GRAINS RESEARCH UPDATE

STRATEGIC STEPS – ENDURING PROFIT

Walpeup

Tuesday 17th July

9.00am to 1.00pm

Walpeup Memorial Hall

Glen Street, Walpeup

#GRDCUpdates

Walpeup GRDC Grains Research Update
convened by ORM Pty Ltd.

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GRDC Grains Research Update WALPEUP

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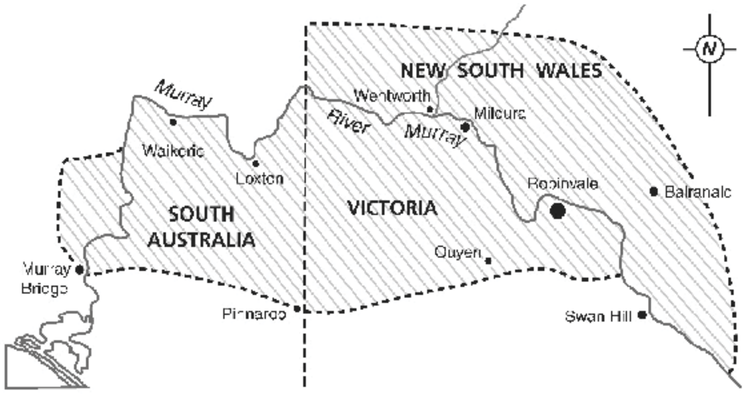

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MSF formed in 1997 in response to a recognition that conservation farming practices had not been widely adopted across the region. Therefore, there was a need to identify the issues restricting the adoption of technology that would enhance the development of profitable and sustainable farming systems. Since it was formed, MSF has achieved a great deal. Increases in farm profitability have been observed as a result of MSF activities, along with environmental and social gains. MSF continues to be guided by farmer members to meet their information needs, whether in the sphere of cereal cropping or livestock management.

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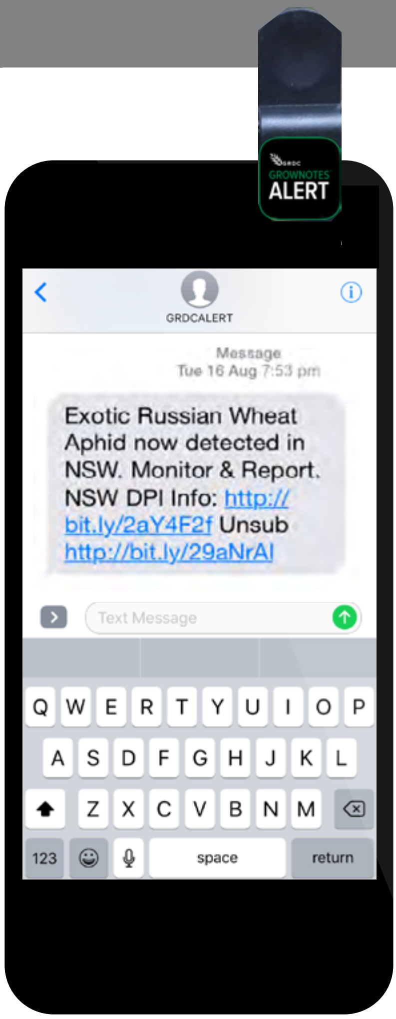

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GRDC GROWNOTES ALERT

Insects, resistance and control

James L. Maino[1,2] Siobhan de Little[1,2], Lisa Kirkland[1,2], Elia Pirtle[1,2], Matthew Binns,[2] and Paul A. Umina[1,2].

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[Φ]Extra technical comment by Protech Consulting Pty Ltd

GRDC project codes: CES00003, UM00057, CES00004

Keywords

- redlegged earth mite, green peach aphid, Russian wheat aphid, insecticide resistance, neonicotinoids.

Take home messages

- Insecticide resistance issues continue to outpace novel control options.
- Redlegged earth mite (RLEM):
  - Insecticide resistance in RLEM has been detected for the first time in eastern Australia.
  - Synthetic pyrethroids (SPs) are completely ineffective against SP-resistant RLEM populations, while some efficacy remains for organophosphates (OPs) against OP-resistant RLEM populations.
- Aphids:
  - Green peach aphid (GPA) has acquired low level resistance to neonicotinoids.
  - Pirimicarb is now mostly ineffective against GPA due to resistance, but remains effective against other crop aphids, highlighting the importance of correct species identification.
  - A variety of insecticide seed treatments have been shown to control Russian wheat aphid (RWA), with the length of protection differing between products.
- The implementation of recently published resistance management strategies (RMS) is vital to maximising the long-term viability of chemical options for pest management.
- Looking to the future:
  - Growth in the use of neonicotinoids will likely see increased insecticide resistance issues and the disruption of beneficial insect services in Australia.
  - Cutting edge forecasting tools are helping to identify patterns in insecticide resistance outbreaks.

Background

Insecticide resistance issues in broad-acre cropping continue to outpace the expansion of novel control options. In this paper, the latest findings on two major pest species that have developed resistance to key chemical groups, the redlegged earth mite (*Halotydeus destructor,* RLEM) and the green peach aphid (*Myzus persicae*, GPA) are discussed.

New research on the efficacy of seed treatments against Russian wheat aphid (*Diuraphis noxia*, RWA) is also presented.

The paper concludes by discussing the future risks of increased reliance on neonicotinoid insecticides and the application of forecasting approaches managing insecticide resistance.

Resistance in redlegged earth mites spreads to eastern Australia

The redlegged earth mite (*Halotydeus destructor*, RLEM) is an important pest of germinating crops and pastures across southern Australia. Four chemical sub-groups are registered to control RLEM in grain crops: organophosphates (OPs) (Group 1B); synthetic pyrethroids (SPs) (Group 3A); phenylpyrazoles (Group 2B); and neonicotinoids (Group 4A). The latter two are registered only for use as seed treatments (Umina et al. 2016).

After remaining confined to Western Australia (WA) for a decade, in 2016, insecticide resistance in RLEM was detected for the first time in eastern Australia (Maino, Binns and Umina, 2017). In WA, resistance to SPs is widespread, while OP resistance is comparatively more restricted (Figure 1). In 2016, following reports of a field control failure in the Upper South East district in South Australia (SA), resistance testing determined this SA population was resistant to SPs and OPs (Figure 2). In 2017, two additional SP resistant populations were confirmed on the Fleurieu Peninsula (approx. 30km apart from each other, and approx. 200km from the 2016 detection).

All SP resistant populations tested to date have been found to possess a target site mutation on the para-sodium channel (Edwards et al. 2017). This mutation confers high level SP resistance (approximately 200 000 times the resistance of a susceptible population) leading to complete spray failures (Figure 2). In contrast, the mechanism conferring OP resistance has not yet been resolved, but resistance is comparatively less than SP resistance, such that OP efficacy will be reduced but not lost entirely.

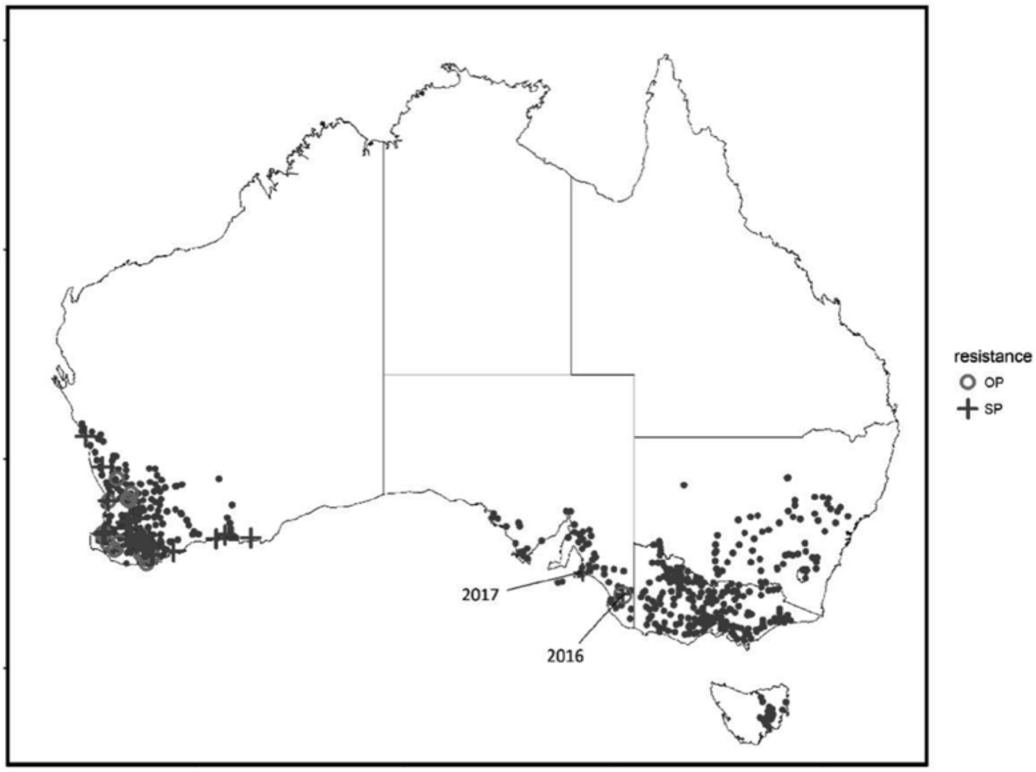

Figure 1. The current known distribution of *H. destructor* in Australia (adapted from Hill et al., 2012) shown as full circles, overlaid with the known distribution of SP and OP resistance across Australia at 2017.

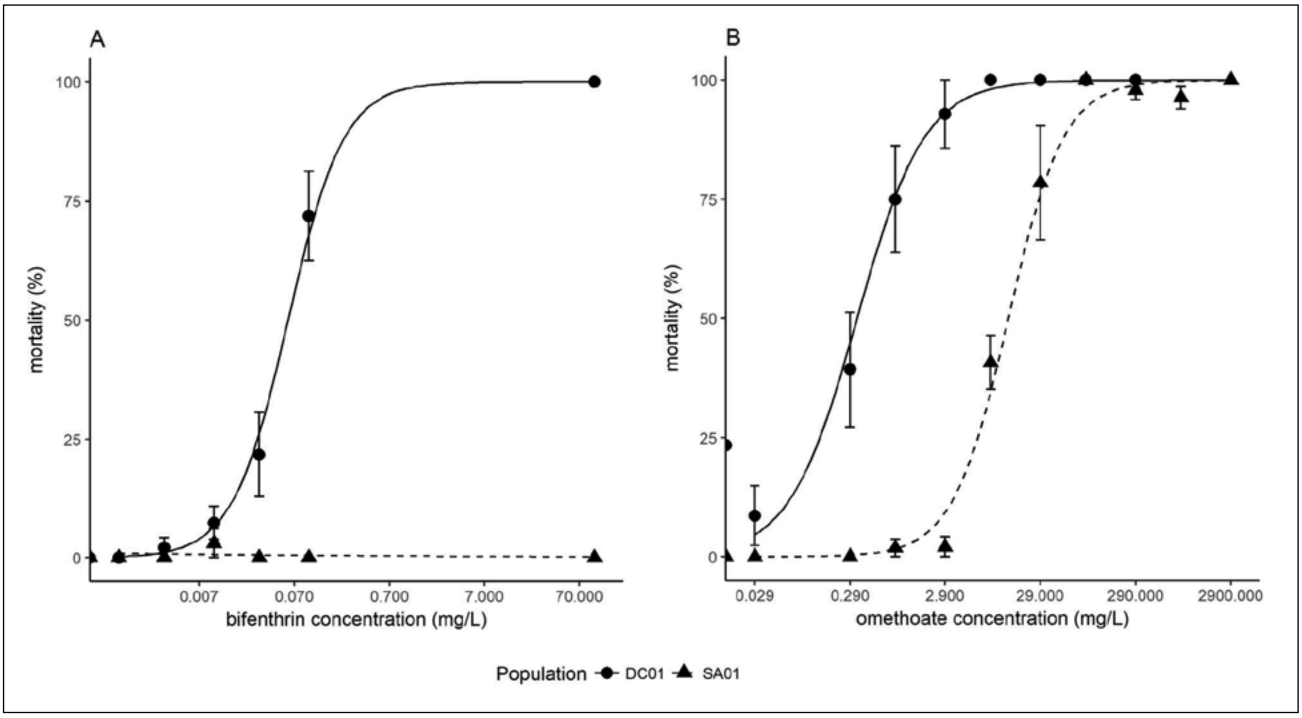

Figure 2. Concentration-mortality curves for redlegged earth mite from a susceptible (DC01) and resistant (SA01) populations when exposed to a synthetic pyrethroid — bifenthrin (A) — and an organophosphate — omethoate (B) — after 8 hrs exposure. Vertical bars denote standard errors. Lines represent fitted values from fitted logistic regression models.

To increase management options for RLEM populations with dual resistance to OPs and SPs, trials run by the University of Melbourne and **cesar** are testing the impact of different management regimes on mite abundance and chemical tolerance in a dual-resistant population. Preliminary results have shown that both foliar applied insecticide groups are largely ineffective on populations with SP and OP resistance, but that high rates of omethoate can still provide control in OP-resistant populations, though the long-term sustainability of this strategy is unlikely. A novel mode-of-action group was also tested as part of this trial and found to be highly effective at suppressing mite numbers, indicating no cross-resistance.

Green peach aphid acquires new resistances

Green peach aphid (GPA) is a widespread and damaging pest of canola and a range of pulse crops, causing damage by feeding and transmitting viruses. Five chemical subgroups are registered to control GPA in grain crops: carbamates (Group 1A); SPs (Group 3A); OPs (Group 1B); neonicotinoids (Group 4A); and sulfoxaflor (Group 4C). Paraffinic spray oils are also registered for suppression of GPA.

Together with CSIRO, **cesar** has been mapping the extent of insecticide resistance in GPA across Australia for the past few years. This ongoing resistance surveillance has continued to show high levels of resistance to carbamates and SPs that are widespread across Australia. Moderate levels of resistance to OPs have been observed in many populations, and there is evidence that resistance to neonicotinoids is spreading.

