3 out of the 17 farmers had any type of rotational grazing management system. Most pastures were set stocked for long periods of the year despite decades of research demonstrating that lucerne persistence decreases dramatically under set stocking. Many conversations indicated a resistance to rotational grazing plus the spread of pasture paddocks across farms make rotational grazing very difficult. If lucerne is to be productive and persistent then significant rest periods need to be enforced on farm.

Conclusion

On average sown species provided the majority of feed available (>62%) within a paddock but there was very large variation from paddock to paddock. Most species used in the pasture mixes can be productive but mixes need not contain more than three different species. Pasture species need to have greater than 50% frequency to be a productive component of the pasture. Each species in the mix needs to be included for a purpose and managed accordingly rather than a "shotgun" approach hoping that one species will work. Grazing management of lucerne needs to consider periods of rest to ensure productivity and persistence.

10

FarmLink Research Report 2016

Pakistani farmer exchange program: “Farmers without fences”

Project Partners

FarmLink
change • adapt • prosper

FGC
Functional Grains Centre

Funding Partners

Australian Government
Australian Centre for International Agricultural Research

Report Author

Cindy Cassidy

Introduction

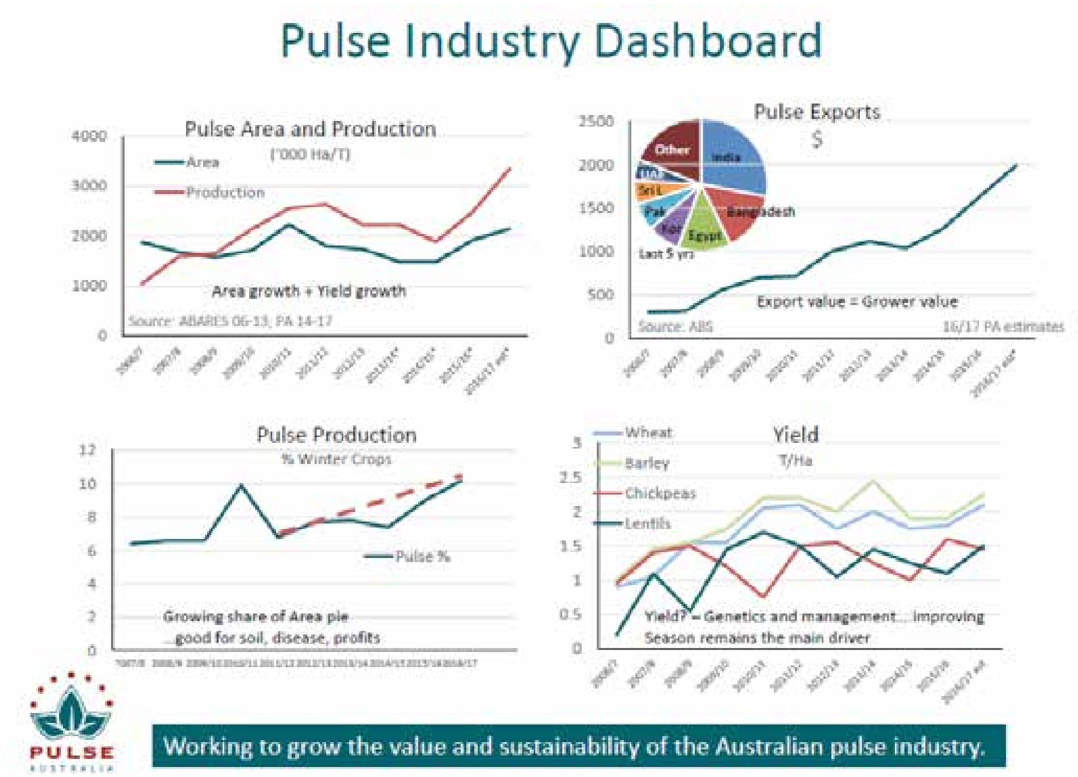
Australian farmers are among the most efficient in the world. In recent years there has been significant investment in research that improves the yield of pulses due to their important role in crop rotations. However, there has been less emphasis on understanding market requirements of our pulses and comparing our products with international markets.

Background

Nationally, pulses average just under 10 per cent of the total area planted to crop however in favourable production areas they can occupy as much as 25% of the total crop area. When grown in rotation with cereals and oilseeds, pulses provide good returns, improve the soil condition, provide a break for important cereal diseases and reduce costs through their ability to fix atmospheric nitrogen for their own use and contributing additional nutrients to the following crop.

In 1990 total pulse production amounted to only 1.3 million tonnes of pulses. The highest level of production to date occurred in 2005–06 when Australian growers produced over 2.5 million tonnes of pulse grain. In 2015, 1.8 million ha of pulse crops produced 2.2 million tonnes of grain, worth A$1.2 billion in exports. The potential for the pulse crop in Australia, assuming all constraints are overcome, is to increase its current size to 4.2 million tonnes, with a commodity value of A$1.504 billion and a farm system benefit of A$538 million – a total of over A$2 billion.

Whilst Australia is the seventh largest producer of pulses internationally it is the third largest exporter, supplying countries in the Middle East, the sub-continent, Africa and Europe (ABARES.



Pakistan is the third largest importer of Australian of Australian chickpeas, following India and Bangladesh. It is also an important market for Australian lentils (based on ABS data).

