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AGRICULTURE VICTORIA

Program

9:00 am	**Welcome**	***ORM***
9:05 am	**GRDC welcome and update**	***GRDC***
9:15 am	**Growing pulses in the central Eyre Peninsula**	***George Pedler,*** *George Pedler Ag*
9:55 am	**Improving productivity on sandy soils**	***Nigel Wilhelm,*** *SARDI*
10.35 am	***Morning tea***	
11:05 am	**Research update on brome grass and other emerging problem weeds**	***Gurjeet Gill,*** *The University of Adelaide*
11.45 am	**Baiting snails according to environmental conditions**	***Jacob Giles,*** *SARDI*
12:25 pm	**Soil moisture probes – what have we learnt so far?**	***Andrew Ware,*** *SARDI*
1.05 pm	***Close and evaluation***	***ORM***
1.10 pm	***Lunch***	

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EPARF provides a positive link between scientists, farmers, industry stakeholders and builds strength and sustainability through collaboration with other grower groups in southern Australia.

VISION

To be an independent advisory organisation providing strategic support for the enhancement of agriculture.

VALUES

To proactively support all sectors of agriculture research on the Eyre Peninsula including the building of partnerships in promoting research, development and extension.

PURPOSE

- Build capacity of the agricultural sector through education and training.
- Promote the advancement and practical application of agricultural scientific research, development & extension in dryland farming systems relevant to Eyre Peninsula and like environments across Australia.
- Provide advice and strategic direction on short, medium and long term needs of the agricultural sector to include current, innovative and future issues.
- Conduct agricultural activities and ensure that farmers, agribusiness and the scientific community are an integral part of the planning.
- Establish interaction with various industry bodies, negotiate funding opportunities and utilise reserves to leverage other funds.
- Be responsive and relevant to our farmer and industry members.

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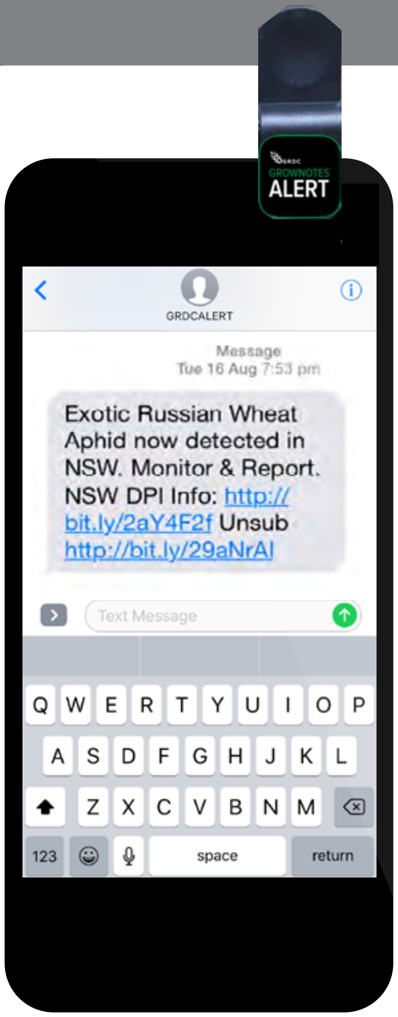

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GRDC GROWNOTES ALERT

Growing pulses in the central Eyre Peninsula

George Pedler.

George Pedler Ag.

Keywords

- pulses, legumes, sandy soils, amelioration, herbicide carryover.

Take home messages

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Pulse economics

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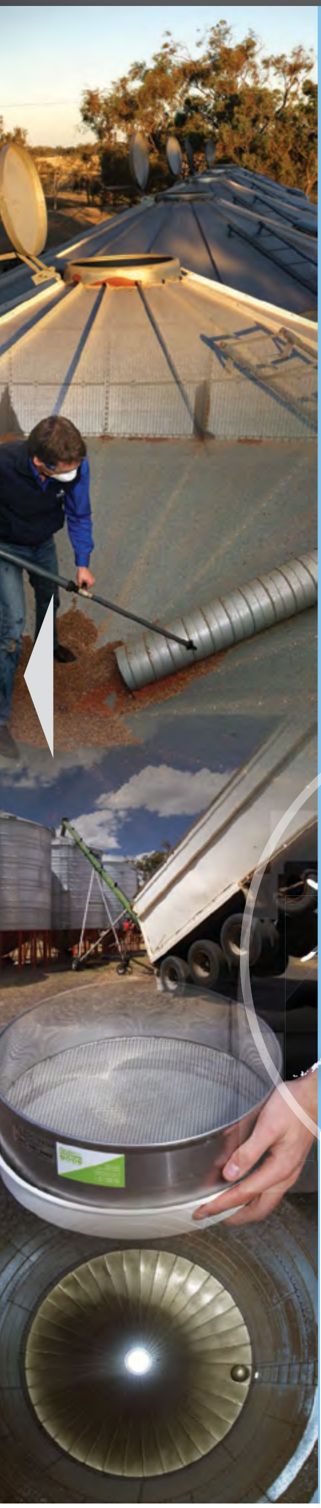

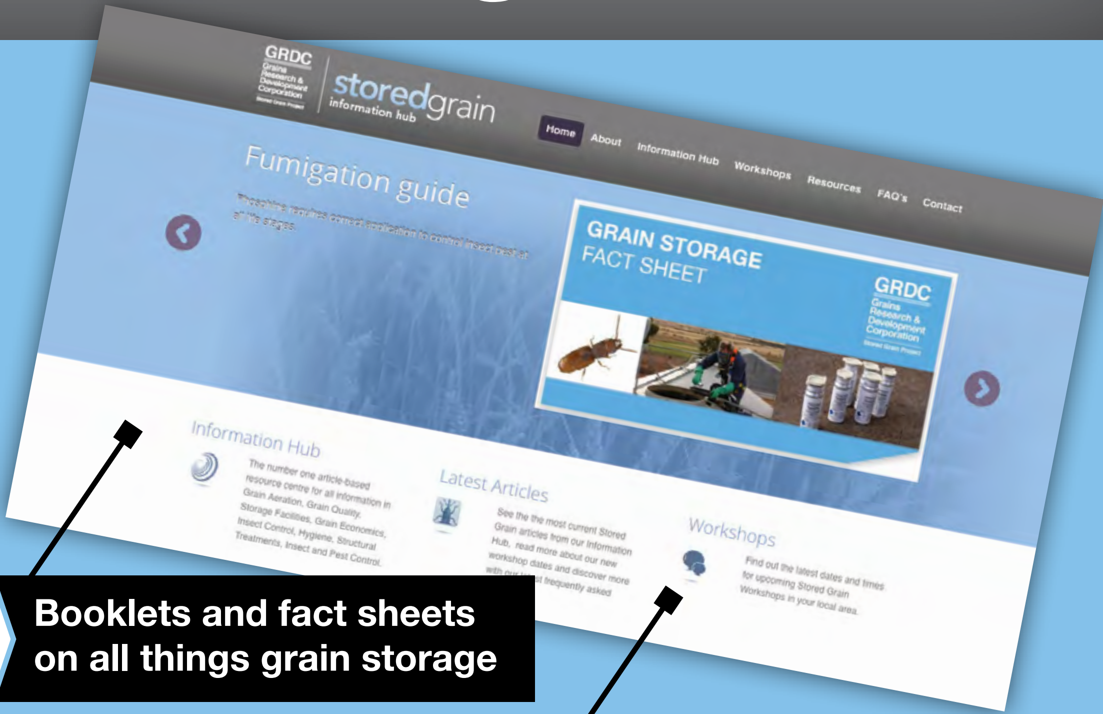

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Improving crop productivity on sands - what is the latest ?

Nigel Wilhelm.

South Australian Research & Development Institute, Waite Research Precinct.

GRDC project codes: CSP00203 (Sandy soils), DAW00244 (Water Repellency)

Keywords

- water repellency, amelioration, mitigation, compaction, nutrition, sand.

Take home messages

- Strategies to improve productivity on a sand are in three categories:
  - Quarantine (set the sandy area aside and reduce costs - cheap but little financial reward),
  - Mitigate (leave the sand as it is but minimise the impact of its problems - cheap but the problem is always there),
  - Amelioration (change the sand into better soil – expensive but potentially good profits and problem solved).
- Deep ripping to relieve compaction regularly produces useful increases in crop yields.
- Well incorporated, solid rates of clay eliminate water repellency. Aggressive tillage (e.g. mouldboard plough, large disc ploughing) will reduce repellency but only for 2-3 years.
- Wetting agents at seeding and seeding near the previous crop row can increase the number of established plants in the current crop on severely repellent sands.
- Deep sands are always low in fertility. Adding extra nitrogen (N), phosphorus (P) and sulphur (S) early almost always works. Zinc (Zn), manganese (Mn) and copper (Cu) applications can also help on some sands, especially the whitest ones.
- Changing the top 30cm of sand to a better soil type with incorporation of clay, N-rich organic matter (OM) and/or extra fertiliser can increase productivity spectacularly but making it profitable is still elusive.
- Soil-borne diseases, pests and weeds can be more of a problem on sands but tend to recede if crop production can be improved (such as by techniques mentioned above).
- Putting together a package of strategies which address the many constraints normally present in sands is the key to large improvements in crop productivity.

Background

Many sandy soils in the Southern region are under-performing because the crops on them are not getting to their water limited yield potential. This is most obvious in the deep sands where the subsurface layers can still be quite wet in summer despite a reasonable crop having been grown on them the previous season. There is always a lack of crop roots in these wet layers. Currently there are many research, development and extension (R,D&E) activities underway attempting to convert this 'unused' water into improved crop productivity on these soils. This paper is a summary of their findings so far which relate to sands on Eyre Peninsula and includes R&D outcomes over the last decade or so.

In this paper when discussing sands it refers to a deep white siliceous sand of a type which can be found around Wanilla, west of Cummins, east of Lock and throughout the Wharminda district. These sands are typically:

- At least 40cm deep before you reach any clay.
- Water repellent in the surface layers.
- Slightly acidic at the surface and the pH is even lower below the cultivated layer.
- Very low in organic matter, especially below the surface.
- Poorly fertile at the surface and only getting worse deeper in the profile.
- Quite strong, especially in a zone at or just below the cultivated layer.

The points summarised below have been made in the context of this sand profile. If the sands you have in mind are not as extreme as this one, then the benefits of the management strategies to follow are likely to be smaller (but the problems you are trying to fix should be smaller too).

This type of sand usually produces poorly performing crops which struggle to establish well (fewer weaker seedlings), have limited tillering/branching, drop off old leaves early in the season and struggle with high disease and weed pressures. There are three categories of management strategies to change this status quo (quarantine, mitigate, ameliorate) and this paper will attempt to outline the strengths and weaknesses of practices within each category in the sections to follow. The boundaries between these categories are not absolute but depend on the attitudes and resources of the manager dealing with each sandy area. The categories are also not exclusive. This means that multiple strategies can be employed to create a new management package for the sandy area.

Quarantine

Quarantining the sandy areas means that you are tired of spending money on those areas for infrequent and small profits, there is no motivation to invest more dollars on those areas in an attempt to break the cycle and the current erosion risk or reality is unacceptable.

Quarantining can be as extreme as fencing off the problem areas and returning them to permanent vegetation (grazed or un-grazed) as a strategy to reduce the financial losses made on them and to stabilise them from an erosion aspect.

Less dramatic are options of simply reducing inputs and accepting low productivity, which may still mean the areas stay in the same rotation and basic management package as the rest of the paddock but with lower rates of inputs.

Quarantining is only attractive if the total areas of sands are small.

Mitigation

Strategies in this category are those which accept the existing properties of the sandy profile but attempt to reduce the impact of those weaknesses on crop production. They are usually relatively low in cost but also relatively low in benefit (compared to amelioration approaches). Table 1 lists some individual strategies and their strengths and weaknesses.

Amelioration

Amelioration is an approach primarily designed to change the deep sand into a different (and better) soil and thus reduce the original weaknesses without losing the strengths of the original profile (e.g. high infiltration rates for water, crops can benefit from small rainfall events, easy to get precise seeding depth and solid seed/soil contact during the seeding operation). They tend to be very expensive on inputs and require effort to implement because it is not cheap to change the nature of soil over large areas and thus they need to have long residual benefits to be cost effective and logistically attractive. Table 2 lists some individual amelioration strategies and their strengths and weaknesses.