Despite widespread resistance to the aphid specific carbamate chemical pirimicarb$^{\Phi}$ in GPA populations (Figure 4), this pesticide remains important to the control of other canola aphid species of similar appearance (e.g. cabbage aphid and turnip aphid). Thus, it is important to properly identify aphids before spray decisions are made. Figure 3 highlights some key features that can be used to distinguish GPA (with a hand lens) from other similar species found on canola. If a hand lens is unavailable, GPA will usually be found on the lowest, oldest leaves, typically in sparse family groups, while turnip aphid and cabbage aphid are more commonly found in large colonies on flower spikes.

$^{\Phi}$*Products containing pirimicarb are not registered for control of turnip aphid in canola. In commercial situations label specification must be adhered to at all times.*

Neonicotinoid resistance conferred by enhanced expression of the P450 CYP6CY3 gene was discovered in Australian GPA populations in 2016 by **cesar** and CSIRO researchers. Laboratory bioassays

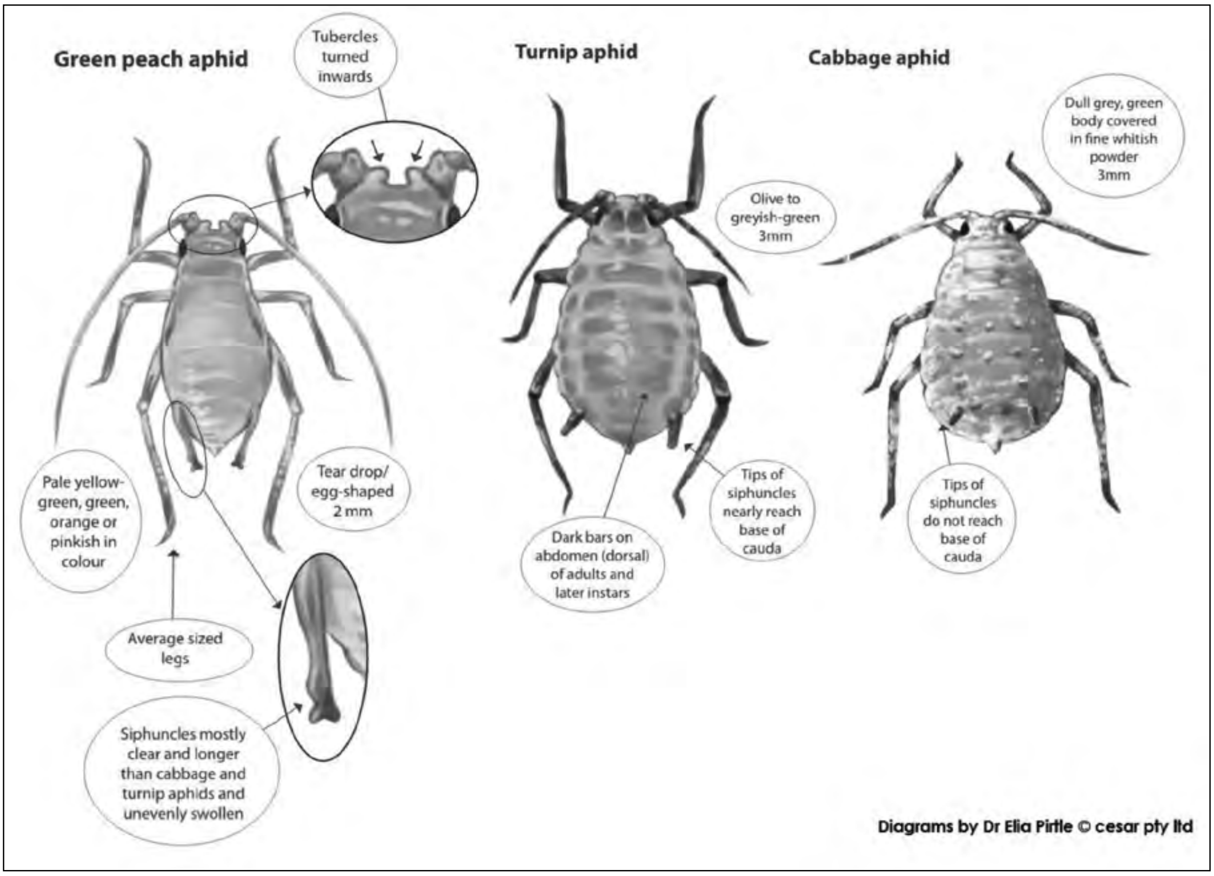

Figure 3. To assess the applicability of pirimicarb to other non-resistant aphid species of similar appearance, green peach aphid should be distinguished using diagnostic traits. If a hand lens is unavailable, green peach aphid will usually be found on lowest, oldest leaves, typically in sparse family groups, while turnip and cabbage aphid are more commonly found in large colonies on flower spikes

revealed these aphids to be approximately 10 times more resistant to a topical application of a neonicotinoid compared to a susceptible population. However, overseas GPA are known to carry an R81T gene mutation of the nicotinic acetylcholine receptor that confers approximately 1000 times resistance to neonicotinoids resulting in field control failures, as well as cross-resistance with group 4C chemicals such as sulfoxaflor. Australian GPA populations may acquire this high level neonicotinoid resistance if neonicotinoid selection pressures remain high, or if there is an incursion of overseas GPA carrying the R81T mutation.

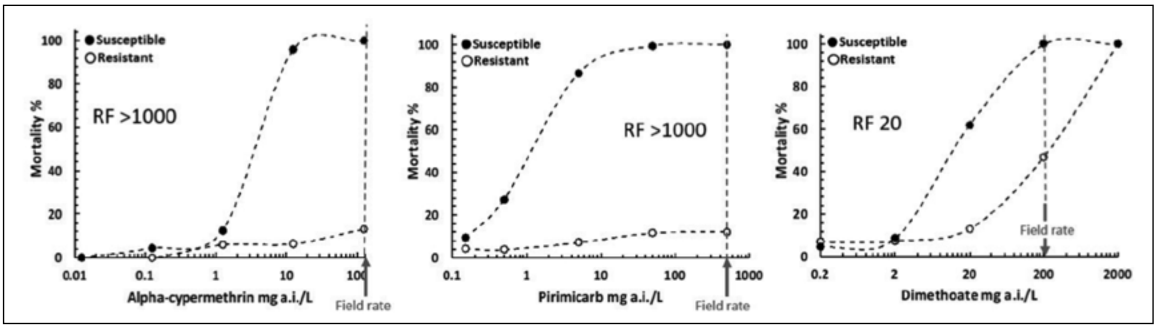

Figure 4. Sensitivity of a typical Australian susceptible and resistant green peach aphid population to the synthetic pyrethroid, alpha-cypermethrin (left panel), the carbamate, pirimicarb (middle panel) and the organophosphate, dimethoate (right panel). RF = Resistance Factor.

Resistance management strategies

With resistance evolution continuing to outpace the discovery of new chemistries with novel modes of action, resistance management strategies (RMS) are more than ever essential to maintain the viability of pest control tools.

RMS for major grains pests have been made available through the National Insecticide Resistance Management (NIRM) working group of the Grains Pest Advisory Committee, a GRDC funded project, which provides strategic advice to GRDC on pest issues. Across these strategies, there are both general and pest-specific practices that can help maintain the viability of chemistries into the future.

General RMS strategies include:

- If applying multiple insecticides within a season, rotate chemistry mode of action.
- Utilisation of non-chemical control options that suppress pest populations.
- Using economic spray thresholds to guide chemical applications.
- Using selective chemicals, if chemical application deemed necessary, in place of broad-spectrum options.
- if using broad spectrum chemicals, consider the secondary impacts to non-target pests and beneficials.
- Compliance with all directions for use on product labels and ensuring proper application coverage.

RMS strategies specific to GPA include:

- Managing the green bridge (in particular, the control of brassica weeds and volunteer crops) on which GPA may persist through summer.
- Stubble retention to decrease visual contrast between seedlings and soil (landing cue for GPA).

RMS strategies specific to RLEM include:

- Control of spring populations immediately before the production of over-summering (diapause) eggs through cultural control (grazing, broadleaf weed removal), or a Timerite® spray (if required) to reduce pest pressure at crop emergence/RLEM hatching the following autumn.

Testing control methods for Russian wheat aphid

Russian wheat aphid (*Diuraphis noxia*, RWA) was first detected in Australia in 2016. The host range of RWA includes more than 140 species of cultivated and wild plants within the family Gramineae (grasses). These include wheat, barley, triticale, rye, oats, pasture grasses and wild genera including *Poa, Bromus, Hordeum, Lolium, Phalaris* and others. Wheat and barley are most susceptible, while triticale, rye and oats are less susceptible.

Unlike other cereal aphids that damage plants by removing nutrients, RWA also injects salivary toxins during feeding that cause rapid, systemic phytotoxic effects on plants, resulting in acute plant symptoms and potentially significant yield losses. Even a few aphids can cause plant damage symptoms to appear as early as 7 days after infestation. These include:

- white and purple longitudinal streaks on leaves
- curled, rolled or hollow tube leaves
- stunted growth or flattened appearance
- discolored leaves
- hooked-shaped head growth from awns trapped in curling flag leaf
- bleached heads

Insecticide seed dressings[Φ] can be effective to combat RWA infestations in establishing cereal crops. **cesar** have tested the relative efficacy and length of activity of various insecticide seed dressings in wheat against RWA, and compared this with another important cereal aphid pest, the oat aphid (*Rhopalosiphum padi*).

[Φ]None currently registered for use in Australia, but their use is permitted under the following permits: PER81133, PER82304 and PER83140.

All seed dressings tested provided effective aphid control up to five weeks after emergence, with higher rates generally providing several weeks extra protection over lower rates of the same product. Oat aphids generally persisted and reproduced on wheat at an earlier time-point than RWA, suggesting that RWA is less tolerant to the insecticide seed dressings tested. This suggests that management of cereal aphids in Australia using insecticide seed dressings is likely to achieve similar, if not better, control of RWA as oat aphid.

Balancing the scales of neonicotinoid seed treatment use

Neonicotinoids are currently the most used insecticide group globally. This over-reliance may be explained by the increased resistance issues surrounding older chemistries like the OPs and SPs. Also contributing to this trend is the convenience of neonicotinoids, in particular, as seed treatments, which are applied at the time of sowing at no extra application cost.

Despite the advantages of neonicotinoid seed treatments, their indiscriminate usage as commonly seen, carries some important costs. Continued wide-scale use of neonicotinoid seed treatments will select for resistance, as is currently being seen in GPA in Australia (de Little et al. 2017). Overseas, where neonicotinoids have been used for longer and more extensively, more cases of resistance have been documented (Sparks and Nauen, 2015). In addition to resistance concerns, widespread neonicotinoid use is likely to impair ecosystem services provided by some beneficial invertebrate and microbial communities, as has been shown in international studies. Industry stewardship and good resistance management are paramount to ensuring neonicotinoid usage is balanced against these issues, and remains a long-term viable control option for grains pests.

Before making a management decision, the question should be asked, is a neonicotinoid seed treatment warranted in this paddock, in this year?

- Wherever possible, assess the risk of damaging pest infestations (or virus risk), based on the prior paddock and seasonal history. In the case of RLEM, for example, a high-risk situation would be indicated by: (i) canola or lucerne to be sown, (ii) high mite numbers the previous year, and (iii) no Timerite® spray the previous spring.
- Unless the pest risk is deemed high, avoid using neonicotinoid seed treatments in consecutive years, preferably no more than one in three years in any given paddock.

With seed treatments, which are not applied in response to immediate pest pressure, the challenge, of course, is the ability to accurately forecast the timing and severity of pest (and virus) occurrences

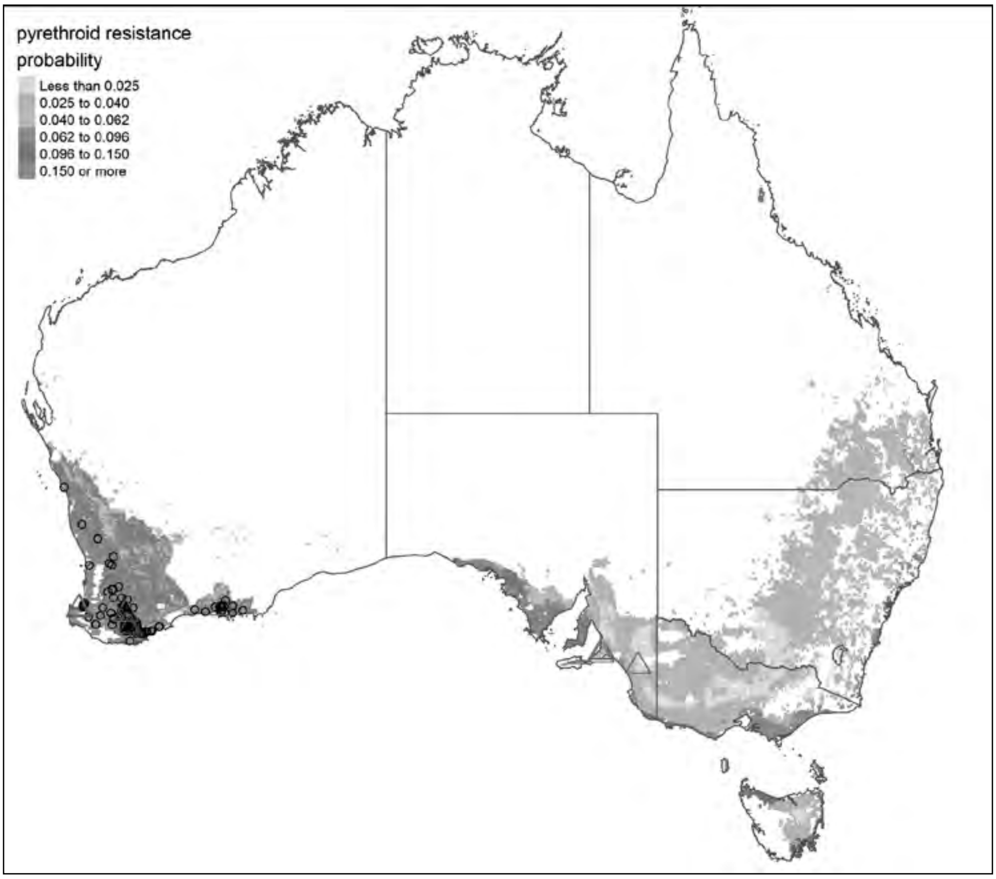

Figure 5. Predicted pyrethroid resistance risk (probability) for RLEM adapted from Maino et al. (*in press*). Known resistant populations used to calibrate the model (open circles) as well as newly detected populations (open triangles) are overlaid.

well ahead of time. Predictive tools may provide useful information here, but are currently not being used for such purposes, or simply do not exist for a particular species of interest.

