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GRAINS RESEARCH UPDATE

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Southern & Central New South Wales Series

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The 2020 spring, what might we expect?

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GRDC project code: 9176117

Keywords

- climate forecast, ENSO, Indian Ocean Dipole.

Take home messages

- Irrigated districts have had a great start to the season, with an early wet up to catchments.
- Forecasts remain for a wetter SNSW and for wetter Victorian catchments. Forecasts are split between wetter and neutral for the Victorian plains.
- The Pacific Ocean shows some chance of becoming a La Niña, where the Indian Ocean must do a 180-degree flip from its current condition to become a negative IOD (i.e. favourable to wet conditions).

Key Question 1

What factors have led to such a good start for much of this region in 2020?

The autumn of 2020 will be remembered for its timely break and high rainfall in places. The rainfall pattern changed in January after the long-term dry period during the 2019 spring and early summer. Summer storms were commonplace on the plains and in the catchments through to April. As a result, stored soil moisture in irrigated paddocks turned out to be both a blessing and a curse when it came to watering up and/or sowing. It was a blessing in the catchments as soils wet up and streamflow was primed to run off much earlier than normal however it added some challenges with the practices of watering up and/or sowing.

Catchment flow during autumn and early winter was higher than normal. Much of this rain was a result of summer weather events rather than the influence of any actual climate drivers. Lower pressure maintained itself in South-Eastern Australia for many of these months indicating plenty of low-pressure troughs to bring tropical moisture down. The one feature that was in play was very warm waters to the North West of Australia, evaporating more moisture and acting as a feed source to enable good rains.

Key Question 2

How is the forecast looking for the remainder of winter and spring?

A preponderance of wetter forecasts has been a feature of world climate forecasts since April, however many models started to forecast wetter in March. Despite models suggesting wetter conditions, average to drier conditions have occurred on the Riverine Plains and the catchments, after the big wet of April. It's important not to focus too much on forecasts in autumn, as tantalising as they may be. History says it's a time of the year where everything is in flux and rapid changes can happen with little warning. Since autumn, models have lost some, but not all, of their enthusiasm for a wetter spring. At the time of writing (10/7/2020) models are split between wetter and neutral being more likely for the Northern Victorian plains, but the majority have a wetter North East catchment. For southern NSW, the majority of models remain convinced that a wetter spring on the plains and in the catchments is more likely.

Key Question 3

Is there anything in particular that we need to be aware of that could affect the forecast?

A common feature of forecasts during this season is the number of them predicting La Niña or negative Indian Ocean Dipole (-IOD) conditions. Both phenomena increase the chances of spring rainfall being wetter. At the time of writing (10/7/2020), the majority of the world models think both can still occur. But like the promise of 'free ice cream tomorrow', eventually we need to see some evidence that the oceans and atmosphere are still interested in these events. As it currently stands, there is more evidence of a La Niña forming than a -IOD, but both seem to be getting a lack of support from the atmosphere above the ocean. In the Pacific Ocean we have cooler water to depth, an outbreak of cooler water at the surface, and decreased cloud at the Dateline. Yet the Southern Oscillation Index and the Trade winds show no real signs of being interested in La Niña. Without the atmospheric support the enthusiasm of the ocean will be in vain. In the Indian Ocean there is a large pool of warmer water with lower pressure and there is greater cloud off the African Coast. Off Indonesia, conditions are normal. To become a -IOD, Indonesia needs to warm up and Africa needs to cool down. This is a much larger task than what needs to happen in the Pacific Ocean area, given the former is halfway toward La Niña and the Indian Ocean is nowhere near -IOD. The models that give monthly outlooks have been doing better, in terms of successfully predicting the drier June and predicting a drier July. If this trend continues then there will be no free ice cream tomorrow and we will be living on good stored soil moisture and unfortunately, looking at reduced inflows when we need them in spring. Trade wind activity in the Pacific and the Indian Oceans holds the key to turning things towards what the models are predicting, or having it slip from view.

Conclusion

Trade winds that provide support for warmer oceans to our north west and north east, hold the key to wetter forecasts coming to fruition.

Acknowledgements

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Useful resources

The break climate risk newsletters and forecasts

http://agriculture.vic.gov.au/agriculture/weather-and-climate/newsletters

Home of the "famous" local climate tool to analyse climate driver effects on rainfall

https://forecasts4profit.com.au/

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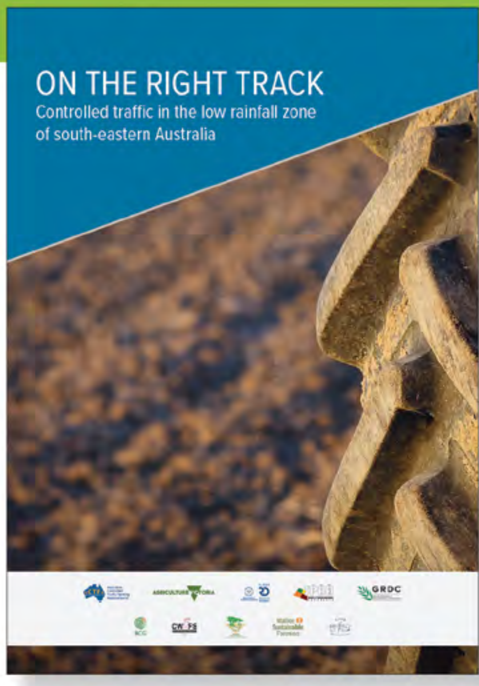

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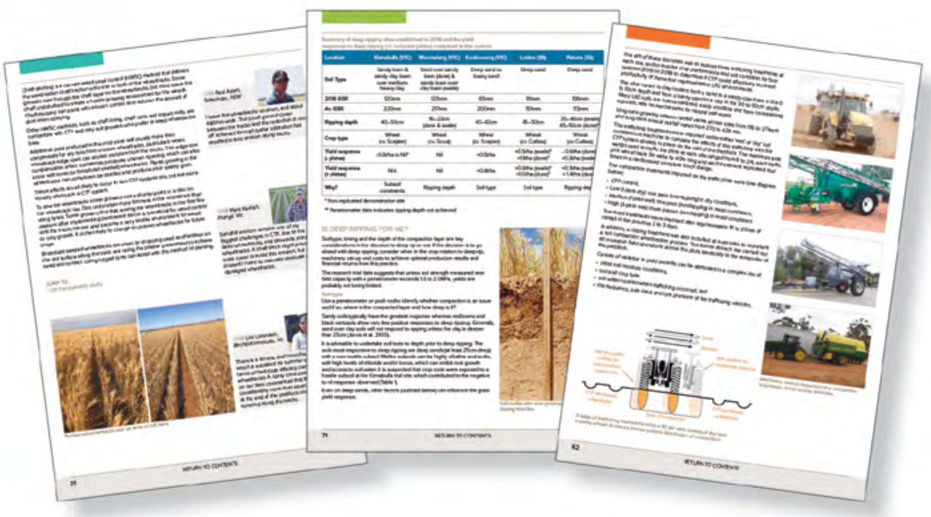

High yielding cereals and canola – with a good start to the season, what management practices still need to be considered?

Tony Napier.

Yanco Agricultural Institute.

Keywords

- wheat, canola, nitrogen, irrigation.

Take home messages

- To develop a nitrogen topdressing strategy you need to have a target yield and get the timing right.
- Allow approximately 40kg N/ha for every tonne of wheat grain yield and 75kg N/ha for every tonne of canola grain yield.
- Stripe rust in wheat and sclerotinia in canola are significant diseases and growers will need to consider an appropriate fungicide strategy.

Background

To achieve maximum yield in any year, there needs to be a high level of management throughout the growing season. With the 2020 season underway, growers now need to consider what they still need to do to take advantage of the good start. At this stage of the season, there are still three main management areas left to consider.

Key Question 1 - What are some of the key management decisions and timings from now on for setting up wheat crops for high yields?

High yielding irrigated wheat production requires effective nitrogen management.

Production of high yielding wheat crops requires split applications of nitrogenous fertiliser over the growing season at three main stages. The first application is usually at sowing, the second (or first topdressing) at mid–late tillering to stem elongation and the third (or second topdressing) at flag leaf to booting. The application of three smaller amounts of nitrogen allows for better matching of crop nitrogen demands.

The speed of biomass production from sowing until the end of tiller development (during the winter months) is relatively slow and thus nitrogen requirement is minimal. Application of large amounts of nitrogen (in excess of the plant's requirement) during this period will promote excess vegetative growth resulting in the crop developing a large canopy. As a result, the crop will have increased risk of foliar disease and lodging.

During stem elongation, the wheat plant undergoes a period of rapid accumulation of biomass in order to build the main structure of the plant both above and below the ground. Nitrogen uptake during this period can be as high as 3kg N/ha/day (Angus 2001). During this growth phase, available nitrogen levels must meet the crop's requirement to ensure that plant growth and leaf area are produced to maximise grain yield. The first nitrogen topdressing is generally applied at the beginning of stem elongation. If nitrogen levels are not sufficient during stem elongation, tillers will start to die off and grain yield will be reduced.