There is a significant deficit in the domestic supply of pulses in Pakistan. Pulses are cultivated on only 5% of total cultivated area. The main pulses produced are chickpea, black gram, mung bean and pigeon pea. Domestic production ranged from 0.45 million tonnes in 2014 to 0.75 million tonnes in 2013. Total imports are around 0.6million tonnes. On average every Pakistani consumes 6-7 kg of pulses annually and demand is increasing. Serious domestic production constrains mean that there is a gap in supply that is being met by imports mainly from Canada, Australia, Burma, Tanzania, Ethiopia. The level of imports is tempered by price.

The Australian government has a keen interest in providing assistance to developing countries such as Pakistan. This interest to help developing countries also often extends to individuals. One way the government assists is by funding agricultural research projects through Australian Centre for International Agriculture Research (ACIAR). An opportunity exists for Australian farmers to participate in this assistance by linking with international farmers in peer-to-peer learning opportunities.

The Project

The Functional Grain Centre is currently undertaking a project with ACIAR to improve the productivity and profitability of pulse production in Pakistan. The project will focus on farmer driven improvements in agronomic practices and value adding opportunities.

The Opportunity

The opportunity exists for Australian farmers to participate in "Farmers without fences" to assist Pakistani farmers in the production and value adding of pulses. Pakistani farmers will benefit from the experience of Australian farmers and Australian farmers will benefit in the following ways:

- Satisfaction of assisting a developing country
- A rich cultural experience
- An opportunity to learn about international pulse markets
- An opportunity network with like-minded Australian farmers and researchers

The Partnership

FarmLink will lead a pilot project that evaluates the value of using international farmer exchange to build the capacity of farmers in developing countries. This will see FarmLink coordinate the 2017 program which will include 5-10 pulse farmers who will travel to Pakistan to meet with farmers there. Discussion will focus on production methods, constraints and the market. This will be a great opportunity to really understand the drivers of the pulse market. Later FarmLink will host Pakistani farmers here in Australia.

References

http://www.pulseaus.com.au/about/australian-pulse-industry

http://www.agricorner.com/status-of-pulses-crops-in-pakistan/

11

FarmLink Research Report 2016

Fungicide responses for blackleg control in different canola resistance groups

Project Partners

Trial Site Location

Temora Agricultural Innovation Centre

Report Author

Gus MacLennan

Introduction

Heavy reliance on popular blackleg genetics has the potential for widespread breakdown of the effectiveness of these genes and the role they play in protecting the national crop from the number one disease in canola. 60-70% of eastern Australia's canola crop consists of varieties which rely heavily on the resistance grouping "A", typically these varieties are open pollinated and are therefore able to be retained for use across a number of years. Increased plantings and a return to more normal seasons have seen the level of blackleg pressure increase and the effectiveness of the group "A" genes diminish in some areas. This trial examines the effectiveness of blackleg genes with and without protection from fungicides.

A small plot trial was established in Temora (southern NSW) to examine the performance of genetics and foliar fungicides for the control of blackleg. In order to ensure disease pressure was across all blackleg groupings a small amount of canola stubble collected from a 2015 canola NVT was spread over the trial post sowing.

Crop / Target		Application	
Variety, resistance grouping	Bayer 3000TR (B), Bonito (A), Stingray (C), Hyola 525RT (ABD), 44Y89 (BC), Hyola 474 (BF), GT41 (ABF)	Timings	ST – Seed treatment
14th July: 4-6 leaf	47	87%	65%
12th August: Green bud-Elongation	44	81%	64%
Sowing date	16/05/2016	Water Volume	98 L/ha
Herbicides	As per canola system	Droplet size	Medium
Target	Blackleg (Leptosphaeria maculans)		
	Disease pressure	Moderate to High. A light scattering of stubble collected from all genetic groups was applied after seeding.	

Table 1: Trial details

The wet 2016 season was particularly conducive for blackleg pressure especially through the cooler months of June, July and August.

Aviator® Xpro was applied as the foliar fungicide at 550mL/ha, this is a new fungicide for 2017 registered for blackleg control in canola, it contains two active ingredients (prothioconazole + bixafen) of which bixafen is a new mode of action for the canola market.

No.	Fungicide	Rate / 100 kg / Ha	Variety	Resistance Grp	BL rating (bare)
1 2	Seed treatment ST fb Aviator Xpro x 2	800mL 800mL fb 550mL fb 550mL	Bayer 3000TR	B	MS
3 4	Seed treatment ST fb Aviator Xpro x 2	800mL 800mL fb 550mL fb 550mL	Bonito	A	MR
5 6	Seed treatment ST fb Aviator Xpro x 2	800mL 800mL fb 550mL fb 550mL	Stingray	C	MR
7 8	Seed treatment ST fb Aviator Xpro x 2	800mL 800mL fb 550mL fb 550mL	Hyola 525RT	ABD	R-MR
9 10	Seed treatment ST fb Aviator Xpro x 2	800mL 800mL fb 550mL fb 550mL	Hyola 474	BF	R-MR
11 12	Seed treatment ST fb Aviator Xpro x 2	800mL 800mL fb 550mL fb 550mL	44Y89	BC	R-MR
13 14	Seed treatment ST fb Aviator Xpro x 2	800mL 800mL fb 550mL fb 550mL	GT41	ABF	R

Table 2: Trial protocol and details

#- All seed treated with DC-155 (experimental new mode of action fungicide seed treatment) + Poncho® Plus.