Forecasting future resistance issues

To bring further focus to the resources directed to resistance management, researchers from **cesar** and the University of Melbourne have applied modern forecasting approaches to identify spatial relationships in the evolution of resistance. This novel approach synthesised large data sets on resistance, land usage, and environmental factors, and found that resistance in RLEM is related to chemical pressure (average number of chemicals used annually), but more surprisingly is also more likely to develop in regions with particular climatic properties (Figure 5). The study highlighted risks in eastern Australia before the recent detection of resistance in SA, and will be used to guide resistance management in the future.

Useful resources

https://grdc.com.au/resources-and-publications/all-publications/factsheets/2015/07/grdc-fs-greenpeachaphid

https://grdc.com.au/FS-RLEM-Resistance-strategy-West

https://grdc.com.au/FS-RLEM-Resistance-strategy-South

https://grdc.com.au/TT-RWA

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Umina, P. A. et al. (2016). 'Science behind the resistance management strategy for the redlegged earth mite in Australian grains and pasture'.

Acknowledgements

The research presented here is made possible by the significant contributions of growers through both trial cooperation and the support of the Grains Research and Development Corporation. The authors would like to thank them for their continued support. We would also like to acknowledge other collaborators including Julia Severi (**cesar**), Ary Hoffmann (University of Melbourne), Owain Edwards (CSIRO), Jenny Reidy-Crofts (CSIRO), Svetlana Micic (DAFWA), and Alan Lord (DAFWA). The authors also acknowledge the assistance of Ken McKee and David Landmeter (Syngenta Australia), Shane Trainer (Bayer Crop Science) and Colin Edmondson (Advanta Seeds).

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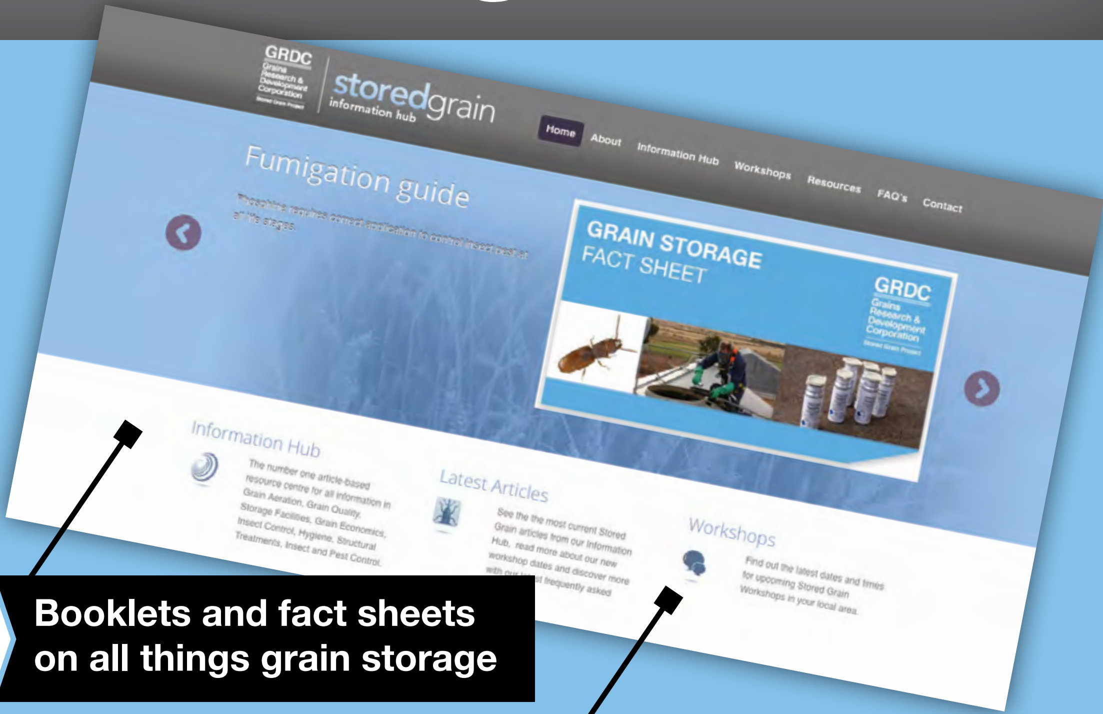

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Long fallows maintain whole-farm profit and reduce risk in the Mallee

David Cann and James Hunt.

La Trobe University, Melbourne.

GRDC project code: UHS11009

Keywords

- long fallow, whole-farm economics, crop simulation, break crops.

Take home messages

- Many of the farming system benefits of long fallow can only be quantified at the whole-farm level.
- A long fallow-wheat rotation was more profitable than continuous wheat production and a chickpea-wheat rotation when the price of chickpeas was below $800/t.
- If using fallow tactically, a good rule of thumb for the southern Mallee is to only sow wheat if mineral nitrogen (N) (kg/ha) + plant-available water (mm) at sowing is more than 100 units, and chickpeas if plant available water (PAW) is more than 50mm.

Background

Managing soil nitrogen (N) and water is a vital part of maximising wheat yields in the Mallee. Long fallowing — the practice of leaving a field out of production for an entire growing season — was traditionally used to accumulate soil water and N for future crop use, but declined in popularity during the 1980s as profitable break crops (including pulses and canola) were made available in the region. However, despite the additional income provided by break crops, whole-farm profits across the Mallee have stagnated in recent decades, due to rising input costs and declining growing season rainfall across southern Australia (van Rees et al. 2014).

Previous economic studies have suggested that the yield benefit provided by long fallow to following crops does not outweigh the missed income opportunity that break crops offer. However, these conclusions have been based on simplistic gross margin analyses, and ignore the whole-farm benefits provided by long fallows, such as increased timeliness of operations and reduced income variability. As wheat production in the Mallee now requires increasing investment to return the same profit as previous years, long fallowing may provide growers with an opportunity to decrease exposure to risk and income variability, without sacrificing profit.

This study aimed to use whole-farm economics to reassess the profitability of long fallow-based rotations in the Mallee compared to continuous wheat and wheat-break crop rotations. The project also attempted to calculate a threshold level of soil water or mineral N which, if not met at sowing, indicates a favourable opportunity to fallow.

Method

The Agricultural Production Systems sIMulator (APSIM) was used to simulate crop production at Jil Jil, near Birchip, over a 20-year period (1997 to 2016). A fallow-wheat (FW) rotation was compared to continuous wheat production (WW) and a chickpea-wheat (CW) rotation over a hypothetical farm area of 4000ha. Each rotation was managed as a farming system and therefore received a unique N fertiliser rate to achieve the most economical yield. Urea was applied at sowing (to the WW and CW rotation) and at stem elongation (to all rotations) to maximise the number of years in which wheat grain protein fell between 10.5% and 12.5%. A whole-farm environment was simulated through adjusting the sowing window of each rotation to reflect the proportion of 4000ha that was cropped (i.e. the FW rotation was sown in half the time of the WW and CW rotations). APSIM was used to measure annual yield, wheat grain protein and N fertiliser application.

Whole-farm income was calculated using five-year average (2012 to 2016) crop prices for Birchip (Australian Premium White (APW) = $260/t; chickpea = $620/t). Wheat grain proteins were used to determine the grain grade and therefore value of the wheat. Variable costs were calculated based on the 2016 PIRSA Farm Gross Margin Guide, with costs modified for each rotation. It was less expensive to grow wheat after long fallow or chickpeas, as the selective herbicide pyroxasulfone (Sakura®) was only applied to wheat grown after wheat ($40/ha). Weed control during the summer fallow was estimated at $20/ha, with a long fallow costing an additional $60/ha to maintain weed-free with herbicides. The same whole-farm costs (including machinery operating costs, labour and drawings) were applied to all rotations. An additional 6% was added to variable costs to account for interest and borrowing costs. Annual cash flow was calculated as gross income minus all variable, whole-farm and finance costs.

Annual cash flow of all three rotations was examined to determine if there was a common condition between unprofitable years in the WW and CW rotations. The aim was to devise a rule by which growers could know at sowing the likelihood of a crop failing to return a profit, and could elect to fallow. Once traits were identified for each rotation, 'opportunity sowing' rotations were created, in which crops were replaced with fallows if conditions were not met.

Results and discussion

Yield results

Wheat grown after long fallow yielded 1.5t/ha more than wheat grown after wheat (Table 1). Wheat in the long fallow rotation had access to significantly more PAW and mineral N at sowing compared to the other rotations. Wheat grown in continuous sequence required the most urea to achieve economical yield, whilst wheat grown after chickpeas had access to the least PAW.

While previous studies have shown an increase in the yield of wheat grown following a pulse crop such as chickpeas, this is largely due to legume N-fixation. As all rotations were supplied with sufficient N fertiliser to achieve economical yield, wheat grown following chickpeas did not yield higher than wheat after wheat, but did require less N fertiliser. While chickpeas do fix atmospheric N, the low level of mineral N at wheat sowing suggests that sufficient soil water is essential in mineralising N into plant-available forms.

The yield benefit provided by fallow is larger here than estimated in several other studies, due to the whole-farm nature of the research. Reducing the sowing window from 28 days (as seen in the WW rotation) to 14 days (FW rotation) improved wheat yield by 0.2t/ha by itself, while the unique fertiliser rules allowed wheat grown after fallow access to additional N through linking urea applications to soil moisture content.

Profitability and risk

The fallow-wheat rotation was also the most profitable system over the twenty-year period (Figure 1). During the first five years, when rainfall was high, the continuously cropped rotations performed best. However, during the Millennium drought (Years 6 to 13), both the WW and CW rotations made a net loss, while the FW rotation returned a series of small, but consistent profits. The value of long fallowing is therefore highest when in-crop rainfall is low.

The FW rotation not only returned more profit than other rotations, it also carried the least risk (Table 2). Long fallows reduce total costs and therefore a farm's exposure to risk in years of low in-crop rainfall, depressed grain prices or high input prices. The low standard deviation of the FW rotation also indicates less variability in profit between years. While returns are lower than continuous cropping during good years, income was more reliable across the entire 20 years.

Table 1. Mean plant-available water (PAW), N and yield results for all rotations averaged for the period 1997to 2016.

Rotation	PAW at sowing (mm)	Mineral N at sowing (kg/ha)	Urea applied (kg/ha/year)	Wheat yield (t/ha cropped)	Chickpea yield (t/ha cropped)
WW	56	60	102	1.8	
CW	36	53	87	1.7	0.9
FW	190	155	63	3.3	

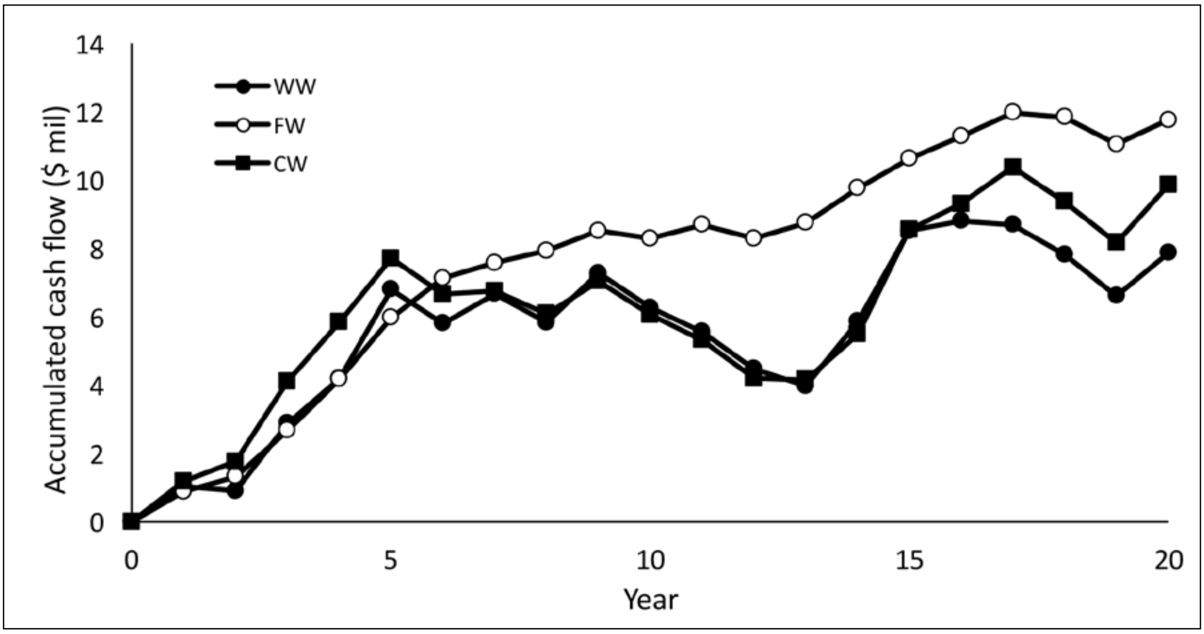

Figure 1. The accumulation of cash flow over 20 years (1997to 2016) for all rotations.

Price sensitivity

The profitability of all rotations was highly sensitive to changes in grain prices (Table 3). The FW rotation had the greatest advantage over the CW rotation when the price of wheat was high and chickpea prices were low. When the prices of both commodities were depressed, the FW rotation was also preferred. Once the price of chickpeas rose to $800/t, the opportunity cost of the FW rotation was too great to return a higher cash flow than the CW rotation.

Opportunity sowing rotations

Continuous wheat production was profitable in 10 of 20 years (Fig. 1). In eight of 10 loss-returning years, the mineral N content of the soil (kg/ha) plus PAW (mm) at sowing equalled **less than 100 units**. The chickpea phase of the CW rotation was profitable in 11 of 20 years. In eight of the nine loss-returning years, the PAW content of the soil (mm) at sowing was **less than 50mm**. These two criteria were used to create 'opportunity sowing' rotations. These rotations were the same as the WW and CW, except that paddocks were fallowed instead of sown if the PAW and N criteria were not met at the prescribed sowing dates.

Table 2. Total farm costs, annual cash flow and cash flow variability for all rotations.

Rotation	Average total farm costs ($ million)	Average annual cash flow ($ million)	Standard deviation of annual cash flow ($ million)
WW	1.6	0.39	1.3
CW	1.6	0.49	1.3
FW	1.2	0.59	0.6

Table 3. Difference in average annual cash flow ($ million) of FW and CW given a range of wheat and chickpea prices. Negative values represent a higher cash flow for CW than FW.