Due to the high demand for nitrogen over the stem elongation period, plant nitrogen reserves may be low when it reaches the booting stage.

Irrigated wheat crops may require a second nitrogen topdressing to achieve the target yield. Low nitrogen availability during grain filling will cause low grain protein concentration. The second topdressing should be applied before booting as delaying the nitrogen application until after flowering will not increase yield potential.

Determining a target yield

Having a target yield is useful to calculate an accurate nitrogen budget for irrigated wheat. When targeting a high yield, all management factors must be adequately addressed including varietal selection, sowing time and water availability.

After sowing and throughout the growing season, the crop needs a higher level of monitoring to ensure the target yield is still achievable. Having an adequate plant population is a key consideration in achieving a high yield. If the plant population falls below the general recommendation (150–200 plants/m^2; minimum 120 plants/m^2) the target yield may need to be lowered.

Low and uncertain irrigation water availability is a major factor limiting irrigated wheat yields. A high yielding wheat crop requires approximately 5.5ML/ha (from rain and irrigation). Achieving a grain yield of 8 t/ha with 5.5 ML/ha of water would give a water use efficiency (WUE), or water productivity, of 14.5 kg/ha/mm. If irrigation water is unavailable or the allocation is reduced during the growing season, growers should consider lowering the target yield and reduce inputs accordingly to ensure the crop is still profitable.

Preparing a nitrogen budget

For the nitrogen budget, allow approximately 40kg N/ha for every tonne of wheat grain yield. Therefore, if the target yield is 8t/ha, the crop needs a total of 320kg N/ha. The nitrogen will come from three sources including nitrogen already in the soil at sowing (pre-sowing soil test), nitrogen mineralised during the growing season and the amount of nitrogen applied as fertiliser during the growing season.

An irrigated wheat crop requires approximately 100–120 kg N/ha at sowing which includes starting soil nitrogen and nitrogen fertiliser applied at sowing. Therefore, if the soil test indicates 90kg N/ha prior to sowing and 145kg/ha of MAP (15kg N/ha) is applied at sowing, the crop will have a total of 105kg N/ha (and 32kg P/ha). If the pre-sowing soil test indicates a lower level of nitrogen in the soil of 75kg N/ha, applying 160kg/ha of DAP will supply 29kg N/ha giving a total of 104kg N/ha (and 32kg P/ha). Where the starting nitrogen is even lower, the addition of another nitrogen fertiliser will be required at sowing to achieve the base requirements of 100–120 kg N/ha.

The first decision regarding topdressing of irrigated wheat should be made when the crop is approaching stem elongation (GS31, first node visible). If the number of tillers is 500– 800 tillers/m^2 the crop is on target to yield 8t/ha and a minimum of 30–50 kg N/ha should be applied. If establishment was poor and the tiller count is below 500 tillers/m^2 a yield of 8t/ha is unlikely, and therefore, a new lower yield target should be considered. If the tiller count is above 800 tillers/m^2 (sown with high levels of soil N available) there is no need to topdress. The first topdressing is generally applied between the first and second node stage. In situations where the starting N levels are low, topdressing can commence a few weeks earlier during mid tillering.

The second decision regarding topdressing is made between flag leaf emergence and booting (GS41–GS47). Topdressing at this stage with 60–90 kg N/ha is usually required to achieve 8t/ha with a grain protein concentration above 11.5%. Delaying topdressing after this time will reduce the effectiveness of the application. It is especially important to time the application of this topdressing so that it occurs before irrigation or rainfall to minimise nitrogen losses through volatilisation.

Table 1. An example nitrogen budget for a high yielding (8t/ha) irrigated wheat crop.

Target yield	8t/ha
Total nitrogen required during season	8t/ha x 40kg N/ha = 320kg/ha
Mineral nitrogen at sowing	75kg N/ha
Fertiliser at sowing – DAP at 160kg/ha	29kg N/ha
Estimated mineralisation during the season	60kg N/ha
First topdressing – Urea at 120kg/ha	55kg N/ha
Second topdressing – Urea at 180kg/ha	83kg N/ha
Total nitrogen budget	302kg N/ha

Disease management of wheat

Wheat foliar diseases are most likely to cause yield loss when there is increased biomass, humidity and prolonged green leaf retention. Stubble-borne and soil-borne wheat diseases are likely to occur in retained stubble systems. During the second half of the season growers need to monitor for all leaf diseases, especially stripe rust. Wheat varieties also vary in their levels of stripe rust resistance. To limit its infection and spread, it is recommended to sow varieties with a resistance rating of moderately resistant (MR) – moderately susceptible (MS) or better. There are seed and fertiliser treatments available to suppress stripe rust on wheat plants at earlier growth stages until adult plant resistance (APR) activates around heading. Foliar fungicides should be applied to protect the youngest three leaves. Generally, this would occur at GS39 (flag leaf emergence). Under high disease pressure, an earlier application at GS31 (first node) and then GS39 might be warranted.

Key Question 2 - What are some of the key management decisions and timings from now on for setting up canola crops for high yields?

A higher level of nutrient management is also required for high yielding irrigated canola.

High yielding irrigated canola crops with high oil content (above 42%) require adequate nitrogen levels for the target yield. To achieve a 4t/ha canola crop, approximately 14t/ha of total biomass is required with a harvest index of 0.28.

Canola dry matter production and thus plant nitrogen requirement is relatively low during the early emergence and rosette stages, prior to the commencement of stem elongation and branch initiation. Once 'bud visible' commences, the crop will go through a rapid growth period until the end of flowering. Nitrogen topdressing needs to provide enough nitrogen for maximum plant growth during this period. If all the nitrogen fertiliser is applied at sowing, achieving the target yield is unlikely. When targeting a maximum grain yield, it is recommended that some nitrogen needs to be delayed and applied as a top-dressing before the crop starts flowering.

Determining a target yield

The target yield is required to calculate an accurate nitrogen budget for irrigated canola. When targeting a high yield, all management factors must be taken into account, including varietal selection, sowing time and irrigation scheduling.

After sowing, the crop needs to be regularly monitored to ensure the target yield is still achievable. Establishing the desired plant population is a key factor in achieving a high yield. The general recommended plant population for maximum irrigated canola yields is about 40 plants/m^2. Research has shown that crops with an evenly distributed plant population of 20 plants/m^2 can still achieve very high yields. When the plant population falls below this, consider lowering the yield target.

Sowing time also needs to be considered when determining a target yield. In the irrigated regions of southern NSW and northern Victoria, sowing generally occurs during April to minimise the risk of early winter waterlogging, and high temperatures causing heat damage during flowering/early podding.

Low and uncertain irrigation water availability is a common factor limiting irrigated canola grain yields. A high yielding canola crop will need about 5.0ML/ha (from rain or irrigation). Achieving a grain yield of 4t/ha with 5ML/ha of water would give a water use efficiency (WUE), or water productivity, of 8kg/ha/mm. Growers will also need to consider lowering yield expectations if irrigation water supply becomes limited.

Preparing a nitrogen budget

Every tonne of canola grain produced requires about 75kg N/ha (depending on nitrogen uptake efficiency). Therefore, a 4t/ha canola crop requires a total of 300kg N/ha. The nitrogen will come from three sources – nitrogen already in the soil at sowing (pre-sowing soil test), nitrogen mineralised during the growing season and nitrogen applied as fertiliser.

A pre-sowing soil test (0–100 cm) should be conducted to determine the amount of nitrogen in the soil at sowing. Soil tests need to be conducted early enough to have the results back before sowing. Soil nitrogen levels can vary considerably depending on farming practices and cropping history while the mineralisation rate is influenced by the level of organic carbon and available moisture in the soil.

Nitrogen uptake is relatively low in the early growth stages of an irrigated canola crop. The general recommendation for a high yielding irrigated canola crop is to apply a portion of the nitrogen fertiliser at or before sowing and the rest by topdressing after the crop has established. Applying all of the nitrogen fertiliser at sowing can increase the risk of excess foliage, crop lodging before maturity, and can result in more leaf and stem disease.

If the crop is healthy and has a uniform plant population of greater than 20 plants/m^2, maximum yields can still be achieved and high nitrogen topdressing rates should be applied. If establishment is poor and the plant population is below 15 plants/m^2, a yield of 4t/ha is unlikely and nitrogen topdressing rates will need to be lowered accordingly.

The water budget developed at the beginning of the season should be reviewed before topdressing as this will help with decisions on yield targets and crop inputs. If irrigation allocations are low or uncertain, nitrogen topdressing rates will need to be reassessed. When nitrogen is topdressed, it should be applied just before an irrigation or rainfall to improve nitrogen uptake efficiency and to minimise losses through volatilisation. A rainfall of 10mm is enough to wash topdressed fertiliser into the soil.

An irrigated canola crop with a yield target of 4t/ha requires a total of approximately 310kg N/ha throughout the growing season. If 50kg N/ha is present in the soil before sowing and a further 50kg N/ha will become available from mineralisation during the season, 210kg N/ha must be applied as fertiliser to reach the target yield.