*- MS = Moderately susceptible, MS-MR = Moderately susceptible to Moderately resistant, MR = Moderately resistant, R-MR = Resistant to Moderately resistant, R = Resistant.

All varieties emerged well and due to the constant rainfall disease pressure was high and present early on.

Blackleg severity and NDVI assessments were carried out on August 18, six days after the second application of Aviator Xpro, at this point the crop was at 6-8 leaf stage and the "complete" fungicide control treatments would still have been providing protection whereas the seed treatment only would have passed its protection period. Late season assessments were conducted on lodging (% based on a whole plot) and internal cankering (see table 3) which was conducted on 20 individual stems from each plot collected soon after harvest.

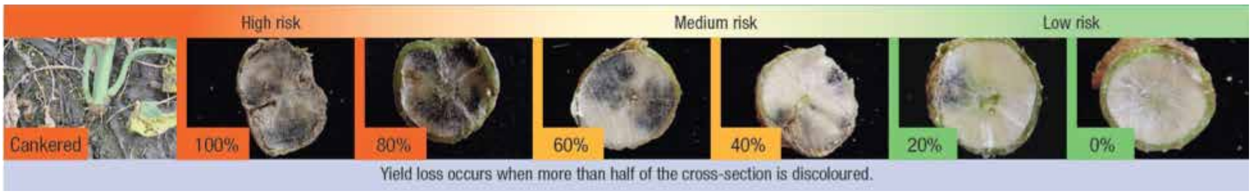


Table 3: Internal stem cankering scale (source: GRDC 2016 spring blackleg management guide)

Whilst data was collected across the entire trial, replicates 2 and 3 were excluded from the analysis due to the impacts of water logging which occurred in spring. Harvest was carried out in mid-November using a small plot harvester calculating yield with oil analysis also conducted on individual treatments.

Photo 1: Bonito (MS) – No foliar fungicide left, 2 x Aviator Xpro right

Photo 2: Hyola 474 (R) – No foliar fungicide left, 2 x Aviator Xpro right

Results

Early assessments indicated all varieties, regardless of genetics or blackleg rating, were exhibiting some blackleg lesions on the leaves and particularly the older leaves. Disease severity was noticeably lower where the two applications of Aviator Xpro had been applied at 4-6 leaf and green bud – elongation however the difference between sprayed and unsprayed was noticeably greater on lower rated varieties.

NDVI, which is a reflection of green leaf mass, showed positive increases across all varieties where Aviator Xpro applications had been made, the only exception to this was Hyola 474 which showed a small decrease of -0.2.

Hyola 474 which was the only variety with the highest possible blackleg rating (R) recorded the lowest levels of disease severity of all the varieties whilst Bayer 3000TR recorded the highest levels which is reflective of its lowly MS rating.

