MAINTAINING PROFITABLE FARMING SYSTEMS WITH RETAINED STUBBLE

Across various rainfall environments in SA, Victoria and central and southern NSW

KEY 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 2nd wheat crop or if sowing canola into large stubbles
- Early monitoring is essential to see how effective actions are to allow for re-planning

Background

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 sixteen farming systems groups and research organisations which include BCG, CSIRO, CWFS, EPARF, Farmlink Research, 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.

In 2016, grain yields have been 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

a. Tine =

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

b. Disc =

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 retaining 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). The proportion of farmers using either disc or tined seeders would be similar to the YP and mid-north areas, although the percentage using tined seeders would be higher in many areas. In relation to establishing a crop in stubble retained systems, the following issues arose-

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

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 practiced provides an additional reason to harvest low. The prototype Integrated Harrington Seed Destructor (iHSD) was tested in Temora, NSW in December 2015, Inverleigh in December 2015 and Furner, SA in January 2016 at a constant speed of 4km/hr to compare the efficiency and cost with non-weed seed destruction methods (Table 3).

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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)	Yield (t/ha)	Cost $/ha	Cost $/ton
60cm	9.5	10.6	5.4	2.19	$63.2	$28.7
15cm	5.7	6.2	9.6	2.05	$105.3	$50.1
% Change to 15cm	-41%	-42%	+78%	-6%	+40%	+57%

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)*

Harvest height	Efficiency (ha/h)	Speed (km/hr)	Fuel efficiency (l/ha)	Harvest Yield (t/hr)	Grain (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 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)

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

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.

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 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 as humus 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).

TABLE 4 A screenshot of Dr Clive Kirkby's stubble nutrient humification calculator to estimate the amount of fertiliser (N and S only) as Sulphate of ammonia (kg/ha) that would need to be applied to a cereal stubble load of 10t/ha with a humification rate of 20% to assist in rapid breakdown of the residual stubble. *(Financial support provided by NIEI, EH Graham Centre, CSIRO and GRDC project DAN00152)*

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		

TABLE 5 A screenshot of Dr Clive Kirkby's stubble nutrient humification calculator to estimate of the amount of fertiliser (N·P·S) as Urea and Single Superphosphate (kg/ha) that would need to be applied to a cereal stubble load of 10t/ha with a humification rate of 30% to assist in more rapid breakdown of the residual stubble. *(Financial support provided by NIEI, EH Graham Centre, CSIRO and GRDC project DAN00152)*

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		

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 & 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.

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!

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

Cropping system	Crop Type	Average Total Cost 2014-16 ($/ha/yr)	Average Net Margin 2014-16 ($/ha/yr)	Average 3yr Profit-Cost ratio ($/ha/yr)
Aggressive	Canola RR	$524	$722	1.4
Aggressive	Wheat (yr 1)	$525	$378	0.7
Aggressive	Wheat (yr 2)	$504	$394	0.8
Conservative	Canola TT	$452	$694	1.5
Conservative	Wheat (yr 1)	$415	$289	0.7
Conservative	Wheat (yr 2)	$419	$261	0.6
Sustainable	Vetch (Hay)	$463	$416	0.9
Sustainable	Canola TT	$426	$769	1.8
Sustainable	Wheat	$492	$422	0.9
Sustainable	Barley	$478	$441	1.0
SYSTEM AVERAGES				
Aggressive		$517	$498	$0.96
Conservative		$429	$415	$0.95
Sustainable		$465	$512	$1.12

TABLE 7 Average net margins across all crop types for each crop system by opener type between 2014 and 2016 at Temora, NSW.

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

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).

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.

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.

(contract sowing at $45/hr, # increased speed at harvest $400/hr, ## fuel @ $1.20L)*

	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 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.

Pre-sowing Nitrogen Application	Emergence Plants/m²	GS30 Plant Dry Matter (t/ha)	GS30 Plant nitrogen (%N)	GS30 Nitrogen uptake (kgN/ha)	Anthesis Plant Dry Matter (t/ha)	Anthesis Nitrogen uptake kgN/ha)	Grain Yield (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	0.43

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.

Graze treatment	Stubble treatment	Gross income ($/ha/year)	
		Assuming grazed stubble has no value	Assuming grazed stubble has value as per methods
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 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.

Phase	Stubble Treatment	Grain Yield 2009-2016: 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			

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, 4 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 & 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 5 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). One of the negatives of using a less diverse rotation (canola-wheat-wheat) in a full stubble retained system is that there can be a significant reduction in the grain yield in the 2nd wheat crop (Table 11). This difference is presumably due to lower N availability due to immobilisation in the retained stubble treatment (as establishment was good and weeds, pests and disease were controlled).

Similar results were observed in a crop systems experiment where wheat (1st wheat) was either sown into canola stubble or into 7.2 t/ha wheat stubble (2nd 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 2nd wheat crop (Table 12). Many farmers in the south west slopes also observed decreases in the grain yield of their 2nd consecutive wheat crop compared to wheat sown after canola in 2016 in stubble retained 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 window 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.