Chickpea price		$400/t	$600/t	$800/t	$1000/t	$1200/t
Wheat price	$150/t	0.2	-0.2	-0.6	-0.9	-1.3
	$200/t	0.3	-0.1	-0.4	-0.8	-1.1
	$250/t	0.5	0.1	-0.3	-0.6	-1.0
	$300/t	0.6	0.3	-0.1	-0.5	-0.8
	$350/t	0.8	0.4	0.1	-0.3	-0.7

Table 4. Average annual cash flow of set rotations and opportunity sown rotations.

Rotation	Average annual cash flow ($ million)	Annual cash flow – opportunity sowing ($ million)
WW	0.39	0.69
CW	0.49	0.76
FW	0.59	

Using these rules improved cash flow by $0.30 million and $0.27 million for the WW and CW rotations, respectively (Table 4). Cash flow for opportunity-sown rotations was higher than in the standard fallow-wheat rotation. These rules improve whole-farm finances by minimising losses in dry years, and maximising production when stored soil water is high.

Conclusions

When whole-farm finances are taken into consideration, long fallow-wheat rotations appear capable of lowering total farm costs and income variability, and maintaining whole-farm cash flow when compared to continuous wheat production and chickpea-wheat rotations. Incorporating a long fallow into a rotation reduces value-at-risk and inter-annual income variability, as well as reducing the sensitivity of the rotation to changes in crop or input prices. The value of long fallow to whole-farm finances is largest during dry seasons, when crop prices are low, and when the price of urea, fuel and other variable inputs are high. It is important that growers remain flexible and reserve the option to fallow land, particularly when stored soil water and N are low. Long fallows, therefore, continue to be a valuable tool available to grain growers in the Mallee for not only the accumulation of soil water and N for future crop use, but also the reduction of costs whilst maintaining profit margins.

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Acknowledgements

The scholarship for this work was provided through the GRDC and its support is gratefully acknowledged. We also thank Bill Malcolm for helpful discussions on this topic.

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Improving crop productivity on sandy soils

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GRDC project code: CSP00203

Keywords

- sands, constraints, ripping, spading, on-row sowing.

Take home messages

- Assessing the yield gap and the level of yield increase that the rainfall of a modified soil site can support, along with season specific effects, is an important step in assessing the risk of sand amelioration options.
- For higher cost interventions knowing the likely longevity of effect is essential. Deep soil disturbance has shown effects for up to four years but it appears that the organic matter treatments tested to date have had most of their effect within two years of application.
- Characterisation of sites across the sandy soils of the Southern cropping region indicated that compaction and a range of nutritional deficiencies are common issues.
- Analysis of herbicide issues flagged glyphosate and the breakdown compound AMPA as residues of interest but their impact is still under investigation.
- Yield responses in 2017 at Ouyen were largely driven by ripping and response to nitrogen (N) input, while at Lameroo, moderate interventions using a fertility band concept had limited impact on a high N background.
- Economic analysis of long-term trials has assessed the return on investment for a range of treatments and highlighted the seasonal response effects on profit-risk.

Background

There are opportunities to increase production on Mallee sands by developing cost effective techniques to diagnose and overcome the primary constraints to poor crop water-use. Commonly recognised constraints that limit root growth and water extraction on sands include compaction (high penetration resistance), poor nutrient supply and low levels of biological cycling and poor crop establishment. Anecdotal evidence of herbicide related issues has been widespread in sandy soils across the low-medium rainfall region. Biological breakdown of herbicides in sandy soils may be limited due to a relatively small microbial biomass, limited organic matter to fuel microbial activity, and reduced activity due to limited soil moisture. It is thought that the issue may be arising from long-term accumulation of herbicide residues and/or inadequate plant-back periods compared to label recommendations. However, there has been little measurement of how much, and what type, of herbicide residues may have accumulated in sandy soils of the target region.

The Sandy Soils Project is aimed at increasing productivity on poor performing sands. There are a range of activities included under this umbrella of funding:

- Analysis of chemical (nutritional, herbicide), biological (nutritional, disease) and physical constraints on transects of sand across the Southern cropping region.

- Monitoring of the residual (up to five years) effects of a range of ripping and spading treatments with and without fertilisers, organic matter and clay.
- Implementation of a range of new experiments at seven sites across the Southern region testing a range of approaches to overcoming constraints and increasing water use and crop productivity.
- Machinery optimisation and soil (DEM) modelling will be used to support the implementation of new trials, to understand how machinery set-up influences profile modification, and to develop guidelines for implementation.
- Economic and risk modelling will assess the cost-benefit outcomes of a range of project treatments, and be used to develop a framework to support decision making based on prioritising the underlying soil constraints.
- A programme of validation and demonstration trials to extend the reach of experiments and provide local information regarding best bet treatments.

Common approaches to overcome physical constraints include techniques to fracture compacted layers (e.g. ripping) and techniques that both fracture the soil and mix and/or invert it (e.g. spading, plozza plough, mouldboard plough). Ripping is less costly to implement and the impacted soil area is far more discrete. Soil profile mixing and/or inversion are more costly to implement and create higher erosion risks. Erosion risks can be mitigated with recent developments such as the ‘spade and sow’ single pass operation. Mixing can address multiple soil constraints as it improves the physical environment for root growth, reduces issues of water repellence and enhances nutrient fertility through incorporation of amendments. Soil modelling has been used to understand the impact of key operational parameters for spading on the extent of topsoil mixing and to compare the mixing through spading with other ploughing techniques. The modelling approach has also been used to support machinery optimisation and implementation of core research trials. An alternative to mixing approaches is the construction of permanent fertility strips; facilitating nutrition access to the crop by increasing inputs (including granulated amendments) to concentrated parts of the paddock. Permanent fertility strips have been tested elsewhere but not explored in the Mallee environment.

In this paper the most recent data from the Sandy Soils project are presented including analysis of the key constraints to production, results of new experiments implemented in 2017, residual benefits from treatments implemented up to four years ago and economic analysis of interventions to increase production on sandy soils.

Method

Analysis of constraints

Soils have been sampled from sandy soils in nine paddocks across the Southern region and analysed for chemical, biological and physical constraints to one metre depth. Herbicides assessed at 0-10, 10-20, and 20-30cm depths included glyphosate and its break-down product, AMPA, Trifluralin, Prosulfocarb, three imidazolinones (Imazapic, Imazapyr, Imazamox), 2,4-D, Triclopyr, and MCPA. Germination assays (lucerne) were also carried out and scored compared to a herbicide-free sand control.

*Monitoring of residual value of sandy soil intervention*s

Sites established in 2015 (Bute) and 2014 (Cadgee, Brimpton Lake and Karoonda) have been monitored for ongoing yield effects in response to a range of interventions including spading and/or ripping with and without organic matter, clay and fertiliser. This long term monitoring has allowed for the assessment of the return on Investment (marginal return/total costs*100) for a range of amelioration strategies.

New Sandy Soils experiments

In 2017 new experimental sites were established at Ouyen, Lameroo and Yenda (data for Yenda not presented here). The Ouyen site (Moodie and Macdonald 2018) has deep sandy soils with high penetration resistance (>2.5 MPa) and poor sub-surface fertility and two experiments; a ripping trial and a spading trial were established. The ripping trial included shallow (20cm) and deep (30cm) ripping treatments with/without placement of N or nutrient packages (containing phosphorus (P), potassium (K), sulphur (S), zinc (Zn), copper (Cu), manganese (Mn)) at the target depths. Surface banding (~7.5cm) treatments were included as controls. The trial design allows the impact of physical disruption to be isolated from nutrient placement. The spading trial included spading (30cm) with/without the incorporation of a range of organic amendments (vetch hay, oaten hay,

Table 1. Estimates of the physiological (Phys) yield potential, unmodified soil yield potential, attained yield and physiological yield gaps for an average growing season at each of the Sandy Soils Experimental sites.

Site	GS Rain (mm)	Fallow Rain (mm)	*Phys Yield Potential (t/ha)	Yield Potential in Unmodified Soil (t/ha)	Attained Yield (t/ha)	Phys Yield Gap (t/ha)
Waikerie	157	22	1.95	1.67	1.00	0.95
Carwarp	174	28	2.03	1.35	1.00	1.03
Ouyen	213	30	2.92	2.89	1.50	1.42
Karoonda	235	26	3.34	2.73	1.50	1.84
Murlong	251	21	3.54	3.28	1.50	2.04
Yenda	252	43	4.07	3.09	2.50	1.57
Lameroo	270	28	4.13	3.11	2.50	1.63
Bute	298	24	4.68	3.86	3.50	1.18
Brimpton Lake	377	21	6.33	3.12	3.00	3.33
Cadgee	410	34	7.34	3.33	1.30	6.04

**Physiological yield potential = (growing season rain + 0.25 fallow rain x 22)/1000 and yield potential in unmodified soil was estimated using APSIM set up with plant available water characterisations.*

vetch-oaten mixture, chicken litter, compost), and/or fertiliser. The Lameroo site is a swale-dune paddock with issues of moderate water repellence, high penetration resistance and poor sub-surface fertility (for nutrients other than N). The first experiment, located on a non-wetting deep sand, focussed on evaluating the impact of a variety of inputs at seeding (clay, organic matter, biochar and placement depth) as options seeking to optimise the crop response to the fertility strip concept. The second experiment focussed on evaluating the impact of an edge row sowing configuration - optimised for developing fertility strips on deep sands - but imposed on the full range of soil types in the paddock (dune, mid-slope and swale). See Desbiolles et al. (2018) for further detail.

Results and discussion

Analysis of constraints

An important consideration before making radical changes to the soil profile is the yield that the local rainfall can support. An estimate of the physiological yield potential for wheat in an average season was determined and by subtracting farmer data (attained yield) from this value the physiological yield gap for each of our experimental sites was determined (Table 1).

The yield gap highlights the limits of any potential yield gains that we want to capture and places it in the context of the environment, and local knowledge of yield gains that can be made from simple interventions like change in crop sequence and fertiliser management. Because the sites have been characterised for plant available water capacity we were also able to use APSIM to estimate the water and nitrogen driven yield potential of unmodified soil. Where the gap between the physiological yield potential and the unmodified soil yield potential is relatively small (eg. Waikerie) it suggests that gains from soil modification may also be small (Table 1). While these estimates will be refined with further characterisation, they do moderate expectations with respect to anticipated yield gains and the level of investment that should be made in amelioration strategies, particularly in low rainfall regions.

Penetration resistance is an assessment of the potential for physical constraints to limit root growth. Measurements were commonly moderate (>1.5 MPa) within the top 20cm and high (>2.5 MPa) within the top 30cm (Figure 1). Nutrients commonly measured at marginal levels included N, P, Zn, Cu, and Mn (data not shown).

A survey of herbicide residues in sandy soils in the southern low rainfall region did not find Prosulfocarb, imidazolinones (Imazapic, Imazapyr, Imazamox), Triclopyr, MCPA Trifluralin or 2,4-D at a significant level. Glyphosate and its breakdown product AMPA were measured at all nine sites, where the combined residue load (glyphosate plus AMPA) represented between 0.7 and 6.1 typical applications. The majority (~85%) of the herbicide residue was found in the top 10cm, and was predominantly AMPA (~80%) rather than glyphosate. Little is known of the toxic effects of AMPA and how it may affect root growth and function. However, the concentrations measured here had no impact on the germination of lucerne seeds in a lab bioassay.

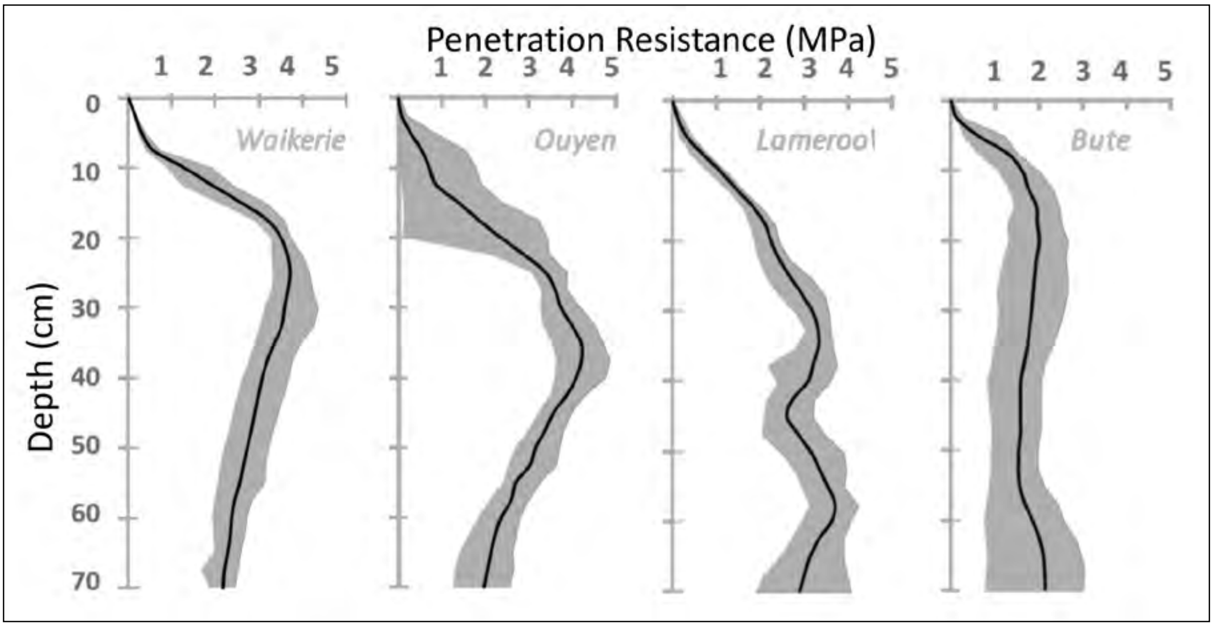

Figure 1. Penetration resistance (Mpa) in response to depth at key Sandy Soils Research sites. Black line represents the average, with the shaded grey indicating the range at the site.