A base application of DAP provides early nitrogen for the canola seedlings and all the phosphorus requirements for the 4t/ha target. If possible, the DAP should not be sown with the seed but banded close by to avoid negative effects on establishment. The timing of the nitrogen fertiliser (urea) will vary depending on location, paddock history, climate zone and soil type. The first application of nitrogen (urea) is often applied at sowing in southern NSW. If high rates of nitrogen are applied at sowing, it is essential that the N is separated from the seed. The second nitrogen application is normally applied around the 'bud visible' (green bud) stage and before the crop reaches flowering.

Disease management of canola

During the second half of the season, canola growers need to be on top of their sclerotinia management strategy. Sclerotinia is a significant disease of canola with no commercial canola cultivars in Australia with resistance to sclerotinia stem rot. Management of the disease relies on the use of cultural and chemical methods of control. Foliar fungicides should be considered in those districts which are at a high risk of disease development (e.g. where the disease frequently occurs, has a long flowering period, is fully irrigated, receives reliable spring rainfall). There are several foliar fungicides currently registered for use in Australia to manage sclerotinia stem rot.

Plants become susceptible to infection once flowering commences. Research in Australia and Canada has shown that an application of foliar fungicide around the 20–30% bloom stage (20% bloom is 14–16 flowers on the main stem, 30% bloom is approximately 20 flowers on the main stem) can be effective in reducing the level of sclerotinia stem infection. Most registered products can be applied up to the 50% bloom (full bloom) stage.

The objective of the fungicide application is to prevent early infection of petals while ensuring that fungicide also penetrates into the lower crop canopy to protect potential infection sites (such as lower leaves, leaf axils and stems). Timing of fungicide application is critical.

Key Question 3 – How to determine the timing and number of spring irrigations?

Irrigated wheat

Spring irrigation of a wheat crop is one of the major factors influencing grain yield. The decision of when and how often to irrigate is complex and depends on several factors including available soil

Table 2. An example nitrogen budget for high yielding (4 t/ha) irrigated canola crop.

Target yield	4t/ha
Total nitrogen required during season	4t/ha x 75kg N/ha = 300kg/ha
Mineral nitrogen at sowing	50kg N/ha
Fertiliser at sowing – DAP at 150kg/ha	27kg N/ha
Estimated mineralisation during the season	50kg N/ha
First nitrogen application – Urea at 150kg/ha	69kg N/ha
Second nitrogen application – Urea at 230kg/ha	106kg N/ha
Total nitrogen budget	302kg N/ha

moisture, rainfall, time of irrigation water availability in relation to plant development, potential yield benefit, risk of waterlogging or lodging, and returns from using the water on another crop or simply selling it.

Regardless of how many irrigations you intend to apply to your wheat crop during the growing season the most important factor to consider is that adequate moisture is available during the heading stage. **Head emergence is the most sensitive growth stage to moisture stress in a wheat crop.**

If you are planning to limit the number of spring irrigations applied to a wheat crop it is important to find a balance between irrigating before significant moisture stress to the wheat plants occurs while also ensuring adequate moisture is available during head emergence.

If only one irrigation is going to be applied to the crop, the best timing for this is around mid-stem elongation. The crop will still have time to increase biomass with some moisture remaining for the critical flowering and early grain fill stages. Any late season rainfall will also then be more beneficial.

If two irrigations are possible, the first irrigation should be applied at early stem elongation with the second applied between flag leaf emergence and flowering.

Timing of the first irrigation is very important to maximise water productivity and speed at which the water can be applied. If the first irrigation is not applied until the soil profile is very dry it will take much longer and use considerably more water for the irrigation, both of which are not desirable. One irrigation applied once the soil has dried to depth can use almost as much water as two irrigations applied at the correct times.

An experiment conducted by NSW DPI at Leeton NSW in 2015 found that two spring irrigations produced the highest wheat grain yield (7.61t/ha), but one irrigation provided the highest water productivity (1.7t/ML). Another important point from that experiment was that ponding the irrigation water for 48 hours did not reduce grain yield (due to the excellent soil structure) but it did increase water use and subsequently reduced water productivity by 25%.

Irrigated canola

Spring irrigation of a canola crop is one of the major factors influencing grain yield. The decision of when and how often to irrigate canola is complex and depends on several factors including available soil moisture, rainfall, time of irrigation water availability in relation to plant development, potential yield benefit, risk of waterlogging or lodging, and returns from using the water on another crop or selling it.

A fully irrigated canola crop will require between two and four spring irrigations to achieve maximum grain yield depending on the irrigation system being used, location, rainfall and soil water holding capacity. In a dry winter when the soil profile is dry to depth it is very important to irrigate as soon as possible in the new irrigation season (usually early–mid August) or significant grain yield reduction will occur.

When irrigation water is limited, one irrigation applied at early flowering will give the best grain yield response and economic return in a dry season. Canola is very sensitive to moisture stress at flowering, particularly early flowering, and moisture stress during this period can dramatically reduce grain yields. Supplying adequate moisture to the crop at this time will maximise the number of pods that set seed and later irrigations will maximise seed size.

Canola is less tolerant of waterlogging in the period from flowering to maturity than most cereal crops. It is therefore very important that the opportunity time with each irrigation or large rainfall event is within the guidelines for each soil type, or reduced grain yield will occur.

Irrigation scheduling

Scheduling irrigations is important to ensure that the crop is irrigated before moisture stress occurs.

There are several methods available to assist with irrigation scheduling. The methods are divided into either plant based or soil-based tools. Daily evapotranspiration (ETo) figures are a common plant-based tool while soil capacitance probes and gypsum blocks are soil-based options.

The use of ETo requires growers to access weather data from the internet and keep records for each of their fields. A crop coefficient that depends on the growth stage of the crop is also required. Once familiar with this method and the plant available water for each soil type it is easy to use to predict when future irrigations will be required.

There are several providers of services to install and monitor soil capacitance and gypsum blocks as well as an increasing number of data logging methods allowing the soil moisture data to be accessed in the field or in real-time from the internet.

It is important that this equipment is installed in locations that are representative of the majority of the field or the results may be misleading.

Regardless of method used, it is important to monitor crop water use in order to avoid crop moisture stress. Do not allow soil water to deplete below 60% of plant available water capacity (PAWC) referred to as readily available water (RAW). The point of timely irrigation is commonly known as the 'refill point'. Plant growth and yield potential will decline considerably if soils are allowed to dry down beyond the point of RAW, which is particularly important in crops fully irrigated for maximum yield potential. Readily available water will vary across soil types. Successfully growing an irrigated wheat and canola crop and achieving high levels of water productivity is dependent on matching the layout with the soil type and creating bay sizes that allow ponded water to be on the field for as short as practical, preferably less than 10 hours.

Reducing the number of irrigations can often increase water productivity in irrigated canola but it is important that timing of the irrigations is planned to maximise grain yield.

Conclusion

There has been a good start to the season so far, but it is very unlikely that there will be sufficient irrigation water during spring to fully irrigate crops. Nitrogen application rates and timing must be made in conjunction with how much water the crop is likely to get. Lower water allocations will mean lowering the target yield and lowering nitrogen topdressing rates. When high water allocations are available, growers can increase their nitrogen topdressing rates to achieve higher target yields. Growers can only target maximum yields in years of full irrigation allocations.

Crop monitoring is recommended every year for disease management. A targeted fungicide program will help avoid yield loss.

Acknowledgements

I would like to acknowledge the authors of "Irrigated wheat in southern cropping systems" and "Irrigated canola in southern cropping systems". These two publications were produced as a part of the "Southern irrigated cereal and canola varieties achieving target yield' project which was made possible by the significant contributions from both NSW DPI and GRDC. Many of the recommendations in this paper were taken from these two manuals.

Useful resources

https://grdc.com.au/resources-and-publications/all-publications/publications/2018/irrigated-canola-in-southern-cropping-systems

https://grdc.com.au/resources-and-publications/all-publications/publications/2018/irrigated-wheat-in-southern-cropping-systems

https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/04/irrigated-wheat-in-the-murrumbidgee-and-murray-fact-sheet

https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/winter-crops/wheat,-barley-and-other-winter-cereals/eight-tonnes-hectare-irrig-wheat

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www.ifarmwell.com.au An online toolkit specifically tailored to help growers cope with challenges, particularly things beyond their control (such as weather), and get the most out of every day.

www.blackdoginstitute.org.au The Black Dog Institute is a medical research institute that focuses on the identification, prevention and treatment of mental illness. Its website aims to lead you through the logical steps in seeking help for mood disorders, such as depression and bipolar disorder, and to provide you with information, resources and assessment tools.

www.crrmh.com.au The Centre for Rural & Remote Mental Health (CRRMH) provides leadership in rural and remote mental-health research, working closely with rural communities and partners to provide evidence-based service design, delivery and education.

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www.rrmh.com.au Rural & Remote Mental Health run workshops and training through its Rural Minds program, which is designed to raise mental health awareness and confidence, grow understanding and ensure information is embedded into agricultural and farming communities.