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TABLE 12 Wheat grain yield in crop following canola (wheat yr 1) compared to 2nd wheat crop at crop systems experiment at Temora, NSW 2014-2016 in disc and tines x 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	

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.

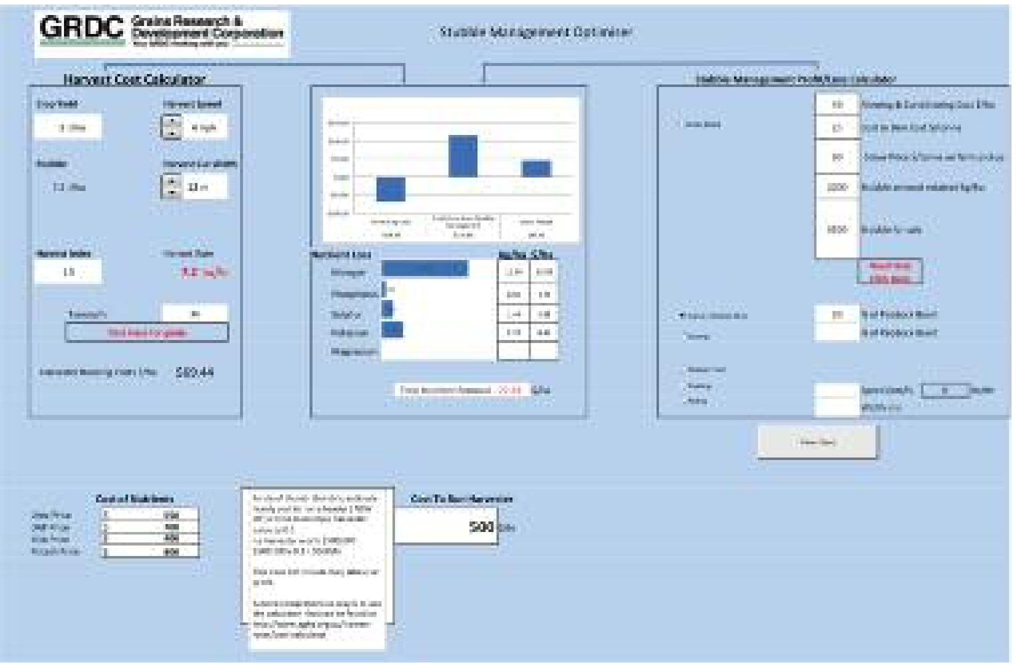
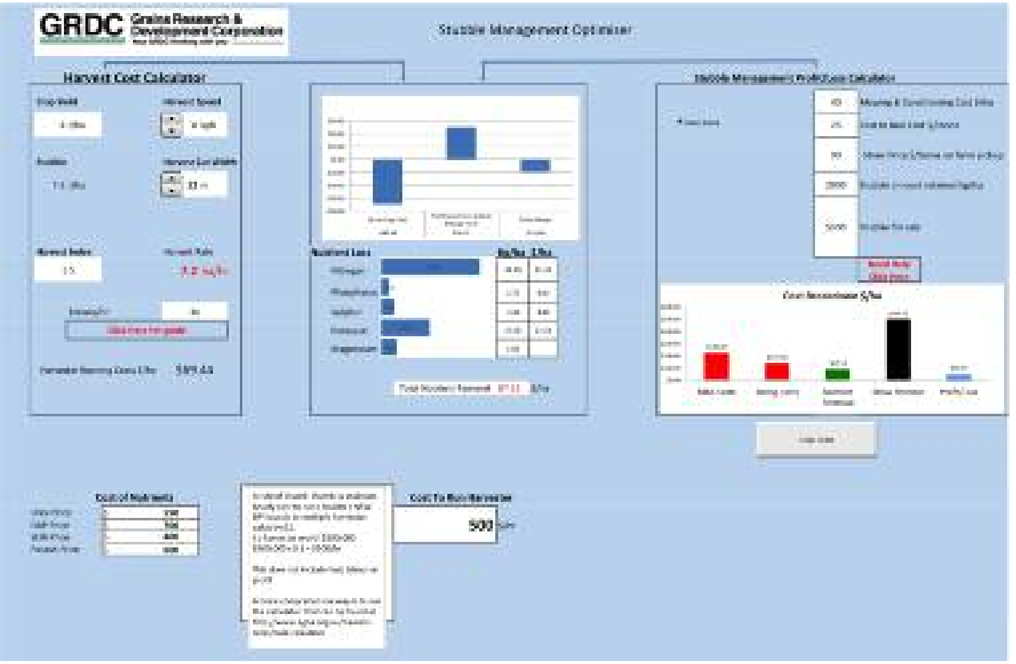


FIGURE 2 The estimated effect on profit from harvesting a 5t/ha wheat yield with 5.5t/ha of the remaining 7.5t/ha stubble load being baled and sold (valuing the loss of nutrients).



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).

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 & 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 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).