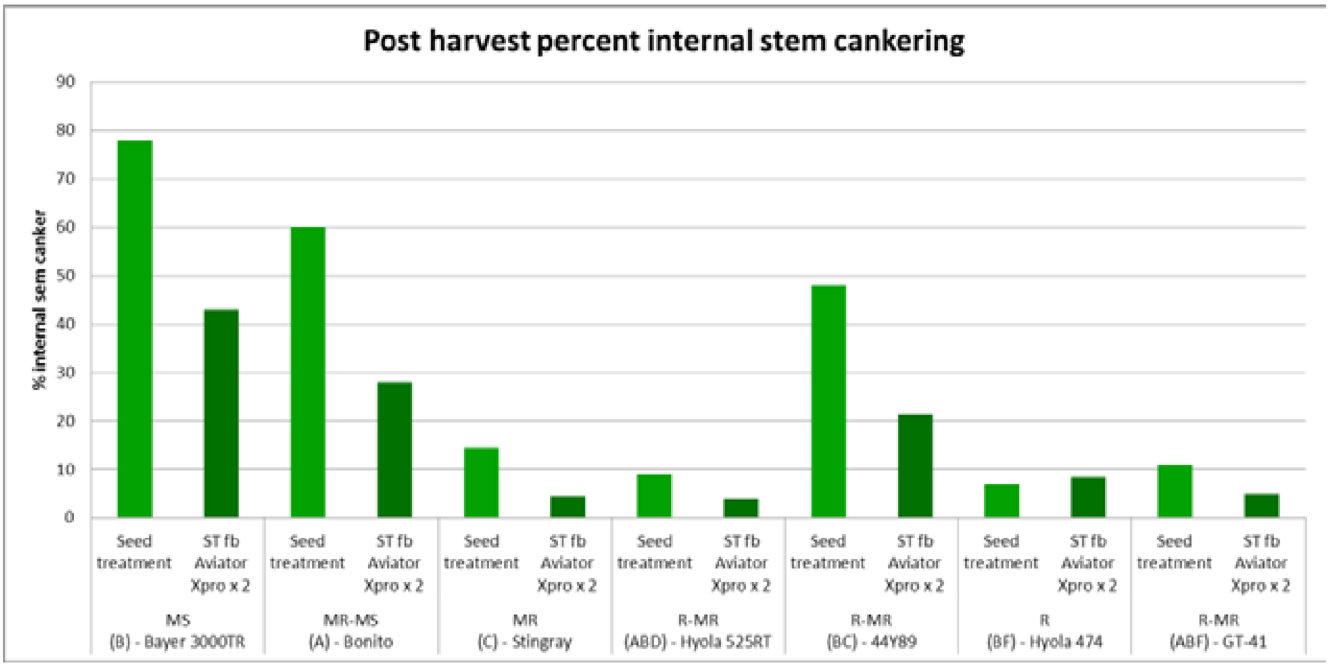
Photo 3: Bonito seed treatment only

Photo 4: Bonito full fungicide program

Photo 3 shows the lower leaves of Bonito beginning to prematurely senesce due to blackleg infecting the older growth, whereas in Photo 4 the foliar applications of Aviator Xpro have kept the lower leaves relatively disease free and greener for longer.

Aside from actual yield stem, cankering is usually your best indication of yield impact from blackleg and assessment can be conducted any time from pod fill to post harvest (whilst stems are still green). Leaf lesions are not necessarily a good indicator of yield impact as varieties or crops with good disease resistance may still exhibit the leaf lesions, however the genetics halt the advancement of the disease and prevent lesions entering the plant's vascular system, forming a stem canker and resulting yield loss. According to the GRDC blackleg management guide, internal infection levels exceeding 50% will result in yield loss.

Graph 1 shows that both Bonito and Bayer 3000TR had significant levels of stem cankering above 50% where no additional fungicides were applied over that of the seed treatment, where Aviator Xpro was applied these levels were greatly reduced to below 50%.



Graph 1: Internal stem cankering results

44Y89 recorded unusually high levels of cankering considering its higher blackleg ranking of R-MR. These higher levels could be due to the popularity of this variety in the Temora district and resulting increase spore pressure however Stingray would be equally if not more popular and it didn't suffer the same levels of cankering. All other varieties with blackleg ratings of MR or greater did not exhibit high levels of cankering.

				Yield		$/Ha
				Harvest		
No.	Fungicide	Variety	Blackleg rating (bare)	% yield of non-sprayed	% Oil	return on investment*
1	Seed treatment#	Bayer 3000TR	MS		45.2	
2	ST fb Aviator Xpro x 2			238	46.9	$305.38
3	Seed treatment	Bonito	MS-MR		46.3	
4	ST fb Aviator Xpro x 2			168	47.9	$423.84
5	Seed treatment	Stingray	MR		47.2	
6	ST fb Aviator Xpro x 2			103	48.2	-$16.22
7	Seed treatment	Hyola 525RT	R-MR		47.3	
8	ST fb Aviator Xpro x 2			115	47.2	$21.92
9	Seed treatment	44Y89	R-MR		44.8	
10	ST fb Aviator Xpro x 2			119	45.8	$82.05
11	Seed treatment	Hyola 474	R		47	
12	ST fb Aviator Xpro x 2			119	46.9	$85.11
13	Seed treatment	GT41	R-MR		46.4	
14	ST fb Aviator Xpro x 2			118	48.4	$52.11

Table 5: Grain yield, oil and return on investment.

**-Includes applications costs, oil bonification and GM price differential*

Grain yields have been expressed as a percentage of the "seed treatment only plot" of the same variety, so that comparison can be directly compared to these two treatments. Actual yields from all varieties ranged from 0.55t/ha up to 2.38t/ha, however in addition to blackleg, weed control was also a limiting factor and where some herbicide systems didn't give adequate control of toad rush the yields were subsequently severely impacted.

Whilst all varieties experienced increased grain yields over and above that of just a seed treatment, the biggest gains were had in the varieties Bayer 3000TR (238% increase) and Bonito (168% increase) both of which are rated MS-MR or lower for blackleg. From a return on investment point of view that equated to a $305.38/Ha return on Bayer 3000TR and $423.84/ha for Bonito where two applications of Aviator Xpro were conducted.

Yield gains in other varieties may not have been a direct result of improved blackleg protection but rather the overall improvement in plant health which allowed those varieties to retain lower leaves for longer which, in a long wet season such as that experienced in 2016, resulted in those plots achieving close to their maximum potential yield. Despite the lack of blackleg observed in the better rated varieties, all except Stingray had a positive ROI, the possible reasoning for Stingray not doing as well where Aviator Xpro was applied could be that it is the only variety of these which is not a hybrid and possibly has the shortest season length meaning its top-end potential is lower.

Conclusions

Foliar applications of blackleg fungicides such as Aviator Xpro or Prosaro achieve the largest gains on varieties such as Bayer 3000TR and Bonito which are both rated MS-MR or lower for blackleg resistance.

Canola varieties rated R-MR or better are unlikely to benefit from foliar blackleg sprays for disease control, however some secondary benefit from green leaf retention may be seen in years where moisture is not limiting.

Blackleg management should be tackled with an integrated approach using buffer zones, rotations, varietal selection and fungicides.

Contact

Gus MacLennan
Customer Advisory Representative
Bayer Crop Science
Email: angus.maclennan@bayer.com
Phone: 0407 641320

Contributed Article 01

Commonwealth Bank Agri Insights
Wave 6, October 2016

Introduction

This research is part of Commonwealth Bank's bi-annual Agri Insights survey. The Wave 6 (October 2016) results show the farming investment outlook is picking up at the national level, on the back of solid seasonal results across much of the country. The survey finds 76 per cent of Australian farmers think data sharing is valuable for themselves and the broader sector, and 58 per cent of farmers actively share their own production data.