Monitoring of residual value of Sandy Soil interventions

An experiment established at Bute by Trengove Consulting in 2015 compared the effects of all combinations of increased inputs of annual fertiliser, ripping and 5 and 20t/ha chicken litter (20t/ha chicken litter not presented here (Trengove et al. 2018)). Compared to a nil control yield of 4.4t/ha/3 yrs, there was a yield gain of 3t/ha with relatively high inputs of annual fertiliser (N, P, S, K, Zn, Cu, Mn at a cost of $430/ha), 2t/ha extra grain yield with chicken litter at 5t/ha (cost $180/ha) and 2.4t/ha response to ripping (cost $60/ha). The cumulative yields for combinations of two factors were quite similar (8.2-8.9t/ha), while the combination of the three treatments yielded 9.6t/ha. There were strong seasonal responses to the treatments with barley in 2016 highly responsive to nutrition and lentils in 2017 relatively more responsive to ripping than the other treatments. The lowest cost intervention was ripping and this generated the most substantive return on investment at 1342% while chicken litter with ripping generated 521%.

Long-term spading trials developed in the New Horizons Program have demonstrated cumulative yield gains at Karoonda and Brimpton Lake of an additional 2t/ha grain over four years, with a smaller gain (1.3-1.6t/ha) from incorporation of high rates of lucerne based organic matter. Gains from the incorporation of organic matter appear to be short-lived (~two years) at these sites. Yield gains at Cadgee (+1.6t/ha) were driven by the incorporation

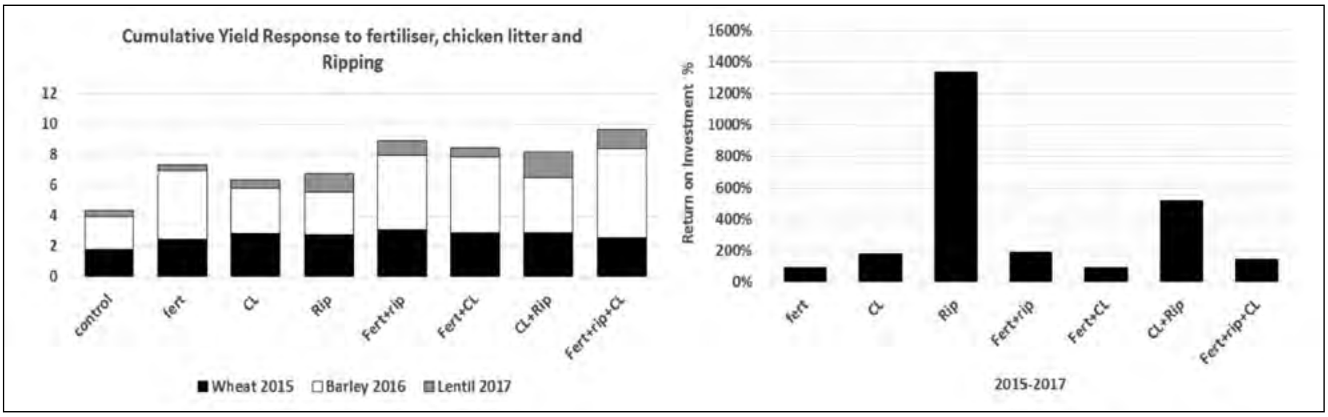

Figure 2. Cumulative (2015-2017) yield response and return on investment (%) to fertiliser, chicken litter and ripping at the Bute site implemented and managed by Trengove Consulting.

of organic matter, and not the physical impact of spading, with gains appearing to increase over time (Fraser et al. 2016). Site specific responses at these long-term sites highlight the need to identify the underlying constraints and to understand the components of the response in economic terms before investing in modifications.

New Sandy Soils experiments

In the relatively low rainfall season of 2017 at Ouyen, deep ripping reduced penetration resistance to ~40cm and resulted in a wheat yield gain of 0.9t/ha while shallow ripping (20cm) had little impact on penetration resistance or yield. Deep placement of nutrients had no effect on production above the physical impact of ripping. Spading also reduced penetration resistance to the target depth (30cm) but resulted in a relatively small yield gain (<0.4t/ha) above the control (1.4t/ha). The smaller relative gain from spading compared to ripping may be due to lower plant establishment caused by poorer seeding depth control in the spader-seeder approach used. All spaded treatments outperformed the non-spaded control, with the exception of the spaded oaten hay which likely immobilised N (Figure 3). Incorporation of N rich organic matter (vetch hay, chicken litter, compost) significantly increased yield (0.6 and 1t/ha), grain protein, and harvest index. Ongoing monitoring will evaluate the continuing effects on penetration resistance, nutritional legacy effects, rates of organic matter decomposition, and crop water-use.

In 2017, the Lameroo site had good conditions for mineral N supply (>100 kg N/ha/m depth at sowing) from a preceding legume pasture phase and above average growing season rainfall. As a result, most of the relatively low cost/ low input interventions of the fertility strip concept did not have a significant impact in the first year of inputs. Their effects, if important, are expected to increase with time. While the amendments in fertility strip treatments banded at 10cm furrow depth did not yield more than the zero-amendment baseline, 100kg/ha clay + 100kg/ha organic matter applied at a 20cm furrow depth was the only fertility strip treatment to show an early effect (4.0t/ha versus 3.5t/ha wheat, Desbiolles et al. 2017).

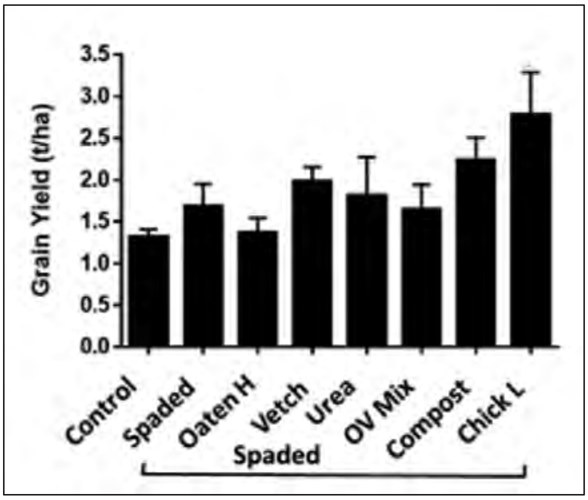

Figure 3. Wheat grain yield response to spading and spading with organic matter inputs at Ouyen in 2017 (site established and managed by Moodie Agronomy).

Conclusions

Substantial opportunities to increase yield on poor sandy soils have been demonstrated in recent trials. However understanding the rainfall-limited yield potential and season specific effects is important for assessing the likely scope of yield gains and the associated investment risk. Of critical importance to the higher cost interventions is the longevity of effect. While effects of deep soil disturbance have proven measurable after four years, organic matter inputs appear to often lose effect after two years. Determining the most economic treatment options for growers by diagnosing key constraints, optimising treatments (both machinery and inputs) and understanding longevity in the system is a large and ongoing effort in the Sandy Soils Project.

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Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. This work is funded under the GRDC project CSP00203; a collaboration between the CSIRO, the University of South Australia, the SA state government through Primary Industries and Regions SA, Mallee Sustainable Farming Inc. and AgGrow Agronomy and Research P/L. We would like to acknowledge the inputs of the wider project team, Bill Davoren, Willie Shoobridge, Stuart Sheriff, Chris Saunders, Mustafa Ugcul, David Davenport, Nigel Wilhelm, Tanja Morgan, Barry Haskins and Rachael Whitworth.

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Optimising performance from rhizobial inoculants for pulse crops sown in suboptimal soil conditions

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GRDC project codes: DAS00128, UA00138

Keywords

- nodulation, inoculants, dry sowing, seed treatment.

Take home messages

- Standard inoculation practices are unlikely to deliver satisfactory nodulation where extended dry conditions are combined with other stresses such as low pH.
- Good nodulation can be achieved when dry sowing beans and lupins if inoculation rate is increased. Doubling the rate of peat inoculant significantly improved nodulation.
- Granules are not a cure-all for dry sowing situations, responses were variable.
- Agrochemicals and fertilisers at sowing can affect rhizobial survival – avoid contact between these and rhizobia.

Background

Pulse and pasture legumes can provide an abundant, inexpensive and sustainable source of nitrogen (N) for Australian cropping systems through fixation by root nodule bacteria (rhizobia). Cereal yields are consistently greater following legumes due to these N inputs, and other benefits including disease and weed breaks and improvements to soil structure and biological function.

Not all pulses in Australian farming systems are well nodulated and fix optimal N. N fixation is dependent on an adequate number of suitable root nodule bacteria (rhizobia) (Drew et al. 2012, Denton et al. 2013). When suitable rhizobia are not present in sufficient numbers naturally in the soil then they must be provided at sowing in the form of a commercial inoculant product.

In low rainfall cropping systems, sowing pulse crops early in the season into dry soils can offer substantial crop growth advantages in these short-season environments. However, rhizobia are sensitive to desiccation and the consequences of dry sowing on rhizobia survival in different inoculant formulations are poorly understood.

Work is presented from trials which aim to optimise guidelines for inoculation when dry sowing; considering the extent to which dry sowing affects nodulation, nitrogen fixation and grain yield of pulses. Impacts of different inoculant formulations and other stresses on nodulation at sowing, such as soil acidity and seed applied pesticides are also considered.

When is inoculation of pulse crops necessary?

Inoculation provides one of the most cost-effective ways to improve legume performance where the legume (or another from the same inoculation group) has not previously been grown and/or where conditions are detrimental to the survival of rhizobia in the soil.

Chickpea and lupin are typically responsive to inoculation in the GRDC southern region because they have been less widely grown and their rhizobial requirement is more specific than for some other legume species. The first time they are grown, nodulation can often be improved by increasing the rate of inoculation.

Pea, bean, lentil and vetch are nodulated by the same species of rhizobia and have been widely grown in southern region. These rhizobia survive reasonably well in neutral/alkaline soils, so many Victorian and South Australian soils support adequate populations of rhizobia for these legumes, and therefore, inoculation via a commercial product is not necessary. Nonetheless, inoculation of these legumes is still necessary where:

- They have not previously been grown.
- Where they have not been grown in the past five years or if nodulation of the previous crop was not satisfactory.
- If they are grown on acidic soils (pH_{CaCl2} <6.0) because the pea/bean rhizobia from previous crops may not persist at a high enough number in acidic conditions for optimal nodulation.

What rhizobia inoculant types are available?

The use of granular and liquid inoculants in Australia has increased markedly over the last two decades (Denton et al. 2009, 2017). Granular and liquid inoculant application systems provide an opportunity to separate rhizobia from toxic chemicals, such as pickles applied to the seed coat.

Peat slurry inoculants supplied at high quality by inoculant companies have been used effectively over the last sixty years in Australia. However, the method of their application to seed can be inconvenient, especially when dealing with large volumes of pulse seed when there are time pressures around sowing. Peat inoculants that carry the ‘Green Tick’ logo (Figure 1) have been approved by the Australian Inoculants Research Group, NSW DPI. This logo indicates that the product meets minimum quality standards for purity and number of rhizobia per gram of product. It is recommended that you choose inoculants displaying this ‘Green Tick’ logo wherever possible.

Granular inoculants generally contain fewer rhizobia per gram of product than moist peat inoculants. Their quality standard is the responsibility of the manufacturer, and therefore, they do not display the ‘Green Tick’ logo.

Figure 1. The Green Tick Logo.

Inoculation when dry sowing

Extension publications on the topic of inoculation when dry sowing state that; ‘sowing peat slurry inoculated seed into dry soil is not generally recommended where a legume crop is sown for the first time, since under some conditions the applied rhizobia may not survive at adequate numbers to provide satisfactory nodulation’. Dry sowing is less of a concern where a legume has been grown frequently and the soil is favourable to rhizobial survival. In these conditions the risk of nodulation failure is much lower. Hence, where the option is available, dry sowing is best restricted to paddocks where the legume has previously been grown.

Despite the potential impact of dry sowing on nodulation, it is still common practice. The three main granular rhizobia inoculant products available in Australia are all recommended by the manufacturers for use when dry sowing. There are anecdotal reports of success but there has been limited research to appropriately compare the performance of current formulations against peat applied to seed or to understand the limits of their efficacy. Field trials (funded by SAGIT) were conducted at two sites in South Australia in 2017 assessing a range of inoculant formulations at different rates and in combination. Treatments (Table 1) included peat on seed and freeze-dried inoculant, neither of which are currently recommended for use when dry sowing, but were included with the aim of providing better guidelines for growers around dry sowing.

Table 1. Inoculant treatments and products used in trials at Wanilla and Farrell Flat in 2017.

Wanilla Bean Trial		Farrell Flat Lupin Trial	
Treatment	**Product - Group F (Strain WSM1455)**	**Treatment**	**Product - Group G (Strain WU425)**
Nil	Uninoculated	Nil	Uninoculated
Peat	BASF Nodulaid®	Peat	BASF Nodulaid®
Peat + Freeze dried	BASF Nodulaid® + New Edge EasyRhiz™	Peat + Freeze dried	BASF Nodulaid® + New Edge EasyRhiz™
B. Granule	BASF Nodulator®	Granule	BASF Nodulator®
Peat + B. Granule	BASFNodulaid®+ Nodulator®	Peat + Granule	BASFNodulaid®+ Nodulator®
A. Granule	Alosca Granules	2 x RR Granule	BASF Nodulator®
N. Granule	Novozymes® TagTeam™ granules		

Note: All products were sourced direct from the manufacturer except Alosca granules which were sourced from Landmark.