Table 1. Mitigation strategies for deep sands and their major strengths and weaknesses.

Practice	Strengths	Weaknesses
Near row seeding to reduce impact of water repellence	• Cheap if you already have precision guidance and a high trash flow seeder • Also makes better use of last year's fertiliser	• Of little benefit in years when repellency is less of a problem • Works best in ungrazed stubble • Can be counterproductive if there are weeds and/or diseases in last year's stubble row
Wetting agents at seeding	• Low cost • Allows all existing management strategies to continue.	• Of little benefit in years when repellency is less of a problem • Requires a fluid delivery system on the seeder • Improves the number of plants established but not their vigour
Seeding approaches which increase plant numbers (eg cross sowing, higher seeding rate, ribbon or split seeding boots)	• Simple to implement • Low cost if timing is not compromised • Compensates for poor tillering/crop vigour	• Of most benefit only in those years when repellency is a major problem. • Improves the number of plants established but not their vigour
Increasing fertiliser application rates or types	• Simple to implement • Uses existing resources • Can have carry over benefits	• Can be expensive so relies on substantial crop improvements to be profitable • Need to know which nutrients are in worst supply • Will not increase plant numbers
Change crop type to one more adapted to sand (eg rye instead of wheat, lupins instead of lentils)	• Reduced erosion risk • More grazing potential • Can be low direct cost • Has been used historically to good effect	• Can complicate weed and pest control • Reduces efficiencies of operations, esp seeding and spraying • Can replace a high value crop with a low one

Table 2. Amelioration strategies for deep sands and their major strengths and weaknesses.

Practice	Strengths	Weaknesses
Aggressive tillage (eg mouldboard ploughing, large disc ploughing, spading)	• Will reduce repellency • Can bury weed seeds and disease inoculum • Will disrupt some compaction layers • Can be conducted with cheaper implements • Can be used to incorporate soil amendments	• Carry over benefits may be short • Can increase plant numbers but not necessarily vigour • Can mineralise OM which is already low in the profile • Incorporation of soil amendments is only shallow • Trafficability can be an issue after implementation
Deep ripping	• Cheapest of the amelioration options • Easiest of the amelioration options to implement • Can be implemented at many times of the year • Current management strategies can be maintained • Can be used to incorporate soil amendments to depth	• Trafficability can be an issue after implementation • Achieving shallow and consistent seeding depth with solid seed/soil contact can be tricky • Only addresses high soil strength • May need to be repeated every few years
Clay spreading and incorporating	• Eliminates water repellency • Improves the quality of soil in the incorporated layer • Can produce a 'permanent' change • Makes weed control much better	• Very expensive • Only an option if shallow suitable clay is close to the sandy area • Clay rates too high can cause new problems • Poor incorporation reduces benefits
Delving clay to the surface and incorporating	• Eliminates water repellency and compaction • Improves the quality of soil in the incorporated layer • Can produce a 'permanent' change • Makes weed control much better • Cheaper than clay spreading	• Expensive • Only an option if shallow suitable clay is under the sandy area • Poor incorporation reduces benefits
Incorporation of N-rich organic matter	• Produces large growth benefits • Can be sourced on-farm • Can have carry over benefits	• Large volumes of OM are difficult to handle and incorporate • Opportunity cost of OM can be high • Long term benefits are uncertain • Applications strategies not well understood • Better at producing biomass than grain
Change crop type to one more adapted to sand (eg rye instead of wheat, lupins instead of lentils)	• Reduced erosion risk • More grazing potential • Can be low direct cost	• Can complicate weed and pest control • Reduces efficiencies of operations, esp seeding and spraying • Can replace a high value crop with a low one

In conclusion, Table 1 and 2 summarise a wide range of strategies which are available, or under development, for improving the productivity of sands. Many of them only target one or two soil weaknesses and as most sands have multiple constraints, a package of strategies is almost always required to maximise impact. Identifying those constraints and implementing strategies well to overcome them are the key to substantial improvements to crop performance on sands. For some constraints (e.g. subsoil infertility), strategies are still being developed.

Useful resources

GRDC web site and GroundCover for articles and reports from current and recent R&D projects e.g. CSP00203 (Sandy soils) and DAW00244 (Water Repellency).

Clay Spreading and Delving Fact Sheet (GRDC)

Clay spreading and delving on Eyre Peninsula : a broadacre clay application manual for farmers. 2006, compiled by Rachel May; editors: David Davenport et al.

Acknowledgements

This summary of management options for improving sands has been drawn together from a vast array of existing and recent R&D projects, both from published information and also from personal communications. The author is very grateful for their freely given experience and ready access to project data.

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 authors would like to thank them for their continued support.

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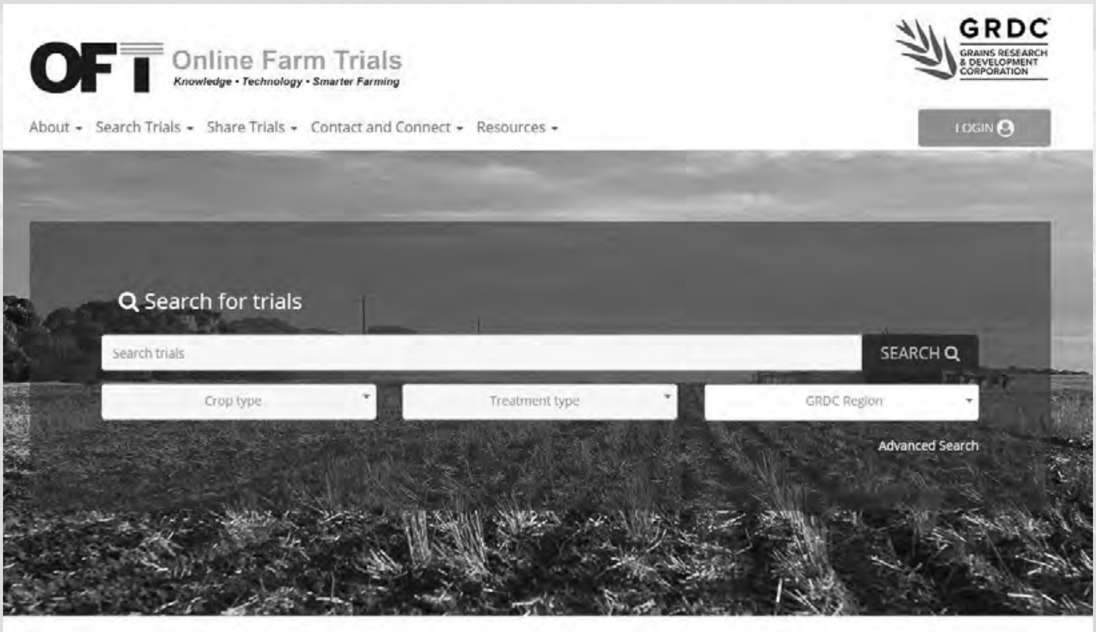

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Latest research on brome grass and susceptibility of emerging weed species to harvest weed seed capture

Gurjeet Gill, Sam Kleemann and Ben Fleet.

School of Agriculture, Food & Wine, The University Of Adelaide.

GRDC project code: UA00156

Keywords

- brome grass, weed seed dispersal, management.

Take home messages

- Increasing incidence of brome grass in cropping paddocks in southern Australia appears to be associated with selection of biotypes with greater seed dormancy by crop management practices used by the growers.
- Higher levels of seed dormancy allow brome to germinate and establish after pre-sowing weed management, resulting in greater in-crop weed establishment. This change in weed behaviour also appears to be associated with high seedbank persistence from one year to the next (~25%). Therefore, multiyear control strategies are required to exhaust brome seedbanks to low levels.
- Weed seed dispersal prior to crop harvest differed greatly between weed species. Bedstraw, statice, turnip weed and Indian hedge mustard showed no pre-harvest dispersal (100% retained); whereas barley grass had shed 94% of its seeds at harvest time. Seed retention in brome grass varied from 50-75% and was influenced by growing season rainfall and crop being grown. These results indicate harvest weed seed control (HWSC) tactics are unlikely to improve barley grass management but may have some benefits for brome control.
- A preliminary kiln study showed that temperatures in excess of 450 degrees Celsius for at least 40s were required to guarantee the complete kill of brome grass seed. As burning standing stubbles are unlikely to provide the required level of heat exposure, narrow windrow burning should be considered to improve weed seed kill.

Brome grass ecology and management

Rigid brome (*Bromus rigidus*) tends to be the main brome species present on farms around Lock and many other areas of the Eyre Peninsula (EP). This species tends to have high seed dormancy, which usually breaks around late May/June when most of the crops on the EP have already been sown. This species was investigated extensively in a previous GRDC project UA00060 (2003-07). Germination in *B. rigidus* was found to be strongly inhibited by exposure to light and 15-30% of its seeds persisted from one year to the next. This weed species also occurs extensively in high rainfall areas around Warooka on the York Peninsula.

Great brome (*Bromus diandrus*) tends to be more common in the lower and upper North and in the Mallee. This species has increased in prevalence in the last 10 years, which appears to be related to increased adoption of no-till farming and intensification of cereal-based cropping systems (i.e. wheat on wheat), where less herbicide options are available for its control. Most attributes of *B. rigidus* and in-crop populations of *B. diandrus* are very similar. Germination in both species is inhibited by light and a large number of plants emerge after the crops have been sown. Some of the increase in abundance in crops of these brome species can also be explained by the adoption of earlier sowing or even dry sowing. In situations where brome grass infestations are high, it can reduce wheat yields by 30-50%.

On-farm selection for increased seed dormancy and delayed seedling emergence after the opening rains appears to be responsible for the increasing dominance of this weed species. Our research has clearly shown higher levels of seed dormancy in brome grass populations collected from cropping fields than those from non-crop situations such as fence-lines or roadsides (Figure 1). Populations collected from intensively cropped situations in 2015 were much slower to emerge and reach 50% of final emergence (t_{50}) than those sourced from the fence-line and other non-crop habitats (cropped t_{50} ~40 d; fence-line t_{50} ~20 d). This two-fold difference in seedling emergence time between brome populations was related to the variation in seed dormancy. A similar trend was observed in populations of brome grass collected from the paddocks and fence-line situations in 2016.

These results clearly indicate that management practices used by growers to control brome in cropping paddocks have caused a shift in weed population behaviour. This increase in seed dormancy has been caused by selection of individuals in these populations that possess genes for greater seed dormancy that enables them to escape pre-sowing weed control tactics such as tillage or knockdown herbicides. The process of selection for increased seed dormancy would work similarly to the selection for herbicide resistance. Over time weed management practices in cropping paddocks would select for biotypes that possess higher dormancy and select against or remove those with low dormancy. Such selection pressure would not occur on the fence-line or non-crop areas or pastures.

Seeds of highly dormant populations of brome grass were responsive to chilling (i.e. exposure to 5°C), a process which has been shown to increase gibberellic acid production within the seed, a hormone known to break seed dormancy and stimulate germination. In the field this means that the dormant brome grass seed requires not only moisture, but also a period of colder temperatures to germinate. Therefore, germination of most of the seedbank of brome would not occur until cooler-moist conditions in late autumn-early winter, thus allowing it to evade early season weed control tactics (e.g. knockdown herbicides) and survive pre-emergence herbicides. Another biological mechanism that appears to delay seedling emergence in the field is the strong inhibitory effect of light on seed germination in rigid and great brome. Strong inhibition of germination by light is likely to aid brome infestation in the field in no-till systems by enabling seeds to remain ungerminated on the soil surface even after adequate rainfall until after the sowing of the crop, thus preventing seedlings from being killed by knockdown herbicides. This feature of brome grass ecology

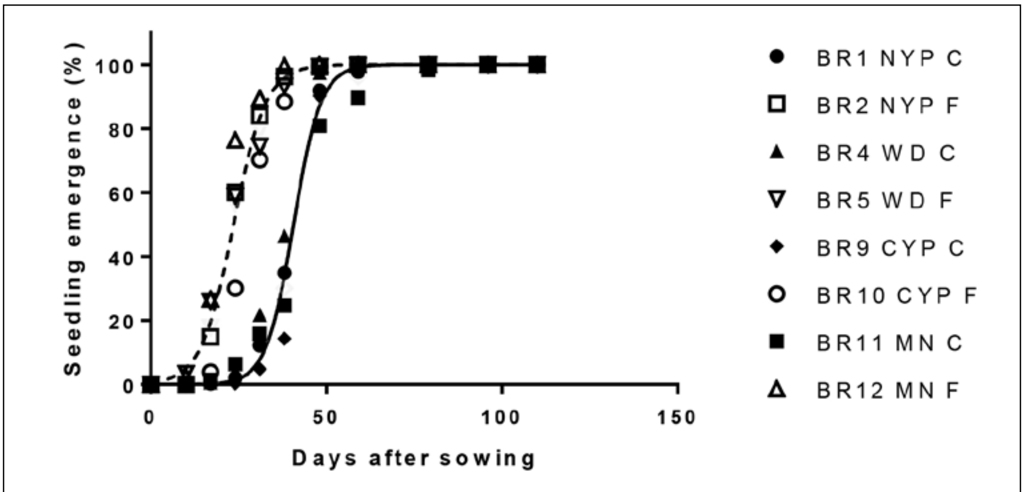

Figure 1. Differences in germination and seedling emergence pattern between cropped (closed symbols; solid line) and adjacent fence-line (open symbols; broken line) populations of great brome (*B. diandrus*) collected in 2015 across south-eastern Australia. A similar trend was observed in populations collected in 2016.

helps in explaining why it has proliferated under no-till, where seeds remain on the soil surface until being buried by the sowing pass, which would remove the inhibitory effect of light.