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www.farmerhealth.org.au The National Centre for Farmer Health provides leadership to improve the health, wellbeing and safety of farm workers, their families and communities across Australia and serves to increase knowledge transfer between farmers, medical professionals, academics and students.

www.ruralhealth.org.au The National Rural Health Alliance produces a range of communication materials, including fact sheets and infographics, media releases and its flagship magazine *Partyline*.

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Soil amelioration – magnitude of crop productivity improvements on hostile subsoils?

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GRDC project codes: DAV00149, UA00159

Keywords

- sodic subsoils, amendments, soil pH, exchangeable sodium percentage, root growth, grain yield.

Take home messages

- Deep placement of organic and inorganic amendments increased grain yield in the order of 20 to 40% for three successive years on a sodic subsoil at Rand.
- Deep placement of organic and inorganic amendments increased root growth and soil water use from the deeper clay layers during the critical reproductive stages of crop development.
- Improvements in grain yield with deep placement of organic and inorganic amendments were associated with a reduction in subsoil pH and exchangeable sodium percentage (ESP%) and an increase in microbial activity.
- Genotypic variability in grain yield response of wheat cultivars grown on sodic subsoils has identified varieties and associated traits for enhanced performance and future breeding.

Background

In the Australian grain belt soil constraints are often expressed as lower water use efficiency (WUE) of grain production and are compared with water limited yield, otherwise known as potential yield. The difference between constrained and potential yield is referred to as the yield gap. Among different soil constraints, sodicity is associated with the largest yield gaps across most of the wheat-cropping areas of Australia, with an estimated yield loss of $A 1300 million per annum (Orton et al. 2018). Sodic soils exhibit a range of physiochemical properties including the presence of high subsoil exchangeable sodium (Na) concentrations which cause soil dispersion leading to poor subsoil structure, impeded drainage, waterlogging, denitrification and high soil strength. These properties restrict the rooting depths of crop species and subsequent water and nutrients extraction (Incerti and O'Leary 1990; Passioura and Angus 2010) leading to significant yield gaps (Adcock et al. 2007) that affect the profitability of cropping systems (Orton et al. 2018).

In southern NSW winter crops commonly have sufficient water supply either from stored soil water or rainfall during the early growth stages. However, the reproductive phase is often affected by water stress or terminal drought and this is thought to be the major cause of variable grain yield (Farooq et al. 2014). The effect of water stress in the reproductive phase is further impacted by shallow root depth induced by subsoil sodicity. Key to improving crop productivity under such a condition is to improve root growth in and through sodic subsoils to enable use of deep subsoil water late in the growing season. Water use at this late stage has a two- to three-fold greater conversion efficiency into grain yield (Kirkegaard et al. 2007) than seasonal average based conversions efficiencies (i.e. 50 – 60kg/mm versus 20 – 25kg/mm, respectively).

While there are large advantages to be gained by improving the soil environment of sodic subsoils, the various amelioration approaches (deep ripping, subsoil manuring, applying gypsum, improved nutrition and use of 'primer-crops') have produced variable results (Adcock et al. 2007; Gill et al. 2008). Furthermore the use of subsoil organic material is impacted by limited local availability, the high cost of suitable organic ameliorants delivered in-paddock, the sometimes large quantities required, the lack of suitable commercial-scale machinery and the poor predictability of when and where the amelioration will benefit crop productivity (Gill et al. 2008; Sale et al. 2019).

Gypsum application has been the most widespread traditional approach used to correct subsoil sodicity however the problems have included; surface application when the problem is evident in the subsoil, the large quantities of gypsum required to displace significant amounts of Na and the somewhat low solubility of gypsum.

Genetic improvement is also frequently advocated as an avenue for improving crop productivity and adaptation under different hostile soil conditions (McDonald et al. 2012; Nuttall et al. 2010). Little is known about genetic variation for subsoil constraints tolerance and how they relate to different plant traits such as elemental toxicity tolerance, canopy cover, rooting depth and harvest index and the integration of these factors in yield response of different genotypes. This limited knowledge is also due to the practical difficulties in measuring dynamic and variable soil constraints under field conditions.

To overcome sodic subsoil constraints within an economic framework a new approach was required that firstly commences with improved identification of the range of constraints present in the soil, the spatial variability of these constraints and synergising the combined approaches of inorganic and organic amendments with genetic solutions. This complex issue will be tackled by research within two GRDC investment projects (UA00159, DAV00149). This paper reports 2019 experimental results from these projects and is aimed at increasing WUE of grain crops on sodic subsoils by either ameliorating them with various organic and inorganic amendments or by identifying plant varieties and traits linked to sodicity tolerance.

Method

Rand amendment site

A field experiment was established on-farm near the township of Rand in southern NSW during February 2017. The site was located in a paddock that had been cropped with a cereal-canola rotation for more than 50 years. The physiochemical properties of the soil for this site are given in Figure 1. The soil is a Sodosol (Isbell 2002), with a texture-contrast profile increasing in clay content at depth. The increasing levels of exchangeable Na relative to calcium (Ca) and/or magnesium (Mg) in subsoil results in a decrease in soil structural stability and higher dispersion as shown in Figure 1. The high clay content in this subsoil layer has a bulk density of 1.55g/cm^3 that restricts water movement, and consequently the saturated hydraulic conductivity value is low at 0.03cm/hr.

The experimental plots were 2.5m wide and 20m long. There were 13 treatments comprising 1) the control, 2) surface application of gypsum, 3) surface application of chicken manure, 4) surface application of pea hay, 5) deep ripping, 6) deep placement of gypsum, 7) deep placement of chicken manure, 8) deep placement of wheat stubble, 9) deep placement of wheat stubble + nutrients, 10) deep placement of pea hay, 11) deep placement of pea hay + nutrients, 12) deep placement of liquid nutrients and 13) deep placement of pea hay + gypsum + nutrients. The experiment was a randomised complete block design with four replicates. Ripping and deep placement of amendments were carried out with a 3-D ripping machine (NSW DPI). The machine can deliver inorganic and/or organic amendments at two depths from 10cm to 30cm. The machine is also capable of delivering liquid fertilisers at depth. The experimental plots were sown to barley (cv. La Trobe⌽) and wheat (cv. Lancer⌽) in 2017 and 2018, respectively. In 2019 the experimental plots were sown on the 10 April to hybrid canola (cv. Pioneer®45Y92CL) at the seed rate of 4.4 kg/ha with an air seeder at 25cm row spacing. During sowing 90kg Mono-Ammonium Phosphate (MAP) (20kg P/ha and 9kg N/ha) was drilled in all plots and 100kg N/ha top-dressed in late June. In the 2019 growing season (April to November) this site received 215mm rainfall. Mean plant density as measured by seedlings counts three weeks after sowing was 37.7 ± 1.9 (mean ± SE of 60 plots) plants/m^2.