In our sixth Commonwealth Bank Agri Insights report we're seeing some of our strongest results to date, with farmers intending to increase investment across the majority of aspects in their operations.

The survey results come as the national Agri Insights Index, measuring overall investment intentions for the forthcoming 12 months, reaches a near-record high of 10.2 points. This is just 0.1 points below the strongest index result to date, recorded in April 2015 and is underpinned by robust producer intentions particularly across the financial and physical aspects of farming.

Farmers are more likely now than at any time since the Index was launched in 2014 to be planning a boost in investment in fixed infrastructure and plant and equipment. The results show 25 per cent of farmers plan to increase their expenditure on plant and equipment in the year ahead and 36 per cent plan to spend more on fixed infrastructure.

Horticulture producers are especially positive, with a record number saying they will increase the scale of their operations in the year ahead (19 per cent saying they will scale up, compared with eight per cent this time last year). Meanwhile, 18 per cent of cotton growers, 14 per cent of both lamb and beef producers, and 10 per cent of summer grain growers say they will scale up their operations in the same period.

Investment intentions are also positive for almost all other sectors, and intentions have strengthened among cotton, lamb, beef, summer grain and wool producers.

Beef

Producers are rebuilding herds after a prolonged period of liquidation. Good rains in swathes of dry pastoral country have unleashed these long-held plans, and the recent run of high cattle prices will have improved many producers' cash flow positions. As a result, Australian beef producers continue to have very strong expansionary intentions.

Lamb

Australian prime lamb enterprises will continue to expand modestly over the next 12 months. Strong prices throughout winter have likely buoyed restocking intentions. Export demand remains robust, though a now modestly higher Australian dollar does pose some downside risk. Lamb is an expensive protein, so consumers may trade down to cheaper meat alternatives.

Wool

The Australian wool industry by and large remains in a phase of consolidation. While global wool supplies are now much tighter, retail demand remains somewhat subdued. Modest consumer confidence in richer countries generally suggests modest growth in purchases of discretionary items like woollen clothing. Nonetheless, the Australian 2016-17 selling season has opened strongly, which may encourage some additional production.

Summer Grain

Summer grain growers indicate modest industry expansion. Growers can capitalise on stronger moisture profiles. And some might potentially have higher water allocations this season. Export prospects look a little better given the lacklustre results of China's reserve grain auction sales. A larger Australian winter harvest though will add more comfort to feed availability and place downward pressure on summer grain prices.

Winter Grain

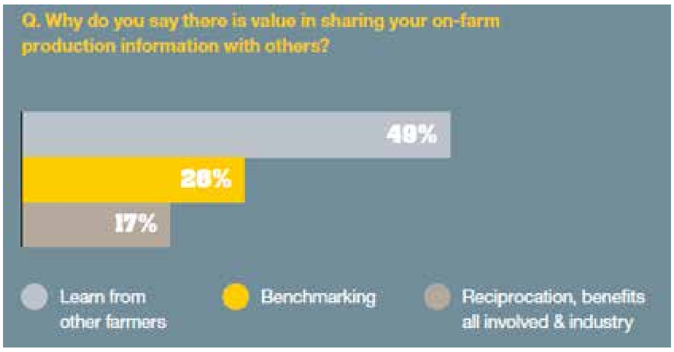
Australia is looking at a bin-busting winter grains harvest for 2016. Much larger Australian wheat, barley and canola crops will add to already very comfortable global supplies. Wheat and feed prices have dropped to multi-year lows as a result.

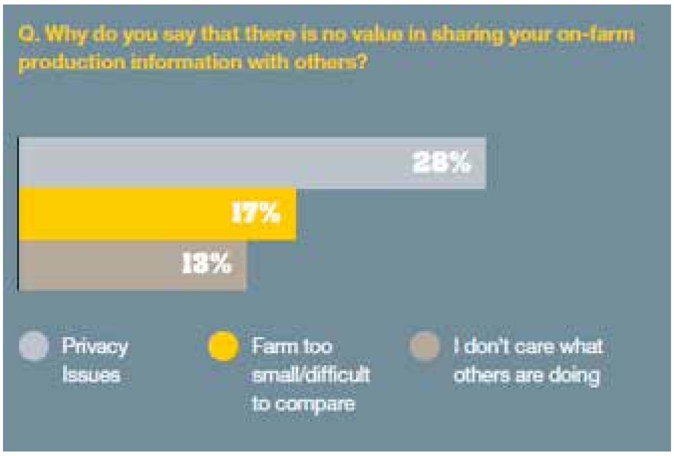
This year, we've seen the Australian agriculture sector ride some highs and some lows, from challenges around dairy pricing, to abundant rain in many states. The data represented in this report was collected prior to the recent adverse weather conditions which farmers have been experiencing. Throughout all this, our farmers are focused on the future.

AgTech

In our most recent survey we asked Australian farmers about digital technology and their attitude to data sharing, a ripe topic of discussion in this new age of AgTech.

We sought farmers' views on the value of using digital technology in their farming operations and sharing their data among their farming peers. What we learned is that farmers are quite open to sharing data, seeing themselves less as competitors, and more as part of an ecosystem that works together to stay competitive on a global scale.