Greater seed dormancy in rigid brome grass populations from cropping fields could have also contributed to the development of a more persistent seedbank. A field study undertaken at Lock showed that 20% of the seedbank of rigid brome persisted from one season to the next, with seeds remaining viable in the soil for up to three years (Figure 2). Similar levels of seedbank persistence in great brome were shown in the long-term study at Balaklava, where more than 25% of seedbank persisted from one season to the next. Seedbank carryover of this magnitude could be an important factor in the proliferation of brome grass where crop rotations have often provided effective control just for one year (i.e. pasture-wheat rotation) or under cereal monoculture.

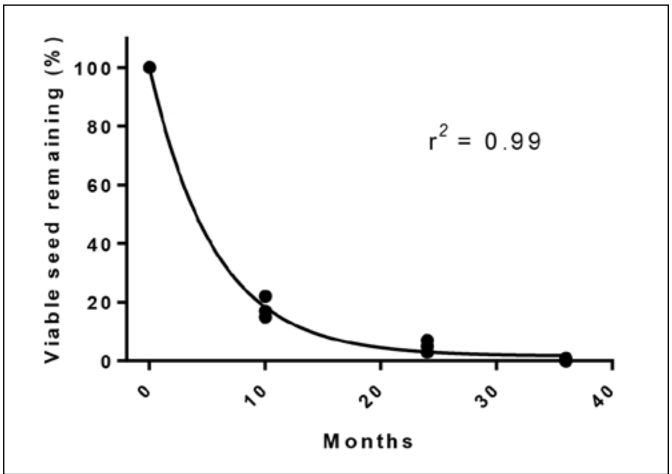

Figure 2. Longevity of rigid brome (*B. rigidus*) seed in the field at Lock from 2003 to 2006. In some populations seedbank persistence can be as high as 30%.

Given the high level of seedbank persistence of brome grass, long-term control of brome would need an effective multi-year management program. Fortunately, the introduction of imidazolinone-tolerant wheat (Clearfield™) has widened grower's options for the management of brome in the wheat-phase. Use of break crops such as a legume or canola in combination with Clearfield™ cereals can provide a range of herbicide options for brome control and can be included in a rotation to prevent crop competition and weed seed-set. However, brome is a prolific seed producer even when growing in crop competition (80 to 270seeds/plant) and weed populations can rebound sharply if management tactics used do not provide a high level of weed control.

Seed dormancy in wild turnip and barley grass

Wild turnip seeds were found to have a high level of seed dormancy and even after nine months after maturity, germination in different populations ranged from 3 to 40%. This high level of seed dormancy was reflected in long-term persistence of the seedbank with some populations showing seedling emergence even in the third season of the study. The results of this research show that presence of physiological dormancy regulated within the embryo is the main mechanism controlling wild turnip germination and this high level of seed dormancy leads to long-term persistence of its seedbank. Since wild turnip plants can set a huge amount of seed, weed seed production needs to be managed every year.

Barley grass has been generally considered to have low seed dormancy and little or no seedbank persistence from one year to the next. Our research has shown this to be not true at least for the in-crop populations of barley grass. Surprisingly, some barley grass populations showed only 20-30% seedling establishment in 2016 and there was some concern that they had low seed viability. However, populations with low seedling establishment in 2016 showed much higher seedling emergence in 2017. Therefore, high seed dormancy in some cropping populations of barley grass appears to cause much greater seedbank persistence and establishment in the second year after seed set. Selection pressures imposed by weed-control tactics used in crops appears to have selected for more persistent barley grass populations in southern Australia. Similarly, Shergill et al. (2015) reported higher persistence for cropped populations of barley grass, whereas previous studies (Peltzer & Matson 2002; Popay 1981; Powles et al. 1992) showed that seeds of barley grass have a short-lived seedbank and very few seeds are likely to persist beyond one year. Seedbank carry-over could be an important factor in the observed increase of barley grass in crops in the southern region.

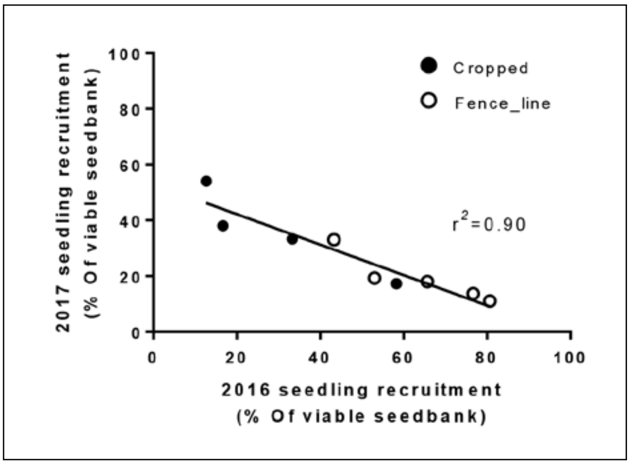

Figure 3. Seedling recruitment (2016 and 2017) of cropped & fence-line populations of barley grass from seedling trays carried-over from 2016.

Weed seed dispersal & susceptibility of emerging weeds to harvest weed seed capture and control

At present there is a high level of interest in the grains industry in harvest weed seed control (HWSC) including weed seed catchers, weed seed destructor technologies and narrow windrow burning. The effectiveness of these practices depends on the amount of weed seed retained on the plant and present above the cutter bar height at crop harvest. Field studies conducted over the past two seasons at Roseworthy have investigated the seed shedding behaviour of several emerging weeds until the crop was harvest-ready (≤12% moisture content). The pattern of seed shedding was determined by regularly collecting seeds from the seed traps placed on the soil surface in the crop canopy.

Table 1. Effect of brome and barley grass density (low, medium and high) on panicle lodging at the harvest-ready stage of wheat (≤12% moisture content). Panicles found ≤15 cm crop harvest height were scored as lodged.

Weed density (plants m^2)	Brome grass	Barley grass
	% panicles ≤15 cm harvest height	
Low (10-20)	30 ± 18.2	73 ± 4.1
Medium (35-50)	47 ± 11.4	63 ± 2.7
High (140-200)	80 ± 2.0	68 ± 2.4

Barley grass (*H. glaucum*) was particularly prone to early seed dispersal and <6% of seeds produced were retained in panicles at the harvest-ready stage of wheat (Figure 4). Barley grass was also the first weed species to reach maturity, producing viable seeds and initiating seed shed at 43-45 days before crop harvest. Relative to barley grass, bifora and brome grass (*B. diandrus*) were slower to reach physiological maturity and initiated seed shed 21-25 days before crop harvest. Weed seed retention was much higher for bifora (50%)and brome grass (75%) and bedstraw showed no seed dispersal prior to crop harvest (100% retained). Even though brome grass had high seed retention (75%) until harvest in 2016, many panicles (30-80%) had lodged below the crop harvest height of 15cm (Table 1). The severity of lodging in brome grass increased with weed density, which could be related to weaker stems at its higher density and this could be an important escape mechanism from HWSC for this species.

Based on the level of seed dispersal observed in this study, bedstraw, statice, turnip weed, and Indian hedge mustard were the most suitable weed species for harvest weed seed capture. Despite bifora and brome grass shedding some seed prior

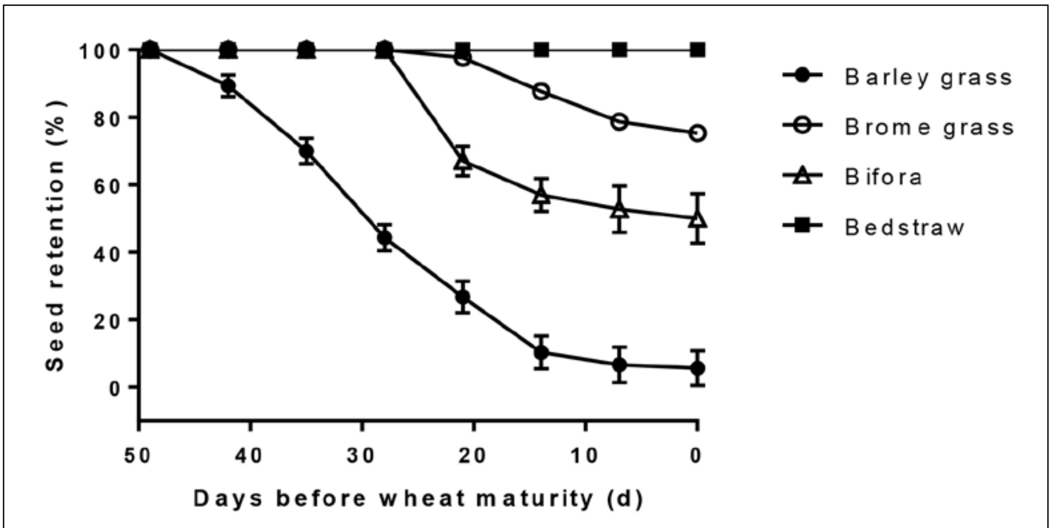

Figure 4. Seed retention of brome grass (O) relative to barley grass (●), bifora (△) and bedstraw (■) in relation to wheat maturity (≤12% grain moisture content) at Roseworthy in 2016. Bars show ± standard errors.

Table 2. Effect of temperature and duration of exposure on the percentage (%) germination (survival) of brome grass seed. Values in mean column with different letters are significantly different (P = 0.05). SAGIT funded project (S416).

Duration (s)	Temperature (°C)					
	200	250	300	350	400	450
20	100 *a*	98 *a*	100 *a*	91 *a*	71 *b*	68 *b*
40	97 *a*	93 *a*	98 *a*	59 *b*	7 *c*	0 *c*
60	98 *a*	89 *a*	72 *b*	2 *c*	0 *c*	0 *c*

to harvest, >50% of seeds were retained for HWSC. In contrast, sowthistle and barley grass appear to be the least suitable weed species for HWSC and show a high level of shed seed prior to crop harvest.

Results from a preliminary kiln study showed that both temperature and duration of exposure were important factors for killing weed seeds (only brome grass data presented). Temperatures in excess of 450°C for at least 40s were required to achieve complete kill of brome grass seeds (Table 2). Even at these high temperatures (450°C), short exposure (20s) failed to completely kill brome seeds with more than 68% remaining viable after the treatment. These preliminary results clearly suggest that short hot burns associated with burning standing stubbles are likely to only achieve partial kill of weed seeds. Therefore, narrow windrows of high biomass are required to generate the temperatures and exposure times needed for killing brome grass seed.

Even though our studies have shown that several weed species retain most of their seed until crop harvest, little is known about the proportion of weed seed that subsequently exits in the grain, straw and chaff fractions under commercial harvest conditions. An important factor in many HWSC systems (i.e. chaff carts, chaff lining and HSD) is that they only target the portion of weed seed exiting the harvester in the chaff fraction. Narrow windrow burning is the exception and will control weed seeds exiting both in the straw and chaff fractions provided a hot, and long burn is achieved. Further research is therefore required to clarify this aspect of weed seed collection to determine the relative effectiveness of each HWSC system in the long-term management of these emerging weeds.

Acknowledgments

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 authors would like to thank them for their continued support.