Faba bean at Wanilla

In this trial, faba bean (PBA Samira⁽ᵇ⁾) was sown dry at Wanilla on the Eyre Peninsula. This was a particularly harsh test as the soil was sandy with a pH_{CaCl2} 4.3 and seed was in the ground dry for four weeks (time of sowing (TOS) - 28 April) before a germinating rain event occurred. There were large differences in the performance of the different inoculants (Figure 2). Novozymes® TagTeam™ granules alone and BASF Nodulator® granules combined with peat slurry provided the best nodulation and surpassed the nodulation provided by the standard peat slurry inoculation on seed (Peat) (Figure 2). The result was partly explained by the number of rhizobia per gram of product (data not

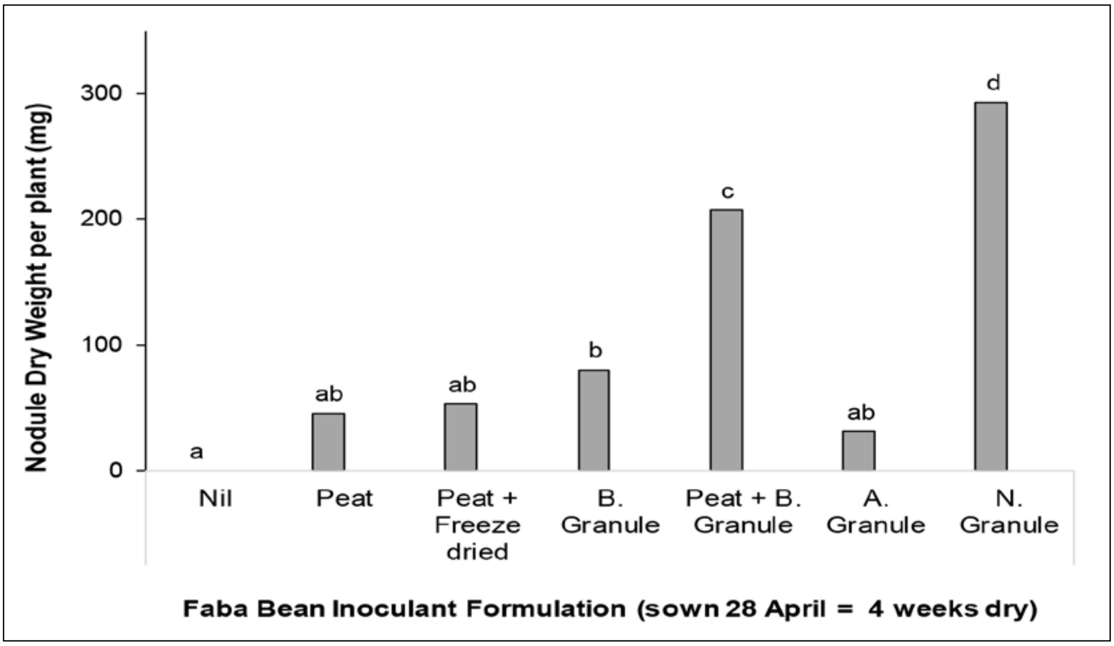

Figure 2. Effect of inoculant formulation on nodulation (measured by nodule dry weight per plant at 22 August) of faba bean when sown into dry soil at Wanilla, Eyre Peninsula SA. Different letters above columns indicate significant treatment difference at P<0.05. All inoculants are group F (strain WSM1455) as outlined in Table 1.

shown), in that the more rhizobia applied to seed (or in furrow) the greater the likelihood of rhizobia survival when seed germination occurs.

Despite a very dry finish at Wanilla which limited faba bean grain yields, all inoculants improved yields for the dry sown treatments (Table 2). Following a similar pattern to nodulation, both Novozymes® (N) granules and peat slurry on seed with granules (Peat + B. Granule) resulted in the highest yields.

Table 2. Grain yields (t/ha) of faba bean (PBA Samira⁽ᵖ⁾) at Wanilla, SA in response to different inoculation treatments when sown into dry soil.

Wanilla Bean Yields	
Inoculation Treatments	**Yield t/ha**
Nil (Uninoculated)	0.13
Peat	0.30
Peat + Freeze dried	0.30
B. Granule	0.39
Peat + B. Granule	0.49
A. Granule	0.33
N. Granule	0.57
l.s.d.	*0.06*

Note: All inoculants are group F (strain WSM1455) as outlined in Table 1.

Lupin at Farrell Flat

In this study, lupin (PBA Barlock⁽ᵖ⁾) was sown at Farrell Flat in the Mid North of SA. This was a less stressful environment with a loamy soil of pH_{CaCl2} 5.1 compared to Wanilla. Seed was in the ground dry for seven days (TOS - 13 April) before a germinating rain event. Different inoculant treatments were used in this trial compared to the Wanilla site (Table 1) as Novozymes® do not produce a lupin inoculant and Alosca granules could not be sourced for this trial.

Results indicated that there were no significant differences between lupin inoculant formulations (Figure 3). Inoculation with all formulations improved grain yield of lupin when dry sown at Farrell Flat, SA (Table 3). Peat slurry inoculation on seed provided the best yield response (Table 3).

Table 3. Grain yields (t/ha) of narrow-leaf lupin (PBA Barlock⁽ᵖ⁾) at Farrell Flat, SA in response to different inoculation treatments when sown into dry soil.

Farrell Flat Lupin Yields	
Inoculation Treatments	**Yield t/ha**
Nil (Uninoculated)	1.64
Peat	2.90
Peat + Freeze dried	2.67
Granule	2.48
Peat + Granule	2.50
2 x RR Granule	2.46
l.s.d.	**0.34**

Note: All inoculants are group G (strain WU425) as outlined in Table 1.

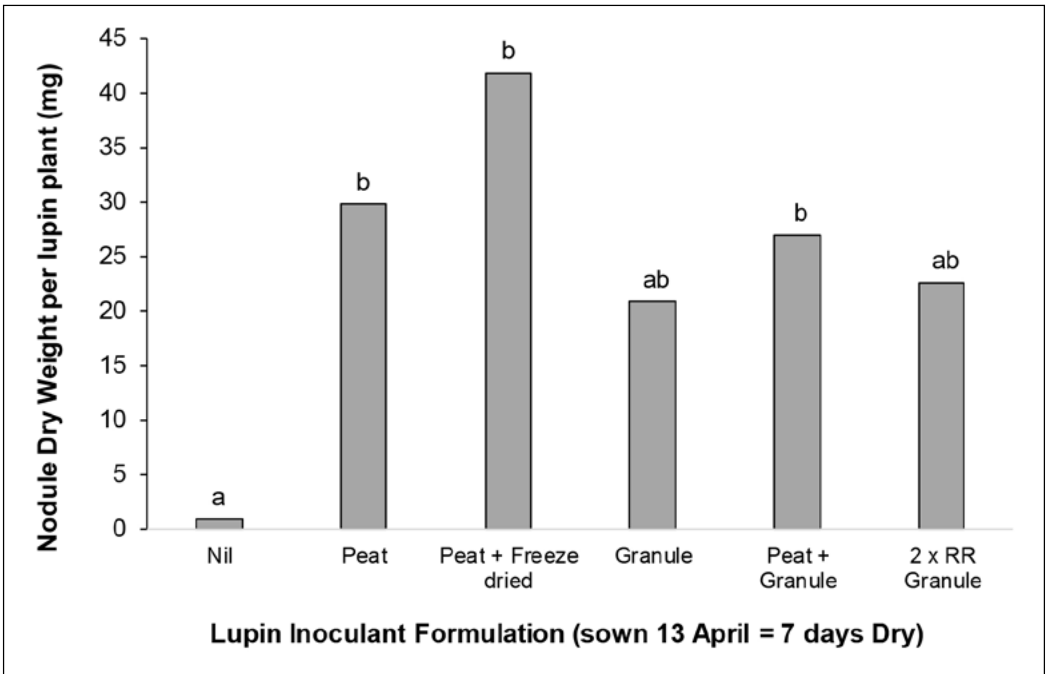

Figure 3. Effect of inoculant formulation on nodulation of lupin when sown dry at Farrell Flat, SA (TOS - 13 April with seven days between sowing and sufficient rainfall for germination). Nodule weight per plant was measured on the 13 July. Different letters above columns indicate significant treatment differences at $P<0.05$. All inoculants are group G (strain WU425) as outlined in Table 1.

Impact of inoculation rate and rhizobia strain

In a second faba bean trial at Wanilla, dry sown on 28 April 2017, the commercial group (Gr) F rhizobia strain (WSM1455) and two strains of rhizobia with putative acid tolerance (SRDI954 and SRDI969) were compared. Peat cultures of each strain were produced at SARDI and applied to seed at one of three rates (0.5, 1.0 or 2.0 times the recommended rate) within 24 hours of sowing. The 0.5 rate was chosen to reflect that in practice, inoculation is not always optimal and sometimes reduced rates are used to reduce costs and improve the flow of seed through machinery.

At the recommended inoculation rate (and the 0.5 rate) the current commercial faba bean strain (WSM1455), failed to satisfactorily nodulate faba bean at this site (pH 4.3) (Figure 4). In comparison the two strains with putative acid tolerance could nodulate faba bean at all three application rates.

Applying the commercial strain at double the recommended rate resulted in good nodulation.

Similar results were measured in an inoculation rate trial for lupin (data not shown) where doubling the rate of peat inoculant also increased nodulation of lupin sown into a dry soil.

Can additives reduce the efficacy of rhizobial inoculation?

Care needs to be taken where rhizobia are applied with pesticides on seed, especially where seed is to be sown into dry soils at inoculation responsive sites. Rhizobia are best applied last and application time as close as possible to sowing. Within six hours of sowing is commonly recommended by inoculant manufacturers.

The impact of seed applied pesticides on rhizobia is often masked where there are naturalised rhizobia present in the soil. However, the impact is often evident on acid soils or when dry sown, where there are no background rhizobia. An example of such an impact is shown in Figure 5. The treatment of faba bean seed with Apron®Φ (Metalaxyl) or P-Pickel T® (PPT; Thiram and Thiabendazole) fungicide prior to the application of a rhizobia (as a peat slurry to the seed) caused significant reductions in both the amount of nitrogen fixed and grain yield. These reductions were attributed to fewer rhizobia surviving on the seed and reduced nodulation (data not shown).

ΦNot registered for use on faba beans. Application was for research purposes only. In a commercial situation, label recommendations must be adhered to at all times.

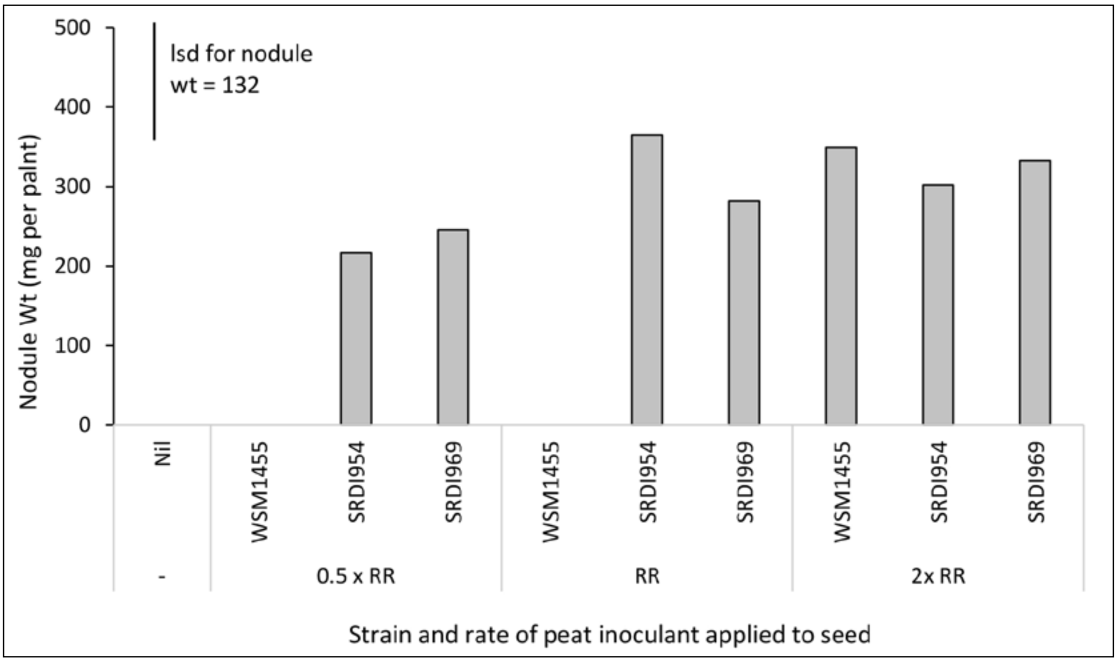

Figure 4. Effect of inoculation rate and rhizobia strain on nodule weight of faba bean (PBA Samira⁽ᵇ⁾) at Wanilla, Eyre Peninsula SA in 2017. Treatments were; uninoculated (nil) control, the commercial Gr F rhizobium strain (WSM1455) and two strains with putative acid tolerance (SRDI954 and SRDI969) applied at one of three rates to seed (0.5, 1.0 or 2.0 times the recommended rate (RR)).

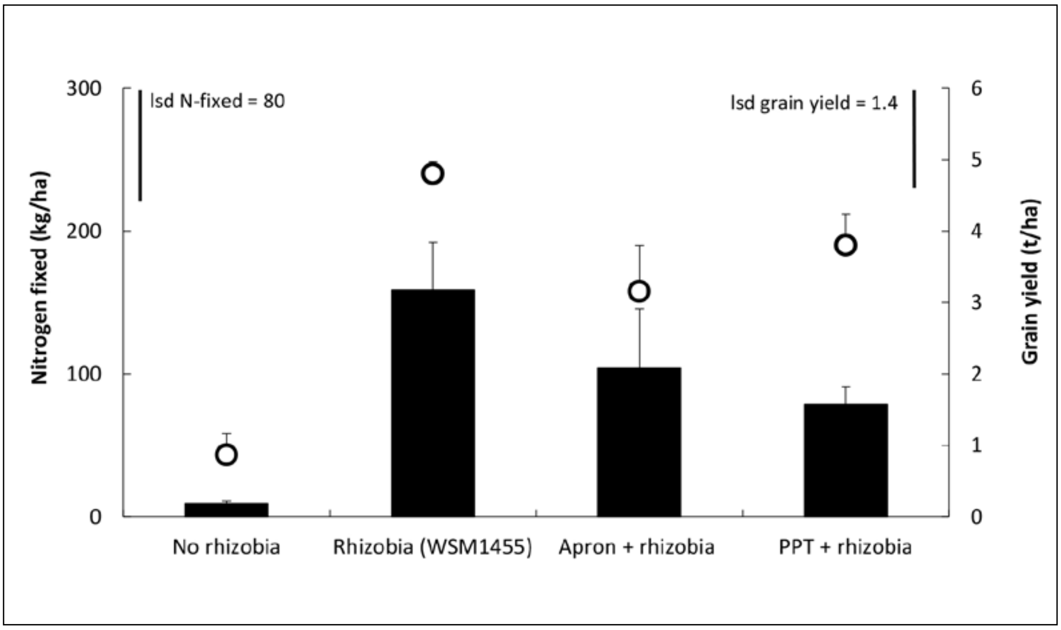

Figure 5. Effect of pesticide application to seed on nitrogen fixation (left axis, columns) and grain yield (right axis, circles) of faba bean (PBA Samira⁽ᶦ⁾) inoculated with Group F rhizobia (WSM1455) at Ballyrogan (site $pH_{(Ca)}$ = 4.6) Victoria, 2016. Standard error of means shown as bars above columns and circles.