(image #AB7O1291. Thorpe Farm; Tasmania.)

(image #L10043981. Doolin Farm; NSW.)

New South Wales

Farmers across New South Wales are keen to use farm data to improve their own businesses and to share learnings with other farmers, but some say they are uncertain how to use the data they collect. Capital improvement is also an area of focus for farmers in New South Wales. They are among the most likely in the country to invest in both fixed infrastructure and plant and equipment across their farming operations.

People

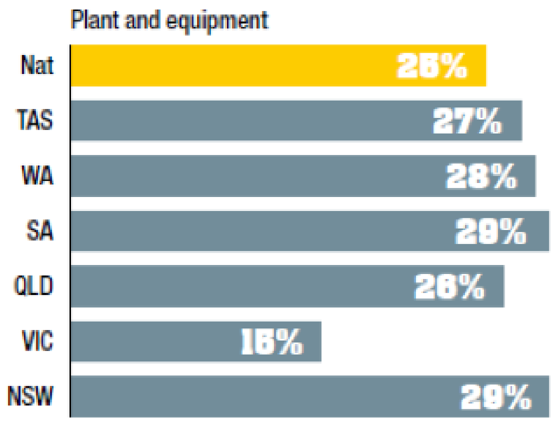
9% of NSW farmers intend to increase their family involvement within their operations, remaining steady year on year and wave on wave.

Financial

21% of NSW farmers intend to invest more in technology, compared to the national average of 20%.

Physical

42% of NSW farmers intend to increase investment in fixed infrastructure, compared to a national average of 36%, this is the strongest fixed infrastructure result for NSW to date. 29% also intend to increase investment in plant & equipment, again ahead of the national average and again the strongest investment intentions for plant and equipment since the survey was launched.



Contributed Article 02

Imagery and other spatial data - What does it mean?

Project Partners GrainGrowers Limited

Report Author

Dr Ben Jones

Introduction

Imagery from satellites, UAVs and other sensors is likely to be the next leap in crop scouting efficiency for farmers and advisers. Imagery can be used to target areas for in-person crop inspection much more efficiently and comprehensively than from the cab of a ute. Satellite imagery can be ordered online, or collected on-farm with UAVs and crop sensors. Most products rely on sensors measuring the visible and near infra-red, but there are other bands (red-edge, thermal, short-wave infra-red) and types of sensor (radar, LIDAR).

Interpreting imagery throughout the season requires some understanding of how the crop and other things in the paddock (stubble, soil, weeds) look in the bands that are being measured. There's also a need to understand how they combine into pixels of various sizes, how sensitive the imagery can be to spatial variation in the crop, how that changes as the crop develops, and how it's affected by the legends chosen for presentation.

As with soil sensing technologies like EM38 and gamma-radiometrics, using imagery can be as simple as looking for patterns as a starting point for ground truthing. More advanced use can also be considered - extrapolating to things like biomass and likely yield. This works better at some points in crop development than others.

Accessibility is key

GrainGrowers ProductionWise now incorporates season-long NDVI imagery, integrated into paddock records and readily accessed for on-farm decision making. ProductionWise uses Sentinel (10m) and Landsat (15m) satellites with several images possible per month, subject to cloud. ProductionWise users new and old are eligible for 1000ha of free imagery across their farms for the 2016 season. From 2017 on, growers and advisers can access this imagery at very competitive rates through ProductionWise (www.productionwise.com.au, or contact GrainGrowers for further information on 1800 620 519).

How crop, soil, stubble and weeds look to a sensor

Satellites and most UAV sensors see the world in distinct 'bands' (Figure 1). Live vegetation reflects a lot in the near infra-red, but little in the visible (red or blue; a bit more in green). The amount of reflection in near infra-red differs between species, and also depends on plant health. Compared to plants, soils reflect much more in the visible. Stubble also reflects quite a lot in the visible and near infra-red.

The widely used 'NDVI' (Normalised Difference Vegetative Index) compares the difference between near infra-red and red to the sum of the two; it's effectively 'plant – soil'. Some UAVs don't measure red and near infra-red at the same time, so they make a 'blue NDVI' by using blue instead of red. This probably makes more sense where soils are less red, but less sense where the crop itself reflects in the blue. On the scale of NDVI, water is negative (it reflects more in the visible), soil is a small positive number, stubble is higher (around +0.2), and plants +0.3 (up to 0.9).

Weeds are often just as reflective as crop plants in the near infra-red, and for this reason overly-healthy looking areas in a NDVI image can be as important to ground truth as poor-looking areas. Different species of vegetation can be discriminated on the visible, and between the red and near infra-red regions, which is known as the 'red edge'.