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Successfully baiting round snails prior to egg laying on the Lower Eyre Peninsula in accordance to environmental conditions

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GRDC project code: LEA00002

Keywords

- snails, baiting, management, breeding, egg laying.

Take home messages

- Relative humidity >90% facilitates snail movement and feeding.
- A higher level of baiting efficacy is achieved if baiting is conducted just prior to the snails' egg-laying period.
- Snail activity during and after rainfall events is dependent on the significance of the rainfall event, wind and temperature.
- Summer weed control and cultural methods of snail control play a crucial role in managing populations where numbers are high.

Background

Research conducted on Lower Eyre Peninsula by Gontar and Nash in early 2016 found that by understanding the snail life cycle and reproductive activity, improved snail control could be possible. They found that hydrated and fed snails are capable of entering into a reproductive phase in March and may seek to lay eggs anytime from early April. This means that growers who wait to bait snails at seeding may miss the opportunity for control prior to egg laying.

In order to understand if active snails could be controlled through baiting during the January-March period (prior to traditional baiting practices) a trial was conducted at Mt Greenly on Lower Eyre Peninsula in 2017 and again in a similar nearby location at Frenchmans in 2018.

Methods

Baiting trials

In 2017 the field trial comprised replicated strips (2) of 1.5% metaldehyde snail bait. The bait was 2.5mm diameter and applied @ 7.5kg/ha at two timings (6 February and 6 March) with untreated plots to account for natural population changes. Treatment strips were 50m wide, such that the resulting plots were 50m x 200m with 3 count points within each plot and 10 counts taken at each point. Initial population density for each plot over the trial was evaluated prior to baiting, with final counts taking place seven days post treatment.

Snail activity monitoring

A Brinno TLC100 time lapse camera was placed in the same field trial paddock, within one of the untreated control (UTC) replicates. The camera was located approximately 1m from the ground pointing vertically down. The field of view achieved was approximately 0.5 x 0.5m. The camera was set to take an image every 30 seconds. The camera was accompanied by an LED light bar connected to a 12 volt battery through a Kemo twilight switch, to allow the camera to take shots at night.

Immediately adjacent to the camera, a Hobo micro weather station was also established to closely monitor weather conditions at ground level. The weather station provided data on soil moisture, leaf area wetness and two sets of temperature and relative humidity data – one at ground level and the other approximately 40cm from the ground (i.e. at upper stubble height).

Analysis of the camera/weather data was undertaken by watching video and timing the snail activity each night. This was later matched with climate data.

Reproduction monitoring

From 2016-18 50 snails were collected regularly throughout the periods monitored. They were then preserved in ethanol until dissection at a later date. A subset of 25 snails were measured (shell diameter) then dissected, with the presence of food in their gut recorded, as well as the length of the albumen gland. The albumen gland of snails is known to enlarge relative to the size of the snail's shell as the snail moves into a reproductive phase (Baker, 2012).

Results

Table 1 shows the poor response to baiting during the warmer period in February, which during 2017 was a period that did not support snail activity. During the week post baiting only two hours of significant snail movement was observed. Such low levels of snail activity are seen when conditions are dry, which is usually linked to hot, windy weather with a lack of rainfall. Baiting during such a period is ineffective.

Table 2 shows the snail's mortality rate (measured as population control) as a result of baiting early March during ideal conditions. These conditions were linked mainly to dew events with only two hours due to rainfall at the end of this period and a total of 15 hours of substantial snail activity post baiting. This demonstrates the effectiveness of baiting when climatic conditions are suitable such as what was experienced during the week following the 6 March 2017. In March 2018 no significant control was seen due to a lack of snail activity throughout the baiting period.

Timing of baiting and risk

Snails commence egg laying once they have sufficient physical condition for breeding and there is sufficient soil moisture present to ensure their eggs will not dry out in the soil. To control the breeding population from reproducing, methods of control must take place prior to egg laying. Figure 1 illustrates a gradual increase in the size of a snail's albumen gland from the beginning of

Table 1. Snail population counts (snails/m^2) before and after bait treatment on 6 February 2017. Population control represents the decrease in population that can be accounted for by baiting.

February 6th 2017 baiting treatment							Average
Monitoring point	1.1	1.2	1.3	2.1	2.2	2.3	
Snails/m^2 before	40	68	64	27	37	46	47
Snails/m^2 after	25	39	39	24	28	35	32
Population change	-0.38	-0.43	-0.39	-0.11	-0.24	-0.24	-0.30
Population control (%)	0.27	0.31	0.29	0.08	0.18	0.18	22

Table 2. Snail population counts (snails/m^2) before and after bait treatment on 6 March 2017. Population control represents the decrease in population that can be accounted for by baiting.

March 6th baiting treatment							Average
Monitoring point	1.1	1.2	1.3	2.1	2.2	2.3	
Snails/m^2 before	25	37	33	29	22	27	29
Snails/m^2 after	3	12	10	5	7	1	6
Population change	-0.88	-0.68	-0.70	-0.83	-0.68	-0.96	-0.79
Population control (%)	0.62	0.48	0.49	0.59	0.48	0.68	56

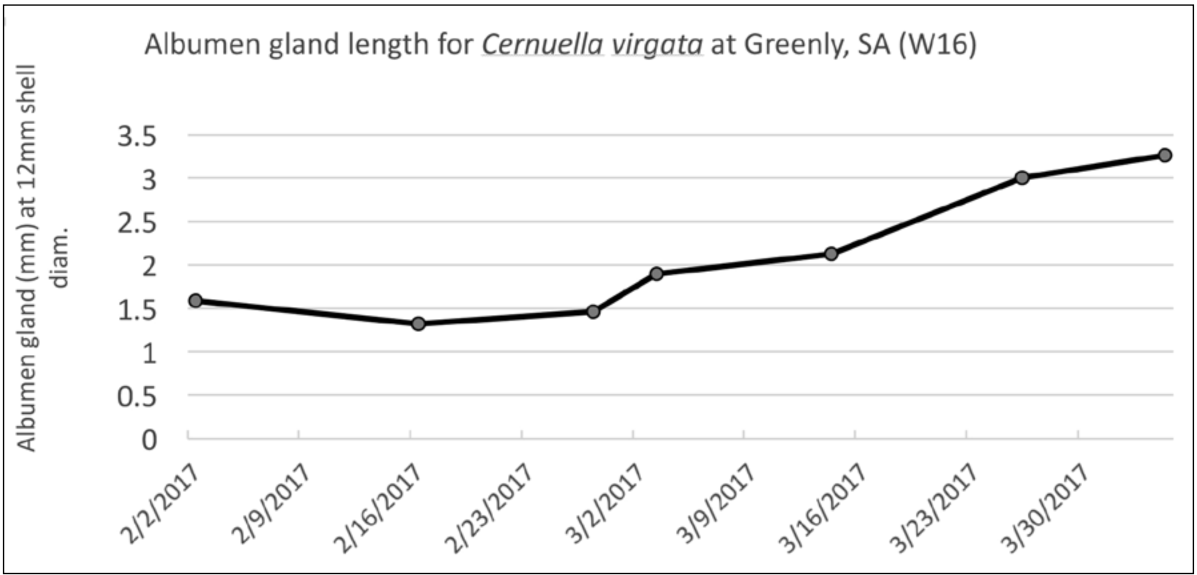

Figure 1. Average albumen gland size from 2 February until the 30 March 2017 at Greenly, SA.

autumn when environmental conditions begin to facilitate reproductive preparedness. From the commencement of this period until egg laying, snails will be active more consistently for greater periods of time in order to feed and gain condition. This activity correlates with cooler temperatures, more humid conditions and more frequent rainfall events.

During 2016 snails began to lay eggs on 21 April whereas in 2018 it was the 3 May. These dates when correlated with respective rainfall events demonstrate that snail egg-laying activity was triggered by surface soil moisture caused by rainfall events. It was observed that snails will take opportunities to lay come early April given their

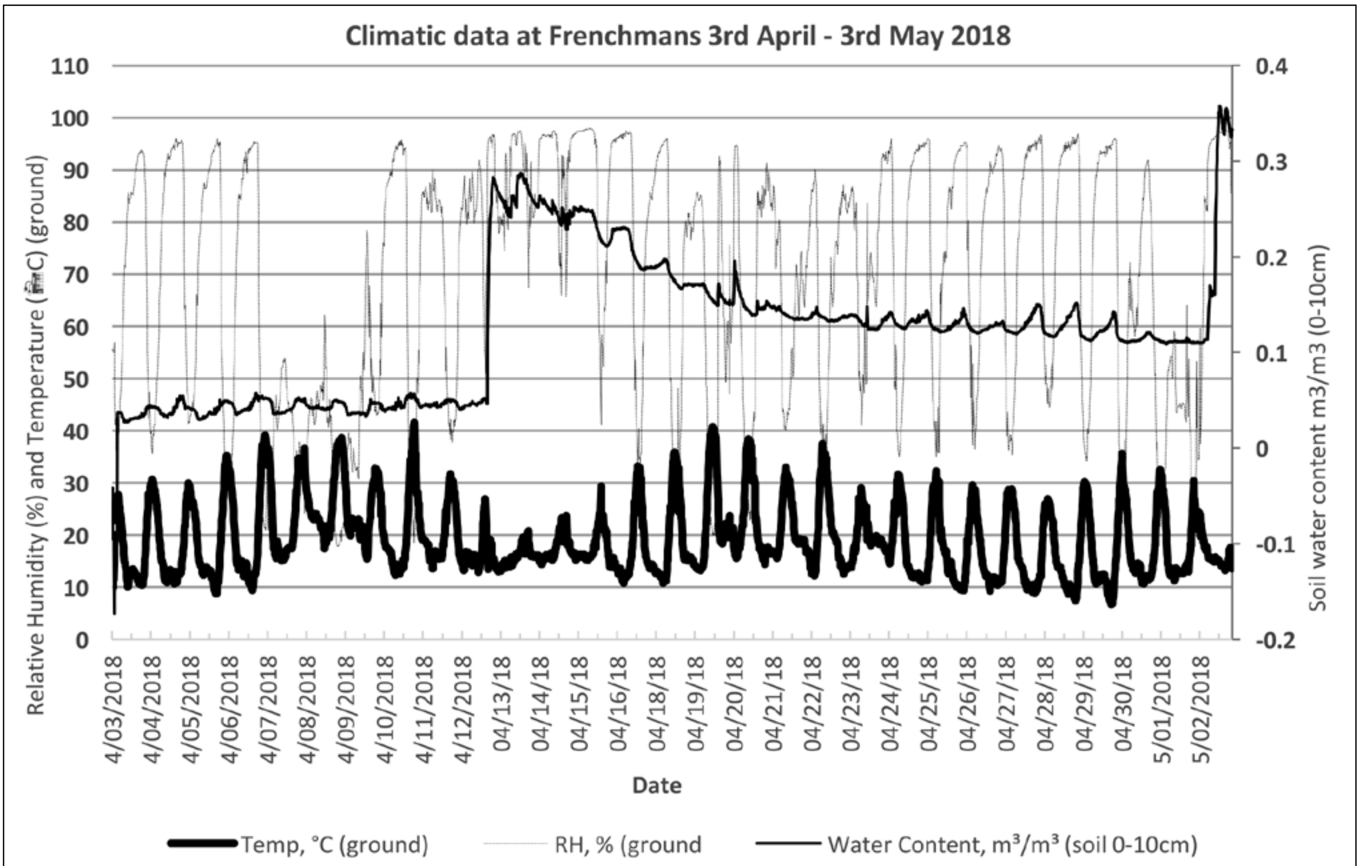

Figure 2. Ground temperature, relative humidity and soil moisture content (0-10cm) at Frenchmans, 2018.

physical condition is suitable for reproduction. The exceptionally dry March in 2018 saw a laying date of the 3 May. This was 12 days later than in 2016 where around 60 hours of activity were monitored in the last two weeks of March allowing for sexual preparation and an earlier laying date.

Figure 2 displays climatic data obtained in a trial paddock leading up to egg laying on 3 May 2018. The high frequency of nights with a relative humidity >90% were conducive to high level of activity as snails prepared for egg laying. Growers paddocks observed on the Eyre Peninsula that were baited during mid-late April in 2018 saw high levels of control. Baiting on an ‘optimum’ forecast for snail activity on the 23 April 2018 saw no significant kill. This was due to a false weather forecast that actually resulted in heat and lack of rain, both of which are not conducive to snail activity.