Recent laboratory tests have also indicated that zinc sulphate, Thiram (thiram) and P-Pickel T® (thiram and thiabendazole) seed treatments are highly toxic to pea and chickpea rhizobia (Denton et al. 2018). In contrast, Gaucho®Φ insecticide (imidacloprid) did not significantly reduce the number of rhizobia or nodulation in field pea in the laboratory and greenhouse studies (Denton et al. 2018).

ΦGaucho 600 Red is registered for use on field peas but Gaucho 600 is not registered on field peas. In commercial situations label recommendations must be adhered to at all times.

Where pesticide application is necessary, granular rhizobial inoculant may provide a better option as they reduce direct exposure of the rhizobia to the pesticide.

Conclusions

Peat slurry applied at the recommended rate worked well at the Farrell Flat lupin site but failed at the Wanilla faba bean site, where rhizobia was not able to survive the prolonged dry conditions in an acid soil. However, faba bean nodulation was restored to satisfactory levels when both the rate of inoculation was increased and/or the inoculant strain was changed to the new strains of rhizobia with putative acid tolerance.

Granules are not a cure-all for dry sowing situations. On only one occasion (Novozymes® Group F at Wanilla) was their performance exemplary.

Work to understand more about how rhizobia survive and nodulate under a range of stressful (dry and/or acid) soil conditions is continuing so that improved inoculation recommendations can be provided. Our results to date indicate that to optimise nodulation when dry sowing, application of rhizobia in high numbers is required which can be achieved by increasing the rate of inoculant applied.

In practice, inoculation is often used in conjunction with other seed additives. Growers should be very wary when using additives such as fertilisers, seed-applied fungicides and organic products with rhizobia. The use of these products in conjunction with inoculation may lead to reduced rhizobial survival, nodulation, N fixation and grain yield. Nodulation failures are usually not able to be rectified until the following season.

Useful resources

Inoculating Legumes: A Practical Guide http://www.grdc.com.au/Resources/Bookshop/2015/07/Inoculating-Legumes

https://grdc.com.au/tt-legume-n-fixation

https://grdc.com.au/tt-nitrogen-fixation-in-field-pea

www.ua.edu.au/legume-inoculation

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Acknowledgements

The research presented in the paper is made possible by the significant contributions of growers through both trial cooperation and the support of SAGIT (project S217) and the GRDC (projects UA00138, DAS00128). The authors would like to thank them for their continued support.

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Notes

The effects of stubble on nitrogen tie-up and supply

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GRDC project codes: CSP186, CSP174

Keywords

- nitrogen, soil organic matter, immobilisation, crop residue, stubble retention.

Take home messages

- Cereal stubble should be thought of as a source of carbon (C) for microbes, not as a source of nitrogen (N) for crops. In no-till systems, only approximately 6% of the N requirement of crops is derived from the stubble.
- Nitrogen tie-up by cereal residue is not just a problem following incorporation — it occurs in surface-retained and standing-stubble systems and can reduce wheat yields by 0.3t/ha to 0.4t/ha.
- Management is reasonably straightforward — supply more N (5kg N for each t/ha of cereal residue) and supply it early to avoid impacts of N tie-up on crop yield and protein.
- Deep-banding N can improve the N uptake, yield and protein of crops, especially those in stubble-retained systems.

Background

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

The process of 'N-tie up' (immobilisation) — put simply

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

A worst-case scenario

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

In this case, the cereal stubble (high C and low N – usually at a C:N ratio of approximately 90:1) is well mixed through a warm, moist soil giving the microbes maximum access to a big load of C (energy) — but not enough N (microbe bodies need a ratio of about 7:1). The microbes will need all of the available N in the stubble and the mineral N in the soil, and may even break-down some existing organic N (humus) to get more N if they need it. The microbes will grow rapidly, so when the crop is sown there will be little available mineral N - it's all 'tied-up' by the microbes as they grow their population on the new energy supply. Some of the microbes are always dying as well but for a time more are growing than dying, so there is 'net immobilisation'. As the soil cools down after sowing, the 'turnover' slows, and so is the time taken for more N to be released (mineralised) than consumed (immobilised) and net-mineralisation is delayed. Meanwhile — the relatively N-hungry canola crop is likely to become deficient in N as the rate of mineralisation in the winter is low. This temporary N-deficiency if not corrected or avoided, may or may not impact on yield depending on subsequent conditions.

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

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

In modern farming systems, where stubble is retained on the surface and often standing in no-till, control-traffic systems, less is known about the potential for immobilisation. In GRDC-funded experiments as part of the Stubble Initiative (CSP187, CSP00174), the dynamics of N in stubble-retained systems are being investigated. Examples from recent GRDC-funded experiments in southern NSW are provided in this paper and the evidence for the impact of immobilisation are discussed and some practical tips to avoid the risks of N tie-up are provided.

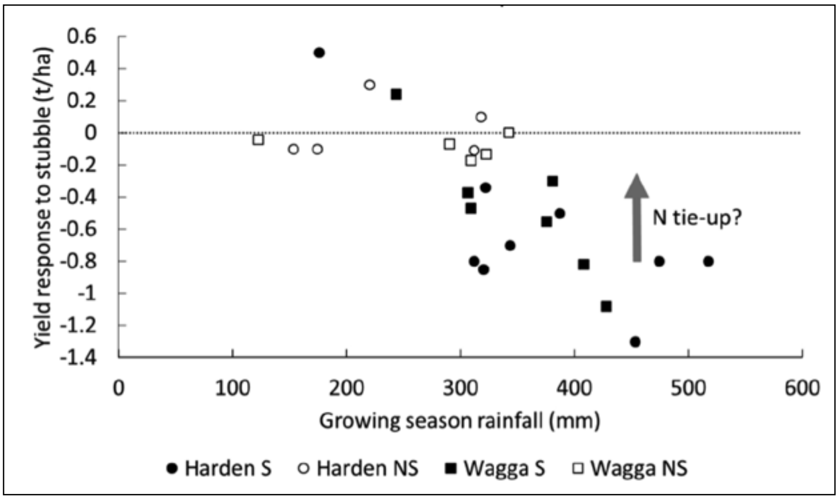

Figure 1. Effect of retained stubble on wheat yield is worse in wetter seasons at the Harden (circles) and Wagga (squares) long-term tillage sites. Open symbols indicated where difference between retained and burnt were not significant (NS), solid symbols indicated where difference between retained and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

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

Harden long-term site

In a long-term study at Harden (28 years) the average wheat yield has been reduced by 0.3t/ha in stubble retained versus stubble burnt treatments, but the negative impacts of stubble were greater in wetter seasons (Figure 1). Nitrogen tie-up may be implicated in wetter years, due to higher crop demand for N and increased losses due to leaching or denitrification. But we rarely found significant differences in the starting soil mineral N pre-sowing. For many years, sufficient measurements were unavailable to determine whether N tie-up was an issue.

In 2017, two different experiments in sub-plots at Harden were implemented to investigate the potential role of N tie-up in the growth and yield penalties associated with stubble. A crop of wheat (cv. Scepter⁽ᵈ⁾) was sown on 5 May following a sequence of lupin-canola-wheat in the previous years. In both the stubble-retained and stubble-burnt treatments 50kg N/ha or 100kg N/ha broadcast as urea at sowing in one experiment were compared (Table 1), and in another experiment 100kg N/ha surface applied or 100kg/N deep-banded below the seed were compared (Table 2). The pre-sowing N to 1.6m was 166kg N/ha in retained and 191kg N/ha in burnt, but was not significantly different. Plant population, growth and N content at GS30 did not differ between treatments (data not shown) but by anthesis, the biomass and tiller density were significantly increased by the additional 50kg/ha of surface-applied N in the stubble-retained treatment, while there was no response in the stubble burnt treatment. At harvest, both stubble retention and increased N improved grain yield, but the increase due to N was higher under stubble retention (0.6t/ha) than stubble burnt presumably due to improved

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

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

water availability. The increase in yield with higher N, and the low protein overall (and with low N) suggests N may have been limiting at the site, but the water-saving benefits of the stubble may have outweighed the earlier effects of immobilisation.

Deep-banding the N fertiliser had no impact on crop biomass or N% at GS30, but increased both the biomass and N content of the tissue at anthesis more in the retained-stubble than in burnt stubble (Table 2). Retaining stubble decreased biomass overall but not tissue N. N uptake (kg/ha) at anthesis was significantly increased by deep-banding in both stubble treatments, however the increase was substantially higher in the stubble-retain treatment than in the burn treatment (38kg N/ha compared with15kg N/ha). The overall impact of deep-banding on yield persisted at harvest, but there was no effect, nor interaction with stubble retention, presumably due to other interactions with water availability. However the fact that deep-banding N has had a bigger impact in the stubble retained treatment provides evidence of an N-related growth limitation related to retained stubble. Its appearance at anthesis, and not earlier, presumably reflects the high starting soil N levels which were adequate to support early growth but the cold dry winter generated N deficiencies as the crop entered the rapid stem elongation phase. The increased protein content related to both burning and deep-banding and its independence from yield, suggest on-going N deficiencies generated by those treatments.

Temora site

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

Burning

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

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

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

Table 3. Effect of stubble burning on grain yields at Temora in Phase 1 and 2. Crops in italics are canola, and bold are the 2nd wheat crops.

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

** indicates where yields are significantly different*

Grazing

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

Deep N placement

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

Post-sowing N tie-up by retained stubble

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

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

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

Table 5. Effect of grazing stubble on grain yields at Temora in Phase 1 and 2. Crops in italics are canola, and bold are the 2nd wheat crops.

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

** shows where significantly different (P<0.05)*

Table 6. Effect of deep banding vs surface applied N (122kg N/ha as urea) at seeding, at Temora NSW in 2016 (starting soil N, 58kg/ha). The crop captured more N early in the season which increased biomass and yield in a very wet season. (Data mean of three stubble treatments).

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

**indicates significant differences (P<0.01). (Data source: Kirkegaard et. al., CSIRO Stubble Initiative 2016 CSP00186).*

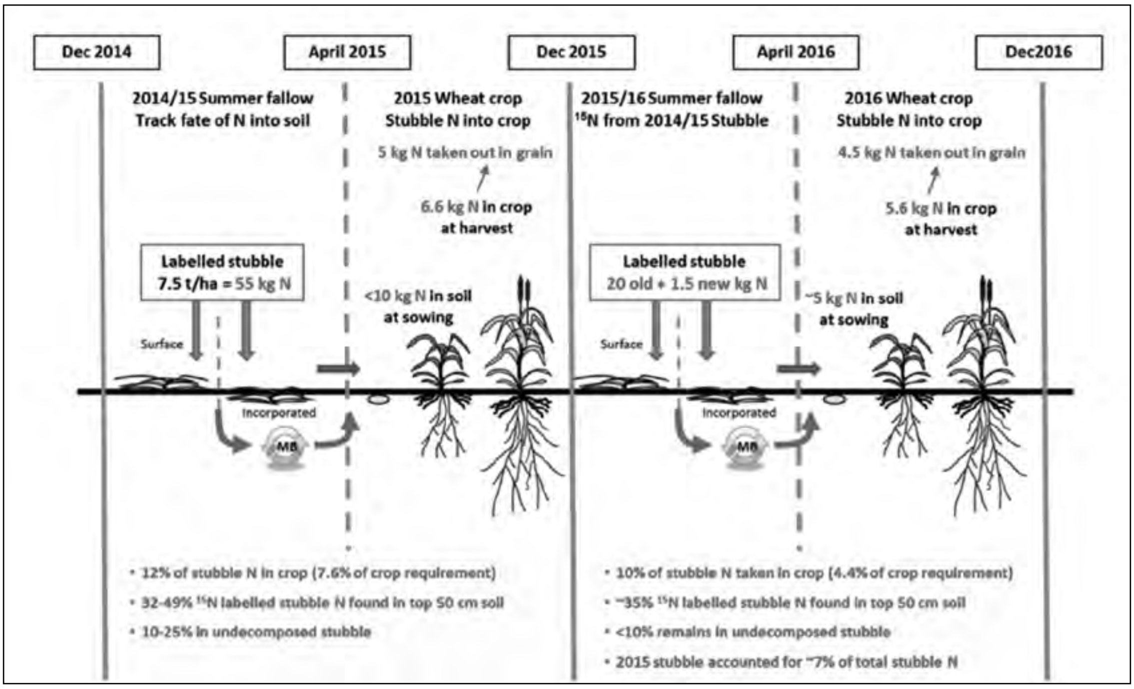

Figure 2. The fate of the N contained in retained wheat stubble over two years in successive wheat crops following the addition of 7.5t/has of wheat stubble containing 55kg/ha N. The successive crops took up 12% (6.6kg N/ha) and 10% (5.6kg N/ha) of the N derived from the original stubble representing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

growth reduction observed in the stubble-retained treatment, although due to the overall water limitation at the site, this did not translate into yield.

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

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

Conclusion

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

Useful resources

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

References

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Hart PBS et al., (1993) The availability of the nitrogen in crop residues of winter wheat to subsequent crops. *Journal of Agricultural Science* **121**, 355-362.

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Hunt JR et al. (2016) Sheep grazing on crop residues do not reduce crop yields in no-till, controlled traffic farming systems in an equi-seasonal rainfall environment. *Field Crops Research* **196**, 22-32

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. We would especially like to that the Coleman family (Temora) and the O'Connor family (Harden) for the long-term use of their land for these experiments. We also acknowledge the expert technical assistance provided by CSIRO staff (Brad Rheinheimer, Mel Bullock, John Graham, staff at Ginninderra Research Station) and Farmlink Research (Paul Breust, Tony Pratt, Colin Fritsch) who managed and measured the experiments.

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Notes

Inspection of local research trials

Andrew McMahen and Nathan Sydes.

Landmark.

How to get there

Trial site is located at four kilometres north of Ouyen on the Calder Highway; on the right after passing Yetman Road.