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)

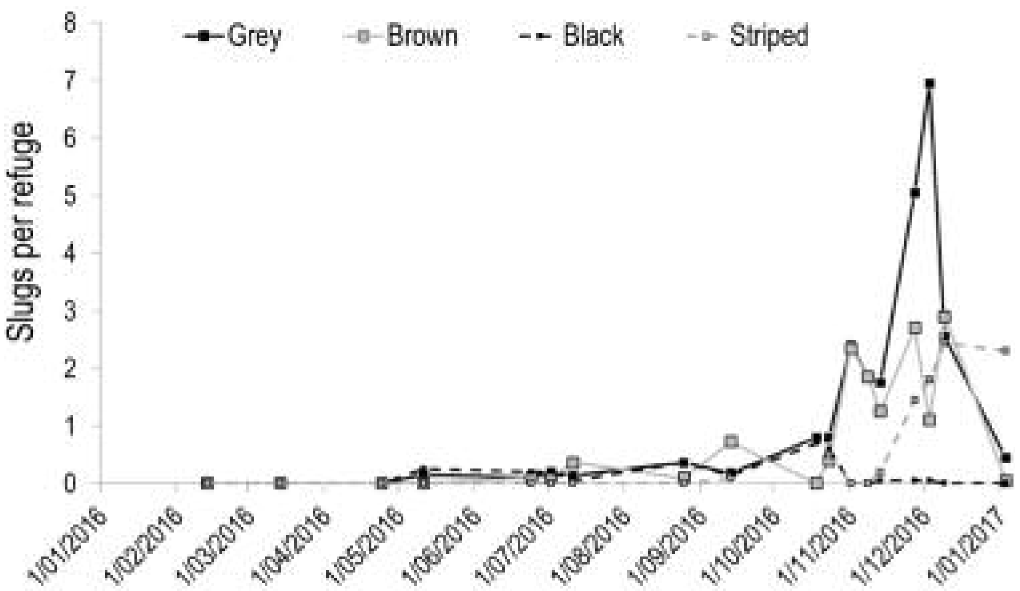
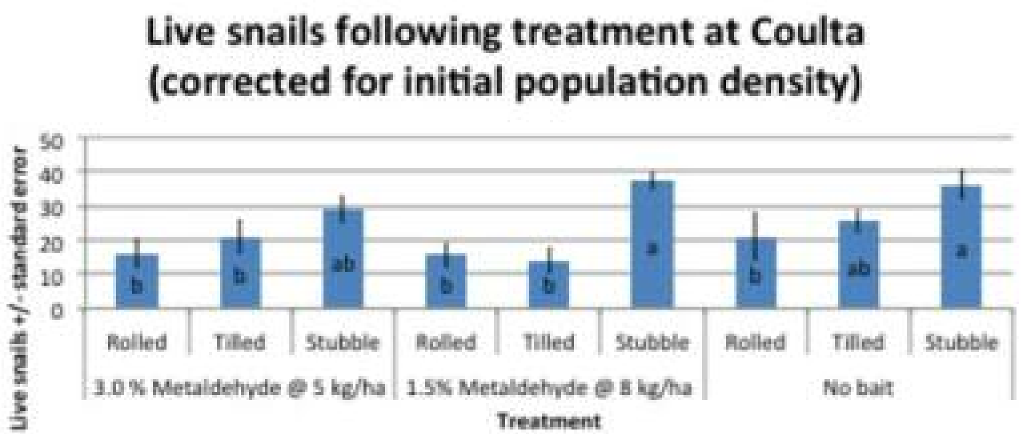


FIGURE 4 Mechanical treatment by baiting experiment in canola stubble at Coulta, Lower Eyre Peninsula, SA



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 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 6 people, 2 fire control units (1 with 5000L and the other with 500L) and you are not able to leave the paddock until NO smoke is detected.

Conclusion

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.

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

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

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.

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SELF-WEEDING CROPS – A POTENTIAL TOOL IN HERBICIDE RESISTANCE MANAGEMENT

For farmers, weeds are not just irritating – they are a costly problem.

Australian grain growers alone lose $3.3 billion and nearly 3 million tonnes of harvest to weeds each year. And while weeds are largely controlled by use of synthetic herbicides, many species, and particularly annual ryegrass, are evolving resistance. There are around 15 modes of action for annual ryegrass control but there is now resistance to 11 of them. With this limitation in options for control, other approaches are needed to slow down resistance.

We know from previous work over a long time that plants put out a cocktail of chemicals from their roots in response to challenges from other plants. The question that arises is whether those cocktails could be managed and utilised to give effect to weed control, (i.e. could plants do their own weed control?)

Researchers at the Graham Centre in Wagga Wagga, have screened over 70 canola varieties in the laboratory for their ability to inhibit the root growth of annual ryegrass. From this work the top and bottom ones were taken into the field to see whether the capabilities could be repeated. Over three seasons the research looked at how well annual ryegrass could be controlled. An unexpected benefit for one variety was that several other weed species were also controlled (Figure 1). In 2015, on a wild radish site there was also a variety that was free of wild radish (Figure 2).

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FIGURE 1 A comparison of a good self-weeding variety (left) and a poor self-weeding variety (right) where no herbicides were used in crop.

FIGURE 2 A wild radish-free plot where no herbicides were used in the crop.