Discussion

Cultural methods of snail control (i.e. cabling, rolling, etc.) have been shown to be highly effective at controlling snails (Brodie 2017). Such methods are well known to provide the best control on hot days when the chances of desiccation of snails is greater. If snails have food sources or the climatic conditions are not harsh enough (i.e. <35°C) to desiccate snails, then such methods are not as effective (Baker 2015).

Research conducted during this project shows that snails respond to climatic change rather than seasonal change throughout the year. This understanding of their behaviour provides growers with an opportunity to bait during periods of high activity prior to egg laying, which occurs following certain climatic conditions. The end result is more effective snail control via baiting. Egg laying is triggered by rainfall and once snails are sufficiently conditioned for breeding. High levels of activity are seen following a ground inversion (dew) or rainfall event that results in >90% relative humidity. A combination of surface soil moisture, low wind speed and day time temperatures below 30°C will greatly increase the chance of a ground inversion or dew. A heavy dew will facilitate around 8 hours of activity in a night. Bureau of Meteorology current weather observations, while not perfectly accurate are a very good guide to when relative humidity reaches >90%.

Baiting efficacy is further increased if ground cover and alternative food availability is decreased (Baker, 2015).

Conclusion

Cultural methods play an integral role in snail control over the summer months and should not be forgotten as they are a useful tool if implemented correctly. With increasing knowledge and a level of predictability in the weather, baiting is becoming another means by which snails can be controlled prior to egg laying in order to have an effect on a populations breeding potential going forward. However, if conditions do not facilitate snail activity, baiting efficacy will be compromised.

While snails must be active for baiting to be successful, if one waits too long for optimum conditions, snails will lay their eggs and the opportunity to control the breeding population prior to egg laying will be lost. Yearly differences between time of egg-laying, make determining when it’s best to bait more difficult and must be taken note of. If snails have been highly active through March they are more likely to lay earlier.

The level of risk involved in baiting prior to egg laying can be reduced by baiting closer to egg laying, however, not so close that the opportunity is missed.

Useful resources

BOM Current weather observations:

http://www.bom.gov.au/sa/observations/saall.shtml#WC

EPARF, Soil probe network.

https://eparf.com.au/

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SARDI

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This work was conducted on behalf of LEADA under the GRDC-funded Stubble Initiative (LEA00002).

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Soil moisture probe network - using soil water information to make better decisions on the Eyre Peninsula

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Keywords

- soil moisture probes, Yield Prophet®.

Take home messages

- A network of soil moisture probes and weather stations has been established across the Eyre Peninsula.
- The 'live' data can be viewed by visiting the https://eparf.com.au/ website and then clicking on the yellow Soil Moisture Probe Network icon in the top right-hand side and logging on using the user name: EPARF and password: EPARF.

Background

Water is the principal limiting factor in rain-fed cropping systems in South Australia. The research that French and Schultz (1984) conducted linked growing season rainfall to grain production, providing growers and advisers with a target yield potential. However, this had deficiencies in that it didn't account for out of season rainfall and treated the water holding capacity of all soils equally.

A better understanding of the how plant available water content varies with changes to soil type and how valuable out of season rainfall can be to cropping systems in different environments improves the French Schultz model by allowing growers to define better define target yields, but also make informed in-season decisions based on the information they receive.

Being able to monitor soil moisture in real time by using technology such as soil moisture probes connected to the mobile phone network allows growers and advisers access to improved soil water information, allowing them to make more informed decisions.

In 2016 SAGIT and EPARF provided funding to create and monitor a network of new and existing soil moisture probes across Eyre Peninsula, with the aim assisting growers and advisers to interpret the data produced by the moisture probes and link the soil water information to yield potential so that improved crop decisions can be made.

Method

A network of 32 soil moisture probes across the Eyre Peninsula has been created by linking new and existing (EPNRM and LEADA funded) soil moisture probes found across the Eyre Peninsula and providing access to the data via the EPARF website (Figure 1).

Figure 1. Locations of the soil moisture probes on Eyre Peninsula.

In addition, weather stations capable of logging temperature, humidity and wind speed have also been installed at ten soil moisture probe sites funded through contributions by EPARF and AgFarm. This data can also be accessed by logging into the soil moisture probe network via the EPARF website.

Soil testing for soil chemistry and soil moisture was conducted at 29 of the sites in late March 2017 and again in March 2018. In 2017, 15 of the sites were planted to wheat, seven to pasture, four to pulse crops, three to barley and two to canola. Soil moisture testing and hand harvest samples were conducted at 26 sites in early November, at crop maturity. The sites that weren't tested at this time were not mature and rainfall shortly after meant that soil testing for moisture at these sites was futile.

Seventeen sites were characterised for drained upper limit and bulk density in 2017 and early 2018. Yield Prophet® was also run at eight sites in 2017 (Lock, Cleve, Elliston, Kimba, Ungarra, Warramboo, Pinkawillinie and Karkoo) and a further eight sites in 2018 (Kimba, Yabmanna – Cleve, Cowell, Cootra, Lock, Warramboo, Pygery and Yeelanna. Small trials were established at five sites in 2017 (Pinkawillinie, Warramboo, Ungarra, Karkoo and Rudall), where additional nitrogen (N) was applied in replicated plots adjacent to soil moisture probes.

Results and discussion

Figure 2 demonstrates a soil moisture probe site that was planted to wheat in early May 2017, following a break to the season in late April. The figure shows how soil moisture started from a high point through being able to retain moisture from summer rainfall events, and then gradually declines as soil moisture is used throughout the growing season.

Figure 3 demonstrates a soil moisture probe site that was pasture in 2017. The figure shows how soil moisture started from a low point after summer weeds were allowed to survive and use most of the out of season rainfall, and then how soil moisture was accumulated through the growing season, ending up with more soil moisture at the end of the

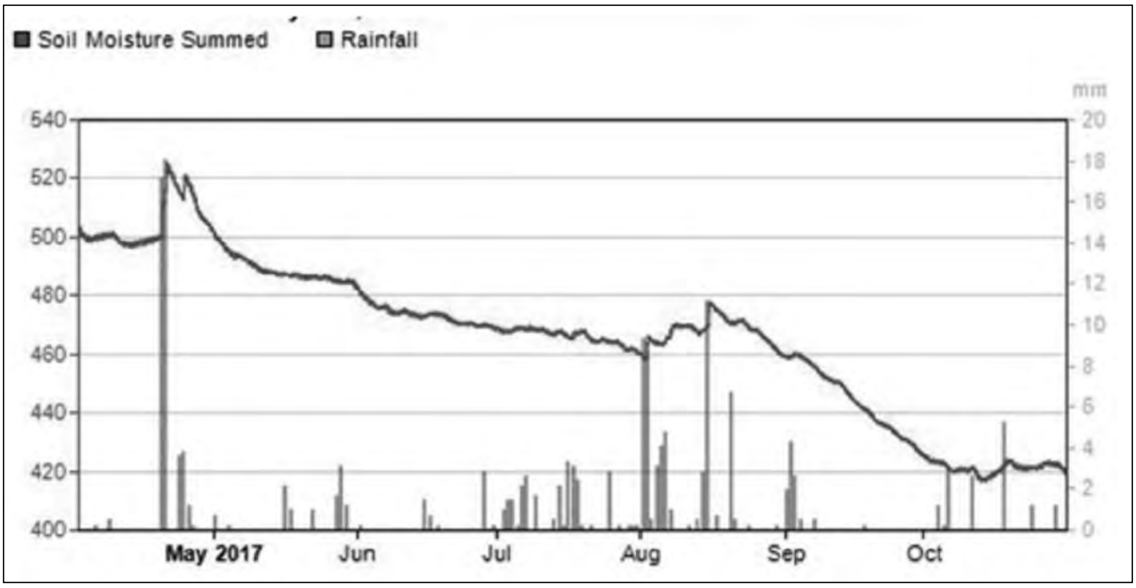

Figure 2. Summed soil moisture chart showing total soil moisture in the soil profile (line) and rainfall (columns) during the 2017 growing season (April-October) at a site that was planted to wheat in 2017.

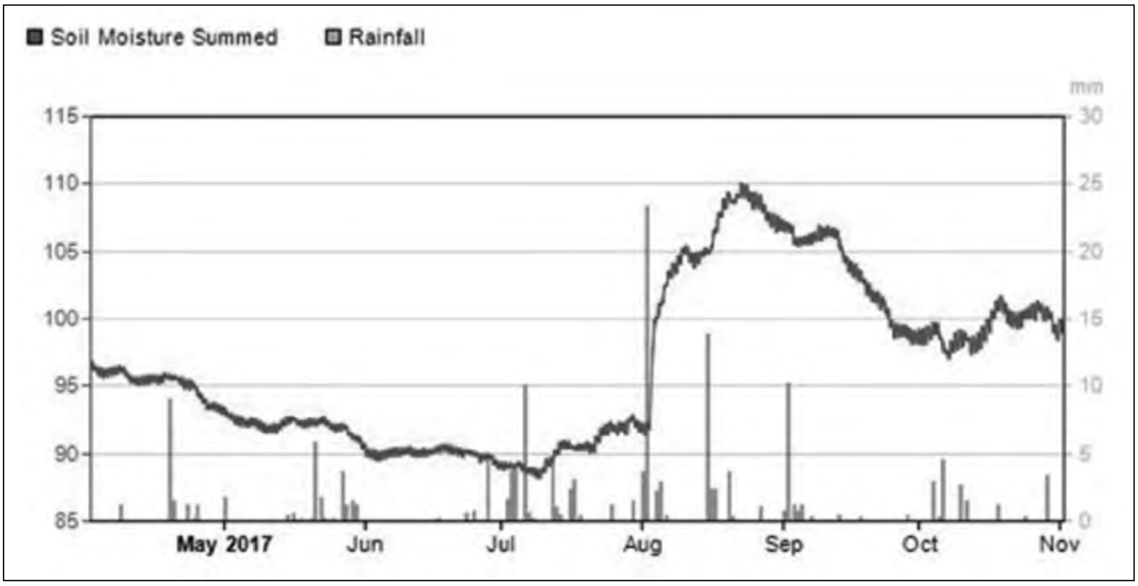

Figure 3. Summed soil moisture chart showing total soil moisture in the soil profile (line) and rainfall (columns) during the 2017 growing season (April-October) at a site that was a regenerated pasture in 2017.

season compared to the start. This may indicate that the poor growth that pastures were able to achieve in 2017 may have a role in conserving moisture for the following wheat crops or also have the potential to be better used to grow more fodder to feed livestock in the pasture phase.

Conclusion

The 2017 growing season was challenging for many growers on the Eyre Peninsula, but having improved knowledge of soil water information will allow a better understanding of yield potentials during the growing season and help tailor inputs such as in-season N applications and assist in grain marketing decisions.

Interpretation of the information that the soil moisture probes are providing will need at least another season to be fully realised. The extra season will help determine the ‘bucket size’ or soil water holding capacity at each site. Then a quick view of the soil moisture probe output through the EPARF website at any time during the season will allow growers to determine how full the bucket is.

Useful resources

https://eparf.com.au/

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Acknowledgements

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Amelioration of sandy soils - opportunities for long term improvement

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Trengove Consulting.

GRDC project code: TRE00002

Keywords

- deep ripping, chicken litter, spading, amelioration.

Take home messages

- Treatments combining deep ripping with surface applied nutrition (synthetic fertiliser or chicken litter) delivered the highest marginal returns, ranging from $934/ha to $1249/ha over three years.
- Depending on treatment cost, these delivered return on investment (ROI) ranging from 142% to 521% over three years.
- Placement of high rates of chicken litter (20t/ha) or matched synthetic fertiliser in the subsoil did not provide any yield advantage over surface application.

Background

Sandy dune soils are an important feature of the dune swale landscape of the northern Yorke Peninsula, SA. Common characteristics of these sands include low water holding capacity, low organic matter, low nutrient availability, compaction, non-wetting and high risk for wind erosion. In 2015, a trial site was established on a sand hill near Bute, SA, to investigate options for amelioration of these constraints. This paper will report on the results of these trials.

Method

Two trials were established on a sand hill near Bute in 2015 investigating treatments including deep ripping, spading, clay, chicken litter (rate and placement) and fertiliser. The soil at the site is described as a siliceous sand and the initial soil test results for the site are shown in Table 1. Treatment responses were measured in three consecutive cropping seasons of Grenade CL Plus⁽ᵈ⁾ wheat in 2015, Spartacus CL⁽ᵈ⁾ barley in 2016 and PBA Jumbo2⁽ᵈ⁾ lentil in 2017. Fertiliser treatments were applied in each season, with all other treatments

Table 1. Initial trial site soil test results, March 2015.