Trials at the Landmark Ouyen trial site

- Wheat and barley time of sowing
- Rhizoctonia
- Barley and lentil nutrition trials
- Nitrogen, phosphorus and potassium
- Liquid versus granule
- Nutrient form
- Commonly used product comparison
- Cruiser 350 versus Gaucho
- Talinor demonstration

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Notes

Notes

THE 2017-2019 GRDC SOUTHERN REGIONAL PANEL

FEBRUARY 2018

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHAIR - KEITH PENGILLEY

Based at Evandale in the northern Midlands of Tasmania, Keith was previously the general manager of a dryland and irrigated family farming operation at Conara (Tasmania), operating a 7000 hectare mixed-farming operation over three properties. He is a director of Tasmanian Agricultural Producers, a grain accumulation, storage, marketing and export business. Keith is the chair of the GRDC Southern Regional Panel which identifies grower priorities and advises on the GRDC's research, development and extension investments in the southern grains region.

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DEPUTY CHAIR - MIKE MCLAUGHLIN

Mike is a researcher with the University of Adelaide, based at the Waite campus in South Australia. He specialises in soil fertility and crop nutrition, contaminants in fertilisers, wastes, soils and crops. Mike manages the Fertiliser Technology Research Centre at the University of Adelaide and has a wide network of contacts and collaborators nationally and internationally in the fertiliser industry and in soil fertility research.

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JOHN BENNETT

Based at Lawloit, between Nhill and Kaniva in Victoria's West Wimmera, John, his wife Allison and family run a mixed farming operation across diverse soil types. The farming system is 70 to 80 percent cropping, with cereals, oilseeds, legumes and hay grown. John believes in the science-based research, new technologies and opportunities that the GRDC delivers to graingrowers. He wants to see RD&E investments promote resilient and sustainable farming systems that deliver more profit to growers and ultimately make agriculture an exciting career path for young people.

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PETER KUHLMANN

Peter is a farmer at Mudamuckla near Ceduna on South Australia's Western Eyre Peninsula. He uses liquid fertiliser, no-till and variable rate technology to assist in the challenge of dealing with low rainfall and subsoil constraints. Peter has been a board member of and chaired the Eyre Peninsula Agricultural Research Foundation and the South Australian Grain Industry Trust.

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FIONA MARSHALL

Fiona has been farming with her husband Craig for 21 years at Mulwala in the Southern Riverina. They are broadacre, dryland grain producers and also operate a sheep enterprise. Fiona has a background in applied science and education and is currently serving as a committee member of Riverine Plains Inc, an independent farming systems group. She is passionate about improving the profile and profitability of Australian grain growers.

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JON MIDWOOD

Jon has worked in agriculture for the past three decades, both in the UK and in Australia. In 2004 he moved to Geelong, Victoria, and managed Grainsearch, a grower-funded company evaluating European wheat and barley varieties for the high rainfall zone. In 2007, his consultancy managed the commercial contract trials for Southern Farming Systems (SFS). In 2010 he became Chief Executive of SFS, which has five branches covering southern Victoria and Tasmania. In 2012, Jon became a member of the GRDC's HRZ Regional Cropping Solutions Network.

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ROHAN MOTT

A fourth generation grain grower at Turriff in the Victorian Mallee, Rohan has been farming for more than 25 years and is a director of Mott Ag. With significant on-farm storage investment, Mott Ag produces wheat, barley, lupins, field peas, lentils and vetch, including vetch hay. Rohan continually strives to improve productivity and profitability within Mott Ag through broadening his understanding and knowledge of agriculture. Rohan is passionate about agricultural sustainability, has a keen interest in new technology and is always seeking ways to improve on-farm practice.

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RICHARD MURDOCH

Richard along with wife Lee-Anne, son Will and staff, grow wheat, canola, lentils and faba beans on some challenging soil types at Warooka on South Australia's Yorke Peninsula. They also operate a self-replacing Murray Grey cattle herd and Merino sheep flock. Sharing knowledge and strategies with the next generation is important to Richard whose passion for agriculture has extended beyond the farm to include involvement in the Agricultural Bureau of SA, Advisory Board of Agriculture SA, Agribusiness Council of Australia SA, the YP Alkaline Soils Group and grain marketing groups.

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RANDALL WILKSCH

Based at Yeelanna on South Australia's Lower Eyre Peninsula, Randall is a partner in Wilksch Agriculture, a family-owned business growing cereals, pulses, oilseeds and coarse grain for international and domestic markets. Managing highly variable soil types within different rainfall zones, the business has transitioned through direct drill to no-till, and incorporated CTF and VRT. A Nuffield Scholar and founding member of the Lower Eyre Agricultural Development Association (LEADA), Randall's off-farm roles have included working with Kondinin Group's overview committee, the Society of Precision Agriculture in Australia (SPAA) and the Landmark Advisory Council.

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KATE WILSON

Kate is a partner in a large grain producing operation in Victoria's Southern Mallee region. Kate and husband Grant are fourth generation farmers producing wheat, canola, lentils, lupins and field peas. Kate has been an agronomic consultant for more than 20 years, servicing clients throughout the Mallee and northern Wimmera. Having witnessed and implemented much change in farming practices over the past two decades, Kate is passionate about RD&E to bring about positive practice change to growers.

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BRONDWEN MACLEAN

Brondwen MacLean has spent the past 20 years working with the GRDC across a variety of roles and is currently serving as General Manager for the Applied R&D business group. She has primary accountability for managing all aspects of the GRDC's applied RD&E investments and aims to ensure that these investments generate the best possible return for Australian grain growers. Ms MacLean appreciates the issues growers face in their paddocks and businesses. She is committed to finding effective and practical solutions `from the ground-up'.

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2017–2019 SOUTHERN REGIONAL CROPPING SOLUTIONS NETWORK (RCSN)

The RCSN initiative was established to identify priority grains industry issues and desired outcomes and assist the GRDC in the development, delivery and review of targeted RD&E activities, creating enduring profitability for Australian grain growers. The composition and leadership of the RCSNs ensures constraints and opportunities are promptly identified, captured and effectively addressed. The initiative provides a transparent process that will guide the development of targeted investments aimed at delivering the knowledge, tools or technology required by growers now and in the future. Membership of the RCSN network comprises growers, researchers, advisers and agribusiness professionals. The three networks are focused on farming systems within a particular zone – low rainfall, medium rainfall and high rainfall – and comprise 38 RCSN members in total across these zones.

REGIONAL CROPPING SOLUTIONS NETWORK SUPPORT TEAM

SOUTHERN RCSN CO-ORDINATOR: JEN LILLECRAPP

Jen is an experienced extension consultant and partner in a diversified farm business, which includes sheep, cattle, cropping and viticultural enterprises. Based at Struan in South Australia, Jen has a comprehensive knowledge of farming systems and issues affecting the profitability of grains production, especially in the high rainfall zone. In her previous roles as a district agronomist and operations manager, she provided extension services and delivered a range of training programs for local growers. Jen was instrumental in establishing and building the MacKillop Farm Management Group and through validation trials and demonstrations extended the findings to support growers and advisers in adopting best management practices. She has provided facilitation and coordination services for the high and medium rainfall zone RCSNs since the initiative's inception.

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LOW RAINFALL ZONE CO-LEAD: BARRY MUDGE

Barry has been involved in the agricultural sector for more than 30 years. For 12 years he was a rural officer/regional manager in the Commonwealth Development Bank. He then managed a family farming property in the Upper North of SA for 15 years before becoming a consultant with Rural Solutions SA in 2007. He is now a private consultant and continues to run his family property at Port Germein. Barry has expert and applied knowledge and experience in agricultural economics. He believes variability in agriculture provides opportunities as well as challenges and should be harnessed as a driver of profitability within farming systems. Barry was a previous member of the Low Rainfall RCSN and is current chair of the Upper North Farming Systems group.

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LOW RAINFALL ZONE CO-LEAD: JOHN STUCHBERY

John is a highly experienced, business-minded consultant with a track record of converting evidence-based research into practical, profitable solutions for grain growers. Based at Donald in Victoria, John is well regarded as an applied researcher, project reviewer, strategic thinker and experienced facilitator. He is the founder and former owner of JSA Independent (formerly John Stuchbery and Associates) and is a member of the SA and Victorian Independent Consultants group, a former FM500 facilitator, a GRDC Weeds Investment Review Committee member, and technical consultant to BCG-GRDC funded 'Flexible Farming Systems and Water Use Efficiency' projects. He is currently a senior consultant with AGRIvision Consultants.

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HIGH RAINFALL ZONE LEAD: CAM NICHOLSON

Cam is an agricultural consultant and livestock producer on Victoria's Bellarine Peninsula. A consultant for more than 30 years, he has managed several research, development and extension programs for organisations including the GRDC (leading the Grain and Graze Programs), Meat and Livestock Australia and Dairy Australia. Cam specialises in whole-farm analysis and risk management. He is passionate about up-skilling growers and advisers to develop strategies and make better-informed decisions to manage risk – critical to the success of a farm business. Cam is the program manager of the Woady Yaloak Catchment Group and was highly commended in the 2015 Bob Hawke Landcare Awards.

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MEDIUM RAINFALL ZONE LEAD: KATE BURKE

An experienced trainer and facilitator, Kate is highly regarded across the southern region as a consultant, research project manager, public speaker and facilitator. Based at Echuca in Victoria, she is a skilled strategist with natural empathy for rural communities. Having held various roles from research to commercial management during 25 years in the grains sector, Kate is now the managing director of Think Agri Pty Ltd, which combines her expertise in corporate agriculture and family farming. Previously Kate spent 12 years as a cropping consultant with JSA Independent in the Victorian Mallee and Wimmera and three years as a commercial manager at Warakirri Cropping Trust.

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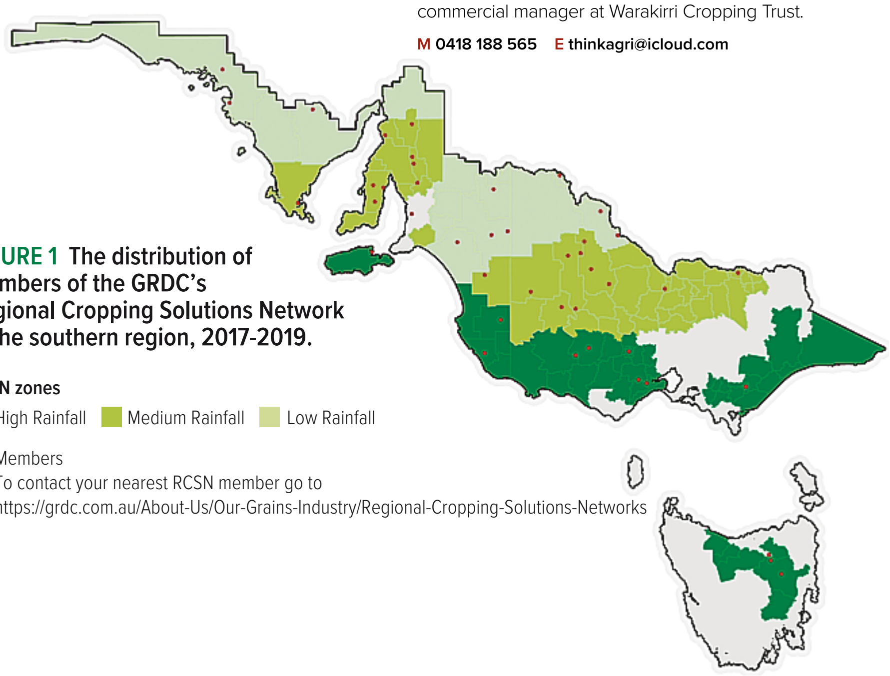

FIGURE 1 The distribution of members of the GRDC's Regional Cropping Solutions Network in the southern region, 2017-2019.

RCSN zones

High Rainfall | Medium Rainfall | Low Rainfall

Members

To contact your nearest RCSN member go to https://grdc.com.au/About-Us/Our-Grains-Industry/Regional-Cropping-Solutions-Networks

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Acknowledgements

The ORM team would like to thank those who have contributed to the successful staging of the Walpeup GRDC Grains Research Update:

- The local GRDC Grains Research Update planning committee that includes both government and private consultants and GRDC representatives.

- Partnering organisation: MSF

You can now provide feedback electronically 'as you go'. An electronic evaluation form can be accessed by typing the URL address below into your internet browser.

To make the process as easy as possible, please follow these points:

- Complete the survey on one device (i.e. don't swap between your iPad and Smartphone devices. Information will be lost).
- One person per device (Once you start the survey, someone else cannot use your device to complete their survey).
- You can start and stop the survey whenever you choose, **just click 'Next' to save responses before exiting the survey**. For example, after a session you can complete the relevant questions and then re-access the survey following other sessions.

www.surveymonkey.com/r/Walpeup-GRU

2018 Walpeup GRDC Grains Research Update
Evaluation

1. Name [ ]

ORM has permisssion to follow me up in regards to post event outcomes.

2. How would you describe your <u>main</u> role? *(choose one only)*

- ❑ Grower
- ❑ Agronomic adviser
- ❑ Farm business adviser
- ❑ Financial adviser
- ❑ Communications/extension
- ❑ Grain marketing
- ❑ Farm input/service provider
- ❑ Banking
- ❑ Accountant
- ❑ Researcher
- ❑ Student
- ❑ Other* (please specify) [ ]

Your feedback on the presentations

For each presentation you attended, please rate the content relevance and presentation quality on a scale of 0 to 10 by placing a number in the box (**10 = totally satisfactory, 0 = totally unsatisfactory**).

3. Insects, resistance and control: *James Maino*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

4. Long fallows may hold the key to reducing risk in the Mallee: *David Cann*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

5. Improving crop productivity on sandy soils: *Therese McBeath*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

6. Optimising performance from inoculants: *Liz Farquharson*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

7. The effect of stubble on nitrogen tie-up and supply: *James Hunt*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

Your next steps

8. Please describe at least one new strategy you will undertake as a result of attending this Update event

[ ]

9. What are the first steps you will take?

e.g. seek further information from a presenter, consider a new resource, talk to my network, start a trial in my business

[ ]

Your feedback on the Update

10. This Update has increased my awareness and knowledge of the latest in grains research

Strongly agree	Agree	Neither agree nor Disagree	Disagree	Strongly disagree
❑	❑	❑	❑	❑

11. Overall, how did the Update event meet your expectations?

Very much exceeded	Exceeded	Met	Partially met	Did not meet
❑	❑	❑	❑	❑

Comments

[ ]

12. Do you have any comments or suggestions to improve the GRDC Update events?

13. Are there any subjects you would like covered in the next Update?

Thank you for your feedback.