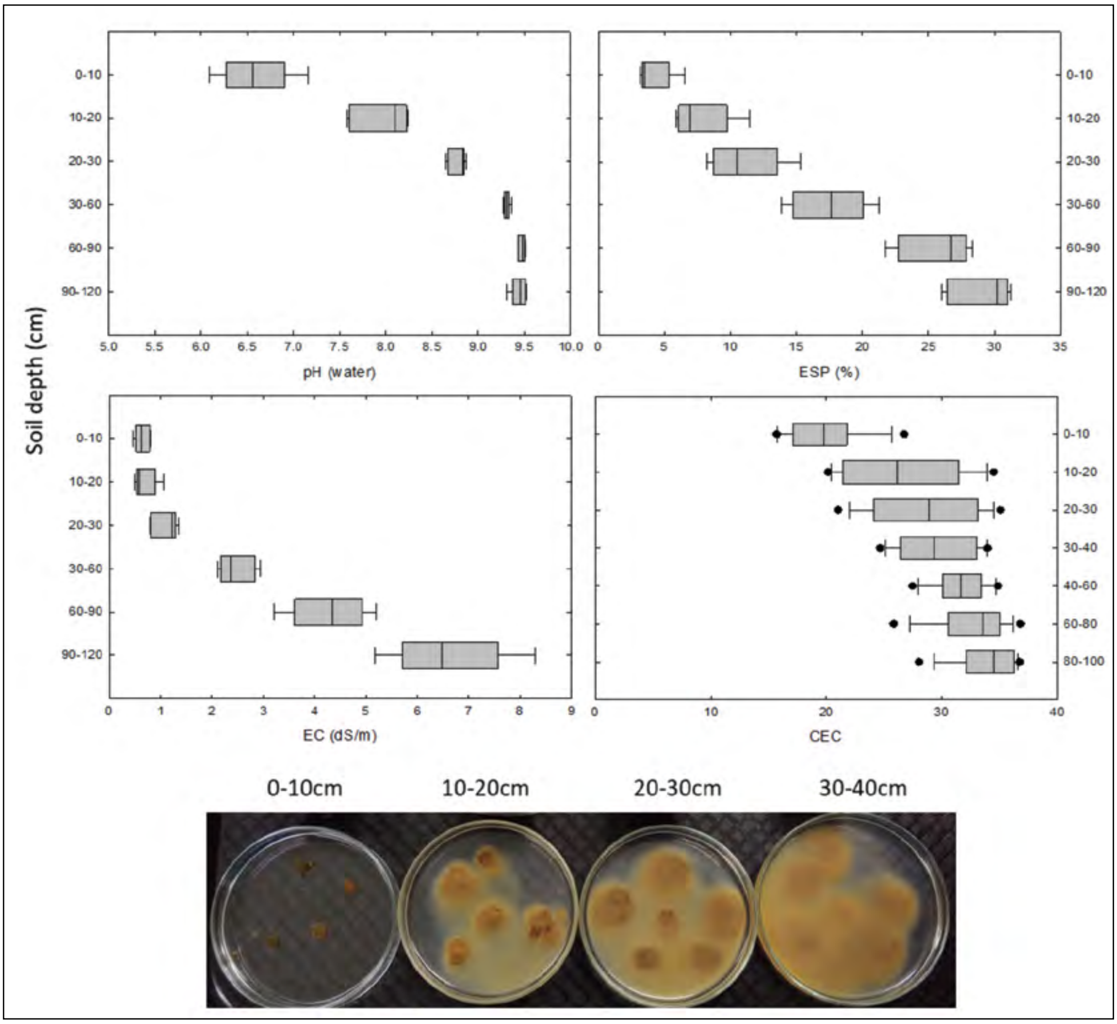

Figure 1. Soil characterisation of the Rand (southern NSW) experimental site. The picture shows the level of soil dispersion at four different depths.

At late flowering soil coring was completed using a tractor-mounted hydraulic soil-coring rig and 45mm diameter soil cores. The break core method was used to estimate rooting depth and exposed roots were recorded at the following depths 0 - 10, 10 - 20, 20 - 40, 40 - 60, and 60 - 100cm. Quadrat samples of 2m^2 were taken at physiological maturity to measure plant biomass and grain yield.

Genotypes screening experiment

In 2019 an experiment was conducted at Grogan in southern NSW, which included 17 commercial wheat genotypes in a row column design with four replicates. The soil profile was slightly acidic in the top 10cm (pH$_{1:5\ water}$ 5.9) and pH dramatically increased with depth (Table 1). The changes in soil sodicity (ESP) followed a similar trend as soil pH with ESP at 10.5% in the topsoil and increasing up to 40% in the subsoil (Table 1).

Table 1. Site characterisation for the Grogan experimental site. Values are means (n=5).

Soil depths (cm)	EC (µs/cm)	pH (1:5 water)	Colwell-P (µg/g)	CEC (cmol(+)/kg)	Exchangeable sodium percentage
0-10	309.40	5.87	58.80	16.66	10.53
10-20	133.00	7.65	7.40	22.06	11.97
20-30	136.90	8.76	2.62	24.53	15.94
30-40	207.66	9.12	2.50	25.55	20.12
40-60	338.94	9.60	1.34	27.17	26.27
60-80	530.40	9.53	1.00	31.63	36.68
80-100	897.20	9.43	1.48	34.07	40.25
100-120	1148.20	9.38	1.50	35.28	40.35

The experiment was sown on 17 May 2019 using a direct sown drill with DBS tynes spaced at 25cm. At sowing 90kg MAP (20kg P/ha and 9kg N/ha) was drilled in all plots and 75kg N/ha was surface applied just prior to stem elongation. Mean plant density, as measured by seedlings counts at four weeks after sowing, was 116 ± 1.6 (mean ± SE of 68 plots) plants/m^2. At different growth stages multispectral images (MicaSense RedEdge-MX) were collected using drone technology to determine different vegetation indices such as normalised differences in vegetation index (NDVI) and leaf chlorophyll index (LCI) as a surrogate of canopy attributes and plant physiological processes (Liu et al. 2019; Satir and Berberoglu 2016; Zhang et al. 2019). Quadrat samples of 1m^2 area were taken at physiological maturity to measure plant biomass and grain yield. Harvest index was calculated as grain yield divided by biomass.

Results

Rand amendment site

In 2019, canola grain yield significantly (P < 0.001) increased following the application of amendments in 2017 (Figure 2). The highest increase was observed for deep placement of pea hay + nutrient treatment and gypsum. Deep nutrients did not improve grain yield compared with the control and consequently it can be assumed the amendment affects were not due to nutritional factors only.

The number of visible roots in the amended sodic subsoil (20 – 40cm depth) were also significantly (P < 0.05) affected by different amendments (Figure 3). Deep placement of both manure and pea hay increased the number of visible roots by more than three-fold. Neutron probe readings taken in September also indicate that the highest root counts were associated with the driest soil water profile (Figure 4). Variation in soil pH measured at different rooting depth during the flowering of canola is shown in Table 2. Compared to control, deep placement of gypsum reduced the soil pH by 0.7 units (8.8 to 8.1) at 20 – 40cm depth. However, pH was not affected by other treatments.

Genotypes screening trial

Significant (P < 0.001) genotypic variation occurred in grain yield among the genotypes tested and ranged from only 0.57 t/ha (Gregory$^{\text{(}}$) to 2.0 t/ha (Scepter$^{\text{(}}$, Emu Rock$^{\text{(}}$ and Mace$^{\text{(}}$; Figure 5). Biomass at final harvest did not significantly differ among the genotypes (data not shown; P = 0.11) and there was no significant (P = 0.09) correlation between grain yield and biomass at final harvest (Figure 6).

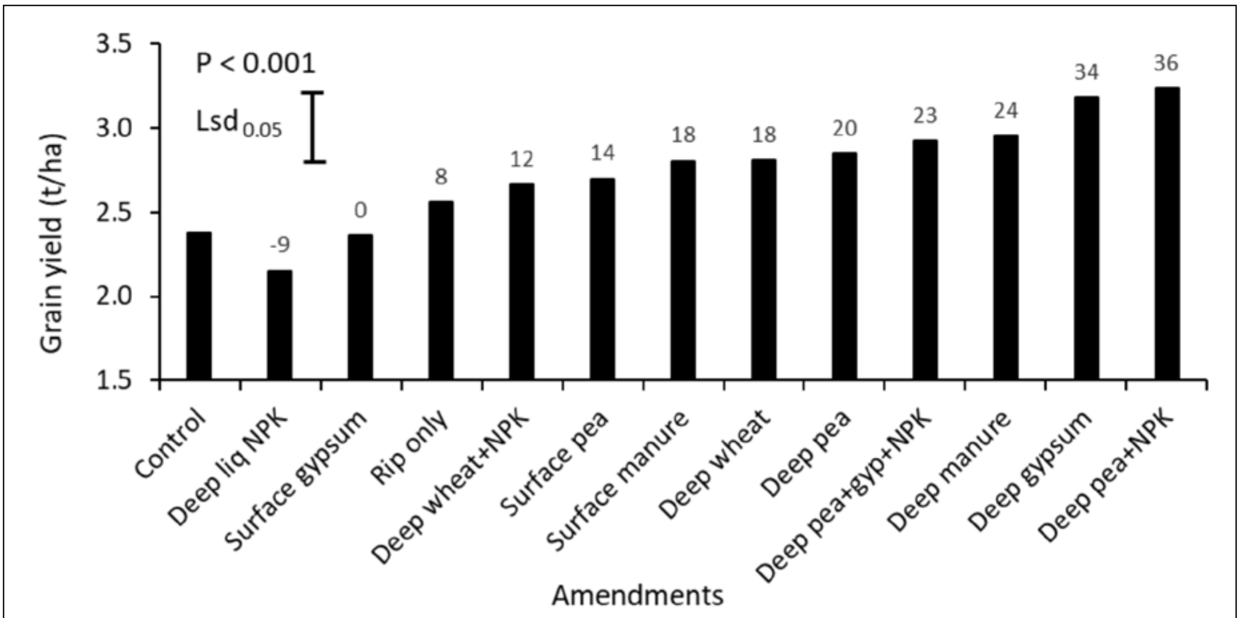

Figure 2. The mean effect of surface or deep-placed amendments on grain yield of canola (cv. Pioneer®45Y92CL) grown in alkaline sodic subsoil in Rand, southern NSW in 2019. Values on the top of each bar represent the percent change in grain yield for individual amendments compared to control.