Soil depth cm	Available N kg/ha	Colwell P mg/Kg	PBI	Colwell K mg/Kg	Available S kg/ha	Organic C %	pH ($CaCl_2$)	pH (H_2O)	Cation Exchange Capacity
0-10	16	48	15	112	4.0	0.46	5.2	5.9	2.8
0-30	33	35	19	117	8.0	0.30	6.6	7.2	3.8
30-60	10	17	19	132	5.5	0.10	7.2	7.9	5.2
60-90	10	7	33	138	4.7	0.16	7.4	8.3	7.1
90-120	10	4	99	87	5.5	0.10	7.8	8.6	9.1

applied once only at trial initiation in 2015. The trials were randomised complete block designs with three replicates. Plots were 10m x 2m and were sown with knife points and press wheels on 250mm row spacing.

Treatment details

Deep ripping

Ripping was conducted with the Peries-Wightman subsoiler, with two tynes spaced 800mm apart and working to a depth of 450mm to 500mm. This machine has a 125mm diameter pipe behind each tyne for delivery of bulk products to near the bottom of the rip line. This had the effect of allowing some topsoil to flow back into the furrow behind the tyne, providing some 'topsoil inclusion'. This same machine was also used for subsoil manure application in Trial 2. Commercial application for deep ripping was costed at $60/ha.

Spading

Farmax spader working to 300mm deep. Commercial application for this was costed at $200/ha.

Clay

Clay was sourced from the 0cm to 40cm layer from the adjacent swale, approximately 35% clay content. At 130t/ha, commercial application for this was costed at $400/ha.

Chicken litter

Chicken litter was supplied from a broiler shed on the Wakefield Plains. Nutrient analysis is shown below (Table 2). At 5t/ha and 20t/ha, commercial application costs were costed at $180/ha and $700/ha, respectively, including product, freight and spreading costs.

Fertiliser

Phosphorus (P) applied as monoammonium phosphate (MAP) and potassium (K) applied as muriate of potash (MoP) were applied to the soil at seeding in each season (Table 3) and zinc (Zn), copper (Cu) and manganese (Mn) were applied as sulphates post emergent as a foliar application. Nitrogen (N) (urea and sulphate of ammonia (SoA)) and sulphur (S) applied as SoA were applied post emergent to the cereals in year 1 and year 2 and for lentils in 2017. Sulphur was applied prior to seeding as gypsum. An additional trial assessing response to K, S and micronutrients found no response to these inputs from 2015 to 2017 (data not presented). Therefore, the economic analysis has only costed the N, P and S as the applications of these more closely reflect grower practice in the district. Commercial application for this was costed at $430/ha over the three years, including application costs for post emergent applications.

Table 3. Nutrient (kg/ha) applied in each season to fertiliser treatment.

Nutrient (kg/ha)	2015	2016	2017
N	99	76	9
P	20	20	20
S	21	21	60
K	50	50	50
Zn	0.26	0.26	0.26
Cu	0.09	0.09	0.09
Mn	0.77	0.77	0.77

Table 2. Nutrient concentration of applied chicken litter

Nutrient		Nutrient conc. dry weight	Moisture content	Nutrient conc. fresh weight	Kg nutrient per tonne fresh weight	Kg nutrient per 5 tonne fresh weight	Kg nutrient per 20 tonne fresh weight
N	Nitrogen	3.8%	8%	3.50%	35.0	175	699
P	Phosphorus	1.72%		1.58%	15.8	79	316
K	Potassium	2.31		2.13%	21.3	106	425
S	Sulphur	0.55%		0.51%	5.1	25	101
Ca	Calcium	3.48%		3.20%	32.0	160	640
Mg	Magnesium	0.73%		0.67%	6.7	34	134
Zn	Zinc	0.46g/kg	8%	0.42g/kg	0.4	2.1	8.5
Mn	Manganese	0.51g/kg		0.47g/kg	0.5	2.3	9.4
Cu	Copper	0.13g/kg		0.12g/kg	0.1	0.6	2.4
B	Boron	0.05g/kg		0.05g/kg	0.05	0.2	0.9
Fe	Iron	4.33g/kg		3.98g/kg	4.0	19.9	79.6

Trial 1

Trial 1 was a factorial trial, assessing four inputs:

- Deep ripping — yes or no.
- Annual fertiliser — yes (Table 3) or no.
- Clay — yes (130t/ha) or no.
- Chicken litter — 0, 5 or 20t/ha.

The factorial of these gives 24 treatments (Table 5). Deep ripping, clay and chicken litter were applied once only in 2015, while fertiliser treatments were applied each year.

Trial 2

Trial 2 assessed:

- Placement of chicken litter or fertiliser: surface placement veruss subsoil (300mm to 400mm deep).
- Spading.
- Matching nutrition of chicken litter with synthetic fertiliser: 20t/ha chicken litter versus matched NPKS from fertiliser. That is 1026kg/ha urea, 800kg/ha MAP, 420kg/ha SoA and 704kg/ha MoP. This synthetic fertiliser nutrition is actually marginally less than that supplied by 20t/ha chicken litter, however rates were applied before final chicken litter analysis was available.

For a complete list of treatments see Table 6.

Table 4. Rainfall received in seasons 2015to 2017 and trial seeding dates.

	2015	2016	2017
GSR	204 (decile 1)	441 (decile 9)	209 (decile 1)
Annual rainfall	309 (decile 2)	696 (decile 10)	369 (decile 4)
Sowing date	20 May	20 May	17 May

Results and discussion

Soil penetrometer resistance

Penetrometer resistance was measured prior to sowing in April 2016, one year after treatments were imposed (Figure 1). These measurements indicate much higher resistance in the control treatment compared with treatments that were ripped or spaded. Ripping was to a depth of approximately 500mm, whereas spading was to a depth of 300mm. These working depths explain differences observed in penetrometer resistance between these treatments, where below 300mm resistance is greater in the spaded treatment, with the difference narrowing with increasing depth until there is no difference below ripping depth of 500mm. In general, crop root growth restriction starts when penetration resistance exceeds 1500kPa and severe restriction when resistance exceeds 2500kPa (Blackwell et al. 2016). Even with deep ripping, penetration resistance exceeds 2500kPa below 300mm — this may indicate an opportunity for further improvement.

Note: Industry standard for measurements is to be taken at field capacity when comparing between sites and soil types. This site received 110mm rainfall in six weeks prior to measurements in March and April 2016, therefore it is assumed the soil was close to field capacity.

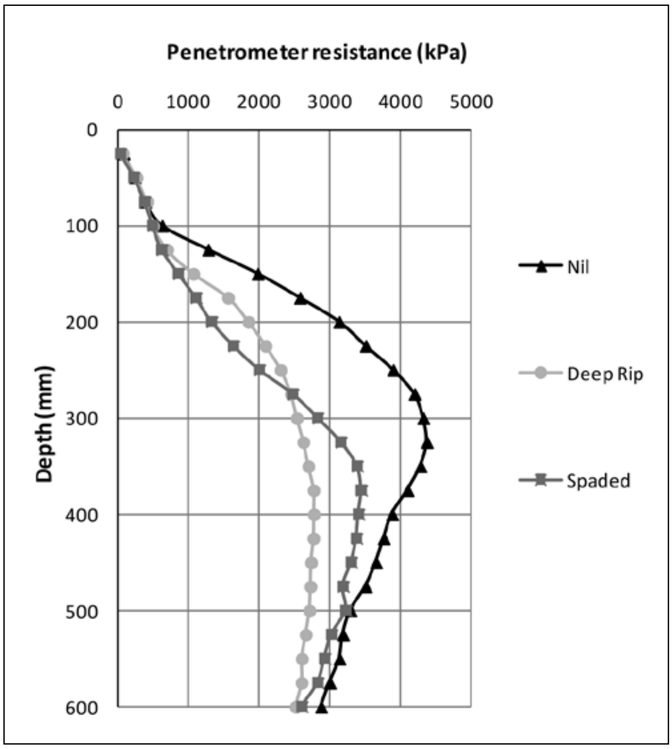

Figure 1. Penetrometer resistance measured in March 2016, 12 months after treatment application.

Soil nutrition

Chicken litter applied at 20t/ha in 2015 increased deep soil N and S measured prior to seeding in 2016 and 2017 (Table 5). However, annual fertiliser and 5t/ha chicken litter were the same as the unfertilised control. Nitrogen recovery also indicates that only 18% of the N applied in 20t/ha chicken litter has been recovered in harvested grain. In addition to the measured deep soil N, the remaining 82% (573kg/ha) may remain in chicken litter (not yet mineralised), be in crop residues or soil organic matter or may have been lost through ammonia losses or leaching. Unless large losses have occurred, this indicates there should still be considerable N in the system to support ongoing crop responses where chicken litter has been applied at 20t/ha. Soil testing will be conducted to measure further changes in soil organic matter this year.

Table 5. Nitrogen balance and deep soil N and S (0-1.2m) measured prior to seeding in the stated season for selected treatments.										
Treatment	Total applied and removed, 2015-2016 (kg/ha)				2015		2016		2017	
	N applied	N removed	NUE (% recovery)	S applied	N (kg/ha)	S (kg/ha)	N (kg/ha)	S (kg/ha)	N (kg/ha)	S (kg/ha)
Nil	0	63		0			68	20	43	74
Annual fertiliser	175	128	37%	48	63	24	73	34	43	66
Chicken litter @ 5t/ha	175	103	23%	25			68	28	44	81
Chicken litter @ 20t/ha	699	190	18%	101			291	140	88	111
Lsd (0.05)							*70*	*40*	*28*	*29*

Trial 1: Crop growth and grain yield responses

Wheat 2015

Large growth responses occurred in year 1 (2015) in response to chicken litter, fertiliser and deep ripping. However, with low growing season rainfall (GSR) (Table 4) and hot conditions during grain fill in that season, the relationship between in season crop growth and yield was not linear (Figure 2). There was an optimum level of canopy production, and an approximate normalised difference vegetation index (NDVI) of 0.5 to 0.65 at GS31 for optimising yield. Beyond this, the larger canopy used too much moisture pre anthesis and yields declined. Below this the crop was constrained by insufficient nutrition and lack of green leaf area. Therefore yields were highest for deep ripping and chicken litter at 5t/ha (Table 6). Combinations of these also produced high yields, but not significantly more than each individually. However, deep ripping in combination with standard fertiliser practice increased yield significantly compared with fertiliser alone. Treatments receiving chicken litter at 20t/ha had lower yields, due to the excessive biomass production. However, yields for these were not significantly less than standard practice, but not better than nil either. Grain quality for these treatments also declined, with high screenings, low test weight and high protein — many of these were graded as AUW1 (data not shown).

Similar results were observed in Trial 2 (Table 7). The combination of applying chicken litter at 20t/ha, clay, deep ripping, spading and applying a normal fertiliser practice (treatment 5) produced the most spectacular failure in the trial. This treatment produced the greatest growth response. The spading process thoroughly mixed in the chicken litter and provided conditions conducive for increased mineralisation of nutrients in the litter, promoting increased biomass production. There was

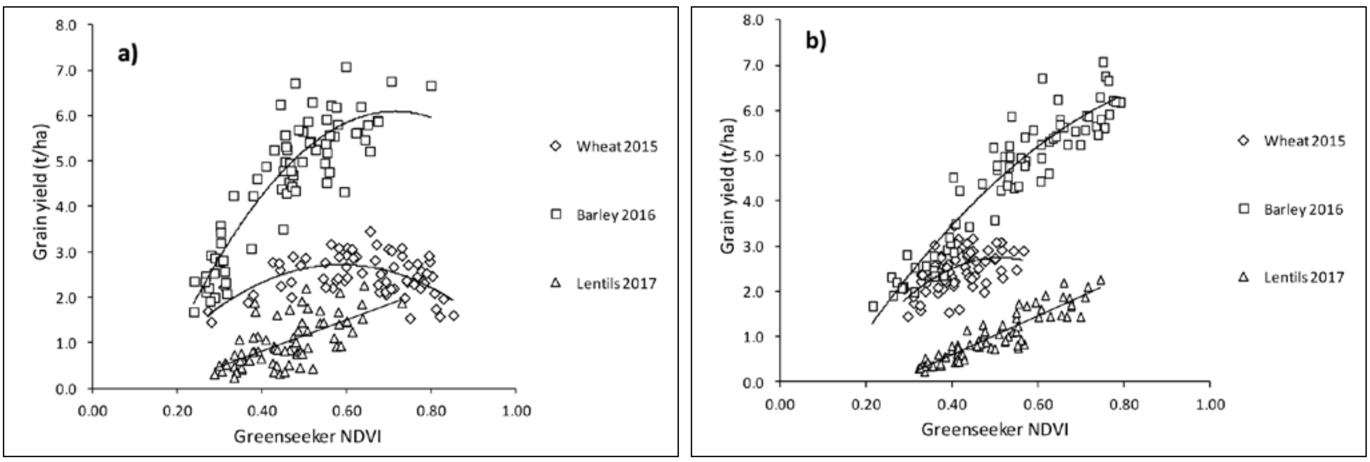

Figure 2 a). Greenseeker NDVI measured at GS31 for wheat and barley and early flower for lentil and grain yield. Wheat R^2 = 0.33, barley R^2 = 0.81, lentils R^2 = 0.41. b) Greenseeker NDVI measured mid-late grain fill (early October) and grain yield. Wheat R^2 = 0.30, barley R^2 = 0.88, lentils R^2 = 0.83.