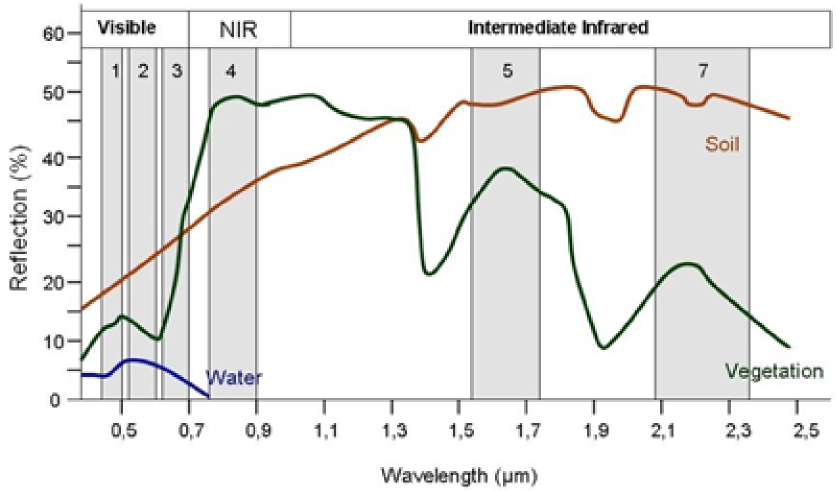


Figure 1. Spectral characteristics of soil, vegetation and water, highlighting red (1), green (2), blue (3), near infra-red (4) and shortwave infra-red (5, 7; data from USGS Digital Spectral library - see resources).

Pixel size

At all except the smallest pixel sizes (<10cm), a satellite or UAV sensor is going to be recording the mixture of plant, soil and stubble underneath it, as well as shadow. This often means a single pixel contains multiple crop rows, up to entire machine widths. The reflectance in the bands will be mixed accordingly. When the crop is small, it's important to remember that the 'plant' component of the image is quite small. A pattern you're seeing might be related to soil, stubble, or pattern of harvest height in a previous crop. Check earlier images to see if the current pattern has coincided with crop growth, or whether it might have been there all along. Even though the plant component may be small, even at 30m resolution satellites can be quite sensitive to it, provided an appropriate legend and processing is used.

Keep realistic expectations about what you might hope to achieve with imagery at a particular scale. Satellite imagery with 10-30m pixel size won't help diagnose problems within machine widths, but it will be good for most of the patterns of crop growth across a paddock that can be managed with a machine. Figure 2 presents the same 20 ha UAV image at a range of pixel sizes as an example.

Wheel tracks and issues with individual rows are easily visible with 3cm pixels. With 1m pixels patterns within machine widths are still readily visible, but with 5m pixels the main features are the patterns across rows (trial strips). With 15 and 30m pixels the trial strips begin to merge, but it's still obvious they're there.