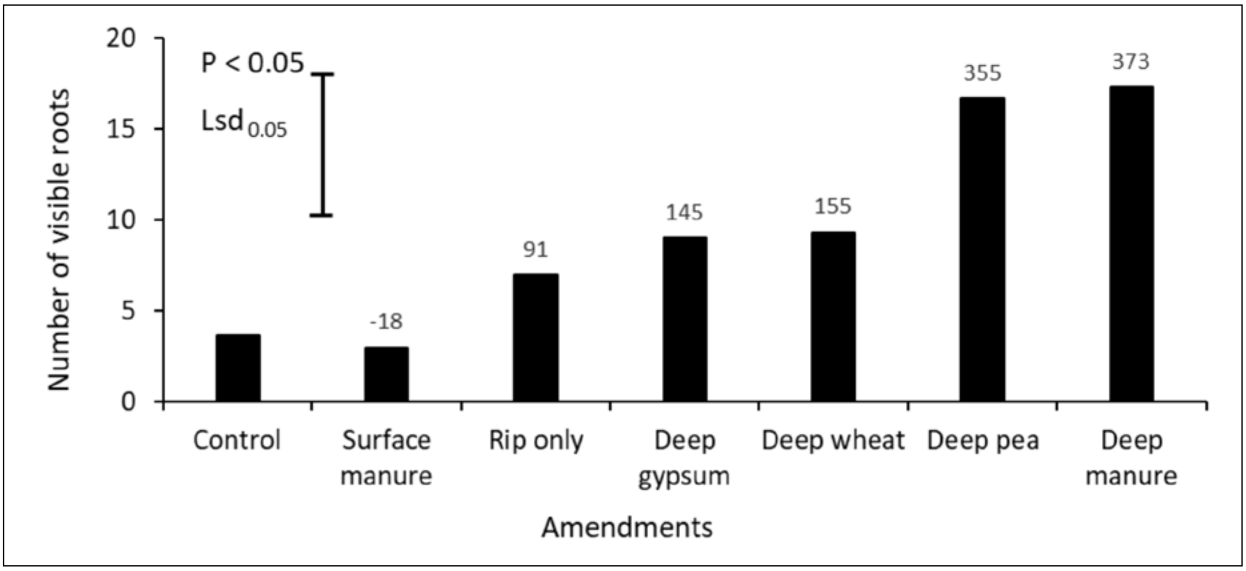

Figure 3. The mean effect of surface or deep-placed amendments on the number of visible roots at 30cm at late flowering of canola (cv. 45Y92CL) grown in alkaline sodic subsoil in Rand, SNSW in 2019. Values on the top of each bar is representing percent change of visible roots compared to control.

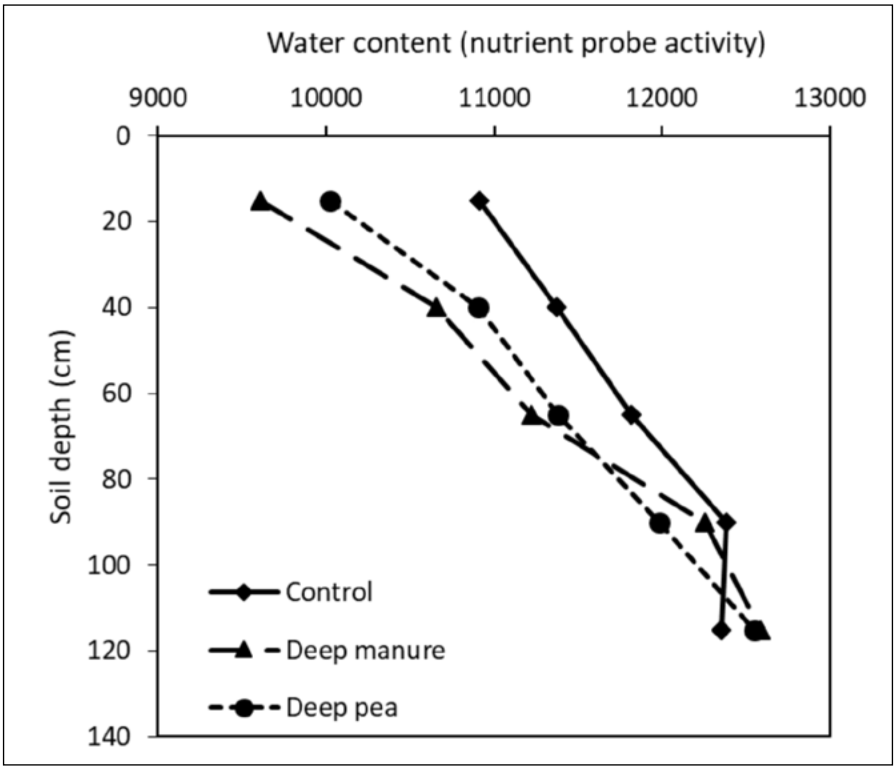

Figure 4. Neutron probe readings taken in September at the Rand amendment site for contrasting treatment comparisons. Results are based on the neutron activity (raw data) where higher values represent higher water content in the soil profile. Values are averages (n = 4).

Table 2. The changes in soil pH in selected treatments at Rand site. Samples were collected at late flowering of canola (cv. 45Y92CL) in September 2019.

Soil depths (cm)	Control	Surface manure	Rip only	Deep gypsum	Deep wheat	Deep pea	Deep manure
0 - 10	6.5	6.8	6.7	6.9	7.3	7.1	6.8
10 - 20	7.7	7.8	8.1	7.1	8.1	8.2	8.0
20 - 40	8.8	8.7	8.8	8.1	8.9	9.0	8.5
40 - 60	9.3	9.4	9.3	9.3	9.4	9.5	9.5
60 - 100	9.5	9.3	9.4	9.3	9.4	9.6	9.3

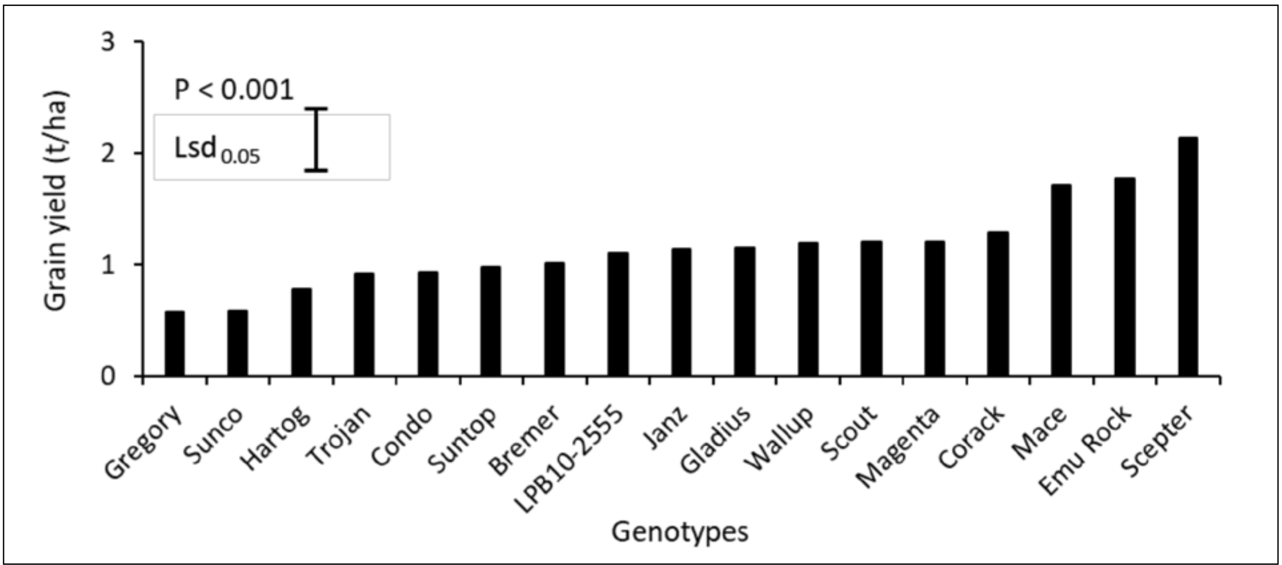

Figure 5. Variations in grain yield of 17 wheat genotypes grown in alkaline sodic dispersive subsoil in Grogan, southern NSW in 2019. Each data point is mean values of n = 4.

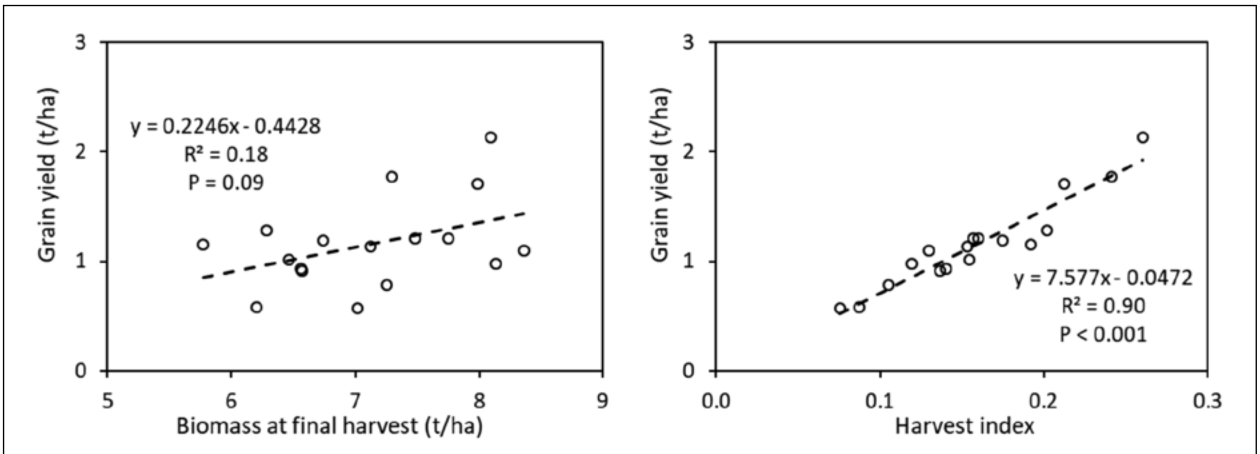

Figure 6. Linear regressions between grain yield and biomass at final harvest (left) and harvest index (right) of 17 wheat genotypes grown in alkaline sodic dispersive subsoil at Grogan, southern NSW in 2019.