Table 6. Trial 1 treatments, treatment costs, grain yields and economic returns.

Treatment	Chicken litter (t/ha)	Ripping	Clay (t/ha)	Annual fertiliser	Amelioration cost ($/ha)	Grain yield (t/ha)			2015-2017 Summary ($/ha)			
						Wheat 2015	Barley 2016	Lentil 2017	Total costs including annual fertiliser	Gross income	Marginal return	ROI (%)
1	0	No	0	No	0	1.79	2.15	0.41	0	1170	0	
2				Yes	0	2.44	4.52	0.39	430	1999	399	93%
3			130	No	400	2.30	2.08	0.54	400	1336	-234	-58%
4				Yes	400	2.52	4.44	0.69	830	2181	181	22%
5		Yes	0	No	60	2.78	2.77	1.22	60	2035	805	1342%
6				Yes	60	3.11	4.83	0.97	490	2594	934	191%
7			130	No	460	2.39	2.59	1.10	460	1802	172	37%
8				Yes	460	2.54	5.16	1.00	890	2489	430	48%
9	5	No	0	No	180	2.88	2.90	0.57	180	1674	324	180%
10				Yes	180	2.89	4.98	0.57	610	2339	559	92%
11			130	No	580	2.45	2.66	0.72	580	1735	-15	-3%
12				Yes	580	2.35	4.84	0.74	1010	2206	26	3%
13		Yes	0	No	240	2.92	3.60	1.67	240	2659	1249	521%
14				Yes	240	2.55	5.85	1.23	670	2840	1000	149%
15			130	No	640	2.96	3.75	1.52	640	2549	739	116%
16				Yes	640	2.40	5.23	1.36	1070	2686	446	42%
17	20	No	0	No	700	2.50	5.66	0.97	700	2588	718	103%
18				Yes	700	2.53	5.60	0.68	1130	2405	105	9%
19			130	No	1100	1.97	5.54	1.08	1100	2496	226	21%
20				Yes	1100	2.15	5.85	0.78	1530	2436	-264	-17%
21		Yes	0	No	760	2.28	5.85	1.68	760	3007	1077	142%
22				Yes	760	2.34	6.15	1.38	1190	2914	554	47%
23			130	No	1160	2.03	5.94	1.55	1160	2890	560	48%
24				Yes	1160	2.26	6.54	1.48	1590	3054	294	18%
Lsd (0.05)					*0.58*	*0.68*	*0.30*		*406*	*406*	*96*	

[a] Grain prices used to calculate gross income depended on grade. Wheat: AUH2 = $260/t, ASW1 = $245/t, AGP1 = $235/t, AUW1 = $235/t, FED1 = $215/t. Barley: Malt = $250/t, Feed = $225/t. Lentils = $600/t.

** Marginal return = gross income - amelioration and fertiliser costs - gross income of nil ($1434/ha).*

Table 7. Trial 2 treatments, treatment costs, grain yields and economic returns.

Treatment	Ameliorant	Placement	Ripping	Spading	Clay (t/ha)	Annual fertiliser	Amelioration and fertiliser costs ($/ha)	Grain yield (t/ha)			Sum 2015 - 2017 ($/ha)		
								Wheat 2015	Barley 2016	Lentil 2017	Gross Income[a]	Marginal Return *	ROI (%)
1	None	-	No	No	0	No	0	1.87	2.30	0.69	1434		
2	20t Chicken Litter	Surface	Yes	No	130	Yes	1590	2.02	5.82	2.20	3133	109	7%
3	20t Chicken Litter	Subsoil	Yes	No	130	Yes	1730	2.50	5.67	1.57	2847	-317	-18%
4	None	-	No	Yes	0	No	200	2.64	2.44	1.64	2240	605	303%
5	20t Chicken Litter	Surface	Yes	Yes	130	Yes	1790	1.44	5.39	1.81	2650	-574	-32%
6	3t Synthetic Fert	Surface	Yes	No	130	No	2270	2.68	6.28	1.34	2860	-844	-37%
7	3t Synthetic Fert	Subsoil	Yes	No	130	No	2300	2.33	5.62	1.33	2682	-1052	-46%
8	3t Synthetic Fert	Subsoil	Yes	No	0	No	1900	2.37	5.08	1.03	2330	-1005	-53%
9	20t Chicken Litter	Subsoil	Yes	No	0	Yes	1330	2.49	5.73	1.08	2535	-230	-17%
10	20t Chicken Litter	Subsoil	Yes	No	0	No	900	3.12	5.28	1.76	3158	824	92%
Lsd (0.05)							*0.67*	*0.66*	*0.33*	*620*	*-814*	*136*	

[a] Grain prices used to calculate gross income depended on grade. Wheat: AUH2 = $260/t, ASW1 = $245/t, AGP1 = $235/t, AUW1 = $235/t, FED1 = $215/t. Barley: Malt = $250/t, Feed = $225/t. Lentils = $600/t.

** Marginal return = gross income - amelioration and fertiliser costs - gross income of nil ($1434/ha).*

Table 8. Nutrient analysis of lentil whole tops for selected treatments in Trial 1, sampled 30 July2017.

Treatment		Phosphorus %	Potassium %	Calcium %	Magnesium %	Sulphur %	Boron mg/kg	Copper mg/kg	Zinc mg/kg	Manganese mg/kg	Molybdenum mg/kg
Nil	1	0.37	2.1	1.08	0.36	0.25	28	5.1	85	147	0.40
Annual fertiliser	2	0.38	2.2	1.15	0.36	0.41	27	10.5	143	330	0.40
Clay	3	0.34	2.0	1.15	0.37	0.25	29	6.6	84	106	0.40
Ripping	5	0.40	2.5	1.21	0.38	0.27	29	5.4	81	127	0.43
5t/ha chicken litter	9	0.40	2.3	1.04	0.35	0.24	27	4.5	75	110	0.40
20t/ha chicken litter	17	0.48	2.7	1.12	0.48	0.28	29	3.5	75	100	0.87
Fert, clay, rip, 20t/ha CL	24	0.53	2.8	1.12	0.37	0.37	26	8.8	107	200	0.61
Lsd (0.05)		*0.03*	*0.3*	*ns*	*0.05*	*0.03*	*ns*	*1.9*	*13*	*43*	*0.19*

insufficient moisture to support this. The treatment hayed off severely, producing the lowest yields in the trial in that year (Table 7).

In 2015, the safest way to apply chicken litter at 20t/ha was to place it in the subsoil, with no additional nutrition applied to the surface (treatment 10, Table 7). Canopy biomass production was slow early, limited by low nutrition in the topsoil. However, the crop responded when the roots reached the chicken litter banded in the subsoil, approx. six to eight weeks after sowing. The delayed biomass response appears to have reduced early moisture use and saved more for the grain filling period. This effect was negated where standard fertiliser was applied to the surface in combination with subsoil manure.

Barley 2016

Crop nutrition was the biggest factor influencing yields in 2016, a decile 9 growing season (Table 4), where response to chicken litter at 20t/ha > annual fertiliser > chicken litter at 5t/ha (Table 9). The yield response to chicken litter at 20t/ha could not be matched by combinations of annual fertiliser and chicken litter at 5t/ha. The addition of fertiliser to 20t/ha chicken litter generated an NDVI growth response (data not shown) over that of chicken litter alone, but the yield response was not significant. In contrast to 2015, the relationship between in season growth and grain yield was positive (Figure 2). The highest nutrition treatments had high grain protein (data not shown) that reduced grain quality from malt to feed.

Deep ripping produced an average response of 0.59t/ha (14%) increase across all other treatments (Table 10). The highest yielding treatments in the trial combined high nutrition and deep ripping and exceeded 6t/ha (Table 6).

Table 9. Chicken litter and annual fertiliser application effect on 2016 barley grain yields.

Chicken Litter (t/ha)	Annual fertiliser	Grain yield (t/ha)
0	No	2.40
5		3.23
20		5.75
0	Yes	4.74
5		5.23
20		6.04
Lsd (0.05)		*0.34*

Table 10. Deep ripping effect on 2016 barley grain yields.

Ripping	Grain yield (t/ha)
No	4.27
Yes	4.86
Lsd (0.05)	*0.21*

Lentils 2017

Lentils were highly responsive to deep ripping, with yields doubling (Table 11). Interestingly the actual yield increase in response to deep ripping is similar for each year, 0.65t/ha for wheat in 2015 (treatment 6 versus treatment 2, Table 6), 0.59t/ha for barley in 2016 (Table 10) and 0.69t/ha for lentils in 2017 (Table 11). Lentils were also rate responsive to chicken litter (Table 12), but surprisingly there was a small negative yield response to annual fertiliser (Table 13). As a result, the highest treatment yields of up to 1.68t/ha were achieved by deep ripping in combination with either 5t/ha or 20t/ha chicken litter (Table 6). District practice annual fertiliser application achieved the lowest yields in the trial of 0.39t/ha (treatment 2, Table 6) although this was not significantly lower than the nil treatment. Lentil grain yield had a positive linear correlation with in season NDVI (Figure 2).

Nutrient analysis of lentil whole tops indicates that the annual fertiliser treatment has the same P and K concentration as the unfertilised control, despite three annual applications since 2015 (Table 8). The fertilised treatment was higher for S, Cu, Zn and Mn— these too have been applied as fertiliser. Chicken litter at 20t/ha has higher levels of P and K than the annual fertiliser treatment and 5t/ha chicken litter. It was also higher in magnesium (Mg) and molybdenum (Mo) (Table 8). In year 1 of the trial (2015), wheat leaf nutrient analysis showed that the 20t/ha chicken litter treatment had the highest levels for all nutrients measured (data not shown), but this has not been maintained two years later with calcium (Ca), boron (B), S, Cu, Zn and Mn having the same nutrient concentration as the unfertilised control.

Soil moisture measurements indicate a drained upper limit (DUL) at the site of 114mm to a depth of 1.2m (Figure 3). The unfertilised control has a crop lower limit (CLL) in lentils of 69mm, giving plant available water capacity (PAWC) of 45mm. CLL is reduced by deep ripping and the application of chicken litter at 20t/ha, increasing the PAWC. The combination of deep ripping and chicken litter application lowers the CLL further, to 46mm, increasing the PAWC to 68mm. That is a 23mm (51%) increase in PAWC. The treatment induced change in PAWC is highly correlated with lentil grain yield (Figure 4). Lentil yield increases at 67kg/ha/mm of increase in PAWC. Extrapolating the line indicates that lentil yield is zero when PAWC is reduced to 40mm. Treatments that lower the CLL and increase PAWC will likely help in seep management too, increasing the moisture required to refill the soil profile after harvest before deep drainage can occur.

Table 11. Deep ripping effect on 2017 lentil grain yields.

Ripping	Grain yield (t/ha)
No	0.67
Yes	1.36
Lsd (0.05)	*0.09*

Table 12. Chicken litter effect on 2017 lentil grain yields.

Chicken litter	Grain yield (t/ha)
0	0.78
5	1.05
20	1.21
Lsd (0.05)	*0.11*

Table 13. Annual fertiliser effect on 2017 lentil grain yields.