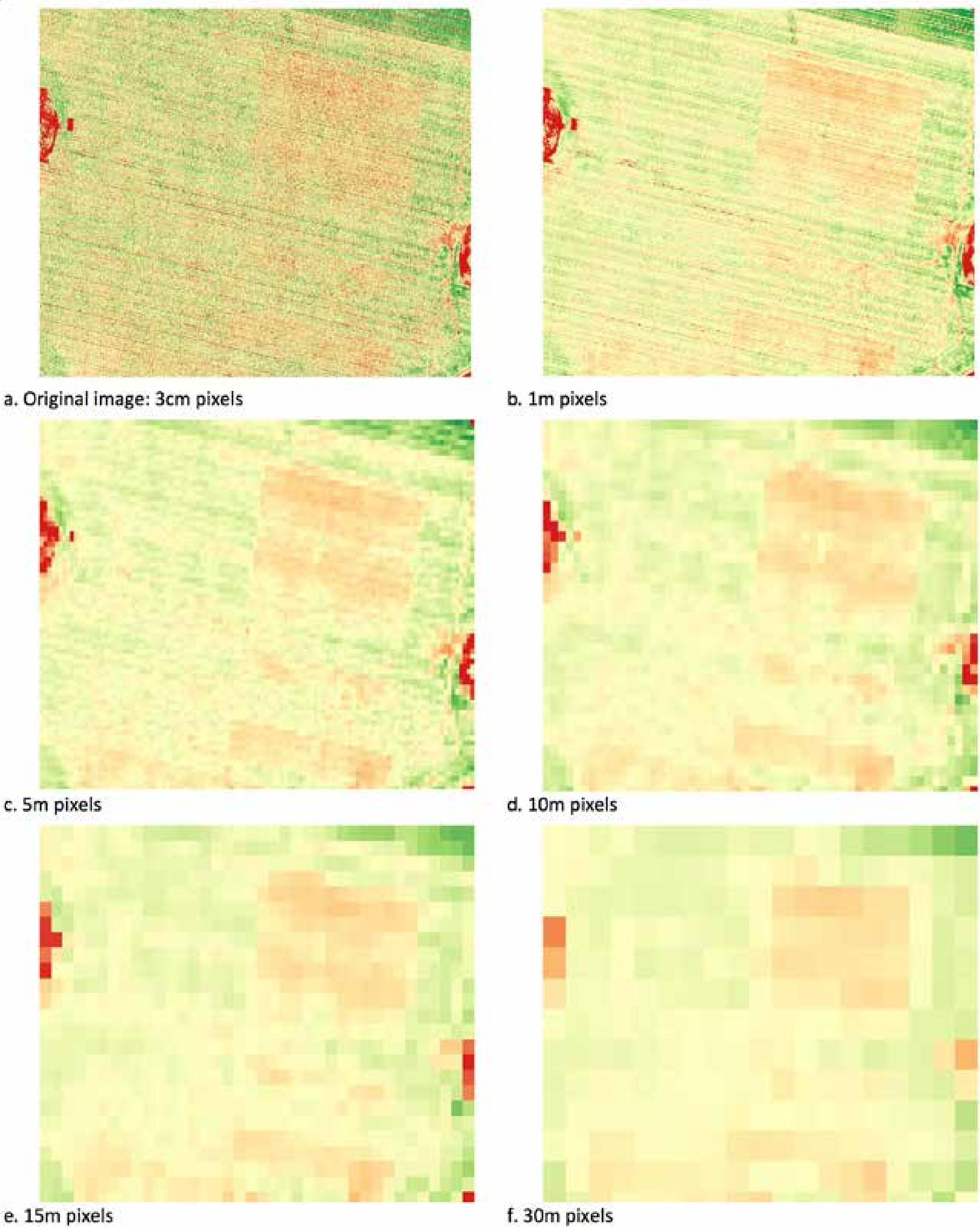


Figure 2. The same 20 hectare scene (an NDVI image of strip-trials in a cereal crop) presented at original (a) and increasingly bigger pixel size (b-f). Original image courtesy Australian UAV.

Even though UAVs can have very small pixels, the images are not necessarily highly detailed. Images can be blurred by wind, and also uncertainty when images are being stitched together. Flying on still days with good light helps to fix this.

Shadow and cloud

Shadow is an issue in two ways: shadows cast by parts of the image itself (crop, stubble), and shadows from cloud. Shadows within images will be a bigger issue with taller crops, and with wider row spacings and/or different sowing angles. The shadows cause the same image to look different at different times of day (or from different angles, in the case of satellites). This can be a limit to comparing absolute NDVI values from different images (if they don't have similar illumination conditions it doesn't make much sense. Similarly with satellites it's important that different bands are processed to reflectances if different images are to be compared). Relative change in NDVI (more or less positive) is more robust.

For UAVs, parts of an image can be taken with direct (full sun) or diffuse (sun behind cloud) light. Clouds also cast shadows across parts of paddocks and can be the cause of spatial patterns in an index like NDVI. If you see patterns that don't make sense, it's often worth checking a colour image for signs of cloud, or comparing the image to a previous or subsequent one to see whether it was an aberration. Cloud effects can also be distinguished by not respecting paddock boundaries and/or crop types. Cloud itself often has very low NDVI where a higher value would be expected.

Crop habit, development and variety differences

Always keep in mind 'what does this look like from above?' If row spacings are wide enough that bare ground or stubble is visible between crop plants, row spacing will affect NDVI. Crops that are naturally erect will tend to have lower NDVI at the same biomass as prostrate (spreading) crops. Prostrate crops will close the canopy early, whereas erect crops at wider row spacings may never close the canopy.

Crops go through distinct phases, and it may not make sense to draw conclusions about biomass/health between two areas of a crop that are in different developmental phases. This often happens with differences in emergence related to soil type, where a cereal that has entered stem elongation has become more erect, and may have lower NDVI than a part of the paddock where the crop is still tillering. Canola is an extreme example; the onset of flowering causes a fall in NDVI, even though the crop is continuing to grow. Heading in cereals and differences in colouring (barley) similarly have an impact on NDVI.

Comparing varieties in the same paddock with imagery and trying to draw conclusions on performance during the season might not make sense unless they are quite similar in development pattern and habit. It does make sense to look at relative differences within the varieties, for example if they are sown across a distinct soil type, or fertiliser treatment.

When does it make sense to extrapolate?

If you have an image of a single variety which emerged at much the same time, at the same row spacing, and is now at a similar developmental stage throughout, it can make sense to extrapolate an index like NDVI. Successful extrapolations have been made to crop biomass, and other measurements like crop nitrogen content. Over large ranges in NDVI, relationships are likely to be curved. As the canopy grows, new leaves and stem grow over old leaves, leading to smaller increases in NDVI as biomass/nitrogen/other measurements of the crop increase.

The period between stem elongation and early grain-fill is when extrapolations between patterns in NDVI and patterns in cereal yield tend to be more sensible. This is in turn related to concepts such as the balance between biomass growth, water use and yield in dryland environments.

Legends and sensitivity

When viewing NDVI data, or data from any other sensor, you need to keep in mind how big the variations you're look for are, compared to the range in the data. Early in the season this might be quite small. Once the crop canopy closes and NDVI gets closer to its maximum (+1), the range in NDVI might also be quite small. Before dismissing data as 'not showing much', try a legend which maximises the visible variation on that paddock. Many sensors measure many more levels than are readily distinguished by the human eye (eg. Many satellites have 4096) and provided they haven't been processed to eliminate it, may show subtle variations. On the other hand, if what you see appears like random noise, it probably is.

Conclusion

As with all sources of information, a basic understanding of how they work and some of the pitfalls helps to make sure they improve efficiency and save time, rather than wasting it. Some time spent looking at crops and considering 'how would this look from a satellite' will help to make sense of the next image when it comes in. There are some simple strategies (for example, checking a previous image) which help to make sense of unusual or suspect patterns in imagery. With some thought, it's also possible to use measurements from images as a surrogate for some feature of the crop (eg. biomass) when making decisions. The next few years in agronomy promise to be exciting as new imagery is released, and products are developed that make imagery still more 'user friendly' for decision makers.

Useful resources

Understanding spectra:

http://landsat.usgs.gov/tools_spectralViewer.php