Significant variation was observed in the harvest index (data not shown; P < 0.001), which ranged from 0.08 (Gregory[(l)]) to 0.26 (Scepter[(l)]). A significant (P < 0.001) and positive correlation between harvest index and grain yield is observed among the studied genotypes (Figure 6).

All the non-destructive vegetation indices; NDVI (P < 0.01), normalised difference red edge (NDRE) (P < 0.001) and LCI (P < 0.001) measured at stem elongation showed significant and positive correlation with biomass at anthesis (Figure 7).

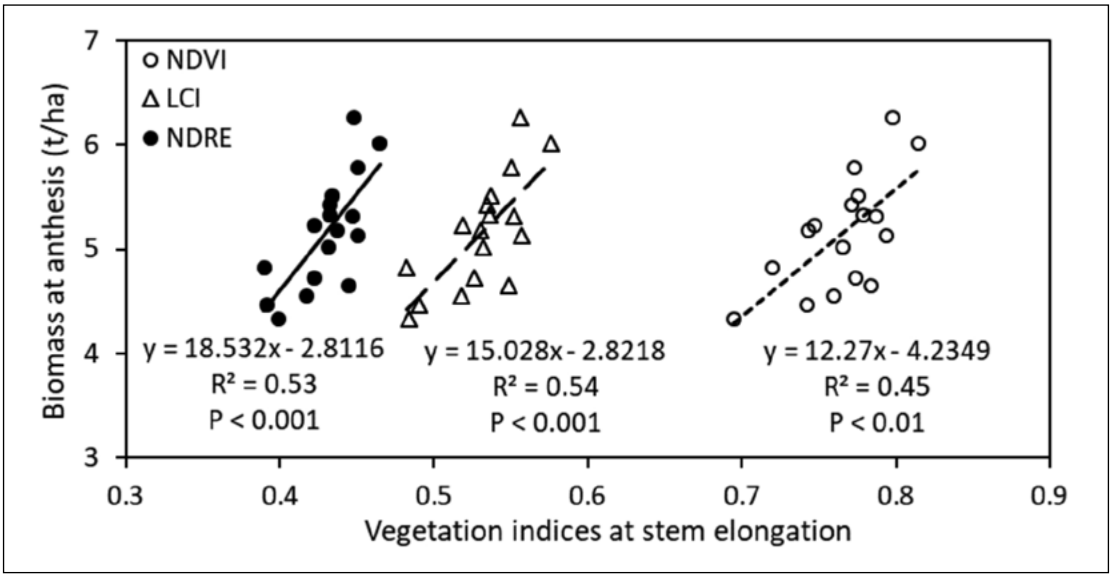

Figure 7. Linear regressions between vegetation indices (measured at stem-elongation) and anthesis biomass of 17 wheat genotypes grown in alkaline sodic dispersive subsoil at Grogan, southern NSW in 2019. NDVI = normalised differences in vegetation index; LCI = Leaf chlorophyll index; NDRE = Normalised difference red edge.

Discussion

The marked increase in the grain yield that occurred at Rand with the deep placement of both organic and inorganic amendments indicates the potential of this approach in reducing the yield gap associated with soil constraints in major cropping regions of Australia. Placement of the amendments in the study site in 2017 resulted in three consecutive years with significant yield improvement, indicating the residual effects of this approach on the yields of following crops (Gill et al. 2012). There was no positive yield response to deep nutrients and this supports other evidence that the responses at Rand are not due to nutritional factors alone. In a year of intensive drought like 2019, the grain yield improvements at Rand may be attributed to the additional root growth in the amended subsoil layer (Figure 3), which facilitated the use of extra subsoil water (Tavakkoli et al. 2019 and Figure 4). Under dryland conditions, water captured by roots in the subsoil layer is extremely valuable as its availability coincides with the grain filling period and has a very high conversion efficiency into grain yield (Kirkegaard et al. 2007; Wasson et al. 2012).

This study also indicates how the deep placement of both organic and inorganic amendments can improve soil chemicophysical properties. Reductions in extremely high soil pH and ESP at 20 – 40cm depth of the amended layers were reported within 14 months following deep placement of the amendments (Tavakkoli et al. 2019) and these changes have persisted into the third (2019) year (Table 2). Furthermore, improvement in soil chemical properties were also associated with increasing soil porosity, infiltration rate (data not shown) and microbial activity, which leads to soil aggregation and ultimately improving soil structure (Tavakkoli et al. 2019).

A major focus of this current research is to understand the amelioration processes of the subsoil application of organic and inorganic amendments. A tentative, but promising finding from our field and controlled environment trials is that farm-grown products like wheat and pea stubbles when mixed with nutrients improve soil aggregation, root growth, water extraction and grain yield and these treatments are comparable to animal manures and gypsum. If confirmed, this means that grain growers have a potentially large supply of relatively inexpensive organic ameliorants already available in their paddocks, which will increase the application options and viability of correcting subsoil sodicity.

Despite demonstrating significant improvements in grain yield with subsoil incorporation of organic and inorganic amendments, the widespread adoption of these practices is still limited by their cost effectiveness. Identifying traits associated with the superior tolerance to different soil constraints may be a low cost technique to tackle this issue (McDonald et al. 2012). Given the intensive drought condition in the study year, considerable genotypic variation was observed with some varieties having three- folds higher grain yield than the other varieties. Based on controlled-environment studies, the high yielding varieties at Grogan; Mace⁽ᵈ⁾ and Emu Rock⁽ᵈ⁾, are moderately tolerant to tolerant to high pH and have roots that can grow relatively well through soils of high bulk density, whereas low yielding varieties such as Gregory⁽ᵈ⁾, Hartog and Sunco are sensitive to one or both of these stresses. The very low harvest index in the trial suggests that there was severe stress around flowering to reduce grain set, as well as during grain filling and the results suggests that perhaps the ability to maintain root growth helped to alleviated the stress in varieties like Emu Rock⁽ᵈ⁾ and Mace⁽ᵈ⁾. Furthermore, different traits associated with this greater yield performance of wheat genotypes are crucial aspects of future breeding programs.

Conclusions

The findings from the current field studies demonstrate initial but promising results of ameliorating alkaline sodic subsoils in medium and high rainfall zones of southern NSW. Deep placement of organic and inorganic amendments resulted in significant yield improvement in three successive years at Rand where subsoil water was present. This yield improvement was facilitated by a reduction in soil pH and ESP% and increased microbial activity that can lead to improved soil aggregation. Furthermore, deep placement of organic and inorganic amendments increased root growth, which in turn increased soil water use from the deeper clay layers during the critical reproductive stages of crop development, thereby increasing grain yield. In addition to soil management, genotypic variability in grain yield of wheat cultivars observed and their associated traits identified in the current study can be used for improving wheat germplasm through future breeding programs.

Acknowledgements

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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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TOP 10 TIPS

FOR REDUCING SPRAY DRIFT

01 **Choose all products in the tank mix carefully**, which includes the choice of active ingredient, the formulation type and the adjuvant used.

02 **Understand** how product uptake and translocation may impact on coverage requirements for the target. Read the label and technical literature for guidance on spray quality, buffer (no-spray) zones and wind speed requirements.

03 **Select the coarsest** spray quality that will provide an acceptable level of control. Be prepared to increase application volumes when coarser spray qualities are used, or when the delta T value approaches 10 to 12. Use water-sensitive paper and the Snapcard app to assess the impact of coarser spray qualities on coverage at the target.

04 **Always expect** that surface temperature inversions will form later in the day, as sunset approaches, and that they are likely to persist overnight and beyond sunrise on many occasions. If the spray operator cannot determine that an inversion is not present, spraying should NOT occur.

05 **Use weather forecasting** information to plan the application. BoM meteograms and forecasting websites can provide information on likely wind speed and direction for 5 to 7 days in advance of the intended day of spraying. Indications of the likely presence of a hazardous surface inversion include: variation between maximum and minimum daily temperatures are greater than 5°C, delta T values are below 2 and low overnight wind speeds (less than 11km/h).

06 **Only start spraying** after the sun has risen more than 20 degrees above the horizon and the wind speed has been above 4 to 5km/h for more than 20 to 30 minutes, with a clear direction that is away from adjacent sensitive areas.

07 **Higher booms increase drift**. Set the boom height to achieve double overlap of the spray pattern, with a 110-degree nozzle using a 50cm nozzle spacing (this is 50cm above the top of the stubble or crop canopy). Boom height and stability are critical. Use height control systems for wider booms or reduce the spraying speed to maintain boom height. An increase in boom height from 50 to 70cm above the target can increase drift fourfold.