Annual fertiliser	Grain yield (t/ha)
No	1.09
Yes	0.94
Lsd (0.05)	*0.09*

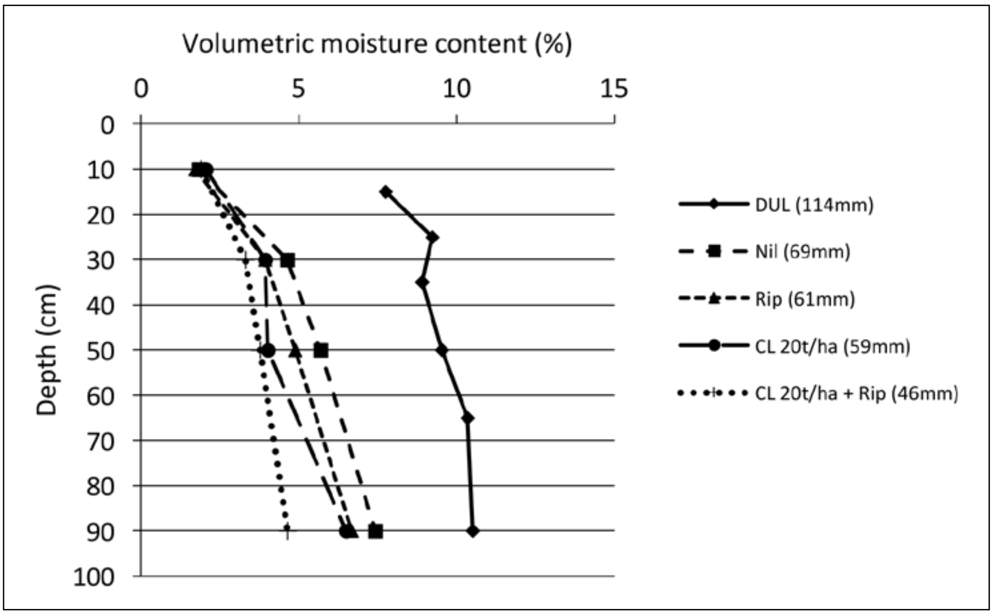

Figure 3. Trial site DUL and lentil CLL for selected treatments. Total mm of soil moisture represented by the line shown in brackets next to legend. DUL estimated from measurements at one wet up site adjacent to trial.

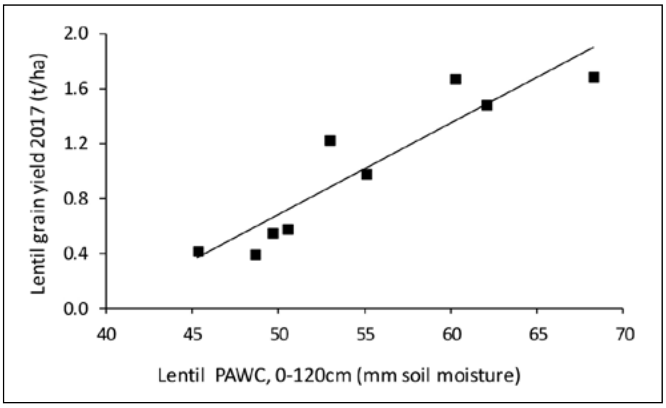

Figure 4. Lentil PAWC measured from 0-120cm post harvest in 2017 and grain yield where y = -0.067x - 2.66, R^2 = 0.86.

Trial 2: Grain yield responses

Surface versus subsoil application

Grain yields for surface application of ameliorants were as similar, or better than comparative treatments with ameliorants placed in the subsoil (treatment 2 vs 3, treatment 6 vs 7, Table 7). In four of the six treatment by year comparisons, yields were not significantly different, and in two of six, yields were higher with surface applications. However, as mentioned earlier, in 2015 with no additional nutrition applied to the surface (as opposed to treatment 3), there was an advantage for subsoil application of chicken litter (treatment 10, Table 7). Delaying access to the chicken litter until the roots reached the banded rows in the subsoil, approximately six to eight weeks after sowing, had the effect of managing the canopy, reducing early moisture use and saving more for the grain filling period.

Chicken litter at 20t/ha versus matched synthetic fertiliser (NPKS)

Grain yields for subsoil applications of chicken litter and matched synthetic fertiliser were the same in all three years (treatment 3 versus 7, Table 7). For surface applications, there was no significant difference between them in cereal years, however there was a 0.86t/ha advantage in lentils for chicken litter at 20t/ha over matched synthetic fertiliser (treatment 2 versus 6, Table 7). Nutrient analysis of lentil whole tops (data not shown) shows P and K concentrations to be similar between these treatments, whereas a difference was observed in Trial 1 when comparing chicken litter at 20t/ha and commercial annual fertiliser (Table 8). However, as in Trial 1, the 20t/ha chicken litter treatments are higher in Mg and Mo.

Spading

Spading without any additional inputs produced yield increases compared with untreated in 2015 and 2017, but not in 2016 where it was severely constrained by nutrition (treatment 4 versus 1, Table 7). While not directly comparable with deep ripping in Trial 1, the yield responses are of similar order. That is 0.77t/ha, 0.14t/ha (not significant) and 0.95t/ha for spading in 2015, 2016 and 2017, respectively. For deep ripping with no nutrition in Trial 1, they were 0.99t/ha, 0.62t/ha (not significant) and 0.81t/ha for 2015, 2016 and 2017, respectively (treatment 5 versus 1, Table 6).

Spading in combination with chicken litter at 20t/ha, clay, deep ripping and applying a normal fertiliser practice (treatment 5) produced low yields in 2015 due to excess biomass production and a dry finish to the season. Whereas in 2016 it had high yields, however in neither season was it significantly different to the unspaded comparative treatment (treatment 5 versus 2, Table 7). In 2017, lentil yields were 0.39t/ha higher in the unspaded (treatment 2). Treatments combining spading with standard fertiliser practices or moderate rates of chicken litter are needed to better assess how spading would be implemented commercially.

Return on investment (ROI)

The unfertilised control generated a gross income of $1170/ha over three years in Trial 1. Annual fertiliser produced a ROI of 93% over the three years, where the N, P and S inputs were costed at $430/ha (treatment 2, Table 6). Given that annual fertiliser treatments are not increasing leaf tissue P and there was no response to S in a third trial (data not shown), it is likely that the application rates of these nutrients are much higher than necessary to achieve optimum yields. If the rates of these were reduced to replacement levels, then the cost of annual fertiliser over three years would be reduced to $308 per hectare. This would in turn increase the ROI for annual fertiliser to 163%.

Treatments achieving higher ROI were deep ripping treatments, either alone or combined with annual fertiliser or 5t/ha chicken litter (treatments 5, 6 and 13). Deep ripping alone had the highest ROI (1342%), which is driven by being the lowest cost treatment, but it does not generate the highest marginal return. The greatest marginal returns are produced by combining deep ripping with 5t/ha or 20t/ha chicken litter or annual fertiliser (treatment 6, 13, 14 and 20). Therefore, investment decisions will depend on the available budget, with investment in deep ripping being highest priority followed by chicken litter or fertiliser.

Deep ripping combined with 5t/ha chicken litter produced the highest marginal return and ROI of 521%. However, there is still scope for improvement to this treatment by responding to the season. In the decile 9 growing season, 2016, barley yield for this treatment increased by 2.25t/ha from addition of fertiliser (treatment 13 vs 14, Table 6).

Deep ripping in combination with 20t/ha chicken litter produced the highest gross income, despite lower yields and poor grain quality in wheat in year 1 (treatments 21 to 24), but these treatments drop down the rankings in marginal return and ROI due to their high cost. However, based on trends to date, these treatments are expected to continue to deliver positive responses, and if so, the ROI for these treatments may improve over the longer term.

The addition of clay produced a low ROI as it is a high cost treatment and does not provide any significant yield responses.

Conclusion

Treatments of deep ripping and chicken litter applied in 2015 generated crop growth and yield responses for three consecutive seasons, and indicate opportunities for long term improvement of sandy soils, depending on soil constraints. The question still remains as to how long some of these treatment responses will last? Treatments combining deep ripping with surface applied nutrition (fertiliser or chicken litter) delivered the highest marginal returns, ranging from $934/ha to $1249/ha over three years. Depending on treatment cost, these delivered ROI ranging from 142% to 521%.

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THE 2017-2019 GRDC SOUTHERN REGIONAL PANEL

FEBRUARY 2018

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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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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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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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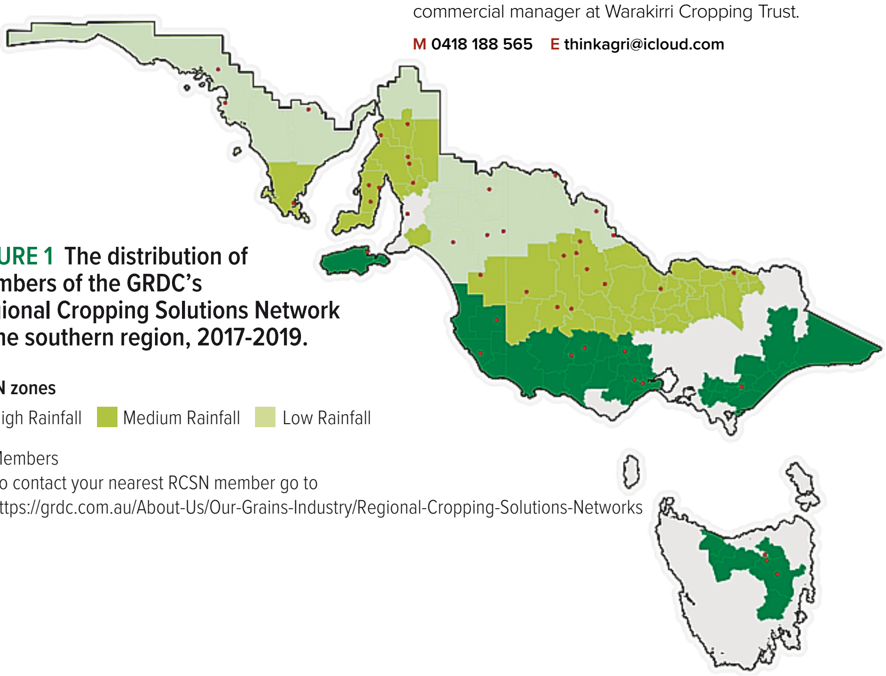

FIGURE 1 The distribution of members of the GRDC's Regional Cropping Solutions Network in the southern region, 2017-2019.

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

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

WE LOVE TO GET YOUR FEEDBACK

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/Lock-GRU

2018 Lock 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. Growing pulses in the central Eyre Peninsula: *George Pedler*

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

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

4. Improving productivity on sandy soils: *Nigel Wilhelm*

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

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

5. Research update on brome grass and other emerging problem weeds: *Gurjeet Gill*

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

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

6. Baiting snails according to environmental conditions: *Jacob Giles*

Content relevance ☐ /10 Presentation quality ☐ /10

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

7. Soil moisture probes – what have we learnt so far? *Andrew Ware*

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.

GRDC™ GROWNOTES

NEWNEWNEW

SPRAY APPLICATION GROWNOTES™ MANUAL

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

The Spray Application GrowNotes™ Manual is a comprehensive digital publication containing all the information a spray operator needs to know when it comes to using spray application technology.

It explains how various spraying systems and components work, along with those factors that the operator should consider to ensure the sprayer is operating to its full potential.

This new manual focuses on issues that will assist in maintaining the accuracy of the sprayer output while improving the efficiency and safety of spraying operations. It contains many useful tips for growers and spray operators and includes practical information – backed by science – on sprayer set-up, including self-propelled sprayers, new tools for determining sprayer outputs, advice for assessing spray coverage in the field, improving droplet capture by the target, drift-reducing equipment and techniques, the effects of adjuvant and nozzle type on drift potential, and surface temperature inversion research.

It comprises 23 modules accompanied by a series of videos which deliver 'how-to' advice to growers and spray operators in a visual easy-to-digest manner. Lead author and editor is Bill Gordon and other contributors include key industry players from Australia and overseas.

**Spray Application GrowNotes™ Manual – go to: https://grdc.com.au/Resources/GrowNotes-technical
Also go to https://grdc.com.au/Resources/GrowNotes and check out the latest versions of the Regional Agronomy Crop GrowNotes™ titles.**

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