08 **Avoid high spraying speeds**, particularly when ground cover is minimal. Spraying speeds more than 16 to 18km/h with trailing rigs and more than 20 to 22km/h with self-propelled sprayers greatly increase losses due to effects at the nozzle and the aerodynamics of the machine.

09 **Be prepared** to leave unsprayed buffers when the label requires, or when the wind direction is towards sensitive areas. Always refer to the spray drift restraints on the product label.

10 **Continually monitor** the conditions at the site of application. Where wind direction is a concern move operations to another paddock. Always stop spraying if the weather conditions become unfavourable.
Always record the date, start and finish times, wind direction and speed, temperature and relative humidity, product(s) and rate(s), nozzle details and spray system pressure for every tank load. Plus any additional record keeping requirements according to the label.

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THE 2017-2020 GRDC NORTHERN REGIONAL PANEL

JANUARY 2020

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHAIR - JOHN MINOGUE

John Minogue runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is chair of the district council of the NSW Farmers' Association, sits on the grains committee of NSW Farmers' Assn and is a winner of the Central West Conservation Farmer of the Year award. His vast agricultural experience in central west NSW has given him a valuable insight into the long-term grains industry challenges.

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Arthur is a grain, cotton and beef producer near Chinchilla, Queensland. He has a business degree from the Queensland University of Technology in international business and management and has completed the Australian Institute of Company Directors course. He is a previous vice-president of AgForce Grains and has an extensive industry network throughout Queensland. Arthur believes technology and the ability to apply it across industry will be the key driver for economic growth in the grains industry.

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Roger Bolte is a fourth-generation farmer from the West Wyalong area in NSW, operating a 6500 ha winter cropping program with his wife and family focusing on cereals, legumes and hay. During his 35-years in the industry, Roger has been involved in R&D in various capacities and has had the opportunity to travel abroad and observe a variety of farming systems. He believes that R&D and education are the cornerstones of the industry and feels privileged to be afforded the opportunity to share his experiences.

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ROY HAMILTON

Roy Hamilton operates Riverina with his wife Leanne, son Sandy and daughter-in-law Sara. He was an early adopter of minimum till practices and direct drill and press wheel technology and is currentlycurrently running CTF on 12m 3-1. The majority of the property (80%) is cropped with wheat, canola, barley, triticale, faba beans while the remainder under pasture runs 1,400 ewes and trade lambs. He has held roles on the south east NSW Regional Advisory Committee, the GRDC's southern region Regional Cropping Solutions Network and was a founding committee member of the Riverine Plains farming systems group.

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Tony is an agricultural consultant. He was a farmer in the Forbes region for 30 years. He is a director of the Rural Industries Research and Development Corporation. He has worked as an agricultural consultant in WA and southern NSW. With a Bachelor of Agricultural Science and a PhD in agronomy, Tony advocates agricultural RD&E and evidence based agriculture.

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Peter operates a private agronomy consulting business based in Quirindi NSW. Prior to this he was facilitator/agronomist for AgVance Farming group, a communications conduit between industry and growers. He is a passionate supporter of research and has been active in extending weed management research information to industry, particularly in central west NSW, is a former director of Conservation Farmers Inc., a former member of the North East Regional Advisory Committee and a participant in Northern Growers Alliance local research group on the Liverpool Plains.

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Graham has conducted a private agricultural consultancy at Emerald, Queensland, for the past 30 years which provides agronomy and farm business management advice in summer and winter, dryland and irrigated crops in grain and mixed grain/grazing farming systems in the region. He has participated in two decades of GRDC and Qld DPI funded farming systems research, development and extension projects, particularly in the areas of weed management, soil fertility and adaption of agronomy practices in CQ climate and farming systems.

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Bruce and his family operate a 3400 ha family grain growing business near Parkes NSW, which produces a mixture of dryland winter cereals, pulses and oilseeds as well as summer dryland cereals, pulses and cotton grown on a 12m zero till CTF platform with full stubble retention. Bruce holds a Bachelor of Agricultural Economics from the University of Sydney and previously worked with PricewaterhouseCoopers in its Transfer Pricing practice. He is an active member of the grains industry and was awarded a Nuffield Scholarship in 2009. Bruce is interested in both transformational or blue sky research and continues to ensure that existing research delivers profitability to grower's businesses.

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DR JO WHITE

Dr Jo White is an experienced researcher with over 15 years' experience in agricultural research programs based at the Department of Agriculture and Fisheries in Queensland (DAFQ) and the University of Southern Queensland (USQ), including 10 years' experience in the field of plant pathology of broad acre summer crops. Jo has a keen interest in developing and delivering on-ground practical research solutions to growers which improve productivity and profitability of their farms and is now working as a private consultant based in Queensland.

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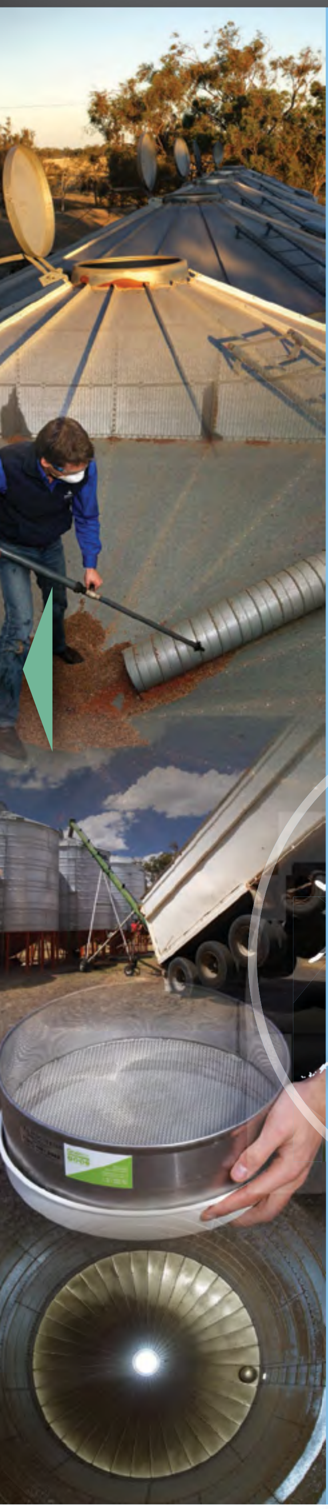

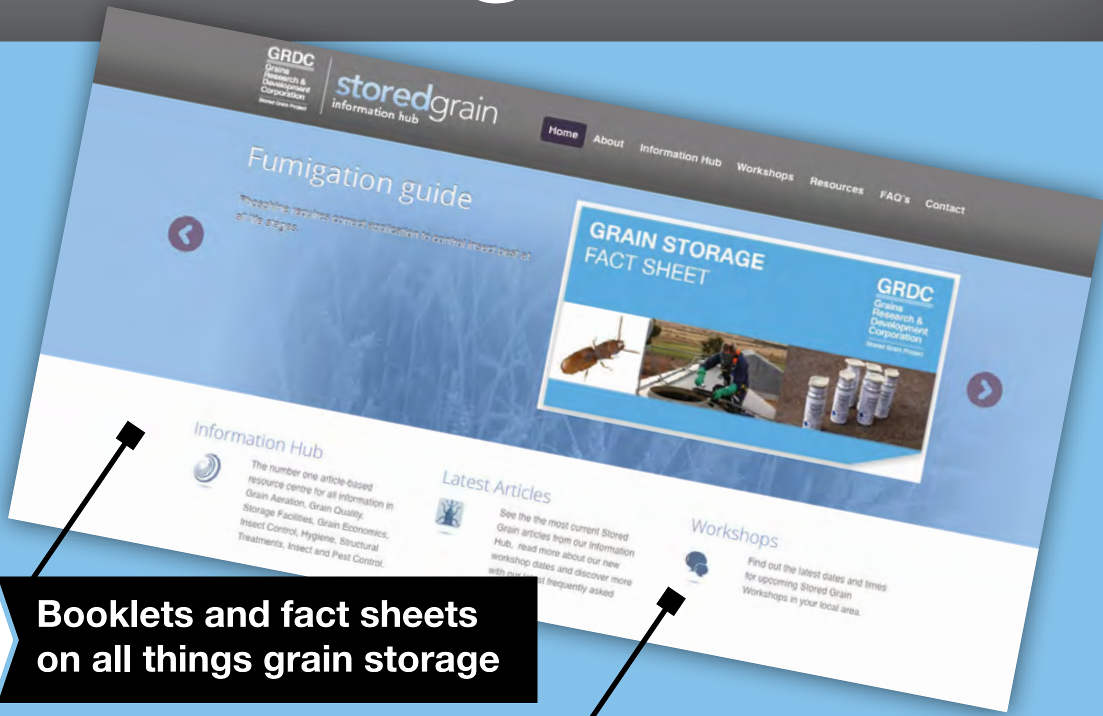

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